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RESEARCH ARTICLE

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Optimisation of multi-tier supply chain distribution networks with corporate social responsibility concerns in fast-fashion retail

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Abstract

This study analyses the problem of multi-tier supply chains, including suppliers, producers, wholesalers, and retailers. Decision-makers should analyse the social, environmental, and economic constraints in a multi-dimensional business context. We analyse these issues by considering the corporate social responsibility (CSR) concerns. A scorecard-based mathematical model, consisting of mixed-integer linear programming, is developed to assist fast-fashion decision-makers in supply chain policy formulation. The model is validated through a practical case study using IBM CPLEX Optimizer. The results indicate that involving the social aspect can increase the profit compared to considering only the economic impact, under high environmental costs with low return on investment. Furthermore, the mathematical model is able for the case study to optimise the distribution network of the entire multi-tier supply chain, considering CSR concerns, in less than 5 s. This research has implications for the advancement of multi-tier supply chain optimisation and provides a basis for future distribution decisions for firm stakeholders.

KEYWORDS

corporate social responsibility (CSR), fast-fashion retail, mathematical model, multi-tier supply chain, optimisation, scorecard

1 | INTRODUCTION

The fashion textile industry is one of the most polluting industries globally. It is associated with many poor working practices such as low pay, forced labour, child labour, and other ethical issues. As a result, there is increasing pressure on firms to consider issues related to corporate social responsibility (CSR), where companies must contribute to the well-being of society apart from the benefit goal (Barauskaite & Streimikiene, 2021). This is often in contrast with the need for increased profitability factors that significantly impact fast-fashion businesses. These complexities stimulate several contemporary supply chain strategies, such as operating multi-tier systems (Sarkis et al., 2019).

The main challenge is the management of CSR in fast-fashion multi-tier supply chains. Balancing economic performance and environmental impact is a trade-off for the textile industry (Illge & Preuss, 2012). It has been proven that the dyadic logic of the supply chain structure fails to capture the network complexity; thus, a multi-tier system can be an excellent alternative to avoid some of these complexities. However, in a multi-tier supply chain, CSR presents additional challenges because of the loss of control. Focal firms have limited control over their partners' sustainability behaviours (Mena et al., 2013), yet these companies are blamed if any social or environmental harm is induced by a member of their supply chain network (Jabbour et al., 2019).

This topic demands further investigation because regulatory obligations to execute eco-friendly processes make it critical for businesses to operate strategies that can strengthen their competitive edge in the market (Sahoo et al., 2023). In fact, previous studies have enhanced the importance of focal actors to achieve successful output in their sustainable buyer–seller dyads through their collaborations in triads (Jraisat et al., 2021).

The textile industry has experienced extraordinary development (Luque & Herrero-García, 2019). Therefore, the fashion industry has recently experienced economic growth and environmental degradation (Ramkumar et al., 2021). For example, ZARA, one of the leading fashion brands has implemented CSR policies and established ethics and social advisory committees, while H&M has evolved extensively in the recycling aspect of CSR. Additionally, Timberland and Gap have board committees supervising CSR (McElhaney, 2009). The fierce market competition requires a high level of supply chain management development. Therefore, CSR considerations have become crucial foundational aspects for complex supply chains (Li et al., 2014).

Motivated by the increasing importance of distribution networks in supply chain operations and inspired by real-world challenges, we explore the optimal distribution flow with CSR considerations in the fast-fashion field. Our motivation is also stimulated by the high consumption of fast-fashion products because clothing is part of our daily lives (Ki et al., 2021). To this end, we analyse the physical flows between different supply chain elements, which extend beyond the classical direct flow from the supplier to the retail store. Multiple single-level relationships in the fast-fashion supply chain, derived from the quick response of this industry, have been developed, leading to the adoption of the multi-tier supply chain in this study.

Some prior studies have explored the concept of multi-tier supply chains in engineering and management areas to understand resource dependencies (Kalaitzi et al., 2019) and illustrate the procurement mechanisms (Kannan, 2021). However, analyses of CSR considerations used in multi-tier distribution channels are still limited in the literature. This study differs significantly from the works of Liu et al. (2022) in that we quantify the costs and revenues of CSR considerations, that is, economic, social, and environmental. Existing literature on CSR and multi-tier supply chains fails to provide practical decisions on distribution quantities in multi-tier networks. This research gap raises the following research questions (RQs):

> **RQ1.** How CSR vision can be made actionable in fast-fashion multi-tier supply chains?
>
> **RQ2.** How the distribution quantities in fashion multi-tier networks can be decided?

To answer these research questions, we developed a mixed-integer linear model. In addition, a practical case study was conducted to validate the model. The main objective of this study is to provide stakeholders with a model that enables them to analyse the CSR costs and revenues in a multi-tier network. In this paper,

- We analysed and modelled the different CSR-associated costs and revenues among the various distribution channels over the multi-tier fast-fashion supply chain by optimising the distribution quantities.
- We assessed the weight of CSR interventions by prioritising the associated costs that might be conflicting, given a limited budget.

In Section 2, we present a literature review of previous studies together with the objectives of this study. Section 3 describes the methodology: general workflow, prioritisation process, and mathematical model development. Section 4 analyses the proposed framework using a practical example and its results. Finally, we conclude with the findings assessment, research limits, and future research projections.

2 | THEORETICAL BACKGROUND AND LITERATURE REVIEW

In recent decades, fast-fashion has dominated global fashion retail and is characterised as offering high-fashion designs at low prices with increasing demand for these products. Recent fast-fashion strategies include omnichannel retail for buying online and returning in-store (Fares, Lloret, Kumar, & Frederico, 2023). However, with the ongoing development of this business, fast-fashion supply chain infrastructures are experiencing several CSR challenges.

2.1 | Corporate social responsibility aspects

The concept of CSR was originally developed in the late 1930s and has stimulated several debates about its definition since then (Arrigo, 2013). It was first defined as the set of business decisions and policies beyond the direct firm's interest (Davis, 1973; McGuire, 1963) and associated with society's intentions and visions (Bowen, 1953; Gupta & Hodges, 2012). Nevertheless, the connotations of a firm's imperatives in the CSR context were still confusing. To address this ambiguity, Carroll (1979) classified CSR into four aspects: legal, ethical, economic, and philanthropic responsibilities (Arrigo, 2013).

However, these definitions lack a comprehensive assessment of the overall responsibilities of a firm's activities, mainly their environmental responsibility. Therefore, our study adopts a definition that combines environmental responsibility with CSR's economic and social aspects, as discussed by several recent scholars (Barauskaite & Streimikiene, 2021). In 2006, the European Communities Commission defined CSR as a concept in which environmental and social interests are voluntarily incorporated into a firm's decisions beyond the minimum legal requirements (Juscius, 2007). Similarly, Ismail (2009) identified the CSR obligations of a firm, including the environmental aspects with the social impacts on employees, customers, suppliers, communities, and stakeholders. Nonetheless, the link between these definitions and the performance measurement of the CSR aspects is still limited.

Barauskaite and Streimikiene (2021) conceptualised a framework for CSR performance management in companies, and models were proposed to better understand the theoretical concepts of CSR assessment. However, although the models support the development of standardised indicators for performance measurements, they are concerned only with financial assessment. Asiaei and Bontis (2019) solved this confusion by developing CSR performance measures. Their model highlights insightful competency requirements regarding the critical success factors and strategic initiatives of firms within CSR policies and integrates the environmental and social aspects into the balanced scorecard model. Nevertheless, the quantitative analysis of the cost of measuring performance is lacking.

2.2 | Multi-tier supply chain and related mathematical models

A multi-tier supply chain includes several facilities available at each tier (Sawik, 2020). Supply chain globalisation has stimulated a higher level of complexity in the supply chain structure, with sophisticated layers between suppliers, producers, and customers (Humphrey, 2003). The policies of stakeholders have decisively influenced this complexity, aiming to promote sourcing and outsourcing (Mena et al., 2013) and cooperative and collaborative network management (Lloret et al., 2009). Supply chain entities have adopted dyadic supplier–buyer relationships (Fraser et al., 2020). For instance, Nike involves hundreds of second-tier suppliers, while Puma considers suppliers up to the fourth tier (Tachizawa & Yew Wong, 2014). Therefore, the concept of a multi-tier supply chain has been extended to include three different structure configurations, open, transitional, or closed triad, based on the interaction types (Mena et al., 2013).

Several researchers have investigated multi-tier supply chain development. Dou et al. (2018) focused on the green side of the multi-tier supply chain by working on a case study to identify the enablers of suppliers' improvement. Using action research methodology, they concluded that in addition to enabler mapping, managerial support and proximity of suppliers are also essential. However, mapping requires vital information mastery. The associated information-sharing management was undertaken by Viswanathan et al. (2007) who conducted a multi-echelon simulation study with findings concerning inventory synchronisation in a general context. Thus, the fashion industry still needs to develop a new approach to tractability management while optimising coordination, advertisement budget allocation, and luxury production (Choi & Liu, 2019). Currently, there is a lack of studies that specifically focus on the fast-fashion industry.

A set of mathematical models have been developed using mixed-integer linear programming (Zhang et al., 2014) with a real supply chain optimisation provided, considering the three CSR aspects. It is necessary to integrate the decision-making system with the mathematical models, similar to the method presented in a Brazilian case study with the goal of programming for a sustainable supply chain (Vivas et al., 2020). Further, incorporating the three sustainability aspects, that is, social, economic, and ecological aspects, is crucial for multi-dimensional mathematical analysis; however, such models in fast-fashion are still limited in the literature.

2.3 | Research gap

Table 1 summarises the comparative analyses of recent studies highlighting the research gap. It has been observed that there is

TABLE 1 Comparative analysis of the literature.

			CSR cost and revenue aspects					
	Multi-tier SC	Scorecard	Social costs	Social revenues	Economic costs	Economic revenues	Environmental costs	Environmental revenues
Yadav et al. (2019)					x			
Asiaei and Bontis (2019)		x						
Heydari and Rafiei (2020)			x		x	x	x	
Mogale et al. (2020)					x			
Ehtesham Rasi and Sohanian (2021)	x				x	x		
Vafaei et al. (2020)	x				x			
Validi et al. (2020)					x			
Vivas et al. (2020)			x				x	
Liu et al. (2022)	x		x	x	x	x		
Current study	x	x	x	x	x	x	x	x

Abbreviation: SC, supply chain.

limited literature studying multi-tier supply chains with CSR considerations and a lack of comprehensive performance measurement for the CSR aspects. However, scorecards have been argued as important for CSR evaluation (Barauskaite & Streimikiene, 2021), which is emphasised in this study.

3 | RESEARCH METHODOLOGY

To investigate our research questions, we designed our research as described in Figure 1. In this section, we describe the goal of each step and justify the methodology used in relation to the literature. Our study adopts a mathematical modelling approach to seek answers to the research questions. According to Beyer et al. (2016), the main disadvantage of using heuristics is that there is no guarantee of the quality of the solutions. This method can enable finding local, rather than global minima solutions, and there is no measure of how far from optimality the solution is. By contrast, integer linear programming is guaranteed to obtain an optimal solution or a solution guaranteed to be within a specified range from the optimum. Therefore, in this study, we have utilised mixed-integer linear programming.

CSR is generally considered to involve three main aspects: social, economic, and environmental (Asiaei & Bontis, 2019). However, integrating these considerations in supply chain cost analysis is often conflicting, particularly with a limited budget. Therefore, a scorecard is ideal for structuring strategic CSR aspects to proceed with prioritisation in alignment with a firm's policies.

The scorecard model has been previously used for environmental and social evaluations and strategic improvement studies (Hansen et al., 2010). The choice of scorecard method for this study is justified as follows:

- The scorecard considers non-financial strategic factors that widely impact business economic success, which makes it a good starting point to integrate social and environmental aspects into the same management system (Figge et al., 2002).
- The scorecard ensures that all activities are aligned when translating strategy into action (Chalmeta & Palomero, 2011).

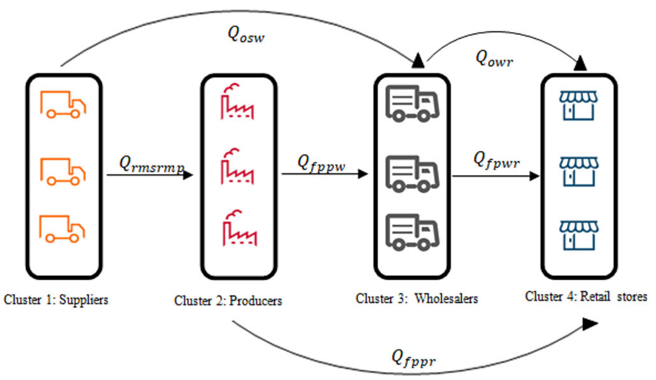

FIGURE 1 Problem definition (see Table 2 for an explanation of variables).

- Corporate performance measurement can be comprehensively conceptualised by considering balanced scorecards with social and environmental measures (Asiaei & Bontis, 2019).

However, scorecards have limited use in quantifying distribution quantity decisions; therefore, we integrated them with the mathematical optimisation model in this study. The model was then coded and executed using the IBM CPLEX software. The advances in hardware and software used by optimisation solvers such as CPLEX have enabled the building and optimal solving of large and complex problems within a reasonable time (Cárdenas-Barrón & Treviño-Garza, 2014). This study does not examine this proposed combination of scorecard prioritisation and linear modelling applied to the fast-fashion multi-tier supply chain optimisation problem to determine the distribution. Rather, this study explores this approach by analysing the development of an integrated framework to determine optimal distribution policies in alignment with strategic scorecard CSR preferences. This section also outlines the problem under investigation and the research methodology used.

3.1 | Problem definition and scope

We assume a supply chain structure of four clusters: suppliers (*s*), producers (*p*), wholesalers (*w*), and retail stores (*r*) (Figure 1). It has been argued that integrated systems of product supply and product distribution channels are important. Claro and Claro (2010) emphasised that a producer can obtain information not only from its upstream ties (first or other upper-tier suppliers), but also from its downstream ties (wholesalers or retailers).

Decisions on distribution quantities among multi-tier interactions within the supply chain structure are the primary contributions of this study. This problem does not involve customer demand as a variable and excludes return flows (reverse logistics). Instead, we focus on the direct supply chain network flow analysis by including costs and revenues generated by rapidly changing customer demand.

3.2 | Scorecard metrics in the model

The balanced scorecard of an organisation involves several metrics, including financial, customer, and internal business processes (Ray & Das, 2010). The financial metrics include the cost and revenue of the implementation of environmental policies, such as the following:

- The cost of environmental pollution control systems (Vivas et al., 2020) is associated with the industrial infrastructure implemented in textile manufacturing sites to assess and control CO_2 emissions during transportation;
- The cost of green quality enhancement (Heydari & Rafiei, 2020) to build and maintain the sustainable life cycle of distribution channels;
- Revenue from recycling and green products (Ahi & Searcy, 2015), as consumers who are aware of the importance of sustainability prefer buying eco-friendly products.

TABLE 2 Parameters and decision variables.

Parameters		
	θp	Environmental impact on upstream tiers linked to the producer; Binary variable: $\theta p \in \{0;1\}$
	θw	Environmental impact on upstream tiers linked to the wholesaler; Binary variable: $\theta w \in \{0;1\}$
	θr	Environmental impact on upstream tiers linked to the retail store; Binary variable: $\theta r \in \{0;1\}$
	$\theta' p$	Economic impact on upstream tiers linked to the producer; Binary variable: $\theta' p \in \{0;1\}$
	$\theta' w$	Economic impact on upstream tiers linked to the wholesaler; Binary variable: $\theta' w \in \{0;1\}$
	$\theta' r$	Economic impact on upstream tiers linked to the retail store; Binary variable: $\theta' r \in \{0;1\}$
	$\theta'' p$	Social impact on upstream tiers linked to the producer; Binary variable: $\theta'' p \in \{0;1\}$
	$\theta'' w$	Social impact on upstream tiers linked to the wholesaler; Binary variable: $\theta'' w \in \{0;1\}$
	$\theta'' r$	Social impact on upstream tiers linked to the retail store; Binary variable: $\theta'' r \in \{0;1\}$
Upstream tiers linked to the producer *p* for distributing raw material *rm* from supplier *s*	R_{rmsrmp}	Environmental revenue
	R'_{rmsrmp}	Economic revenue
	R''_{rmsrmp}	Social revenue
	C_{rmsrmp}	Environmental cost
	C'_{rmsrmp}	Economic cost
	C''_{rmsrmp}	Social cost
Upstream tiers linked to the wholesaler *w* for distributing outlet *o* from supplier *s*	R_{osow}	Environmental revenue
	R'_{osow}	Economic revenue
	R''_{osow}	Social revenue
	C_{osow}	Environmental cost
	C'_{osow}	Economic cost
	C''_{osow}	Social cost
Upstream tiers linked to the wholesaler *w* for distributing final product *fp* from producer *p*	R_{fppw}	Environmental revenue
	R'_{fppw}	Economic revenue
	R''_{fppw}	Social revenue
	C_{fppw}	Environmental cost
	C'_{fppw}	Economic cost
	C''_{fppw}	Social cost
Upstream tiers linked to the retail store *r* for distributing final product *fp* from producer *p*	R_{fppr}	Environmental revenue
	R'_{fppr}	Economic revenue
	R''_{fppr}	Social revenue
	C_{fppr}	Environmental cost
	C'_{fppr}	Economic cost
	C''_{fppr}	Social cost
Upstream tiers linked to the retail store *r* for distributing final product *fp* from wholesaler *w*	R_{fpwr}	Environmental revenue
	R'_{fpwr}	Economic revenue
	R''_{fpwr}	Social revenue
	C_{fpwr}	Environmental cost
	C'_{fpwr}	Economic cost
	C''_{fpwr}	Social cost

(Continues)

TABLE 2 (Continued)

Upstream tiers linked to the retail store *r* for distributing outlet *o* from wholesaler *w*	R_{owr}	Environmental revenue
	R'_{owr}	Economic revenue
	R''_{owr}	Social revenue
	C_{owr}	Environmental cost
	C'_{owr}	Economic cost
	C''_{owr}	Social cost
Capacity limits		
*Cap*1	Capacity limits associated with Q_{rmsrmp}	
*Cap*2	Capacity limits associated with Q_{osow}	
*Cap*3	Capacity limits associated with Q_{fppw}	
*Cap*4	Capacity limits associated with Q_{fppr}	
*Cap*5	Capacity limits associated with Q_{fpwr}	
*Cap*6	Capacity limits associated with Q_{owr}	
Budget limits		
B_{rmsrmp}	Budget limits associated with Q_{rmsrmp}	
B_{osow}	Budget limits associated with Q_{osow}	
B_{fppw}	Budget limits associated with Q_{fppw}	
B_{fppr}	Budget limits associated with Q_{fppr}	
B_{fpwr}	Budget limits associated with Q_{fpwr}	
B_{owr}	Budget limits associated with Q_{owr}	
Decision variable		
Q_{rmsrmp}	Quantity of distributed raw materials *rm* from the supplier *srm* to the producer *p*	
Q_{osow}	Quantity of distributing outlets *o* from the supplier *so* to the wholesaler *w*	
Q_{fppw}	Quantity of distributed final products *fp* from the producer *p* to the wholesaler *w*	
Q_{fppr}	Quantity of distributed final products *fp* from the producer *p* to the retail store *r*	
Q_{fpwr}	Quantity of distributed final products *fp* from the wholesaler *w* to the retail store *r*	
Q_{owr}	Quantity of distributing outlets *o* from the wholesaler *w* to the retail store *r*	

The customer metrics consist of the cost and revenue of process operations triggered by external customer demand, namely:

- The cost of maximising processing time manufacturing (Zhang et al., 2014) to achieve a quick response;
- Revenue from sales of customised items with high-fashion and trendy features.

The internal business process section addresses the cost and revenue of the following internal supply chain process operations:

- The cost of storage distribution (Ehtesham Rasi & Sohanian, 2021);
- Revenue from sales of standard and basic apparel items.

Finally, the employee learning and growth dimension addresses the cost and revenue of social policy adoption outlined as follows:

- The cost of social-level enhancement (Heydari & Rafiei, 2020);
- The cost of external and internal social interventions (Vivas et al., 2020);
- Revenue from CSR projects (Knox & Maklan, 2004);
- Revenue from training programme return on investment (Phillips, 2012) with the working staff.

This scorecard acts as a roadmap for implementing the CSR aspects, that is, the economic, environmental, and social considerations.

3.3 | Linear modelling

We formulated a mixed-integer linear mathematical model to solve the stated multi-tier supply chain problem with CSR considerations in the fast-fashion industry. The model does not include demand and supply as variables but does include the costs and revenues generated by rapid changes in customer demand. The linear programme is used as a maximisation function, subject to upper and lower bounds (Neumaier & Shcherbina, 2004). The programme aims to integrate the distribution flows by deciding on the optimal quantity to be distributed over the multi-tier network.

We describe the sets considered in the mixed-integer linear programme as follows:

- SRM: a set of raw material suppliers indexed by '*srm*' from 1 to |SRM|;
- SO: a set of outlet suppliers indexed by '*so*' from 1 to |SO|;
- P: a set of producers indexed by '*p*' from 1 to |P|;
- W: a set of wholesalers indexed by '*w*' from 1 to |W|;
- R: a set of retail stores indexed by '*r*' from 1 to |R|;
- RM: a set of purchased raw materials indexed by '*rm*' from 1 to |RM|;
- O: a set of distributing outlets indexed by '*o*' from 1 to |O|;
- FP: a set of produced items indexed by '*fp*' from 1 to |FP|.

In the mathematical model, we consider the following assumptions:

- All supply chain clusters are involved in CSR implementation; thus, we study the output to estimate the entire supply chain's cost, profit, and revenue.
- The minimum value of the purchase of raw materials and final products is 20, whereas the minimum outlet purchase value is 0, as it depends on the seasonality of sale periods.

As presented in Tables 2 and 3, we formulated the mixed-integer linear model based on these elements.

In the objective function, the first term (1) refers to the sum of revenues related to the sustainability chosen for each cluster in the supply

TABLE 3 Objective function and constraints.

Objective function	
Maximise: Revenue–cost	$\text{Revenue} = \sum_{rm=1}^{RM} \sum_{srm=1}^{SRM} \sum_{p=1}^{P} Q_{rmsrmp} * (\theta p * R_{rmsrmp} + \theta' p * R'_{rmsrmp} + \theta'' p * R''_{rmsrmp})$ (1) $+ \sum_{o=1}^{O} \sum_{so=1}^{SO} \sum_{w=1}^{W} Q_{osow} * (\theta w * R_{osow} + \theta' w * R'_{osow} + \theta'' w * R''_{osow})$ $+ \sum_{fp=1}^{FP} \sum_{p=1}^{P} \sum_{w=1}^{W} Q_{fppw} * (\theta w * R_{fppw} + \theta' w * R'_{fppw} + \theta'' w * R''_{fppw})$ $+ \sum_{fp=1}^{FP} \sum_{p=1}^{P} \sum_{r=1}^{R} Q_{fppr} * (\theta r * R_{fppr} + \theta' r * R'_{fppr} + \theta'' r * R''_{fppr})$ $+ \sum_{fp=1}^{FP} \sum_{w=1}^{W} \sum_{r=1}^{R} Q_{fpwr} * (\theta r * R_{fpwr} + \theta' r * R'_{fpwr} + \theta'' r * R''_{fpwr})$ $+ \sum_{o=1}^{O} \sum_{w=1}^{W} \sum_{r=1}^{R} Q_{owr} * (\theta r * R_{owr} + \theta' r * R'_{owr} + \theta'' r * R''_{owr})$ $\text{Cost} = \sum_{rm=1}^{RM} \sum_{srm=1}^{SRM} \sum_{p=1}^{P} Q_{rmsrmp} * (\theta p * C_{rmsrmp} + \theta' p * C'_{rmsrmp} + \theta'' p * C''_{rmsrmp})$ (2) $+ \sum_{o=1}^{O} \sum_{so=1}^{SO} \sum_{w=1}^{W} Q_{osow} * (\theta w * C_{osow} + \theta' w * C'_{osow} + \theta'' w * C''_{osow})$ $+ \sum_{fp=1}^{FP} \sum_{p=1}^{P} \sum_{w=1}^{W} Q_{fppw} * (\theta w * C_{fppw} + \theta' w * C'_{fppw} + \theta'' w * C''_{fppw})$ $+ \sum_{fp=1}^{FP} \sum_{p=1}^{P} \sum_{r=1}^{R} Q_{fppr} * (\theta r * C_{fppr} + \theta' r * C'_{fppr} + \theta'' r * C''_{fppr})$ $+ \sum_{fp=1}^{FP} \sum_{w=1}^{W} \sum_{r=1}^{R} Q_{fpwr} * (\theta r * C_{fpwr} + \theta' r * C'_{fpwr} + \theta'' r * C''_{fpwr})$ $+ \sum_{o=1}^{O} \sum_{w=1}^{W} \sum_{r=1}^{R} Q_{owr} * (\theta r * C_{owr} + \theta' r * C'_{owr} + \theta'' r * C''_{owr})$
Subject to	
Q_{rmsrmp} constraints	$\forall srm \in [1; \text{SRM}], \forall p \in [1; \text{P}] : \sum_{rm=1}^{RM} Q_{rmsrmp} * C_{rmsrmp} \le B_{rmsrmp}$ (3) $\forall rm \in [1; \text{RM}] : Cap1 \le Q_{rmsrmp} \le Cap_{rmsrmp}$ (4)
Q_{osw} constraints	$\forall so \in [1; \text{SO}], \forall w \in [1; \text{W}] : \sum_{o=1}^{O} Q_{osow} * C_{osow} \le B_{osow}$ (5) $\forall o \in [1; \text{O}] : Cap2 \le Q_{osow} \le Cap_{osow}$ (6)
Q_{fppw} constraints	$\forall p \in [1; \text{P}], \forall w \in [1; \text{W}] : \sum_{fp=1}^{FP} Q_{fppw} * C_{fppw} \le B_{fppw}$ (7) $\forall fp \in [1; \text{FP}] : Cap3 \le Q_{fppw} \le Cap_{fppw}$ (8)
Q_{fppr} constraints	$\forall p \in [1; \text{P}], \forall r \in [1; \text{R}] : \sum_{fp=1}^{FP} Q_{fppr} * C_{fppr} \le B_{fppr}$ (9) $\forall fp \in [1; \text{FP}] : Cap4 \le Q_{fppr} \le Cap_{fppr}$ (10)
Q_{fpwr} constraints	$\forall w \in [1; \text{W}], \forall r \in [1; \text{R}] : \sum_{fp=1}^{FP} Q_{fpwr} * C_{fpwr} \le B_{fpwr}$ (11) $\forall fp \in [1; \text{FP}] : Cap5 \le Q_{fpwr} \le Cap_{fpwr}$ (12)
Q_{owr} constraints	$\forall w \in [1; \text{W}], \forall r \in [1; \text{R}] : \sum_{o=1}^{O} Q_{owr} * C_{owr} \le B_{owr}$ (13) $\forall o \in [1; \text{O}] : Cap6 \le Q_{owr} \le Cap_{owr}$ (14)

chain, while the second term (2) refers to the associated costs. There are four constraints on each decision variable, with a total of 24 constraints under which the mixed-integer linear model is programmed.

The first constraint of each tier—(3), (5), (7), (9), (11), and (13)—defines the budget constraint associated with every shipment. For each tier, the sum of operational costs should be within the shipping cost for each shipment by summing all the transferred materials and items. The second constraint—(4), (6), (8), (10), (12), and (14)—are associated with the stock cover under which the warehouse is associated with items and materials. These are based on the sales and demand forecast and are set by the planning and allocation teams.

4 | PRACTICAL CASE STUDY AND DISCUSSION

To validate our study, we analysed its application in a real-life scenario. In the following subsections, we describe the considered case, numerical results, and sensitivity analysis, as illustrated in Figure 2.

4.1 | Case description and data collection

We analysed the feasibility of our model for a textile producer in Morocco. The company's name has not been disclosed due to the confidentiality disclosure agreement. The company manufactures cotton-based products and provides 95 products across 16 product ranges. Table 4 outlines the physical flow under study. In this case, we consider two suppliers of raw material ($srm = 2$), one supplier of the outlet ($so = 1$), one producer ($p = 1$), and two wholesalers ($w = 2$). Among the retail stores ($r = 3$), one is local, that is, close to the producer, and can receive products directly shipped from the producer; for the other two retail stores, products are shipped from wholesalers.

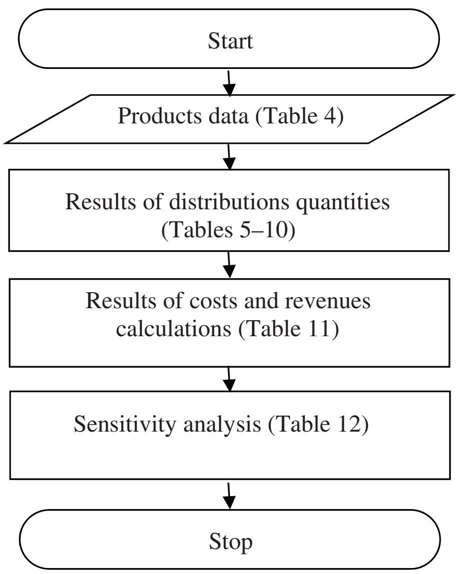

FIGURE 2 Flowchart of data and analysis results.

We analysed the applicability of CSR costs and revenues in this distribution network case study. On the social side, we considered the costs of social actions, such as employee learning and social security costs, and the associated gained revenue, such as decreased defects and increased work performance. On the environmental side, we assessed the costs of combined deliveries and a third-party logistics substitute to decrease CO_2 emissions, together with the return on investment in solar energy installation costs. For associated revenues, we appraised revenues such as the additional sales to customers who seek eco-friendly products and the gain in transportation fees per item sold, with 3% fees instead of 5%, owing to the combined distribution within the defined capacity. This cost and revenue estimation was performed by a retail manager with over 13 years of experience and previous work experience in the producer's company, collaborating with the producer's company CEO. They estimated the associated costs and revenue for those social and environmental actions that lacked data and those that were not applied in this study. Costs and revenues are described in the Appendix (Tables A1–A6), considering the conversion rate (1 euro equates to 10 Moroccan dirhams).

4.2 | Numerical analysis

The mathematical model was coded and programmed using the IBM ILOG CPLEX Optimizer software and run using a computer with a 1.1 GHz processor; the execution time was less than 5 s. The model determines the distribution quantities and simulates the financial metrics, that is, cost, profit, and revenue. The distribution quantity results of the six tiers are outlined in Tables 5–10; the financial metrics are presented in Table 11. We analysed the distribution network for 6 months. This includes the seasonality variation, considering mid-season and winter production to visualise the distribution quantities accordingly. The programme was executed for the six data instances. Results are consistent; hence, the model is validated.

TABLE 4 Physical flows.

Flow type	Description	
Raw material	Jersey	
	Packaging material	
Outlet	Pant man	
	Sweatshirt man	
Final products	Baby	Pyjamas
		Romper
	Kids	Pyjamas
		T-shirt
	Men	V-neck T-shirt
		Crew neck T-shirt
		Underwear
	Women	V-neck T-shirt
		Crew neck T-shirt
		Underwear

TABLE 5 Distribution quantities of raw materials from raw materials suppliers to the producer (per kg for jersey and per unit for packaging material).

	September	October	November	December	January	February
$Q_{rm1srm1p1}$	500	500	700	700	500	500
$Q_{rm1srm2p1}$	200	150	200	200	100	100
$Q_{rm2srm1p1}$	1326	1326	1128	1128	1326	1326
$Q_{rm2srm2p1}$	900	700	1200	1200	500	500

TABLE 6 Distribution quantities of outlets from outlet suppliers to the wholesalers (per unit).

	September	October	November	December	January	February
$Q_{o1so1w1}$	500	200	0	0	700	0
$Q_{o1so1w2}$	1000	300	0	0	600	0
$Q_{o2so1w1}$	600	400	0	0	800	0
$Q_{o2so1w2}$	500	100	0	0	700	0

TABLE 7 Distribution quantities of final products from the producer to the wholesalers (per unit).

	September	October	November	December	January	February
$Q_{fp1p1w1}$	170	220	220	260	175	168
$Q_{fp2p1w1}$	90	108	90	117	70	72
$Q_{fp3p1w1}$	215	245	260	220	170	165
$Q_{fp4p1w1}$	85	100	110	110	81	72
$Q_{fp5p1w1}$	170	220	220	255	180	170
$Q_{fp6p1w1}$	90	108	90	117	75	72
$Q_{fp7p1w1}$	170	220	255	270	170	140
$Q_{fp8p1w1}$	80	105	100	95	81	72
$Q_{fp9p1w1}$	140	160	175	170	100	112
$Q_{fp10p1w1}$	55	70	70	78	54	40
$Q_{fp1p1w2}$	145	160	180	160	115	90
$Q_{fp2p1w2}$	50	65	70	75	50	48
$Q_{fp3p1w2}$	140	160	220	170	115	112
$Q_{fp4p1w2}$	60	70	78	78	54	40
$Q_{fp5p1w2}$	280	320	310	364	252	220
$Q_{fp6p1w2}$	120	144	140	150	108	80
$Q_{fp7p1w2}$	170	220	310	350	220	200
$Q_{fp8p1w2}$	115	140	130	145	90	96
$Q_{fp9p1w2}$	170	320	320	90	250	200
$Q_{fp10p1w2}$	120	144	156	156	100	80

TABLE 8 Distribution quantities of final products from producers to the retail stores (per unit).

	September	October	November	December	January	February
$Q_{fp1p1r1}$	55	60	60	65	40	45
$Q_{fp2p1r1}$	60	55	60	65	45	35
$Q_{fp3p1r1}$	50	60	55	55	50	40
$Q_{fp4p1r1}$	59	60	65	60	40	25
$Q_{fp5p1r1}$	35	35	50	35	30	35
$Q_{fp6p1r1}$	40	35	55	60	35	35
$Q_{fp7p1r1}$	40	35	60	50	35	55
$Q_{fp8p1r1}$	75	75	90	100	75	35
$Q_{fp9p1r1}$	75	70	100	110	55	60
$Q_{fp10p1r1}$	65	79	75	75	55	50

TABLE 9 Distribution quantities of final products from wholesale suppliers to the retail stores (per unit).

	September	October	November	December	January	February
$Q_{fp1w1r1}$	85	110	110	130	85	80
$Q_{fp2w1r1}$	85	110	110	130	85	80
$Q_{fp3w1r1}$	45	54	45	55	35	36
$Q_{fp4w1r1}$	45	54	45	65	35	36
$Q_{fp5w1r1}$	100	120	130	110	85	80
$Q_{fp6w1r1}$	100	120	130	110	85	80
$Q_{fp7w1r1}$	40	50	55	55	45	36
$Q_{fp8w1r1}$	40	50	55	55	45	36
$Q_{fp9w1r1}$	85	110	110	125	90	85
$Q_{fp10w1r1}$	85	110	110	125	90	85
$Q_{fp1w2r1}$	45	54	45	50	35	36
$Q_{fp2w2r1}$	45	54	45	50	35	36
$Q_{fp3w2r1}$	85	110	125	135	85	70
$Q_{fp4w2r1}$	85	110	125	135	85	70
$Q_{fp5w2r1}$	40	55	50	45	35	36
$Q_{fp6w2r1}$	40	55	50	50	45	36
$Q_{fp7w2r1}$	70	80	85	85	50	56
$Q_{fp8w2r1}$	70	80	85	85	50	56
$Q_{fp9w2r1}$	25	35	35	39	27	20
$Q_{fp10w2r1}$	30	35	35	39	27	20
$Q_{fp1w1r2}$	74	80	90	80	55	45
$Q_{fp2w1r2}$	74	80	90	80	55	45
$Q_{fp3w1r2}$	25	30	35	35	25	24
$Q_{fp4w1r2}$	25	35	35	40	25	24
$Q_{fp5w1r2}$	70	80	110	85	55	56
$Q_{fp6w1r2}$	70	80	110	85	55	56
$Q_{fp7w1r2}$	30	35	39	39	27	20
$Q_{fp8w1r2}$	30	35	39	39	27	20
$Q_{fp9w1r2}$	140	160	155	182	126	110
$Q_{fp10w1r2}$	140	160	155	182	126	110
$Q_{fp1w2r2}$	60	72	70	75	54	40
$Q_{fp2w2r2}$	60	72	70	75	54	40
$Q_{fp3w2r2}$	85	110	155	175	110	100
$Q_{fp4w2r2}$	85	110	155	175	110	100
$Q_{fp5w2r2}$	50	70	65	75	45	48
$Q_{fp6w2r2}$	60	70	65	75	45	48
$Q_{fp7w2r2}$	85	160	160	45	125	100
$Q_{fp8w2r2}$	85	160	160	45	125	100
$Q_{fp9w2r2}$	60	72	78	78	50	40
$Q_{fp10w2r2}$	60	72	78	78	50	40

4.3 | Sensitivity analysis and discussion

We performed the sensitivity analysis for the September data, which yielded the highest global supply chain profit. This is owing to the back-to-school season for retailers and the increased purchase of raw materials for producing heavy winter underwear. In the previous numerical analysis, we considered all the costs and revenues: economic, environmental, and social. To assess the system's robustness, we simulated the cost, profit, and revenue in Case 1, where the network neglects the CSR aspects, considering only the economic impact.

TABLE 10 Distribution quantities of outlets from wholesalers to the retail stores (per unit).

	September	October	November	December	January	February
Q_{o1w1r1}	200	100	0	0	400	0
Q_{o1w1r2}	300	100	0	0	300	0
Q_{o1w2r1}	700	200	0	0	300	0
Q_{o1w2r2}	300	100	0	0	300	0
Q_{o2w1r1}	400	200	0	0	500	0
Q_{o2w1r2}	200	200	0	0	300	0
Q_{o2w2r1}	200	50	0	0	400	0
Q_{o2w2r2}	300	50	0	0	300	0

TABLE 11 Costs and revenues (€).

	September	October	November	December	January	February
Cost	106,810	67,949	47,176	46,704	107,480	32,529
Profit	24,838	17,504	13,978	13,851	24,584	9547
Revenue	131,650	85,453	61,154	60,555	132,060	42,076

TABLE 12 Sensitivity analysis results.

	Producer			Wholesaler			Retail store					
	$\theta'p$	$\theta''p$	θp	$\theta'w$	$\theta''w$	θw	$\theta'r$	$\theta''r$	θr	Cost	Profit	Revenue
Case 1	1	0	0	1	0	0	1	0	0	102,600	24,388	126,990
Case 2	1	0	1	1	0	1	1	0	1	99,707	18,814	118,520
Case 3	1	0	1	1	0	1	1	1	0	105,440	23,416	128,860
Case 4	1	0	1	1	1	0	1	0	1	104,410	24,263	128,670
Case 5	1	0	1	1	1	0	1	1	0	103,580	25,499	129,080
Case 6	1	1	0	1	1	0	1	1	0	103,150	27,066	130,210
Case 7	1	1	0	1	1	0	1	0	1	103,980	25,830	129,810
Case 8	1	1	0	1	0	1	1	1	0	105,010	24,983	129,990
Case 9	1	1	0	1	0	1	1	0	1	105,840	23,747	129,580

Subsequently, in Cases 2–9, we varied the other two input parameters among the tiers and checked the variability of outputs. Because the downstream node of each tier was the limiting factor of the distribution quantity for the tier, three nodes (producer, wholesaler, and retail store) were considered to determine the distribution quantities of the six tiers under this study. Moreover, because the economic aspect should always be present, we altered two other variables with the three nodes, which yielded nine cases for the sensitivity analysis (Table 12).

In Case 1, the profit was €24,388, which decreased by 23% in Case 2 (€18,814). This decline is because customers were interested only in the product price rather than the environmental footprint and eco-friendliness of the product. This observation supports the findings of Joergens (2006), which states that customers will likely only purchase ethical fashion products if the price is similar to that of other fashion items, as personal requirements influence buying decisions more than ethical concerns. Furthermore, Chan and Wong (2012) identified that a premium-level price weakens eco-fashion consumption. In Cases 3, 4, 8, and 9, the profits varied by −4%, −1%, +2%, and −3%, respectively, compared with that of Case 1. This variation is because the return on investment is not applicable for the assessed environmental action, such as implementing solar energy equipment. Moreover, the price of solar energy differs among countries but is still highly expensive compared to fossil fuel sources (Gulaliyev et al., 2020).

In Cases 5 and 7, the profits varied by +5% and +6%, respectively, compared with that of Case 1. This increase is explained by the high involvement of the human factor in wholesale and retail store operations. Thus, social enhancement supports a performance increase. This supports the findings of Byun et al. (2018), who identified that the leadership behaviours of high-level leaders cascade to low-level leaders, which increases employee performance and decreases their social loafing. In Case 6, the profit varied by +11% compared with that of Case 1. Unfortunately, the government and companies often neglect the social aspect in many countries where employees generally feel underpaid. This supports the observations of Gnanaselvam and Joseph (2018) that only a small number of firms ensure occupational health services in developing countries. For instance, the authors identified that depression and mental health issues were among the behavioural problems faced by adolescent girls working in the textile industry in India.

5 | CONCLUSION

The management of direct and transitional interactions within the supply chain network, that is, multi-tier management, is a major trend in operations management. This study primarily focused on the case of fast fashion, where fashion model management and quick responses are the stimulating challenges associated with the industry. We presented a mathematical model combined with scorecard analysis considering CSR, integrating the economic, social, and environmental constraints. Linear programming tools were used to identify the optimal distribution quantities. The costs and profits of each CSR dimension were considered together with the capacities and logistics constraints. The study underlines the importance of applied strategic preferences. The metrics associated with finance, customers, internal business processes, and employee learning and growth were first analysed, providing a roadmap for the linear programme variables and constraints. Our findings are derived from using real-life data from a textile factory in Morocco that was used to validate the mathematical model.

5.1 | Practical implications

This study provides a practical decision-making model for supply chain managers concerning their distribution network while accounting for CSR considerations. The practical implications are three-fold:

- *Employee motivation*: Our study demonstrated that improving the social aspect of CSR can generate a greater profit than only considering the economic aspect. This supports the findings of Lee and Ha-Brookshire (2018), stating that a strong corporate ethical climate is pivotal to obtaining positive organisational citizenship behaviour in US fashion retail employees. Embracing greater equity can enable better organisational performance (Bernstein et al., 2020). This extends beyond basic labour rights, including social and health occupational services. Furthermore, retailers are recommended to foster the brand's transparency to promote social ethics, such as the fair payment of all employees and measures against child labour.
- *Increase customer awareness about eco-friendly fashion products*: Because the green movement is the latest market trend, some retailers have started including tags on their garments identifying their association with sustainability concerns in the production process. The green consciousness is changing industries known for polluting, such as the fashion industry (Da Giau et al., 2020). However, previous studies have shown a divergence between consumer interests and actions. Despite their interest in social and environmental concerns, consumers rarely purchase eco-friendly fashion products, owing to concerns such as high price or low quality (Bandyopadhyay & Ray, 2020). Therefore, retailers are recommended to prioritise fashionable styles and design eco-fashion products that will trend with high attraction for customers. Retailers can benchmark the sales success of Nike Air Jordan shoes to promote eco-fashion. If firms launch eco-friendly products as limited editions with a unique style and top fashion design, the purchase of such products will be highly probable, despite the high price, owing to the attractiveness of the product features.
- *Consolidating the purchase*: Upstream purchasing can significantly decrease CO_2 emissions. Particularly for basic products and underwear, the demand is weakly volatile; thus, consolidating orders can decrease CO_2 emissions. Based on a Volvo case study, such transportation optimisations can contribute to an approximately 9% CO_2 emission decrease (Rahman, 2020). However, it might be challenging for retail stores to determine the balance between consolidated orders and stock coverage for the downstream chain. Therefore, retailers are recommended to utilise sustainable economic order quantity and economic production quantity (Soleymanfar et al., 2022), considering the returns. That is, the return of defective products to central warehouses and the return of the last unsold products by the end of sale seasons.

Finally, the suggested model can be applied beneficially to other multi-tier networks. However, the results are unique and cannot be generalised to other cases because the tests are specific to the supply chain configurations and data instances.

5.2 | Theoretical implications

This study combines a scorecard and mathematical modelling to improve our knowledge of how a firm can perform distribution decisions. Although previous studies have suggested that a scorecard can enable a deeper implementation of CSR (Asiaei & Bontis, 2019), there is only very limited knowledge concerning the quantitative alignment of the distribution decisions with the scorecard strategic orientations. This study enriches the multi-tier supply chain literature by incorporating CSR costs and revenues. We have uploaded the repository containing the IBM CPLEX code of our model on GitHub (https://github.com/Multi-tiersSC?tab=repositories) to enable contribution and collaboration with interested researchers to extend features, depending on the multi-tier supply chain configuration and to enable insightful new theoretical findings.

5.3 | Limitations and future research scope

This study presents a set of environmental and social costs and revenues in the model formulation based on existing literature. However, in the case study, we did not consider all the costs and revenues that we defined in our model considered from the literature. This is because their applicability in the practical distribution case under this study is insignificant. For instance, in the local market of the supplier in our case, organic cotton is not used, as mentioned by the retail manager; however, it could leverage insightful implications about its impact. Another limitation of our study is that it does not develop a conceptual framework because it is based on mathematical modelling. It would be interesting to investigate a conceptual framework using empirical data in future studies.

Accordingly, this study could stimulate researchers' motivation in various areas. First, future work can focus on sustainable supply chain management in the Industry 4.0 era (Mukhuty et al., 2022; Srivastava et al., 2022) given the digitalisation challenges (Jraisat et al., 2022; Sharma et al., 2022) and the emergence of circular economy (Agrawal et al., 2021; Jaeger & Upadhyay, 2020). Future research may investigate other case studies in which the applicability of these CSR aspects would be more comprehensive, especially following the pandemic (Fares & Lloret, 2022, 2023; Fares, Lloret, Kumar, Frederico, Kumar, et al., 2023).

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APPENDIX

TABLE A1 Cost and revenue of tier 1 deciding on the distribution quantity Q_{rmsrmp} (Moroccan Dirham/unit).

	Cost			Revenue		
Description	environmental To encourage the producer to make one trip purchase each month, instead of eight, the supplier must give a 5% discount on each kg of jersey sold. It is obtained by multiplying the supplier's selling price of 1 unit of raw material times the discount percentage	economic The global purchase cost(purchase price + distribution cost) of 1 kg of jersey	Social To motivate the staff who takes care of the producer orders, the supplier will provide them an additional social security. This cost equals the monthly cost of the additional social security per one staff divided by the quantity of units that one staff can prepare in 1 month	Environmental By encouraging the client to buy more for a 5% discount, the supplier will have more available space to make bigger stock and gain on transportation and importation fees (3% fees instead of 5%)	Economic The selling price of 1 kg of jersey sold	Social When the staff is motivated, they double performance; therefore, the staff cost will decrease from 6% to 3%
rm1srm1p1	4	61.2	0.06	1224	80	1836
rm1srm2p1	4	61.8	0.06	1236	80	1854
rm2srm1p1	0.1	0.816	0.005	0.016	1	0.0245
rm2srm2p1	0.1	0.824	0.005	0.016	1	0.0247

TABLE A2 Cost and revenue of tier 2 deciding on the distribution quantity Q_{osow} (Moroccan Dirham/unit).

	Cost			Revenue		
Description	Environmental To encourage the distributors to buy two times the normal quantity to reduce trips, the supplier should provide a 5% discount on each item sold	Economic The global purchase cost of one item sold (purchase price + distribution cost)	Social For an additional social security, the cost per 1 item sold	Environmental The gain on transportation fees per one item sold: 3% fees instead of 5%	Economic The selling price per 1 item	Social When staff is motivated they double performance; therefore, the staff cost will decrease from 6% to 3%
o3so1w1	7.5	123.6	0.03	2.47	150	3708
o3so1w2	7.5	122.4	0.03	2.45	150	3672
o4so1w1	9	148.32	0.03	2.97	180	44.496
o4so1w2	9	146.88	0.03	2.94	180	44.064

TABLE A3 Cost and revenue of tier 3 deciding on the distribution quantity Q_{fppw} (Moroccan Dirham/unit).

	Cost			Revenue		
	Environmental	Economic	Social	Environmental	Economic	Social
Description	The global investment on solar energy cost divided by 10 (life time) divided by 12 (number of months per year), times the ratio of each month's sold quantities	Global cost (production + distribution) per item. It equals the supplier's production cost per one unit + the distribution cost (3%)	Cost per item of training provided for staff. It equals the global cost of training per month divided by each month's sold quantities	The part of revenue (electricity bill + additional sales to customers who seek environmentally friendly products) per item sold	Selling price	The gain on reduced scrap per item sold. It equals the monthly gain on reduced scrap times the percentage of consumed raw material, divided by monthly sold quantities
fp1p1w1	1.25	28.84	1.67	1.7	37	1333
fp2p1w1	1.25	28.84	1.67	1.7	37	1333
fp3p1w1	1.25	28.84	1.67	1.7	37	1333
fp4p1w1	1.25	28.84	1.67	1.7	37	1333
fp5p1w1	0.833	30.28	1.75	1.19	39	0.933
fp6p1w1	0.833	30.28	1.75	1.19	39	0.933
fp7p1w1	0.833	30.28	1.75	1.19	39	0.933
fp8p1w1	1667	25.96	1.5	2.04	33	1.6
fp9p1w1	1667	25.96	1.5	2.04	33	1.6
fp10p1w1	1667	25.96	1.5	2.04	33	1.6
fp1p1w2	1.25	29.68	1.67	1.7	37	1333
fp2p1w2	1.25	29.68	1.67	1.7	37	1333
fp3p1w2	1.25	29.68	1.67	1.7	37	1333
fp4p1w2	1.25	29.68	1.67	1.7	37	1333
fp5p1w2	0.833	31.16	1.75	1.19	39	0.933
fp6p1w2	0.833	31.16	1.75	1.19	39	0.933
fp7p1w2	0.833	31.16	1.75	1.19	39	0.933
fp8p1w2	1667	26.71	1.5	2.04	33	1.6
fp9p1w2	1667	26.71	1.5	2.04	33	1.6
fp10p1w2	1667	26.71	1.5	2.04	33	1.6

TABLE A4 Cost and revenue of tier 4 deciding on the distribution quantity Q_{fppr} (Moroccan Dirham/unit).

	Cost			Revenue		
	Environmental	Economic	Social	Environmental	Economic	Social
Description	The cost per item sold of the investment on solar energy	Global cost (production + distribution) per item	Cost per item of training provided for staff. It equals cost of training times percentage of consumed raw materials divided by sold quantities	The part of revenue (electricity bill + additional sales to customers who seek environmentally friendly product) per item sold	Selling price	The gain on reduced scrap per item sold
fp1p1r1	1.25	28.56	1.67	1.7	55	1333
fp2p1r1	1.25	28.56	1.67	1.7	55	1333
fp3p1r1	1.25	28.56	1.67	1.7	55	1333
fp4p1r1	1.25	28.56	1.67	1.7	55	1333
fp5p1r1	0.833	29.988	1.75	1.19	59	0.933
fp6p1r1	0.833	29.988	1.75	1.19	59	0.933
fp7p1r1	0.833	29.988	1.75	1.19	59	0.933
fp8p1r1	1667	25.704	1.5	2.04	49	1.6
fp9p1r1	1667	25.704	1.5	2.04	49	1.6
fp10p1r1	1667	25.704	1.5	2.04	49	1.6

TABLE A5 Cost and revenue of tier 5 deciding on the distribution quantity Q_{fpwr} (Moroccan Dirham/unit).

	Cost			Revenue		
Description	Environmental Use 3PL company for delivery instead of their own vehicles to minimise CO_2 emissions. Therefore, the distribution cost will increase from 2% to 4%	Economic Global cost (purchase cost + distribution cost) per item	Social For an additional social security	Environmental The gain on transportation fees per one item sold: 3% fees instead of 5%	Economic Selling price	Social When staff is motivated they double performance; therefore, the staff cost will decrease from 6% to 3%
fp1w1r1	0.7548	37.74	0.025	0.755	48	1.13
fp2w1r1	0.7548	37.74	0.025	0.755	48	1.13
fp3w1r1	0.7548	37.74	0.025	0.755	48	1.13
fp4w1r1	0.7548	37.74	0.025	0.755	48	1.13
fp5w1r1	0.7956	39.78	0.025	0.796	50	1.19
fp6w1r1	0.7956	39.78	0.025	0.796	50	1.19
fp7w1r1	0.7956	39.78	0.025	0.796	50	1.19
fp8w1r1	0.6732	33.66	0.025	0.673	43	1.01
fp9w1r1	0.6732	33.66	0.025	0.673	43	1.01
fp10w1r1	0.6732	33.66	0.025	0.673	43	1.01
fp1w2r1	0.7696	38.48	0.025	0.770	48	1.15
fp2w2r1	0.7696	38.48	0.025	0.770	48	1.15
fp3w2r1	0.7696	38.48	0.025	0.770	48	1.15
fp4w2r1	0.7696	38.48	0.025	0.770	48	1.15
fp5w2r1	0.8112	40.56	0.025	0.811	50	1.22
fp6w2r1	0.8112	40.56	0.025	0.811	50	1.22
fp7w2r1	0.8112	40.56	0.025	0.811	50	1.22
fp8w2r1	0.6864	34.32	0.025	0.686	43	1.03
fp9w2r1	0.6864	34.32	0.025	0.686	43	1.03
fp10w2r1	0.6864	34.32	0.025	0.686	43	1.03
fp1w1r2	0.7622	38.11	0.025	0.762	48	1.14
fp2w1r2	0.7622	38.11	0.025	0.762	48	1.14
fp3w1r2	0.7622	38.11	0.025	0.762	48	1.14
fp4w1r2	0.7622	38.11	0.025	0.762	48	1.14
fp5w1r2	0.8034	40.17	0.025	0.803	50	1.21
fp6w1r2	0.8034	40.17	0.025	0.803	50	1.21
fp7w1r2	0.8034	40.17	0.025	0.803	50	1.21
fp8w1r2	0.6798	33.99	0.025	0.680	43	1.02
fp9w1r2	0.6798	33.99	0.025	0.680	43	1.02
fp10w1r2	0.6798	33.99	0.025	0.680	43	1.02
fp1w2r2	0.777	38.85	0.025	0.777	48	1.17
fp2w2r2	0.777	38.85	0.025	0.777	48	1.17
fp3w2r2	0.777	38.85	0.025	0.777	48	1.17
fp4w2r2	0.777	38.85	0.025	0.777	48	1.17
fp5w2r2	0.819	40.95	0.025	0.819	50	1.23
fp6w2r2	0.819	40.95	0.025	0.819	50	1.23
fp7w2r2	0.819	40.95	0.025	0.819	50	1.23
fp8w2r2	0.693	34.65	0.025	0.693	43	1.04
fp9w2r2	0.693	34.65	0.025	0.693	43	1.04
fp10w2r2	0.693	34.65	0.025	0.693	43	1.04

TABLE A6 Cost and revenue of tier 6 deciding on the distribution quantity Q_{owr} (Moroccan Dirham/unit).

	Cost			Revenue		
	Environmental	Economic	Social	Environmental	Economic	Social
Description	Use 3PL company for delivery instead of their own vehicles to minimise CO_2 emissions. Therefore, the distribution cost will increase from 4% to 6%	The global purchase cost of one item sold (purchase price + distribution cost)	For an additional social security	The gain on transportation fees per one item sold: 3% fees instead of 5%	The selling price	When staff is motivated they double performance; therefore, the staff cost will decrease from 6% to 3%
o3w1r1	2.57	128.54	0.025	2571	150.00	3856
o3w1r2	2.55	127.31	0.025	2546	150.00	3819
o3w2r1	2.55	127.30	0.025	2546	150.00	3819
o3w2r2	2.52	126.07	0.025	2521	150.00	3782
o4w1r1	3.09	154.25	0.025	3085	180.00	4628
o4w1r2	3.06	152.77	0.025	3055	180.00	4583
o4w2r1	3.06	152.76	0.025	3055	180.00	4583
o4w2r2	3.03	151.29	0.025	3026	180.00	4539