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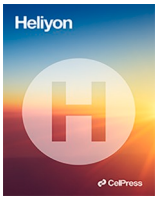

A comprehensive theoretical framework for sustainable network contracts: Contracting dimensions and Contract classification

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ABSTRACT

Disruptions in the supply chains/networks result in both performance failures and a poor return on investment (ROI) of network assets. We propose that addressing this situation requires the governance of exchange relationships through contracts guided by sustainability principles. Specifically, we refer to these contracts in the supply and distribution context as "sustainable network contracts", and the overall framework as the "sustainable contracting framework (SCF)/theory". Despite the critical role of sustainable network contracts for all key stakeholders in the network, we identify a gap in the existing literature regarding the theory of sustainable network contracts. We bridge this gap by extending the extant dimensions of contracts, as described in Transaction Cost Economics and Relational Exchange Theory, to include sustainability dimensions - constituting the 'what' of theory building. To inform sustainable contracts, we propose and employ three factors: costs, benefits, and risks (CBR). We present the 'how' of the theory building, outlined in a five-step approach along with an analytical tool, to demonstrate the practical application of our framework. Additionally, we provide a rationale for adopting sustainable network contracts (the 'why' of the theory building). Our research methodology involves collecting interview-based data from senior executives (CXOs) (secondary and primary), collecting primary and secondary cost data (objective), integrating behavioral elements (subjective), and employing constrained optimization techniques to determine quantity allocation under various contract policies. Further, we map the proposed eight distinct contract types onto the CBR-space, thereby highlight the relevance of the contract types to real-world practices. This mapping considers network externalities, risks, and allows for a coordinated sustainable approach to contracting from the buyer's (retailer's) perspective. For managers, our framework would serve as an important tool that would inform the contract evaluation process, facilitate local versus global decision-making, safeguard network investments, and help align the interests of buyers and suppliers in each contracting cycle.

1. Introduction

Common industry practice typically revolves around supplier selection and quantity allocation based solely on supplier-quoted prices and transportation costs. The total order quantity is divided among suppliers, and a standard purchase order contract is provided [1]. This price-focused and transactional approach neglects significant factors such as environmental and social considerations and constraints (Natural Resource-Based View - NRBV, [2]), disruption risks arising from potential future regulations and social boycotts, stock-outs

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resulting from such disruptions, and the risk of supplier failure. Even when the total cost of ownership is taken into account [3,4], the network coordinator (retailer) may not be able to anticipate supplier failures, leading to long-term unsustainability in the supply network.

This short-sighted contracting approach exposes the retailer's network investments and increases the vulnerability of suppliers to failure. For instance, retailers often invest significant amounts (often $100 M or more) in constructing efficient and automated distribution centers (DCs), stores, and establishing customer/supplier relationships [5]. Suppliers, in turn, must make reciprocal investments to meet stringent requirements for supporting DC automation. These investments are specific to particular suppliers (or a few suppliers) and are not easily transferable. The loss of such investments or poor performance of these assets necessitates evaluation. Additionally, research by Refs. [6][6,7] indicates that firms affected by supply chain disruptions experience 33–40 % lower stock returns, leading to prolonged recovery periods and reduced investor confidence. Furthermore, poor social and labor practices can result in the erosion of brand equity, impacting financial performance [8,9] and posing input factor risks [10] for both retailers and suppliers. For example, Nike's poor labour practices earned the company a bad reputation and it was forced (by a wide set of stakeholders) to improve it contract manufacturing practices[1] (sustainable wages, safety at work, health issues, excessive work hours, etc.). This case illustrates how the network coordinator cannot absolve itself of unsustainable practices in its supply network and must actively pursue sustainability principles. Similarly, PepsiCo's[2] manufacturing practices (at its contract supplier) in India came under criticism forcing them to stop manufacturing in Kerala, India. New government regulations in a global context can also expose retailers to supply disruption risks. Moreover, retailers are increasingly offering private label brands [11] and facing mounting pressure from customers to provide sustainable products and manage supply chains based on sustainability principles.[3] Key manufacturers and retailers (who act as network coordinators) are responding to stakeholder pressure to make their supply networks sustainable. For example, as indicated by scholars [12,13] global firms and CEOs[4] are increasingly considering sustainability principles in managing supply chains, "… firms such as Alcoa, PepsiCo, General Electric, Ford Motor Company, Nike, Exelon, PG&E, Starbuck's, Johnson & Johnson and Walmart are implementing sustainable practices in their supply chains.". This trend emphasizes the importance of brand creation and management for retailers, as well as a closer collaboration [14] with manufacturers/suppliers for supply chain and operations improvement. Thus, in manufacturing[5] (industrial and consumer goods), retail, fashion (clothing, shoes, etc.), food (agriculture and food processing), etc. we find evidence that sustainability principles are being considered in contracts. Therefore, ensuring sustainable buyer-supplier relationships is becoming even more critical for retailers. Consequently, supply chain risk and the application of sustainability principles are gaining recognition as significant elements in the design, analysis, and management of supply chains in both academia and practice.

From a contracting theory perspective, the literature has predominantly focused on dyadic relationships when hypothesizing and testing transactional contracts driven by Transaction Cost Economics (TCE) [15,16] or relational contracts driven by Relational Contracting Theory [17,18]. Consequently, not only is a network perspective lacking, but also the inclusion of a broader set of stakeholders (both human and non-human) to ensure the consideration of sustainability principles is absent. However, more recently, there has been an increased focus on analyzing networks to understand the structure of network relationships (Social Network Analysis, [19]) and how decision-making evolves within networks (Actor Network Theory, [20,21]).

Furthermore, from the perspective of the theory of the firm, the "firm as a nexus of contracts" perspective and network influence theory are relevant as they emphasize the network of relationships [22] in which a firm is embedded, moving beyond a purely dyadic relationship. Similarly, stakeholder theory expands the focus beyond shareholders but falls short in considering a wider range of affected stakeholders (both human and non-human), thereby missing out on the consideration of sustainability principles. While these theories offer valuable insights by considering important dimensions of contracting, they do not present an integrated perspective on how sustainable supply/distribution networks can be coordinated.

[1] 1) In a May 1998 speech to the National Press Club, a humbled Knight (then Nike's CEO) admitted that "the Nike product has become synonymous with slave wages, forced overtime, and arbitrary abuse." Spar, D. L. (2000) "Hitting the wall: Nike and international labor practices"[Case study]. Boston: Harvard Business School.; 2) Ballinger, J., & Olsson, C. (Eds.). (1997). "Behind the swoosh: The struggle of Indonesians making Nike shoes". Uppsala, Sweden: Global Publications Foundation.

[2] After Coca-Cola, now PepsiCo has decided to take an exit route from Kerala due to labour issues with its franchise Varun Beverages Ltd approaching Labour Department with a mandatory closure notice. "M/s Varun Beverages Ltd manufacturing carbonated soft drinks and packaged drinking water, is intended to be closed down under section 25-O of the Industrial dispute Act 1947 (Act 14 of 1947) and necessary application is filed to the Government, of Kerala on 22.09.2020 …,"; Mint (news media) https://www.livemint.com/companies/news/after-coca-cola-pepsico-to-shut-kerala-s-manufacturing-unit-due-to-protests-11601002786471.html.

[3] 1. https://blog.axdraft.com/contract-management/how-contract-management-helps-your-business-go-green/;2. https://www.eticanews.it/wp-content/uploads/2018/07/ecovadis_contrat_clauses_RSE_20.06.2018_eng_v5-1.pdf3 https://www.worldcc.foundation/About-us/Our-Vision.

[4] 1.) R. Alves, L. Rogge, G. Seinberg, S.Dutta, C. Mork, 2022, "Building supply chain sustainability that can drive revenues and reduce operational risks 2022″, Ernst and Young report on survey of 525 industry executives; 2.) "Deloitte 2023 CxO Sustainability Report", Jennifer Steinmann, Deloitte Global Sustainability & Climate Practice Leader; report based on interview of 2046 CXOs; 3.) J. Henrich, J. D. Li, C. Mazuera, and F. Perez, 2022, "Future-proofing the supply chain." McKinsey and Co.

[5] GE Sustainability Charter identifies how supplier contracts need to be managed: 1) "GE's Suppliers and Contractors shall integrate environmental, health and safety criteria into the development of their products and services in order to eliminate or mitigate negative environmental, health and safety impacts from their products during their total life cycle, while maintaining and/or improving the quality of usage of their products." 2) "GE's Suppliers and Contractors shall adopt a proactive attitude to health and safety issues. Risks linked to their activity shall be identified, evaluated and either eliminated or mitigated."chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.ge.com/renewableenergy/sites/default/files/2022-01/QME11-%20Sustainable%20sourcing%20charter%20-%20Rev%201.0.pdf.

In our study, we adopt a sustainable network perspective of a firm and extend existing contracting theories to provide a more comprehensive, network-oriented theory of sustainable contracting. By incorporating sustainability principles [23,43,24,25,26,27] that form the basis for sustainable supply chain management,[6] we aim to address the gap in the literature. Our theoretical framework enables us to identify the need for addressing both the managerial (subjective) and analytical (objective) aspects involved in sustainable contracting.

Several scholars, including the World Commission on Environment and Development report [28,29,27], have provided specific definitions of sustainability in the context of supply/distribution networks. Furthermore, a more recent perspective called "Ecologically Dominant Logic" [26] has emerged, which prioritizes the environmental health of the planet and the social well-being of society over economic profit, contrasting with the earlier "instrumental logic" that prioritizes economic profit. Drawing from these perspectives on sustainability, we highlight three key features of a forward-looking, sustainable firm:

a) While initially aiming for long-term economic survivability while considering environmental and social dimensions (referred to as the "instrumental logic"), the firm needs to transition towards an "Ecologically Dominant Logic" orientation (Environment first, then Social well-being, and then Economic profits) within a reasonable time frame. b) In this future state, the firm must coordinate its network of entities to ensure adherence to sustainability principles throughout the network. c) The entities within the network are interconnected through sustainability-enabling contracts that embody the features mentioned in a) and b) above. In summary, our focus is on presenting a contracting framework that enables the feasibility of sustainable supply networks (refer to Figure A1 in Appendix A).

Following [26], from a theory-building perspective, we describe the *what*[7](is different) in our proposed work in Table 1 and Table 2a where we describe the limitations of current theories (TCE and Relational exchange theories) and propose additional dimensions (factors that are important-that are important- [30]) for ensuring a sustainable network contracts framework. Further we propose to extend the current notion of the firm (Network theory of stakeholder influence) by that the definition of stakeholders must include human and non-human entities that are directly or indirectly affected/connected to the firm. The *how* (is it better/different) is addressed through Fig. 1 (where we identify 4-features that help implement the theory), and Table 2a which describes how the proposed framework addresses key concerns (the *'what's'*) in contract theory. Further in Fig. 3 and Table 2b we indicate the supplier engagement framework/analytical model and how it would help make the network sustainable, i.e., address the identified factors by influencing the network suppliers. Table 3 also helps us understand how the theory links to the dimensions of TCE. Further, we identify an underlying mechanism (Fig. 2) that explains *why*[8] of the theory or the underlying psychological or sociological phenomenon due to which the network coordinator would be able to influence the suppliers/other entities in the network and achieve the goal of making the contracts sustainable.

In this research paper, we aim to address the following research questions: 1) How can existing contracting theories be extended to incorporate sustainability dimensions, enabling them to inform sustainable network contracts? 2) What factors can be employed to effectively manage sustainable network contracts? 3. How can the trade-offs between the proposed factors (costs, benefits, and risks) be evaluated to classify different types of contracts? 4) How can the proposed theoretical framework for a sustainable network contracting approach be implemented? (Note: This question is intended to provide an outline or overview of the implementation process.)

By exploring these research questions, we aim to contribute to the understanding and development of sustainable network contracts, extending existing contracting theories to encompass sustainability dimensions. We will examine the factors relevant to managing such contracts, evaluate the trade-offs between these factors to classify different contract types, and provide a preliminary outline of how the proposed theoretical framework can be implemented in practice.

We describe the conceptual framework for a sustainability-oriented supply chain network in Figure A1 and the five-step process in Fig. 3 that summarizes key steps involved in the operationalization of the framework and helps employ the three factors to manage sustainable contracts. The three factors for developing the framework include: a) product unit cost, a measure of product complexity; b) benefit, a measure of the importance of the product/service provided by the supplier for the buyer; and c) risk, a measure of supplier inability to provide the promised benefits to the buyer at the specified cost. We first develop (step 2, Fig. 3) and illustrate an approach for assessing cost-based quantity allocation (from a given portfolio of products and a set of suppliers) and the resulting loss potential at the network level. The approach would be considered sufficient for predominantly transactional contracts. But, to evaluate more complex situations, as in the case of higher benefits, costs, and risks, we further develop and illustrate (steps 2 and 3 jointly, Fig. 3) an approach to include supplier risk and retail-manager behavior in the analysis. This more detailed approach, helps inform strategic supplier relationships for transactional and relational contracts. The five-step model allows for updating the contract parameters at the end of each review period. We note that sustainability-related costs, benefits, and risks are considered in the above analysis and the

[6] "Sustainable practices—whether in supply chain management or any other business activity—are a function of two conjoined principles: (1) they must enhance ecological health, follow ethical standards to further social justice, and improve economic vitality; and (2) they must be prioritized whereby the environment comes first, society second, and economics third. This paradigm shift advocates a transition toward a more proactive stance of resource co-creation (rather than "just" conservation) and a prioritization matrix that places the environment front and center, ahead of society and economics."

[7] "Which factors (variables, constructs, concepts) logically should be considered as part of the explanation of the social or individual phenomena of interest? Two criteria exist for judging the extent to which we have included the "right" factors: comprehensiveness (i.e., are all relevant factors included?)" Whetten 1989.

[8] "What are the underlying psychological, economic, or social dynamics that justify the selection of factors and the proposed causal relationships? This rationale constitutes the theory's assumptions—the theoretical glue that welds the model together" Whetten 1989.

Table 1a
Key theoretical perspectives on dyadic contracting.

S. No.	Concept	Reference	Comments	Contracts perspective - advantages and limitations
1	a) Homo-economicus' -Self-interested, independent goals, and utility maximizing behaviour b) New institutional economics perspective	a) Adam Smith 1776 b) Williamson 1975, 1981 c) Schneider 1974	1. Firm needs to invest in stakeholders (in relationships with those who have stake in the firm) 2. Investors are not the only stakeholders 3. The approach identifies specific stakeholders who directly engage with the firm (Johnson et al., 2005; Mitchell et al., 1997).	1. Transaction cost Economics - takes perspective of self-interested actors (agents) who are opportunistic and managers (owners) who have bounded rationality* 2. TCE identifies three dimensions a. Asset specificity (safeguarding problem), b. Behavioural uncertainty (performance evaluation problem), c. Environment uncertainty (Adaption problem)* 3. While the theory is helpful in transactional contracts analysis (dyadic relationships)- but leaves human relational aspects 4. Sustainability principles, a wider stakeholder perspective, or network perspective is missing
1a.	The notion is considered: 'Under socialized concept of man'	a) Baker 1983 b) Granovetter 1985 c) Coleman 1988	a) Even in highly rationalized markets (Chicago Options Exchange), "relations are maintained and affect trade" b) Institutional economics is criticised as "crudely functionalist" - as the function of an institution is assumed to defined only by the function it performs	Scholars point to the limited perspective of 'rational individual' acting with 'profit motives' (single dimension) perspective
2	**Notion of 'Embeddedness'**	**a) Granovetter 1985** **b) Mcaulay 1963** **c) Lohr 1982**	**a) Isolating economics from interfirm exchange behaviour is not realistic** **b) Over time trust-building is likely and important for interfirm relationships** **c) Recourse to legal options destroys future exchange relationships** **d) Japanese business stress relationship building - transactions are clearly embedded in relationships (a competitive advantage)**	**1.While the notion of embeddedness provides us with basis for social networks in which firms are embedded.** **2. Network of other actors (suppliers, customers, employees, etc. and non-human actors) could also be considered by extending this notion.** **3.The notion is a fundamental element of sustainability principles and sustainable contracts, but a direct link to sustainable contracts is not made.**
3	**Notion of 'Social capital': SC**	**a) Coleman 1988; 1990** **b) Nahapiet and Ghoshal 1998**	**a) Function - the value of social structures that could be leveraged** **b) Environmental trustworthiness is important to ensure social capital** **c) Effective norms could serve as social capital**	**1. From sustainable constricts perspective, a network coordinator could build social capital that would help create legitimacy and influence which would be critical to implementing sustainable contracts*** **2. A direct link to sustainable network contracts is not made**
4	**Notion of 'Relational exchange': RE**	**a) Mcneil 1978, 1980** **b) Dwyer, Shurr, Oh 1987**	**a) Relationship more important than the transaction** **b) Transaction is seen embedded in exchange relationship**	**1. RE perspective is critical so sustainable contracts, though a direct link to sustainable contracts in networks is not made - development/testing limited to dyadic relationships.** **2. Sustainability principles require linking with wide spectrum of stakeholders who may not appear to be directly connected to the transaction.** **3. Helps reduce transaction costs***
5	**The commitment-trust theory: CTT**	**a) Morgan and Hunt 1994** **b) Moorman, Zaltman, Deshpande 1992** **c) Moorman, Deshpande, Zaltman 1993**	**a) Trust influences relational exchange (Speckman 1979); it influences relationship commitment** **b) Trust as defined highlights the importance of confidence on part of the trusting party (Rotter 1967)** **c) Relationship cost and benefits affect commitment; shared values directly influence trust and commitment; communication and opportunistic behaviour**	**1. While CTT assumes trust and commitment develop over time, it is essential for strategic relationship and for sustainable relationships (long-term and productive relationships)** **2. Essential even for short-term contracts;** **3. Theory development/testing generally limited to dyadic relationships and sustainable network contracts are not discussed.**
6	**Notion of 'Shared values': SV**	**a) Morgan and Hunt 1994** **b) Dwyer, Schurr, Oh 1987 (p. 21)** **c) Moorman, Deshpande, Zaltman 1993**	**a) Takes time to build relationship between firms and develop shared norms** **b) Typically developed between partners that have close relationship**	**1. SV and related norms take time to develop; development/testing limited to dyadic relationships.** **2. Shared norms related to sustainability principles would be essential to sustainable network contracts and would support such efforts.**

Table 1b
Key theoretical perspectives on networks and stakeholder linked to contracting.

S. No.	Concept	Reference	Comments	Contracts perspective - advantages and limitations
7	**Stakeholder approach/ Stakeholder Theory**	**Freeman and Evan 1990, 2004; Brenner 1993**	**1. Firm needs to invest in stakeholders (in relationships with those who have stake in the firm) 2. Investors are not the only stakeholders 3. The approach identifies specific stakeholders who directly engage with the firm (Johnson et al., 2005; Mitchell et al., 1997).**	**1. Development/testing limited to dyadic relationships 2. A wider set of stakeholders who are affected may be neglected; non-human actors are not considered (Luoma-aho & Paloviita, 2010). 3. Interaction between stakeholders is neglected (Beritelli, 2011) 4. More recent advances in the theory advocate consideration of wider set of stakeholders (Ellis & Sheridan, 2014)**
8	**Social Network Analysis (SNA) and Actor Network Theory (ANT)**	**Otte and Rousseau, 2002 Van der Duim, 2007 Vicsek, Kiraly, & Konya, 2016**	**1. Social Network Analysis (SNA): "a strategy for investigating social structures" (Otte and Rousseau, 2002) 2. Actor Network Theory (ANT): focused on the process of how network stakeholders (human and non-human) affect each other (Vicsek, Kiraly, & Konya, 2016) 3. ANT theory: networks evolve led by a focal actor a. identifying a problem, b. convincing and then c. enrolling others to associate/identify with it, d. mobilizing the network to achieve a goal (Ren, 2010; Van der Duim, 2007). 4. Power, legitimacy, urgency, and proximity may be used to analyze a network**	**SNA 1. Neglects the evolution and dynamics of networks (Albrecht, 2013). 2. Actors are not required to work together for a common or a higher goal; sustainable network contracts would require influencing stakeholders to ensure common goals are met. 3. While SNA concepts help understand networks, the theory is not specifically designed to address sustainable network contracts. ANT: 1. Helpful in understanding process of building influence in a network 2. But does not help identify influential actors 3. Does not help identify how to choose a direction of action is not clear (Van der Duim et al., 2017) 4. In case of sustainable network contracts, a known actor coordinates the network to achieve economic, social, and environmental goals using influence and incentives.**
9	**Network theory of stakeholder influence**	**Timothy Rowley 1997**	**1. Considers social network (SN) theory and influence 3. Considers multiple dyadic interactions 4. Considers stakeholder approach and goes beyond it (Scott 1992; Nohria 1992) 5. Considers how a firm could control other connected entities through control of resources (Pfeffer and Salancik, 1978) and how the environment affects the firm (DiMaggio and Powell, 1983).**	**1 Does not concern itself with a wide set of stakeholders 2. Sustainable network contracts requires longer-term orientation and commitment to sustainability principles. 3. Influence is less through control of resources but more through commitment to shared and higher goals.**
10	**CSR - Company social responsibility TBL - Tripple bottom line (social, economic, and environmental)**	**Chernev and Blair 2015; Homburg, Stierl, and Bornemann 2013 Carter and Rogers 2008**	**1) Largely focused on impact of CSR on customers or firm value 2) Impact of CSR on B2B exchange relationship - not well studied 3) TBL perspective requires that all the three factors be given due importance.**	**1. CSR actions are focused on social goals and the impact on economics may be secondary, though responsible CSR would ensure economic success as well; does not directly concern itself with sustainable network contracts (a means to ensuring sustainability principles are implemented)**
	Sustainable network contracts theory [our proposed framework]	**We refer to key contributions of other scholars in #1 to #10 above Taylor and Todd (1995) Carter and Rogers (2008)**	**1. We leverage Network theory of stakeholder influence (#9 above) and Stakeholder Theory (#7 above) and the principles of sustainability to propose Sustainable network contracts theory 2. We leverage Actor network theory and TAM-PBT (Taylor and Todd 1995) to propose a mechanism (Fig. 2) of how a network coordinator could influence the network to implement sustainable network contracts**	**1. We consider sustainability principles as the basis for our proposed contracting theory - the consideration of a wider set of stakeholders have not been the focus of current contracting frameworks/theories. 2. Unlike Network theory of influence, we show how a network coordinator could influence other stakeholders (suppliers, customers, etc.) to ensure sustainability goals are met and improved upon continuously (Fig. 3 is very helpful in this regard).**

(*continued on next page*)

Table 1b (*continued*)

S. No.	Concept	Reference	Comments	Contracts perspective - advantages and limitations
11			**3. We identify how the proposed theory addresses TCE-based (Table 1) dimensions (safeguarding, evaluation, and adaptation problems) and assumptions on human behavior (bounded rationality and opportunism) - Table 2b; we illustrate how the proposed theory addressed these concerns (Table 2b)**	**3. We also show that while sustainability principles form the basis for our theory, a focus on three factors is needed to ensure long-term and productive buyer-supplier relationships (Table 2b and Fig. 4).**
			4. Based on the literature, we identify four features (Fig. 1) that are then leveraged to propose a framework (Fig. 3) for implementation of the sustainable network contracts theory and an analytical approach for implementing the proposed theory.	**4. We show how our theory is amenable to practical implementation through a 5-step supplier engagement framework (strategic management orientation) - Fig. 3 and it implementation (as illustrated in the E-component) using an optimization-based analytical approach.**
			5. Based on the sustainable network contracting theory, we make eight propositions (Fig. 4) and specify how each type of contract is different from other (Table 3)	**5. We show how our proposed theory addresses the contracting concerns raised by TCE and scholars who proposed Relational exchange theory (Tables 2b and 3)**

Table 1
Summary of key contracting dimensions and issues that guide our framework design.

	Key Contracting Dimensions	Problems	Problem Description
1	**Uncertainty**		
a	**Internal**	**Evaluation**	**Retailer finds it costly or is unable to evaluate or monitor supplier processes; buyer/supplier both face bounded rationality**
b	**External**	**Adaptation**	**Supplier unwilling to adapt to new situation; buyer/supplier both face bounded rationality**
2	**Specific investments**		
		Safeguarding	**Supplier acts opportunistically (misallocating assets)**
3	**Relationships**		
a	**History of relationship**	**Scope limitation**	**Historical inefficiencies in processes/products could limit the potential outcomes in the relationship**
b	**Future interest of a partner**	**Expectation of future business**	**There is an expectation that the other partner would continue the relationship in future**
4	**Stakeholder interests**		
a	**Social**	**Negligence of community interests**	**A partner neglects the interests of employee, community, customers, future generations, non-human actors, i.e., the network of stakholders**
b	**Economic**	**Negligence of shareholder interests**	**A partner neglects the interests of investors**
c	**Environmental**	**Negligence of environmental interests**	**A partner neglects the environmental aspects/needs or health of the planet**

incentives to promote a sustainable network are included. The above evaluation helps chart and manage various contracts in the cost-benefit-risk space (Fig. 4). We interviewed senior managers in the retail industry to obtain their perspective on our propositions and employed their feedback to improve our presentation.

Thus, our work contributes to theory and practice in the following ways: a) we extend the current contracting theory framework (Transaction cost economics that deals with transactional contract and relational exchange theory that deals with relational contracts) to include sustainability dimensions (Table 1 and 2a, 2b. and 3), thus contributing to contracting (operations/supply chain strategy) literature; b) we illustrate the proposed theoretical framework (sustainable network contracting framework), based on prior theories (Fig. 1), define four-features that drive the five-step framework for network management; c) we propose an underlying mechanism (Fig. 2) that would help understand how the retailer could influence the supplier (or other network entities) to ensure sustainable network contracts are implemented; d) we illustrate how the five-step process informs sustainable supplier engagement and management practices; e) we illustrate how the five-step process is linked to a tractable analytical approach to operationalizing the theory using the three factors (cost-benefit-risk), supplier and retailer subjective parameters, mixed-integer programming optimization, and contracting policies f) we illustrate the approach using secondary data and how it could be employed to classify contracts; and g) we describe how the three factors could be employed for choosing appropriate contracts by practicing managers to ensure sustainable contracting framework is implemented.

Table 2a
Depiction of how proposed framework address contracting problems.

	Key Contracting Dimensions	Approaches to solution		
		Transaction cost economics (largely dyadic)	Relational Contracting (largely dyadic)	Sustainable Network Contracts Framework
1	**Uncertainty**			
a	**Internal**	**Screening/Monitoring**	**Relies on shared norms**	**Screening/joint action and risk/task distribution in the network**
b	**External**	**Renegotiation/Legal action**	**Relies on relational norms**	**Joint-action/appropriate stakeholder involvement/periodic review to facilitate adaptation dynamically**
2	**Specific investments**			
		Penalty/legal action	**Relies on social sanctions**	**Applying appropriate safeguarding tools/evaluating results/periodic review/joint-action plans/rebalancing network resource deployment and order allocation**
3	**Relationships**			
a	**History of relationship**	**Does not address**	**Relies on partner abilities**	**Provides a mechanism to leverage supplier's/distributor's accumulated/current abilities to identify sustainable network solutions**
b	**Future interest of a partner**	**Does not address**	**Relies on relational norms**	**Considering relationship 'minimum' and building flexibility, future capability, and capacity in the network to ensure productive and sustainable network relationships/solutions**
4	**Stakeholder interests**			
a	**Social**	**Does not address**	**Does not address explicitly**	**Social stakeholders considered through network approach, addressing social constraints and goals; behaviour of actors in value chain addressed through incentives and feedback loop (training, joint-action, investments, etc.)**
b	**Economic**	**Does not address**	**Relies on relational norms**	**Economic goals considered through evaluation of capacity and capability of actors in the network (resource and capability constraints); behaviour of actors in value chain addressed through incentives and feedback loop (training, joint-action, investments, appropriate technology consideration, etc.)**
c	**Environmental**	**Does not address**	**Does not address explicitly**	**Environmental stakeholders considered through network approach, addressing environmental and goals; behaviour of actors in value chain addressed through incentives and feedback loop (training, joint-action, investments, etc.)**

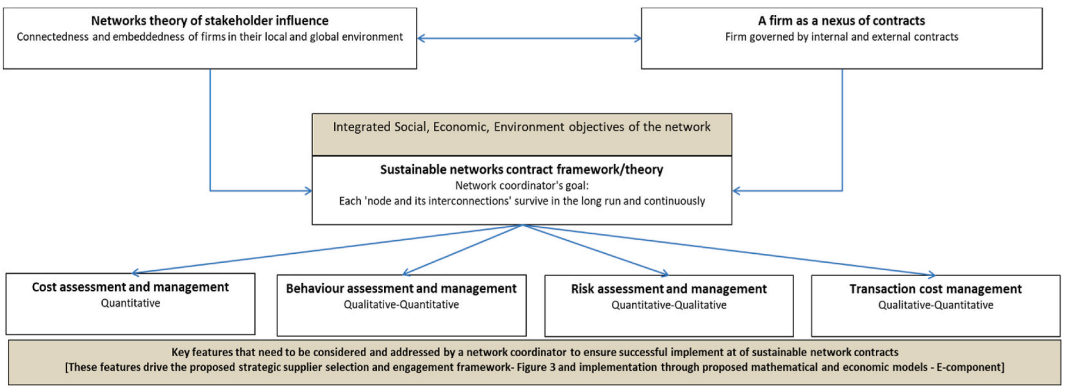


Fig. 1. Key features that need to be considered for implementation of sustainable network contracts.

The rest of the paper is organized as follows. We first present a review of relevant literature. We then briefly review the contracting theories and identify the gap in the extant literature. We also discuss how our three-factor-driven framework addresses this gap. We provide a brief description of data on how the data is collected for three-factor-based analysis. We then review the five-step process (a managerial tool and high-level guideline) for continuity. Next, we briefly describe Step 2 and Step 3 (for continuity) and the nature of the results. We finally discuss the mapping of different types of contracts on the three-factor space and the managerial implications.

Table 2b
Depiction of how Fig. 3 (implementation) address key dimensions of sustainable network contracting framework/theory.

Safeguarding problem	Performance evaluation problem	Adaptaton problem
Step-1: **1. Address adverse selection issue**	**Step-1:** **1. Assess BU (behavioural uncertainty) sources**	**Step-1:** **1. Assess EU (Environmental uncertainty) sources**
Step-2-3: Address moral hazard through incentives/ penalties, allocating appropriate quantities in the network	**Step-2 and Step-3:** **Employ cost, benefit, and risk information to 1. Assess situation** **2. Allocate order quantity**	**Step-2 and Step-3:** **1. Employ cost, benefit, and risk information to learn/adapt to new situaton** **2. Allocate order quantity**
Step-4: **2. Assess asset misallocation issue**	**Step-4:** **1. Employ cost, benefit, risk information to assess performance** **2. Employ contracted incentives to assess real costs**	**Step-4:** **1. Confirm EU incidence** **2. Employ cost, benefit, risk information to assess performance** **3. Employ contracted incentives to assess real costs**
Step-5: **1. Buyer-supplier share learning experience** **2. Address asset misallocation issue, if any**	**Step-5:** **1. Buyer-supplier share learning experience** **2. Jointly address BU incidence** **3. Negotiate new incentives to align performance (employ balanced score-card)**	**Step-5:** **1. Buyer-supplier share learning experience** **2. Jointly address EU incidence** **3. Negotiate new incentives to align performance (employ balanced score-card)**
Two assumptions on human behavior (TCA)		
Assumptions	**How the 5-step processes addresses these issues**	
Bounded rationality (BR)	**Step-1, step-2, and step-3 generate and analyze information to address BR**	
Opportunism (OP)	**Step-1 helps generate inputs to assess OP; Steps 2&3 help address OP through incentives; Step-4 helps confirm incidences of OP; Step-5 helps share information and close the loop; Stakeholder approach in Steps 1–5 reduces OP**	

2. Literature review

The literature on sustainable supply chain contracts is interdisciplinary by nature. While we find contributions in specific areas related to sustainable supply chain and contracting, to the best of our knowledge, we find few articles addressing an integrated approach to sustainable supply-chain contracting. For example, authors [31,32–34] have proposed that sustainability would reduce long-term risks,[9] but do not integrate contract theory elements and thus do not inform us regarding how sustainable supply chains could be operationalized. We review the literature to address the interdisciplinary nature of the topic. Thus, we review four key topics: a) sustainability theory, b) incomplete contracts, c) strategic supplier selection, and d) supply chain risk management.

2.1. Sustainability: natural resource-based view (NRBV), stakeholder theory, and company social responsibility (CSR) review

The NRBV [2] highlights that gaining sustained competitive advantage [35–37], by control of valuable and difficult-to-copy production factors, must be linked to the constraints placed by its physical and social environment. Several authors point to the serious omission of these constraints [[38,39,40]] by the resource-based view (RBV [41,42]: may have led to a lop-sided focus on profits that causes irrevocable stress on the natural environment [43]. NRBV stresses sustainable development [2,44] but does not discuss the implications of ownership structure or a firm's links to other firms. Stakeholder theory and contract theories specifically address these issues.

Stakeholder theory [45,4] and the contrast between the shareholder and the stakeholder views have influenced research on intra-organization issues. It is now established that the shareholder view (in isolation) offers a woefully incomplete picture. There have been efforts to integrate stakeholder theory with the two fundamental theories of the firm: agency theory [46,47] and the firm-as-a-nexus-of-contracts [48,49,4,50,51]. The stakeholder theory was further developed to include the embeddedness (the notion of connectedness of the firm) of the firm [22]. But we find that the consideration of stakeholders assumed is limited to entities that are directly affected by or affect the firm [52]. Thus, considering the notion of sustainability, this stakeholder perspective is narrowly defined. Brundtland Commission WCED (World Commission on Environment and Development) helped define sustainable development [27]: "development that meets the needs of the present without compromising the ability of the future generations to meet their needs." Society and firms now largely agree on the key characteristics of CSR [23,53,54] and the perspective provides a higher goal to a firm (instead of a single-dimensional [economics-only] approach which is exploitative in nature for all stakeholders involved). Such a higher goal (s), when reflected in the vision and mission statements [55] of a firm and properly communicated [56] through words and actions, serve (s) to motivate its employees/internal stakeholders (e.g., Ref. [57]) and external stakeholders (suppliers, customers,

[9] Shrivastava (1995a) define risk as: "the potential for reducing long-term risks associated with resource depletion, fluctuations in energy costs, product liabilities, and pollution and waste management".

Table 3
Description different type of contracts (as illustrated in Fig. 4).

Quadrant (Q) No.	Type of contract	Buyer-supplier relationship	Description
1	**Market contract**	**"Spot"/minimal contact**	**Buyer buys from market; minimal contracting is involved; since market mechanism has limitations, sustainability principles need to be applied by the buyerto ensure stakeholders concerns are addressed (concerned customers, suppliers, environmental footprints of products etc.).**
2	**Transactional contracts-R**	**Specific transaction focused - focus on risk reduction**	**Buyer buys from multiple suppliers; relationship is assumed to be discrete, but risk in the network needs to be assessed/addressed. Sustainability principles and stakeholder concerns must be addressed.**
3	**Transactional contracts-C**	**Specific transaction focused - focus on cost/ complexity reduction**	**Buyer buys from multiple suppliers; relationship is assumed to be discrete, but suppliers in the network need to be chosen with thorough cost (total cost, design, processes) evaluation. Sustainability principles and stakeholder concerns must be addressed.**
4	**Transaction-oriented strategic contracts - CR**	**Strategic focus -focus on fewer suppliers may be needed**	**Buyer may buy from a fewer pre-selected suppliers - strategic suppliers; relationship is assumed to be discrete; but due to higher risk and cost (design complexity) tougher selection and more frequent/ closer monitoring would be necessary. Sustainability principles and stakeholder concerns must be addressed.**
5	**Transaction oriented contract -CRB, with shared norms**	**Strategic focus -focus on fewer suppliers is needed**	**Buyer buys from a few pre-selected suppliers; relationship needs to be strategic but may be transaction-oriented. Shared norms ensure higher mutual understand, trust, and commitment levels. Sustainability principles and stakeholder concerns must be addressed.**
6	**Relational focus - RB**	**Strategic and relational focus - focus on few supplier benefits and individual supplier/network risk**	**Buyer engages with strategic supplier only; Deeper study of benefits offered by supplier and risks/risk mitigation is needed; higher levels of trust/ commitment is needed; Transaction itself is not the focus of relationship. Higher commitment to implementing sustainability principles and stakeholder (a wider set) concerns is needed.**
7	**Relational focus - CB**	**Strategic and relational focus - few suppliers need to be the focus; close engagement to ensure supplier benefits and cost/complexity is well addressed**	**Buyer engages with strategic supplier only; Deeper study of benefits offered by supplier and cost/ complexity mitigation is needed; higher levels of trust/commitment is needed; Transaction itself is not the focus of relationship. Higher commitment to implementing sustainability principles and stakeholder (a wider set) concerns is needed.**
8	**Relational focus - RCB or partial vertical integration (VI)**	**Strategic and relational focus - few suppliers need to be the focus; close engagement to ensure supplier risks, benefits and cost/complexity is well addressed**	**Buyer engages with strategic supplier only; Deeper study of benefits offered by supplier, risk involved and cost/complexity mitigation is needed; higher levels of trust/commitment is needed; Transaction itself is not the focus of relationship. Higher commitment to implementing sustainability principles and stakeholder (a wider set) concerns is needed.**

Notes.
1. Q2 (quadrant 1, Fig. 2) to Q8 all require some form of joint action (Step 1, Fig. 1).
2. Q2-Q4 relate to Step 2 and Q5-Q8 relate to Step 3 in Fig. 1.

investors, etc.) alike [58]. This view also is reflected in the operations and supply chain literature [31,54]. In sustainable supply chain literature [25], point to the cooperation between partner firms and the risk in the supply chain as an important part of sustainable supply chain management. We focus on the triple bottom line (TBL), i.e., social, economic, and environmental aspects (instead of 'economics only' perspective) of the buyer-supplier relationship [23,25], and also consider risk (inability to achieve cost and benefit targets promised) as a part of the three-factor model. Sustainability principles offer an opportunity for innovations (which are based on an integrated perspective) and contributions to production, design, and buyer-supplier relationships (to mention a few) areas. The innovations could help firms differentiate their products in the marketplace [28,29]. Strategic buyer-supplier relationships (establishment and maintenance/dissolution), periodic reviews (ongoing performance, relationship health, changes in tactics, if needed), and potential externalities (imposed by a party) are important features of sustainable contracts. Moreover, concepts such as CSR

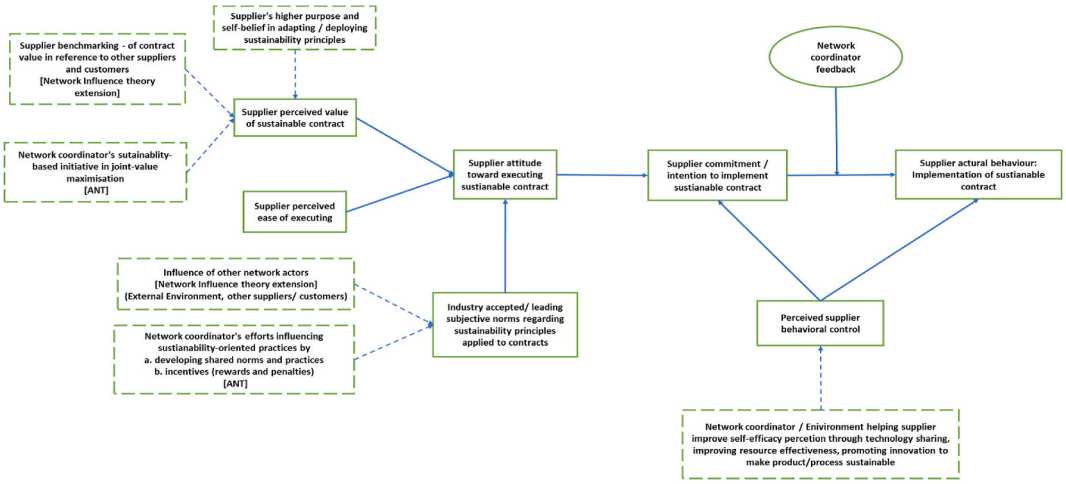
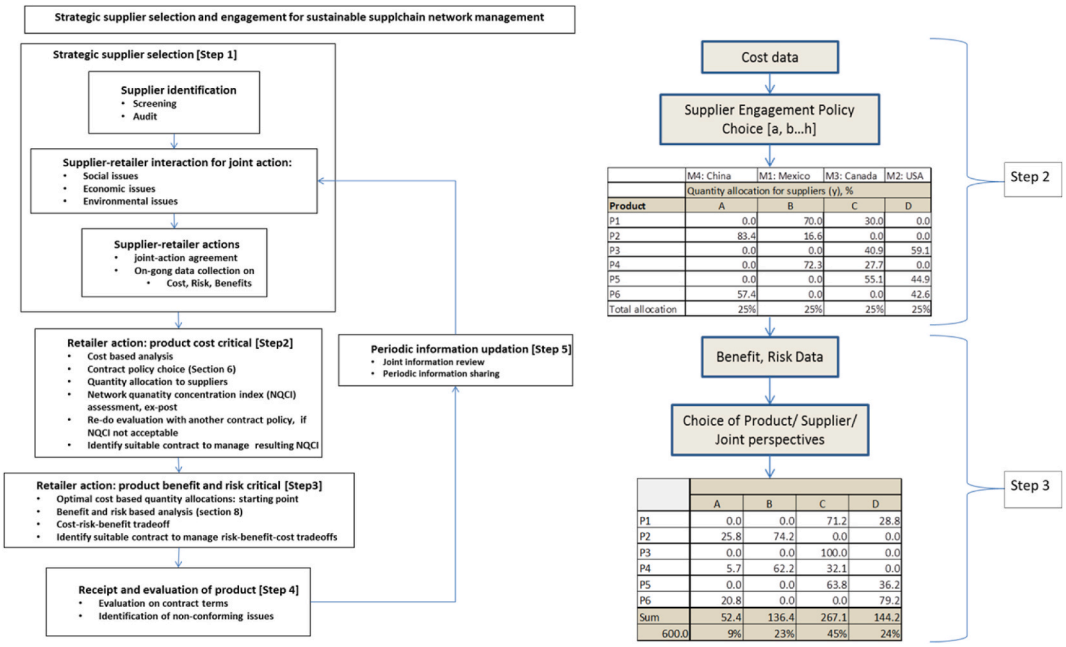


Fig. 2. Proposed mechanism of supplier influence for implementing sustainable network contracts.



	M4: China	M1: Mexico	M3: Canada	M2: USA
	Quantity allocation for suppliers (y), %			
Product	A	B	C	D
P1	0.0	70.0	30.0	0.0
P2	83.4	16.6	0.0	0.0
P3	0.0	0.0	40.9	59.1
P4	0.0	72.3	27.7	0.0
P5	0.0	0.0	55.1	44.9
P6	57.4	0.0	0.0	42.6
Total allocation	25%	25%	25%	25%

	A	B	C	D
P1	0.0	0.0	71.2	28.8
P2	25.8	74.2	0.0	0.0
P3	0.0	0.0	100.0	0.0
P4	5.7	62.2	32.1	0.0
P5	0.0	0.0	63.8	36.2
P6	20.8	0.0	0.0	79.2
Sum	52.4	136.4	267.1	144.2
600.0	9%	23%	45%	24%

Fig. 3. Five-step process for managing sustainable contracts.

(company social responsibility) and network perspective (i.e., viewing the firm as part of a larger social network) of the firm are being adopted by firms to align their decisions with a wider group of stakeholders, rather than that of a narrow group of shareholders.

Based on the above discussion, in this paper, we refer to this view of the (responsible) firm: *a planet-first-aware and responsible entity that considers itself embedded in a network of other entities and interacts with other entities through formal and informal sustainable network contracts with a goal (a higher purpose that includes at least the sustainability principles, i.e., the social-economic-environmental principles) of serving all its stakeholders (human or non-human)*. While other entities may not be planet-first-aware and responsible, the firm (network coordinator) takes ownership of ensuring a sustainable network. Stakeholder theory and principles of connectedness are now being integrated into principles of sustainability – as per a recent definition of CSR (company social responsibility). Thus, we consider a sustainable supply chain network is a network of such sustainable firms (as defined above) that are connected to other firms through sustainable contracts. We take the "Ecologically Dominant logic"" [26] as against the 'instrumental logic'[10] and propose the theory to

[10] ".that asks how can a supply chain benefit from addressing environmental or social issues 77]"; "The key to the instrumental logic is that economic performance is the goal, not sustainability." [26].

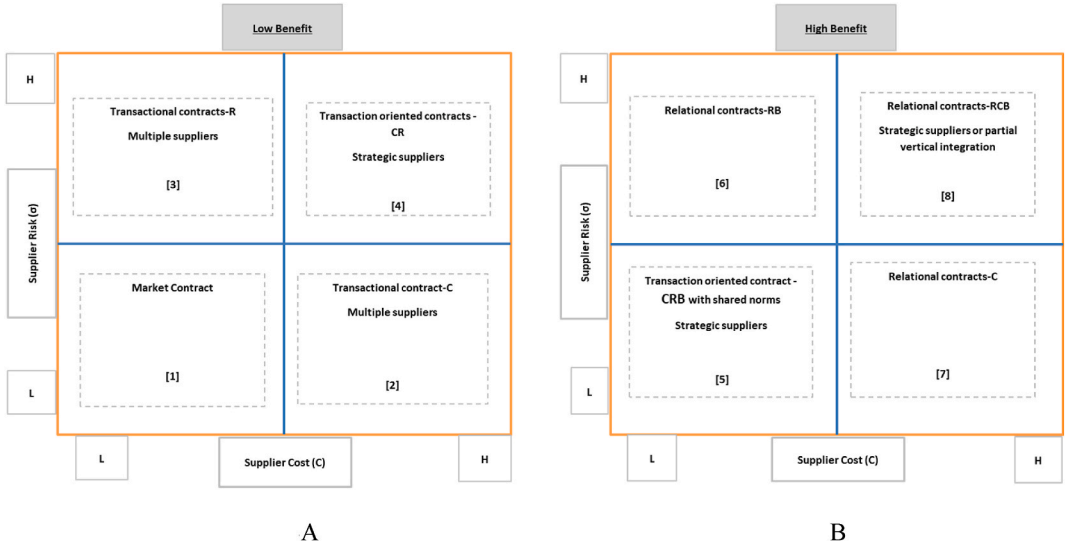


Fig. 4. (A and B): Relation between Type of contracts and Three contracting factors.

enable a responsible coordinator of the network to make the network sustainable. A firm that cannot keep Mother Earth at the center of its strategy would need to reinvent itself for it would not be able to serve a wide set of stakeholders and would not be able to coordinate sustainable networks.

2.2. Incomplete contracts: transaction cost economics (TCE) and relational contracts

Contracts are incomplete because a manager, being boundedly rational, cannot anticipate changes in the (micro or macro) environment of the firm (TCE - initial works by Refs. [15,16,59]). TCE literature focuses on two dimensions of formal contracts: specific investments and uncertainty. The behavior of the supplier could also jeopardize the investments made by the buyer (retailer) in the network or in the dyad. In the case of relational contracts [60,61], a buyer-supplier relationship may not reach its full potential due to a lack of objective measures. While homo-economicus and New institutional economics perspectives [59,62,63] present a one-dimensional (economics only) aspect of human interaction and have been considered 'under-socialized' and 'crudely functionalist' perspectives of human behavior [22,64], other notions such as 'Embeddedness' [22,65] and Relational exchange perspective [17,18,66] are considered more encompassing closer to human behavior as it is concerned with contracts. Other scholars inform us that dyadic relations could be further solidified with shared norms [60] and through commitment and trust [67–69]. We find that while these theories improve upon the single-dimension approach (economics only), they do not address sustainability dimensions in the contracting context and thus stop short of considering a wider network of stakeholders. We extend these theories in our framework so that it informs sustainable contracts.

When we consider a firm that is embedded in a network of entities (other firms that support the firm and governmental/regulatory and consumer advocacy groups/agencies), we find 'firm-as-nexus-of contracts' [48,49,50] view of the firm and consider network stakeholder theory [45,4] as providing the basis for these contracts. While these inform us that a wider set of stakeholders need to be considered (beyond shareholders), they stop short of taking a holistic view (do not consider a wider set of stakeholders that would include human and non-human stakeholder), thus excluding stakeholder who cannot represent their claims or cannot raise their voice when affected by the externalities imposed by the firm. Further networks themselves have been studied by scholars who work on Social network analysis (SNA: which discusses how the structure of the network contributes to the importance of actors, [19]) and Actor network theory (ANT: which discusses the process by which an actor in a network achieves outlined objectives, [20,21,70]).

In Fig. 1 below we represent how the extant theory of the firm perspective could be extended using a network and a wider stakeholder perspective resulting in then translated into the proposed four key features that need to be considered in the proposed Sustainable network contracting framework. These features would inform a network coordinator such as a retailer before signing strategic contracts.

We consider physical constraints as suggested by NRBV [2] as important for suppliers and the network. We refer to the Theory of planned behavior (TPB)-Technology adoption model (TAM) model proposed by Ref. [71] and integrate it with ANT to propose a mechanism by which a network coordinator could influence the behavior of suppliers in a network (to ensure sustainable network contracts are successfully implemented) through strategic contracting and periodic assessment (Fig. 2).

Thus, our framework extends the transactional [15,59,62] and relational [72] contracting to include a wide set of network-stakeholder interests. For future research, we propose that the network approach could be employed to compute the influence of a network coordinator on any network node using SNA.

To operationalize the framework, we identify contracting policies and, for a given contracting policy, we propose a mean-variance-based approach to include risk [73] and for assessing risk-cost-benefit trade-offs. Depending on the risk, cost, and benefit levels for a product (or a product portfolio), a retailer could identify a specific type of suggested contracting approach and employ the analytical approach to reach a quantity allocation scenario. Managers could evaluate several scenarios, given a network, and then make an informed decision. We propose that risk be addressed through strategic-transactional contracts while uncertainty could be addressed through strategic-relational contracts (Fig. 4). Thus, we propose an integrated approach to informing contracts. When we include sustainability-related factors in costs and benefits and in addition consider behavioral aspects (for example risk parameter – as we discuss in this paper), then we are able to inform contracts better.

2.3. Key contracting theories and dimensions of sustainable supply chain framework -gaps in literature

We employ the sustainability perspective (WCED, discussed in Section 2.1) for developing our framework. For example, we consider cost elements related to value addition as well as to externalities – such as the carbon cost of transportation [74] and sustainable wages for workers. We focus on developing a framework that would capture key cost elements, penalties for suppliers who do not conform to sustainable business practices so that the suppliers are incentivized to modify their behavior, and a periodic review process to ensure dynamics are captured by updating contracting parameters. Thus, our framework addresses both the objective and the subjective (behavior) side of contracts. The behavioral issues have been discussed briefly in Section 2. TCE has been discussed to address transactional (or discrete) contracts [59,75] and relational contracting/relational exchange theory has been discussed to address shared norms and long-term relationship [72] oriented contracts.

The two dimensions of contracts that give rise to transaction costs are a.) transaction-specific investments and b.) uncertainty (internal and external uncertainty). Specific investments are made by a party in a network and are not valued outside of the originally intended use. For example, if the retailer invests in a DC (conventional or automated) that coordinates activities between suppliers and stores, the investment cannot be easily relocated or sold because it was designed to serve a specific purpose at a specific location in the network. Such investments need to be safeguarded against internal and external uncertainties. Following TCE we note that uncertainty can be evaluated from the following two perspectives: 1) Internal uncertainty related to performance ambiguity because of the retailer's difficulty in assessing the performance of a supplier. Supplier opportunistic behavior or inefficiency is typically considered as the behavioral aspect of the uncertainty. As a part of the strategic supplier selection process a retailer may screen the supplier; however, the process can be expensive and time-consuming. 2) External uncertainty is imposed by the environment in which the retailer network is embedded. A manager's bounded rationality results in contracts that do not anticipate future events accurately. Without the flexibility of the exchange partners to help solve the issue, disputes would arise. As a result of the contract failure, costly legal action may remain the only recourse. Sustainability-based supplier management approach includes a more comprehensive cost and benefit assessment thereby reducing contract risks. Further, by considering behavioral aspects (supplier incentives – both positive and negative that align supplier behavior and supply chain manager risk-taking attitudes) of suppliers and supply chain managers we further improve the likelihood of the entire supply network.

TCE is silent on the factors that would make the contractual agreements sustainable. It assumes that there is no implicit contract (beyond the explicit one) between the focal actors (retailer and supplier) and the network (social and environmental) in which the focal dyad (retailer-supplier relationship) is embedded. On the other hand, relational contract theory is silent on how supplier efficiency and effectiveness could be leveraged. The theory also does not explicitly address sustainable modeling issues. However one could argue that relational norms are not limited to the dyad and apply to the extended implicit network in which the focal dyad is embedded.

In Table 1 we refer to the key contracting dimensions, the related problems that must be addressed, and a brief description of the problems faced by a party involved in contracting. Table 2 depicts how TCE, relational contracting, and our proposed framework address these issues. We highlight how TCE and relational contracting theories do not take the stakeholder view. These theories focus on the dyadic relationship in isolation and ignore the fact that the surrounding affects the dyad. We consider the dyadic relationship as embedded in a wider network and affected by other relationships (environmental and social implicit contracts).

In Table 3 below, we describe the types of contracts that we consider. We describe a 'strategic' contract as guided by our five-step process. Vertical integration (full or partial) would be a potential solution when the product cost/unit is high (product complexity is high as it requires many values added processes), when potential benefits are high (high quantity, high product criticality, or both), and when risk and uncertainty are high. In this case, a retailer could have full vertical integration or could pursue partial vertical integration (some percentage of the total quantity of the product made in-house) along with a strategic-relational contract. A firm may pursue vertical integration to a limited extent in combination with other types of contracts described in Table 3. Since full vertical integration internalizes contracts, we do not discuss the matter in this paper.

We address the contracting dimensions and gaps not addressed by TCE and relational contract theories in several ways. Firstly, we consider strategic supplier selection and how it could address internal and external uncertainties. Next, we consider the specific assets in the network: retailer investment in an automated DC, supplier selection, training, investment in solving problems at the supplier's end, and sharing best practices that would help the supplier in making deliveries on time to the DC. The DC could then operate efficiently and serve the stores (for example, facing stochastic demand) better. The framework allows for capturing supplier-level and network-level information and bases the optimal decision-making process on such facts. Thus, the framework would improve the

likelihood of achieving contract performance goals. A system of incentives and penalties also serves as continual communication to the supplier for correcting unsustainable behavior (behavior not aligned with sustainability principles).

Thirdly, our framework allows for leveraging supplier effectiveness and efficiencies. This would complement relational contracts. For example, we capture economies of scale for cost allocations and economies of scale and scope for risk analysis. This approach would improve the odds of the supplier making sustainable profits in the future.

Finally, we capture the social and environmental aspects by penalizing supplier behavior that does not conform to norms jointly established to ensure social and environmental compliance (a negative penalty is a reward for contributing beyond contract terms). We also include the ability of the supply chain coordinator (manager) to assess the risks involved (for example, depending on the assessed risk, the framework would re-estimate the distribution of the portfolio of products to the target suppliers). These subjective aspects would help not only design the contracts (that include flexibility) but also coordinate the supply chain *ex-post* within the contracting framework (agreed upon framework). Thus, the framework would help safeguard the retailer's investments in the network, help suppliers to become sustainable in the long run, and help stakeholders provide periodic input to the retailer. This would make the entire network sustainable.

2.4. Strategic supplier selection and sustainable supply chain management -identified literature gaps and proposed approach to solution

Typically, supplier selection and contracting entail a three-step process (1) evaluation of supplier capabilities (e.g., quality and delivery): to build an approved set of suppliers; (2) supplier selection from this set of suppliers for sole or multi-sourcing of materials; and (3) determination of quantity to be ordered from each selected supplier [76,77] based on quoted price and transportation costs. In addition, discrete (transactional) contracts are often negotiated between a buyer and a supplier. If a product is complex (high cost per unit, due to high-value add), such an approach to contracting would increase the risk of contract failure (i.e., the supplier is unable or unwilling to meet contract terms). If the potential benefits offered by a supplier to the buyer (product criticality, quantity ordered, etc.) are high, a contract failure would greatly affect the retailer. Strategic supplier selection would serve a critical role in such scenarios.

Supplier selection is strategically important for companies that spend a significant fraction of their revenue on purchased materials. Consequently, they need to mitigate supply-related risks. Researchers have addressed strategic supplier selection [78,79] and identified risks as well as social and performance concerns. Screening and goal aligning processes, and the two-way commitment make it feasible for buyers and suppliers to share information on products and processes, and on specific challenges that must be addressed. Initial information (prior to strategic relationship formation) and analysis (potential risk and cost evaluation) are typically employed to screen the supplier.

If a strategic relationship is established between the buyer and the supplier, further information may be sought and employed to set improvement targets and a joint mechanism for achieving the goals. Over time, the above process helps in goal alignment between the parties. A buyer's passive monitoring (TCE) and punishment strategies reduce supplier trust and the opportunity for joint action and may lead to a supplier's opportunistic behaviour. A systematic analysis of cost, benefit, risk, and joint action would also inform and improve relational contracts. Hence, our framework reflects the importance of strategic supplier selection and sustainable supply chain network management.

We propose and follow a five-step closed-loop approach to sustainable supplier management as listed below and depicted in Fig. 3:

1. We first decide on the number of suppliers that may be sufficient for developing a strategic relationship. Past experience or an approach based on NQCI (discussed next) could be used.
2. Next, we obtain and update the supplier and network-level cost information through supplier interaction. For a given policy contract, we find optimal total quantity allocation across the suppliers and across products for each supplier. We employ the product cost, sustainability parameters, and supplier assessment parameters (i.e., penalty parameters) to assess optimal allocations. We then find the network quantity concentration index (NQCI). The cost-based approach may be sufficient if cost is the key criterion.
3. When benefits offered by supplier and supplier risk are particularly important, we consider this additional step. The information that forms the basis of computations (risk parameters, risk preferences) would be updated on an ongoing basis but would need to be reviewed periodically. Thus, we modify the allocations in Step 2 above. We start with cost-based solution and then find the optimal total quantity allocation across the suppliers and across products for each supplier, given the benefits and the risks.
4. The retailer then receives the products per contract terms, evaluates the delivery against contract parameters, and imposes (awards) penalties (reward), if necessary, based on the agreed upon sustainability benchmark or metrics.
5. Post-delivery, contract parameters are updated and information (objective and subjective) shared with the supplier. The information could be updated on an ongoing basis but would need to be reviewed periodically. The buyer and supplier re-assess contract terms and make changes if necessary. Step 2 is repeated with updated supplier-specific sustainability parameters in each period.

We refer interested readers to the E-Component for analytical details on the implementation of the five-step process described above.

3. Data collection and methods

3.1. Data/sample collection

We collect data from several sources: 1) Alibaba website (secondary, https://www.alibaba.com/) and through direct quotes (primary data through the same website). These provide us with variable cost information for different quoted quantities. It provided us with information on different supplier scales (small, medium, and large-scale suppliers), their corresponding variable and fixed costs of production. The data was collected over two years. 2) various public websites (for example fixed costs that could not be obtained through Alibaba.com were obtained through other public websites). Sustainability related practices of the retailers were studied and penalties for violating supplier guidelines were obtained. Moreover, the cost of stock-out, the cost of poor quality, and the cost of slow-response time were obtained from published sources. These different cost and penalty (as assessed by the retailer/network coordinator) categories are shown in Table A2 and Table A3 in Appendix A. 3) interviews with senior executives (CXOs) (primary and secondary data [Table A5 and A6, were studied]). The primary interviews were of confirmatory nature (a short survey is attached included separately).

To obtain relevant insights, interviews by CXO level managers from retail (three types: groceries, pharma, produce), pharma packaging, automotive, and textile manufacturing were obtained and studied (secondary data from 12 CXOs was collected). Further, we also interviewed (primary data) CXOs (5) from retail (our partners in the study) and automation equipment supplier (1 CXO). We enclose the interview instrument that we employed for discussing the concepts, issues, and proposition outlines with managers.

3.2. Cost-based analytic approach for optimal quantity allocation (step 1, Fig. 3)

For a realistic evaluation of costs, we consider four geographically dispersed suppliers (US, Canada, Mexico and China) and six products (canola oil, soybean oil, sunflower oil, tomato paste, sweet corn, and wheat flour). Local ownership of the value chain is assumed to be with the supplier (local information), while global ownership is assumed to be with the retailer (network information). In this section, we consider various costs (variable and fixed production, transportation, environmental, and social) and penalties. We also briefly describe the NQCI (network quantity concentration index) that informs the network coordinator (retailer) regarding loss potential [80].

3.2.1. Cost model outline

Given the cost data, the goal of the optimal quantity allocation model is the allocate quantities to each supplier (Step 2 in the five-step model) such that the network cost is optimal. Since we consider social, economic (including exchange rate risk related costs:) [81], and environmental costs, along with penalties, the quantity allocations thus include objective and subjective (penalties for monitoring supplier behaviour) cost considerations. A retailer would employ the above optimization [82] tool to determine, given the data, the contract policies, and the constraints, the most optimal cost-based allocations. The contract policies could be different types, depending upon how the retailer decides to engage with the suppliers. Next, we discuss the type of contract policies that a retailer may employ to coordinate the network. For the interested readers, we refer to E-Component Figure OA2.

3.2.2. Outline of contract policies

Here we discuss the contract policies that a retailer could employ to best use the supplier resources and network information, and meet the customer demand. The second purpose of the contract policies is to address the network risks, given limited information at the network-level, by using supplier penalties and limits to the total quantity allocation for a supplier. The retailer engages with the supplier using these policies. For example, the retailer may request the supplier to supply the goods under a minimum contract policy. This would imply that the supplier must provide the minimum quantity of goods indicated in the contract. The retailer could investigate such policies and employ the model discussed to arrive at an optimal quantity distribution, given cost data. The above approach would help allocate supplier quantities with the goal of effectively utilizing network capabilities and costs, and also address risk at a high/network level. But the approach does not address inherent risks at a supplier level as we do not use product-level risk information. We address this in Section 7. Next, we discuss the need to assess the potential loss for the retailer, given the supplier network and type of contract between retailer and suppliers. For the interested readers we refer to E-Component Figure OA3.

3.2.3. Assessing loss potential in cost-based evaluation

When a retailer and a supplier in a network have a discrete (transactional) relationship, typically, little information is shared between them. In this case, detailed analysis of risk is not possible. For such a situation, we describe a simple formulation to capture quantity (value) concentration in the network (a proxy for quantity allocation risk): network quantity concentration index (NQCI). This measure is employed in cost-based analysis, when the cost is considered critical rather than the associated benefits and risks. In this case, we assume that benefit and risk information on the supplier is not available. We refer to Figure OA1 in "E-Companion" for details of NQCI formulation for the interested readers. When benefits and risk are important to the retailer, we propose a more detailed analysis, starting from the cost-based solution. For interested readers we refer to Figure OA-1 in the E-component.

3.3. Joint cost, risk, and benefit assessment (step 3, Fig. 3)

Next, we consider the situation when there is significant data sharing between the buyer and supplier i.e., we consider the case when the buyer could assess and address risks and benefits at supplier level (Step 3, Fig. 3). We start with the resultant allocations based on one of the above contracting policies. These are referred to as cost-based allocations (results from Step 2 serve as inputs to Step 3, if the relationship allows the buyer access to further information). Then we employ the mean-variance approach along with retail managers risk [83] preferences, to arrive at the final quantity allocations that consider the cost, benefit, and risk aspects.

3.3.1. Conceptualization of benefit and risk offered by a supplier for product

When a supplier promises to supply a certain benefit to the retailer, there is a certain risk associated with the potential contribution. We assume that higher the potential contribution (benefit offered to the supplier: M_{is}), higher the risk (σ_{is}) for the retailer if the supplier is not able to meet the commitment. The benefit (contribution) is a certain quantity of a product, with a given level of criticality, that the supplier contributes, in quantity of a product or in $ terms, to the retailer.

The standard deviation of benefit is defined as: $\sigma_{is} = \sqrt{\sum_{h=1}^{H}\sum_{l=1}^{L} sd_{hl}^2 * \omega_{hl}}$; $\omega_{hl} = \omega 1_{hl} * \omega 2_{hl}$; where i is the product index, s is the supplier index, h is the index for each area, l is the index for factors for an identified area. sd_{hl} is the standard deviation for factor (measured in its unit) and ω_{hl} is the normalizing weight that converts the factor variance to benefit variance; $\omega 1_{\mathrm{hl}}$ is the weight that converts the standard deviation from factor unit to benefit unit and $\omega 2_{hl}$ represents the importance of the factor. Thus, a factor variance may be high but the joint decision (buyer-supplier) may be to give the factor a lower weight in comparison to other factors.

If the supplier is able to meet the commitment, then the return for the retailer is higher as the transaction costs are lower when few (or only one) suppliers are involved.

M_i is a bid (benefit offered by the supplier, in quantity or $ terms) by the supplier and σ_{ij} is the assessment by the retailer (or a buyer-supplier joint decision) regarding the ability of the supplier to provide the benefit by offering the product *i*. If the retailer has prior experience with the supplier then σ_{is} is determined based on the history of the product.[11] If a supplier (say, $s = 1$) cannot provide the benefit M_{i1} per the contract parameters, then the retailer must obtain it through another source.

We use the mean variance technique with consideration for manager's risk preference. We assume that the retail supply manager maximizes her own expected utility derived from the supply of X amount (representing benefit, either quantity or $ amount) of goods by the supplier.

Next, we outline the portfolio considerations for the given set of products and suppliers and how the EV-frontier approach could be employed to combine the cost and risk perspectives.

3.3.2. Portfolio considerations: supplier and product perspectives

We consider six products that are manufactured by four suppliers. There are two aspects to the portfolio as stated next.

Supplier perspective: For a given part and for a given risk aversion parameter for a manager, we need to assess the *most appropriate quantity allocation between suppliers* in order to maximize the expected utility of the retail manager. The comparison between suppliers, for a product, is measured by a supplier correlation coefficient. The correlation coefficient is an aggregate measure for measuring the differences in technology, reliability, on-time delivery, etc. These measures must be agreed upon between the supplier and the retail managers. We note that the economy of scale is captured in considering the cost perspective.

Product perspective: For a given supplier and for a given risk aversion parameter for a manager, we need to assess the *most appropriate quantity allocation between products* in order to maximize the expected utility of the retail manager. In other words, given a supplier, we like to find out which products are best suited for the supplier.

The comparison between different products, given a supplier, relates to the economies of scope. The correlation coefficients between products inform us about the ability of the supplier to make a certain combination of products. The retail manager must study the supplier organization and operations to assess these coefficients. For interested readers we refer to the E-component (Figure OA-4).

4. Results

4.1. Summary of results on cost-based analysis (see 'step 2', Fig. 3)

Here we briefly review the results obtained by using four suppliers from four countries (China, Mexico, USA, and Canada) and a portfolio of six products. We refer interested readers to Table A4 and Figure A2 Appendix A and Figure OA 2 for cost-based analysis.

In this section, we briefly review the result of cost-based optimal quantity allocation to the suppliers and the resulting loss potential assessment for such cost-based allocation. We first compare the following three distinct policy contracts: a) Nominal quantity, c) Minimum quantity, and d) Maximum quantity contract policies for cost and risk evaluation and discuss the cost-risk trade-offs. We find that nominal policy has the highest total cost but also the lowest NCQI (more equitable allocation of quantities) in the range of allocations when multiple suppliers are involved. Also, we find that the maximum quantity contract policy has lowest costs, but the risks are higher

[11] σ_i is the variation is meeting contract parameters (a composite measure for standard deviations quality, on-time delivery, response to change requests etc.); it is an aggregate measure that is computed after summing up the weighted standard deviations of key supplier assessment factors for a given supplier and for a product.

than the min-max quantity contract policy. The min-max quantity contract policy has the lowest (similar to nominal) loss potential and competitive cost. We are also able to find the cost and benefit (reduction in NQCI) of diversification using the above analysis. Although the above approach informs us about cost-based allocations, it provides us with limited insight into risks at the supplier level.

4.2. Results from primary and secondary interviews

While we sought to understand the importance of technology, relationships, supplier selection, and network management to ensure sustainable supply/distribution networks become a reality, we allowed CXOs to stress the topic they were most comfortable with. We found that some (6/18) CXOs were more focused on technology while others (12/18) had a strong sustainable supply/distribution networks orientation. However, some of the CXOs clearly understood the need for technology in establishing or improving sustainable supply chains (8/18) – customer service, responsiveness, quality, employee welfare (injuries), partnership with suppliers, trust, etc. We also obtained good agreement on the classification of contracts, the related propositions, and the 2×2 matrices (Fig. 4) with the CXOs/managers interviewed (8). We had shared our analytical approach with the retailer managers and they provided inputs from time to time and appreciated the results (a mechanism to implement sustainable contracts and to provide product allocations to a global set of suppliers). From CXO responses obtained by consulting companies (Table A6), we observe that sustainability is high on the agenda of CXOs and that a sustainable supply chain is key to achieving this goal.

4.3. Results and sensitivity analysis (see 'step 3', Fig. 3)

Integrated cost and risk analysis helps consider the measurable and immeasurable part of risk. We provide a brief review of results and sensitivity analysis in the E-component. Our goal here is to illustrate how the framework takes supplier and network-level risk into consideration and also considers the risk profile of the manager in the analysis. We start with the cost-based solution and modify it further by considering cost-risk trade-offs. If the supplier benefits are high, or the risk is low, or both, it is likely that a higher allocation would be made to that supplier. We describe and explain the changes in allocations, given changes in supplier engagement policies and manager risk-taking ability.

Sensitivity analysis on two parameters: mean benefit and standard deviation. These parameters may vary, given a supplier, and our intention is to evaluate the changes in the EV frontier, given changes in these parameters. In conducting sensitivity analysis, we assume scaled benefit (between 1 and 10) for a product offered by a supplier. The benefit and standard deviation represent the assessment of the retail manager during the due diligence process while the supplier is being screened as a strategic supplier. These estimates are updated each period as the retail manager learns more about the supplier. For interested readers, we refer to the E-component (Figure OA-5 and Figure OA-6).

The above analysis would be carried out each period (contract cycle), as part of the five-step strategic relationship periodic reviews, and hence could account for dynamics (changes in parameter values, variances, correlation coefficients for products and suppliers etc.). Thus, we find that a retailer would benefit from conducting a sensitivity analysis for each supplier.

4.4. Proposition development

In this Section, we discuss how the three-factor model is helpful in designing a sustainable contract. We consider a combination of factor intensity (high or low) and propose suitable contract for each situation. We discussed the conceptualization of different type of contracts and how they map with corresponding factor condition (high/low) with senior managers, executives, and seasoned consultants and obtained their feedback. The authors also have significant work experience in the area. In addition, we continue to test the ideas with industry and also obtain feedback from other academics. We attach the list of survey questions that were employed for verifying and seeking inputs from respondents. We see survey-based hypothesis testing as the next step (future work).

In this Section we discuss how the three-factor model is helpful in designing sustainable contracts. We consider combination of factor intensity (high or low) and propose suitable contract for each situation. We discussed the conceptualization of different contracts and how they map with corresponding contracts with senior managers, executives, seasoned consultants and obtained their feedback. The authors also have significant work experience in the area. In addition, we continue to test the ideas with industry and obtain feedback from other academics. We attach the list of survey questions that was employed for verifying and seeking inputs from respondents. We see survey-based hypotheses testing as the next step (future work).

A low value of all the three factors: When the cost (which is a proxy for complexity) is low, the risk for obtaining the promised benefits is low, and the magnitude of promised benefits (for example, high-quality of a product, or the supplier provides a key product for the buyer (retailer/OEM), or provides a high quantity of a certain product, or the supplier possesses highly-valued [hard-to-quantify] attributes such as flexibility or managerial ability) are also low, then it is best for the retailer to obtain the product from the market (assuming market is well developed). This implies that the product is simple to make (has low cost/complexity/social/environmental footprint) and multiple suppliers can offer the benefits to suppliers consistently. A buyer-supplier contract may not be advisable as the buyer (retailer/OEM) will have to bear significant cost for signing the buyer-supplier contract while the benefits of such a contract may be minimal. We refer to this as a market contract, essentially a spot transaction (Coase 1937 and 1960). Hence, we propose that:

P1: Under low values of cost, risk, and benefits, a 'market' contract is a sustainable form of contract for the retailer.

We note that while the market may not be able to provide sustainable solutions, the choice of sustainability-oriented products lies with the coordinator and the suppliers in the network. Table 3 provides further details (Q1 Fig. 4).

Next, we consider two cases when benefits are low. First, we consider the case when the costs are high (i.e., the product is complex or needs high-value inputs) and risk is low (there are enough suppliers in the network who could supply the products). In this case, the buyer (retailer/OEM) is better served by finding other suppliers who would provide the same product so that there is an incentive on the part of the suppliers to improve their own costs continually. Since the risk is low, the buyer is not concerned with risk exposure. Hence multi-supplier transactional contracts may be sufficient. Transactional contracts (discrete contracts, Heide 1994; Rindfleisch and Heide 1997) have a 'task-at-hand' orientation. These contracts do not have a high set-up cost (compared to strategic or relational contracts). Although, a relational contract, if it is easy to set up, may be effective as well (for example, in Eastern cultures, relational contracts are implicit in all dealings). But, they may take a long time to develop in other cultures. Hence, we propose that, given the low supplier benefit:

P2a: Under low-risk, high-cost conditions (given low-benefit suppliers), multi-source transactional contracts would be sustainable.

Please refer to Table 3 provides further details and comments (Q2, Fig. 4).

Similarly, when the cost is low but the risk is high, multi-supplier transactional contract is useful for hedging the risk involved. Since the cost is low (complexity is low), a multi-supplier contract, although transactional in nature, would be sufficient for ensuring sustainable operations of the supply chain network. Although, relational contracts may be effective as well (for example, in Eastern cultures, relational contracts are implicit in all dealings) as such contracts bring flexibility to the table. But they may take a long time to develop in other cultures. Hence, we propose that when benefits are low,

P2b: Under low-cost and high-risk conditions (given low-benefit suppliers), multi-source transactional contracts would be sustainable.

Please refer to Table 3 provides further details and comments (Q2, Fig. 4).

But, when the risk of supplier benefits is high and when the cost of material involved is also high, multi-supplier transactional contracts may not be sufficient since there is a need for the supplier to deliver unknown attributes (incomplete contracts, all attributes cannot be specified a priori). Moreover, the supplier who has the best cost structure may not be able to ensure that the goods would be available on time (i.e., if we consider on-time delivery to be a key attribute) as some of the network-oriented issues may not be under the supplier's control. Under these conditions, the network coordinator (buyer: retailer/OEM) may have to promise something more to the supplier to ensure that the supplier offers more flexibility. In strategic relationships, the supplier invests more in due diligence and works with the supplier to help achieve the product portfolio targets. Moreover, the supplier also invests in the relationship by offering higher flexibility than that in transactional contracts. But strategic contracts are also transactional in nature – in that the relationship does not exist beyond the strategic contract, even if the strategic contract is a multi-year, multi-product contract, or of significant value. Hence, we propose that:

P2c: Under high-cost and high-risk conditions (given low-benefit suppliers), multi-source strategic buyer-supplier contracts would be sustainable.

Please refer to Table 3 provides further details and comments (Q4, Fig. 4).

Next, we present three propositions for cases when the benefits are high. First, we consider the case when the risk is low and the cost also low. In this case, we posit that a multi-supplier strategic contract would result in a sustainable relationship (given the Western context), although relational contracts may serve the purpose better but are more time consuming to develop. Since the benefits for the buyer (retailer/OEM) are high, the buyer must find a way to engage with the supplier in a way that incentivizes the supplier to be well-engaged. In this case, transactional contract would not be sufficient as the retailer may need the supplier to be flexible, at times. Moreover, since the benefits are high, switching costs are high for the buyer since significant due diligence may be needed for selecting the supplier. We posit that multi-supplier strategic contracts would result in a sustainable relationship in this case, although relational contracts may serve the purpose better, but are more time-consuming to develop. Again, the supplier also invests in the relationship, for example, by promising higher capacity dedicated to the buyer, and hence may take a broader perspective and may expect the same from the buyer. Hence, we propose that, given high-benefit suppliers:

P3a: Under low-cost and low-risk conditions (given high-benefit suppliers), multi-source strategic buyer-supplier contracts would be sustainable.

Please refer to Table 3 provides further details and comments (Q5, Fig. 4).

Next, we consider the case when the risk is low and the cost is high. In this case, the supplier is very valuable to the buyer and the product/s are complex. The supplier that offers two critical features to the buyer would be hard to replace. In such a case, a buyer-supplier relationship that is based on a transactional orientation [15,16,59,62] may not be enough to ensure a sustainable contract. Sharing norms [72] commitment to work jointly under uncertain situations (resulting in profit or loss), mutual concern for future cash flows (and corresponding expectation), and investment in relationship building become key to trust building and hence to relational contracts. Assuming a Western context, such relational contracts take time and effort to develop and maintain. Moreover, it would also be difficult to build such relationships with more than a few suppliers. Hence due diligence for cultural match would be a key feature (in addition to strategic fit). Hence, we propose that, given high-benefit suppliers:

P3b: Under high-cost and low-risk conditions (given high-benefit suppliers), a relational contract (informed by three factors) would be a sustainable buyer-supplier contract.

Please refer to Table 3 provides further details and comments (Q7, Fig. 4).

Similarly, given a high-benefit supplier, when high-risk (but low-cost) is an important factor, relational contracts would be key to securing sustainable relationships. This would safeguard against failures in the supply chain and avoid significant losses. In such cases, reliance on the buyer-supplier relationship becomes central to mutual success. Moreover, ongoing voluntary information sharing with the goal of reducing variability, improving operations, focusing on innovation, etc. become common practices. Diversification, though important, by itself would not be considered critical to success. Moreover, sharing norms with multiple suppliers may be very difficult as cultural fit is difficult to achieve/find and hard to replicate. Hence, we propose that given a high-benefit supplier:

P3c: Under high-risk and low-cost conditions (given high supplier benefits), relational contracts (informed by three factors) would be sustainable buyer-supplier contracts.

Please refer to Table 3 provides further details and comments (Q6, Fig. 4).

Under high-risk, high-cost conditions, given a high-benefit supplier, the buyer would need to develop a strong relationship with the supplier (following discussion in previous P3b and P3c above). In certain cases, the buyer may consider vertically integrating (VI) the operations of the supplier. This would provide full control of operations, eliminate information asymmetry, and ensure that supplier assets are employed to deliver the sought benefits. Vertical integration replaces contracts with intra-firm agreements. Since all three factors are now important to the buyer, the objective and subjective evaluation outlined in this paper would need to be deployed and reviewed periodically (when VI is not an option). The relationship needs to be further s strengthened by information sharing, joint work agreements, and investment (may need to be of a specific nature in some cases, i.e., specific investments may have to be made) in supplier operations to ensure sustainable operations. In addition, there needs to be a strategic orientation of the relational contract such that buyer and supplier thrive in challenging and dynamic micro and macroeconomic conditions. Hence, we propose that:

P4: Under high-risk and high-cost conditions, given a high-benefit supplier, a strategic relational contract (or VI) would be a sustainable buyer-supplier contract.

Please refer to Table 3 provides further details and comments (Q8, Fig. 4).

The link between the type of contract and the risk, costs, and the benefits offered by a supplier are shown in Fig. 4 and Table 3.

5. Discussion

The motivation for this paper stems from the need to protect assets in distribution and supply networks and the observation that there is a lack of integrative thinking in managing such networks through sustainable network contracts, both in academia and practice. While sustainability practices in supply chains have been discussed in academic journals, there is limited literature that provides the foundation for sustainable contracts. We highlight the limitations of Transaction Cost Economics (TCE) and Relational Exchange (RE) theories in informing sustainable contracts (Table 1), and demonstrate how our proposed Sustainable Network Contracting Framework addresses this issue (Table 2a). To develop an integrated theory of contracting, we combine insights from TCE, RE theories, the Network Theory of Stakeholder Influence, and Stakeholder Theory. However, we recognize that these theories have limited perspectives and do not explicitly consider sustainability principles or contracting. Therefore, we extend the current theory of contracting and address a broader set of dimensions to inform sustainable network contracts. Our proposed contracting framework is based on identified gaps in the literature (Tables 1a and 1b) and insights from the field, which include secondary data analysis (Table A5 and Table A6) as well as primary confirmatory data collected through surveys of CXOs. By bridging the gaps in existing literature and incorporating insights from both theory and empirical findings, we aim to contribute to the development of a comprehensive framework for sustainable network contracts.

Based on our secondary and primary interviews, we have observed that some CXOs (8 out of 18) recognize the importance of sustainable supply chains and the role of technology in achieving sustainability. However, we have also found that a significant number (6 out of 18) of CXOs are primarily focused on technology deployment and narrower gains. For instance, an automation technology provider prioritizes economic benefits despite the technology's clear advantages in reducing injuries and optimizing labor allocation in-store and distribution center floors. In some cases, CXOs working for retailers and distribution centers initially showed enthusiasm for immediate technological gains but required a broader perspective to understand the significance of sustainable networks. However, other CXOs have recognized the importance of sustainable networks and largely agreed with the propositions we presented. Our analytical approach and propositions are based on insights gathered through three-year engagements with the retail and manufacturing industry. Our evaluation of interviews suggests that senior managers, as highlighted by several CXOs in our primary interviews, are still becoming acquainted with the importance of sustainable global supply chain networks. We also refer to interviews conducted by major consulting firms, where CXOs emphasize the significance of sustainability for business success, with sustainable supply chains being key (Table A6, item 7). For example, a significant percentage of CXOs (55%–77 %) express the pressure their companies feel to align with environmental goals due to climate concerns, and a notable portion (55 %–67 %) are taking action in various ways. According to a report from Deloitte (2022), sustainable supply chains are one of the five critical initiatives required to achieve such outcomes. Similar interviews conducted by other consulting firms, such as EY and McKinsey (referenced in Table A6, item 7), have reported similar outcomes from their surveys of CXOs. Thus we believe CXOs are still focused on economic gains but feel a strong need to more towards a 'Mother Earth -first' mindset. We believe our work facilitates that goal.

Based on our review of the literature, particularly the combination of the Actor-Network Theory (ANT) and the Technology Acceptance Model (TAM) with the Theory of Planned Behavior (TPB), and our discussions with managers and CXOs, we propose a mechanism in Fig. 2 that outlines how retailers can influence suppliers and key stakeholders within the network. This mechanism provides valuable insights for practitioners and serves as a foundation for future research in the field. Additionally, we present a strategic supplier engagement framework in Fig. 3, along with an analytical tool (discussed briefly in the main text, with detailed models provided in the E-component of the research paper). These tools are designed to assist managers in effectively implementing sustainable network contracts. Through periodic reviews, managers can incentivize suppliers, make strategic investments in technology and training, and manage supplier behavior. The analytical tool enables the network coordinator and other managers to run what-if scenarios, facilitating the understanding of product distribution across different suppliers worldwide. In Table 3, we demonstrate how the proposed five-step framework addresses the three assumptions in Transaction Cost Economics (TCE) and acknowledges human limitations.

In our research, we emphasize the importance of combining analytical approaches with subjective inputs to offer a more comprehensive solution to supplier management. While analytical approaches, such as quantity allocation, are valuable, we recognize the need to incorporate subjective considerations to ensure the long-term sustainability of contracts. Our proposed approach provides managers with information and tools to consider various factors and make informed decisions over multiple contract cycles. By employing our approach, managers can conduct what-if analyses using practical objective, and subjective inputs for different scenarios. This approach allows for a balanced consideration of incentives, penalties, supplier engagement, contract policies, and objective functions, which are derived from secondary and primary data. These elements collectively contribute to the optimal allocation of quantities to specific suppliers. Through quantity allocation and the implementation of the closed-loop feedback and joint-action framework (Fig. 3), the actions of suppliers can be aligned with those of the sustainable firm serving as the network coordinator. While it is possible to provide elaborate mathematical functions (as proposed by other scholars, see Table of references in, E-component) for supplier social, environmental, and production practices, the task becomes difficult due to the presence of many entities in a complex network. Hence, a mixed model (incentive-based and math-function-based) may be more useful, especially, given the dynamic situation (while the supplier adapts to sustainable processes – both inside and outside its facilities).

To address the issues involved in developing sustainable network contracts, we develop a five-step supplier engagement process that addresses the above three issues. In order to operationalize the five-step process, we first develop a cost-based quantity allocation solution and the network value concentration (network loss potential) that the allocation represents. We then refine the solution using supplier-specific information on potential benefits and risks for each product. A more comprehensive solution thus includes strategic supplier selection process inputs, sustainable cost inputs, behavioral parameter inputs, and specific risk inputs from the supplier and the retail manager. The approach is designed to ensure that the suppliers in the network deliver to their contract terms. The parameters employed could be updated periodically and the analysis re-run by the buyer. Thus, we develop a framework that considers a closed-loop solution to the supply/distribution network optimization problem.

Managers would be able to employ the approach illustrated here to inform their contracting efforts and to understand different contract types. For example, when none of the three factors are critical to decision-making, we believe market contracts would serve the buyer well. This would happen when the buyer is involved in the procurement of routine items where the cost per unit (and hence the complexity of the product) is low and the product is well understood (since many sellers and many buyers are in the market) in the marketplace. But as cost becomes more important (since the product is rare/unique, or requires complex design and manufacturing), such market contracts would not work. Other factors such as benefits offered by the supplier and the risks associated with those benefits become important. Here, the supplier would also have a say (as there are not as many suppliers in the market) and negotiating power. To manage such a supplier, over the long run, the buyer who wants to ensure sustainable supply/distribution networks succeed, must allow for supplier inputs, limitations, and then decide on how to engage with them. Transaction-oriented or relational contracts are important in this regard. When costs, benefits, and risks involved are higher, both parties need to be well engaged on an ongoing basis.

6. Conclusions

We contribute to sustainable supply chain contracting theory and practice in several ways. First, we propose a theoretical framework (Sustainable contracting framework) that would extend the current theory in contracting literature by outlining dimensions for sustainability-oriented contracts. The framework we propose informs strategic, transactional, and relational contracts. Second, we also propose an underlying mechanism (Fig. 2) that could help practicing managers influence network partners. Third, we contribute to supply chain literature by proposing a three-factor (cost-benefit-risk) model that would help capture relationship details and help implement sustainable contracts using the five-step process. Fourth, we identify propositions relating the three-factor condition to the type of sustainable contract. We verify the propositions in a retail context by interviewing senior managers in the industry. Fifth, we propose four features (Fig. 1) that form the basis for the proposed analytical model and the five-step sustainable supply network management framework. Sixth, we illustrate the implementation through the proposed analytical approach that employs the three factors and the five-step process to arrive at sustainable product allocation for a group of suppliers. Seventh, we map the three dimensions to classify various contract types, thereby identifying different types and how they should be managed (Table 3). Eight, we put forward eight propositions that would help future research and managers think through sustainable contracting. Thus, we contribute to theory and practice by illustrating how the three-factor-based model we identify, cost-benefit-risk, informs the different types of contracts. Further, we illustrate how a network coordinator could leverage the proposed supplier engagement framework and the analytical models to inform sustainable network contracting processes (for distribution and supply). We address the concerns raised by TCE and scholars studying relational contracts (Table 2b).

7. Limitations and future research

While we make certain contributions, our work is not without identified limitations. We point these out to further future research. In addition to the analytically oriented limitations of our research, we capture limitations that relate to the empirical side of the research. due to a lack of funding and time constraints, we could collect a limited amount of secondary data (for a limited number of products and a limited number of countries). While this was sufficient for illustrating our approach as applied to practice, further data collection would provide a richer database and the power of an optimal solution would become even more evident. Secondary data collection can be further improved through ongoing data collection at a retailer/network coordinator (say, an OEM). Buyers would need to collect such data over time and create a database of supplier characteristics for each region. This data needs to be collected

through primary (obtaining specific quotes) as well as secondary data collection processes (understanding buyer processes for value addition and upholding sustainability principles). For some of the products (such as oils), we have estimated fixed costs based on recent research on secondary (ethanol) plants. A buyer could further investigate and refine this data by working more closely with suppliers. Thus, collecting good data for future research (for the application of the analytical approach) could be expensive and time-consuming. However it would be able to provide insightful results that a manager could compare with her intuition/experience.

Since our initial interviews have been encouraging and have validated the basic ideas, we propose to conduct a more detailed data collection for statistical evaluation. For future research, we envision developing a survey instrument and obtaining responses from managers in the retail and manufacturing industry to further understand the proposed underlying mechanism.

Data availability

Has data associated with your study been deposited into a publicly available repository? Response: No.

Has data associated with your study been deposited into a publicly available repository? Response: The authors do not have permission to share data.

CRediT authorship contribution statement

Vivek Kumar Dubey: Writing - review & editing, Writing - original draft, Validation, Resources, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e23622.

Appendix A

Table A1

Data for use with optimization model

Break points, variable cost, and fixed cost data with US benchmark (NA)		Break Point 1	Break Point 2	Break Point 3	Variable Cost Modifying Factor1	Variable costs at break point Variable Cost 1	Variable Cost 2	Variable Cost 3	Fixed Cost Modifying Factor2	Fixed costs at break point Fixed Cost 1	Fixed Cost 2	Fixed Cost 3
Canola oil	Mexico	1000	5000	35000	0.75	900	750	600	1.18	44000	176000	924000
Soybean oil	Mexico	1100	5500	38500	0.8	1875	1500	1200	1.1	6776	19360	84700
Sunflower oil	Mexico	1200	6000	42000	0.7	525	487.5	225	1.05	28800	158400	772800
Tomato paste	Mexico	1300	6500	45500	0.7	1050	900	600	1.2	10400	52000	364000
Sweet corn	Mexico	1400	7000	49000	0.6	300	285	277.5	1.1	16000	40000	67200
Wheat flour	Mexico	1500	7500	52500	0.6	1125	525	262.5	1.3	2200	11000	61600
Canola oil	USA	600	3500	26250	1	1200	1000	800	1	33000	154000	866250
Soybean oil	USA	660	3850	28875	1	2500	2000	1600	1	5082	16940	79406.25
Sunflower oil	USA	720	4200	31500	1	700	650	300	1	21600	138600	724500
Tomato paste	USA	780	4550	34125	1	1400	1200	800	1	7800	45500	341250
Sweet corn	USA	840	4900	36750	1	400	380	370	1	12000	35000	63000
Wheat flour	USA	900	5250	39375	1	1500	700	350	1	1650	9625	57750
Canola oil	Canada	750	4000	31500	0.9	1080	900	720	0.9	37500	160000	945000
Soybean oil	Canada	825	4400	34650	0.85	2250	1800	1440	1.1	5775	17600	86625
Sunflower oil	Canada	900	4800	37800	0.95	630	585	270	1.5	24300	142560	782460
Tomato paste	Canada	975	5200	40950	0.9	1260	1080	720	1.15	8775	46800	368550
Sweet corn	Canada	1050	5600	44100	0.85	360	342	333	0.95	13500	36000	68040
Wheat flour	Canada	1125	6000	47250	0.95	1350	630	315	1.1	1856.25	9900	62370

(*continued on next page*)

Table A1 (*continued*)

Data for use with optimization model										
Canola oil	China.	1100	6000	45500	900	850	750	385	1200	27300
Soybean oil	China.	1210	6600	50050	1200	1000	825	8470	26400	125125
Sunflower oil	China.	1320	7200	54600	1100	900	450	594	1440	13650
Tomato paste	China.	1430	7800	59150	1200	1000	800	1144	2340	29575
Sweet corn	China.	1540	8400	63700	900	720	700	3300	15000	91000
Wheat flour	China.	1650	9000	68250	700	400	400	484	3300	10010

1:Mexico, Canada have lower labor costs; data being updated periodically.
2: US, Mexico, Canada have large manufacturers that have similar technology; data being updated periodically.

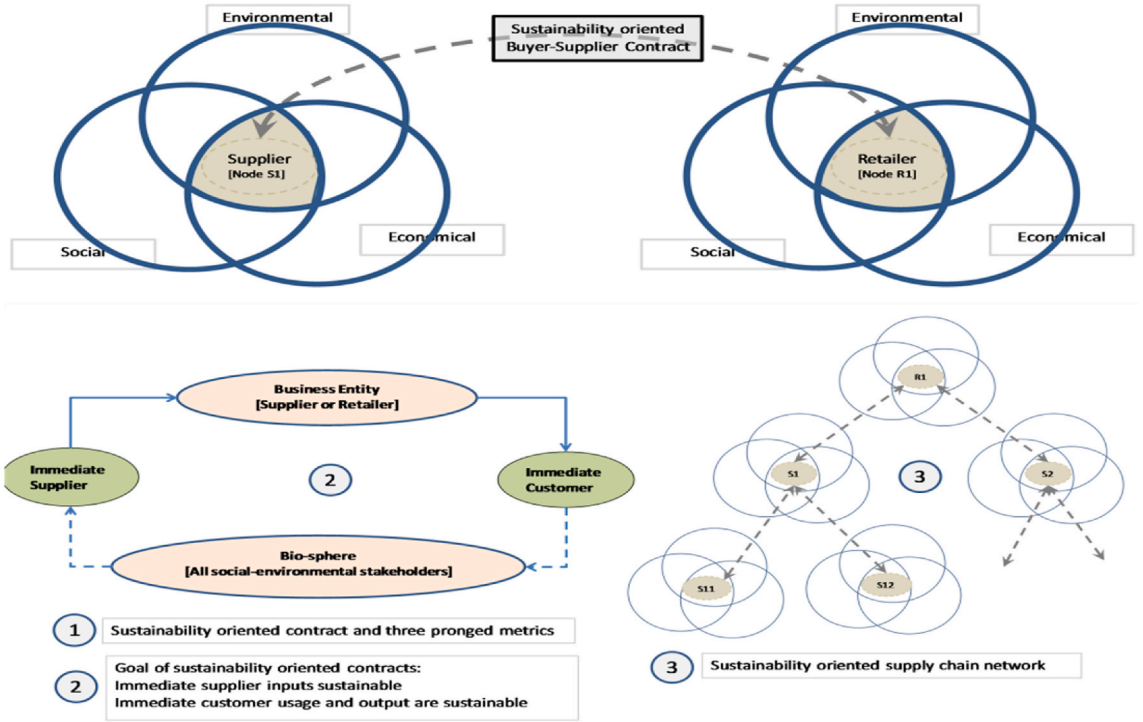

Fig. A1. Essential elements of sustainability-oriented supply chain network.

Notes.

#1: Illustrates the contract as a means of collaboration and communication between buyer and a supplier with a goal of making supplier actions sustainable.

#2: Illustrates the fact that each supplier node must implement sustainability principles by ensuring renewable sourcing from intermediate suppliers, and finally from the biosphere. Similarly, each supplier node must ensure that the product usage by the intermediate customers does not affect the biosphere negatively.

#3: Illustrates a sustainability-oriented supply chain network where each node is linked to the parent node through a sustainability-oriented contract.

Table A2

Estimates for penalties	Supplier	Mexico	USA	Canada	China
Currency Risk	Alpha1	M1	M2	M3	M4
		8.8 %	0.0 %	3.0 %	9.6 %
Stockout/Overstocking	Alpha2_3	M1	M2	M3	M4
	Canola oil	30.9 %	27.7 %	29.6 %	36.4 %
	Soybean oil	24.4 %	21.7 %	23.4 %	29.6 %
	Sunflower oil	31.6 %	26.7 %	29.5 %	39.3 %
	Tomato paste	17.4 %	15.8 %	17.0 %	21.2 %
	Sweet corn	23.2 %	18.8 %	21.3 %	30.2 %
	Wheat flour	14.7 %	15.3 %	15.4 %	15.8 %
Cost of Poor Quality	Alpha 4	M1	M2	M3	M4

(*continued on next page*)

Table A2 (*continued*)

Estimates for penalties	Supplier	Mexico	USA	Canada	China
	Canola oil	37.3 %	40.1 %	41.0 %	60.1 %
	Soybean oil	40.7 %	34.4 %	34.7 %	48.8 %
	Sunflower oil	44.5 %	34.6 %	35.9 %	55.6 %
	Tomato paste	50.9 %	41.9 %	42.7 %	62.7 %
	Sweet corn	34.4 %	26.6 %	27.6 %	43.1 %
	Wheat flour	17.5 %	13.6 %	14.0 %	21.6 %
Cost of ServiceLvl/FillRate Deviation	Alpha 5	M1	M2	M3	M4
	Canola oil	1.5 %	0.6 %	1.0 %	2.2 %
	Soybean oil	1.2 %	0.6 %	1.0 %	2.2 %
	Sunflower oil	0.8 %	0.6 %	0.8 %	1.2 %
	Tomato paste	1.4 %	0.2 %	1.1 %	1.6 %
	Sweet corn	0.6 %	0.2 %	0.4 %	1.2 %
	Wheat flour	1.8 %	0.2 %	0.4 %	2.6 %
Cost of LeadTime Deviation	Alpha 6	M1	M2	M3	M4
	Canola oil	4.5 %	3.2 %	3.7 %	7.0 %
	Soybean oil	5.0 %	4.0 %	4.4 %	7.0 %
	Sunflower oil	5.2 %	3.5 %	4.2 %	8.7 %
	Tomato paste	5.1 %	3.9 %	4.4 %	7.6 %
	Sweet corn	2.8 %	1.7 %	2.2 %	4.8 %
	Wheat flour	3.0 %	2.2 %	1.6 %	4.7 %
Cost of Not meeting Recycling/Return targets	Alpha 7	M1	M2	M3	M4
	Canola oil	9.5 %	4.1 %	2.4 %	9.5 %
	Soybean oil	6.8 %	4.3 %	1.7 %	6.3 %
	Sunflower oil	8.3 %	6.7 %	2.3 %	10.0 %
	Tomato paste	11.6 %	5.0 %	2.0 %	11.0 %
	Sweet corn	16.2 %	5.7 %	3.6 %	11.7 %
	Wheat flour	11.4 %	5.7 %	6.8 %	14.2 %
Environmental Penalty	Alpha 8	M1	M2	M3	M4
[product and process,	Canola oil	20.0 %	24.0 %	23.0 %	40.0 %
not included transportation]	Soybean oil	22.0 %	26.4 %	25.3 %	44.0 %
	Sunflower oil	15.0 %	18.0 %	17.3 %	30.0 %
	Tomato paste	30.0 %	36.0 %	34.5 %	60.0 %
	Sweet corn	34.0 %	40.8 %	39.1 %	68.0 %
	Wheat flour	10.0 %	12.0 %	11.5 %	20.0 %
Social Penalty	Alpha 9	M1	M2	M3	M4
[penalty for not meeting	Canola oil	20.0 %	10.0 %	10.0 %	40.0 %
social obligations]	Soybean oil	40.0 %	20.0 %	20.0 %	80.0 %
	Sunflower oil	20.0 %	10.0 %	10.0 %	40.0 %
	Tomato paste	40.0 %	20.0 %	20.0 %	80.0 %
	Sweet corn	44.0 %	22.0 %	22.0 %	88.0 %
	Wheat flour	10.0 %	5.0 %	5.0 %	20.0 %

Table A3

Key area	Characteristic to be assessed	Description of the characteristic of the benefit offered by supplier to the buyer	Standard	Risk
Economic: Manufacturing related			Deviation	Weight
Internal to organization	Product design	Ability of supplier to design innovative products (cost, risk, and market need perspective)	sd11	ω11
	Process design	Design innovative process	sd12	ω12
	Production - on time	Production processes that meet cost and time targets	sd13	ω13
	Quality -design [84]	Design quality into product	sd14	ω14
	Quality -process	Design quality into process	sd15	ω15
	Trained staff	For various facets of production process	sd16	ω16
	Management practices	For various facets of production process	sd17	ω17
	Spare capacity	For production of additional orders	sd18	ω18
	Responsiveness (lead time)	Respond to changes in demand	sd19	ω19
External to organization (supply base)				
	Supply (raw material)	Ability to secure raw material supply	sd21	ω21
	Supply (semi-finished)	Ability to secure semi-finished material supply	sd22	ω22
	Price volatility of supply	Exposure to price changes (leverage on suppliers or hedging)	sd23	ω23

(*continued on next page*)

Table A3 (*continued*)

Key area	Characteristic to be assessed	Description of the characteristic of the benefit offered by supplier to the buyer	Standard Deviation	Risk Weight
Economic: Manufacturing related				
	Number of potential suppliers	Market maturity (technological, resources, talent)	sd24	ω24
	Quality of other suppliers	Market maturity (technological, resources, talent)	sd25	ω25
	On-time delivery	Supplier (2nd tier) ability to meet cost and time targets	sd26	ω26
	Contract management practices	For various facets of supply management	sd27	ω27
	Responsiveness (lead time)	Respond to changes in demand	sd28	ω28
Economic: Logistics and supply				
Transportation				
	On-time delivery	Ability of the transport organization to deliver on time (per commitment)	sd31	ω31
	Price volatility	Own fleet or outsourced fleet sensitivity to external factors	sd32	ω32
	Capacity (internal and external)	Internal capacity or access to external capacity	sd33	ω33
	Fleet efficiency	Fleet fuel efficiency and effectiveness	sd34	ω34
	Carbon footprint	Reduce wastage and choice of technology for transportation	sd35	ω35
Inventory				
	Raw materials	Too much (costly) or too little (out of stock risk)	sd41	ω41
	Manufactured products	Too much (costly) or too little (out of stock risk)	sd42	ω42
	Supply (semi-finished) products	Too much (costly) or too little (out of stock risk)	sd43	ω43
	Management practices	Ability to manage inventory in manufacturing and supply base	sd44	ω44
Economic: Currency related	Volatility of exchange rates	Exposure of supply chain to international currency exchange rate risks	sd51	ω51
Social: Manufacturing and secondary supply base				
Manufacturing by supplier (primary)				
	Investment in social-stakeholders	supplier investment in previous periods in relevant benefits for social-stakeholders	s61	ω61
	Labor issues resolution practices	Ability to resolve dispute/disagreement with workers/employees	s62	ω62
	Community issues resolution practices	Ability to resolve dispute/disagreement with community	s63	ω63
Supply base (secondary)				
	Investment in social-stakeholders	supplier investment in previous periods in relevant benefits for social-stakeholders	sd71	ω71
	Labor issues resolution practices	Ability to resolve dispute/disagreement with workers/employees	sd72	ω72
	Community issues resolution practices	Ability to resolve dispute/disagreement with community	sd73	ω73
	Flexibility in contracts	Ability of manufacturer to obtain promised goods and services in spite of disruption	sd74	ω74
Political	Exposure to political changes	Ability of manufacturer to obtain promised goods and services in spite of disruption	sd75	ω75
Social change	Exposure to social changes	Ability of manufacturer to obtain promised goods and services in spite of disruption	sd76	ω76
Environmental: Manufacturing and supplier base				
Manufacturing by supplier (primary)				
	Investment in environmental-stakeholders	supplier investment in previous periods in relevant benefits for social-stakeholders	sd81	ω81
	Environmental issues resolution	Ability to resolve dispute/disagreement with environmental-stakeholders	sd82	ω82
Supply base (secondary)				
	Investment in environmental-stakeholders	supplier investment in previous periods in relevant benefits for social-stakeholders	sd83	ω83

(*continued on next page*)

Table A3 (*continued*)

Key area	Characteristic to be assessed	Description of the characteristic of the benefit offered by supplier to the buyer	Standard	Risk
Economic: Manufacturing related			Deviation	Weight
	Environmental issues resolution	Ability to resolve dispute/disagreement with environmental-stakeholders	sd84	ω84
References:	Note: Each item indicates a characteristic of the supplier. The characteristic is assessed by the joint-efforts of the buyer			
1. Tang and Nurmaya 2011	and supplier and updated each period. The measure of the characteristic is number on 1 to 10 scale. Deviation from mean is			
2.Wu and Olson 2010	computed by considering data collected over several periods. Initial assessment may involve using secondary			
3. D. Wu 2010	(previously collected) data regarding the supplier and expert assessment by buyer agents, which is updated each period.			

$$\sigma_{is} = \sqrt{\sum_{h=1}^{H}\sum_{l=1}^{L} sd_{hl}^{2} * \omega_{hl}} \; ; \; \omega_{hl} = \omega 1_{hl} * \omega 2_{hl}$$

Where i is the product index, s is the supplier index, h is the index for each area, l is the index for factors for an identified area. s_{hl} is the standard deviation for factor (measured in its unit) and ω_{hl} is the normalizing weight that converts the factor variance to benefit variance; $\omega 1_{hl}$ is the weight that converts the standard deviation from factor unit to benefit unit and $\omega 2_{hl}$ represents the importance of the factor. Thus, a factor variance may be high but the joint decision (buyer-supplier) may be to give the factor a lower weight in comparison to other factors.

Table A4
Sample output depicting minimum quantity policy contract costs and quantity allocations

Summary of costs, $			Costs, $		Costs, % of Total
Total transportation cost			19,75,06,093		21 %
Total manufacturing cost			76,21,85,764		79.4 %
Total variable manufacturing cost			75,45,95,344		78.6 %
Total fixed cost			75,90,420		0.8 %
Total cost			95,96,91,856		
	Mexico	USA	Canada	China	
Transportation cost, for each supplier	2,84,90,051	2,56,47,413	8,15,68,841	6,17,99,788	
Percent of total transportation cost	14 %	13 %	41 %	31 %	
Variable manufacturing cost, for each supplier	5,48,84,974	23,89,97,161	35,11,17,670	10,95,95,538	
Percent of total variable cost	7 %	32 %	47 %	15 %	
Fixed cost, for each supplier	16,50,000	33,78,375	23,34,758	2,27,288	
Percent of total fixed cost	22 %	45 %	31 %	3 %	
Variable manufacturing cost, for each product	Canola oil	Soybean oil	Sunflower oil	Tomato paste	Sweet corn	Wheat flour
	12,10,91,152	27,56,83,242	5,55,67,372	16,38,87,077	7,36,07,449	6,47,59,053
Percent of total variable cost	16 %	37 %	7 %	22 %	10 %	9 %
Quantity manufactured		Mexico	USA	Canada	China	Total SKU demand
	Canola oil	37,112	37,888			75,000
	Soybean oil			51,975	38,025	90,000
	Sunflower oil		47,250	32,750		80,000

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Table A4 (*continued*)

	Mexico	USA	Canada	China		
	Tomato paste		28,575	61,425		90,000
	Sweet corn		55,125	39,875		95,000
	Wheat flour		59,063	40,938		1,00,000
Total manufactured quantity		37,112	2,27,900	2,26,963	38,025	5,30,000

	Mexico	USA	Canada	China
Target allocation quantity (%)	7 %	43 %	43 %	7 %
Maximum quantity	2,27,900	2,27,900	2,27,900	2,27,900
[That could be allocated to a supplier]	43 %	43 %	43 %	43 %
Minimum quantity	37,100	37,100	37,100	37,100
[That must be allocated to each supplier]	7 %	7 %	7 %	7 %

Quantity allocations, product vs. Supplier	Mexico	USA	Canada	China
Canola oil	49 %	51 %	0 %	0 %
Soybean oil	0 %	0 %	58 %	42 %
Sunflower oil	0 %	59 %	41 %	0 %
Tomato paste	0 %	32 %	68 %	0 %
Sweet corn	0 %	58 %	42 %	0 %
Wheat flour	0 %	59 %	41 %	0 %
Quantity allocations, total	7.0 %	43.0 %	42.8 %	7.2 %

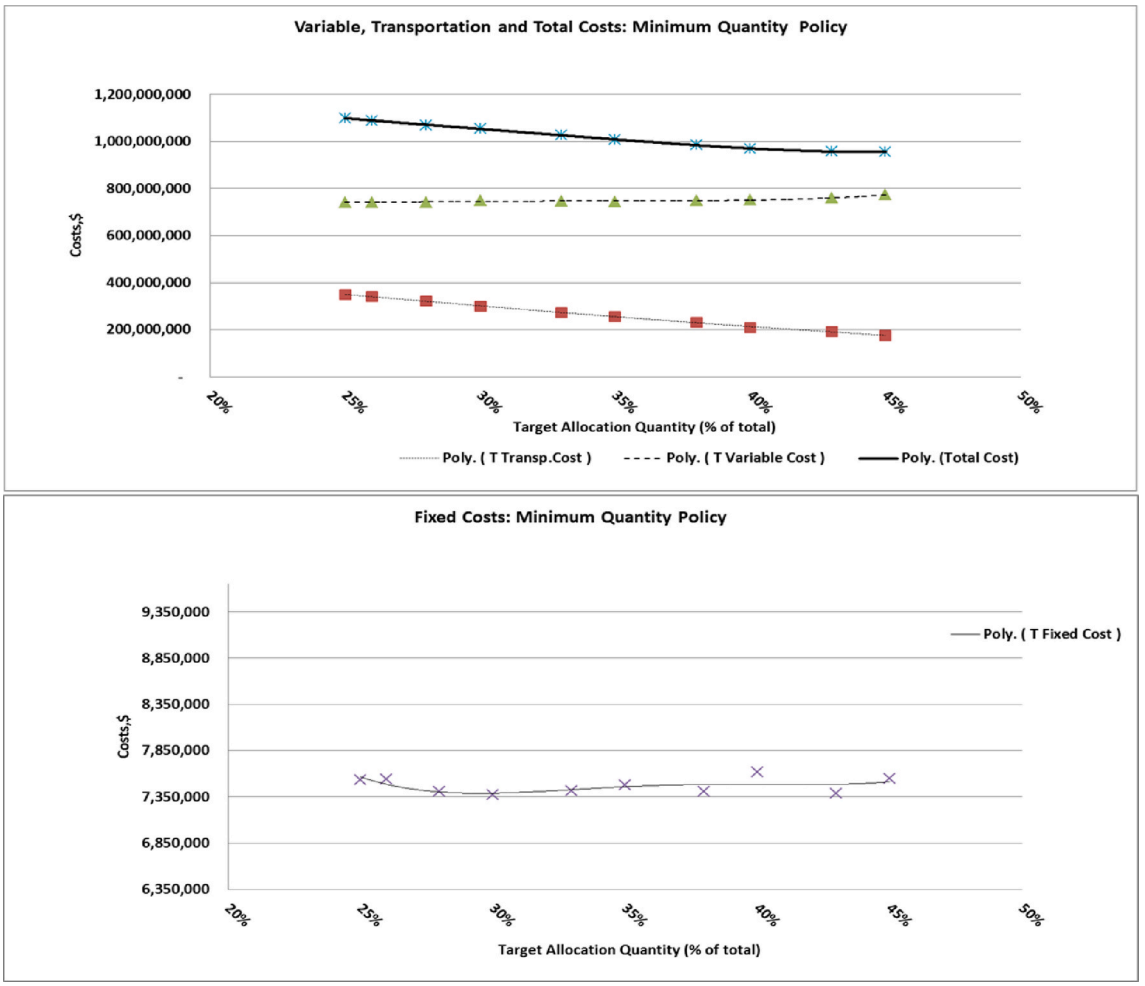

Fig. A2. Changes in costs as target quantity allocation are changed.

Table A5
Summary of approach to secondary data collection

Sl. No.	Source of information	Approach to information gathering (primary) and key observations (secondary)
	PRIMARY data	NOTE: Primary data collected is largely confidential, but modified results are presented in text
1	Retailer-R1	In-depth discussions/w FIVE CXO level executives over 2 yrs period
2	Provider of full-case technology	Throught in-depth and ongoing discussions/w CXO level executives, managers over 2 yrs - regarding industry challeges and potential (including DC automation) solutions
3	Conventional DCs-R1	Bi-weekly meetings over 2 yr period with two managers and one CXO level individual Data collected through internship with retailer (primary) - discussions helped create models
4	Semi-automated DCs - R1	Bi-weekly meetings over 2 yr period with two managers and one CXO level individual Data collected through internship with retailer (primary) - discussions helped create models
5	Automated DC- supplying R1S1, R1S2, R1S3 (retail stores retailer R1)	In-depth discussions w/four managers and two supervisors (8 h); notes made by gradute students
6	Data collected at stores	Three graduate students collected data (operations) at two local stores: five observations, 4hr each, were made Data was collected by discussions with store-managers, supervisors, and operators on the floor Further data was obtained from 230 stores by coordinating through local store managers (primary/ secondary)
7	SECONDARY data: Other automated DCs Secondary data- CXO interviews, Other automated DCs	Reports and white papers obtained through provider of full-case technology Observations made on executive statements
8	Semi-structured interviews with senior managers at RILA conferences	Helped us understand key issues facing the industry and discuss our approach to developing a decision-making framework for automated DC investment; The discussions with our partner (managers and CXOs) retailer confirm the concerns and priority of the industry leaders;
9	Automation technology suppliers - value to DCs and growth	The article and interviews discuss several DC automation technologies (including supplier A) and their growth in retail sector.

Table A6
Excerpts from interviews with CXOs from Retail industry (secondary data)

Sl. No.	Source of information	Key insights from CXO interviews
1	Cardinal Health, Medical supplies -Retailer R5 (15 yr experience with automation equipment supplier M1)	Responsiveness, quality, flexibility - are key; logistically: transparency, focus on cost, and information accuracy Need for a strong automation technology solution partner - with commitment, flexibility, and long-term perspective. Automation has resulted in improved productivity and effectiveness; in future- need to continually improve network SC costs. ". CXO–CH–1/KM 1.“The trust we’ve built over the course of our long-standing supply chain partnership with YY also played an important role in our decision.” CXO–CH–2/MB 1. "Cardinal Health utilizes a broad network of replenishment and distribution centers to ensure that customer products are aggregated and distributed in a manner that optimizes the total cost of supply chain in terms of inventory, transportation, labor and infrastructure costs …." 2. "Providers need supplier partners that are responsive, flexible and innovative, deploying best practices that will reduce costs, enhance efficiency and increase quality. " CXO-W-3/KH, “Cardinal Health was the very first client we worked with in the U.S. some 15 years ago, … We appreciate our long-term relationship and partnership.”
2	Kroger - grocery, retail - Retailer R6 (17 year experience with automation equipment supplier M1)	Retail industry is adapting automation in a big way; one-touch handling on delivery side and one touch handling on delivery side is the goal; Warehouse design - need to consider long-term supply chain strategy and network; Being able to build mixed pallet is key;. Injuries- shoulder and back: due to repetitive motion; employee turnover - a problem; not only warehousing is efficient, but also the logistics is better. CXO-K-1/JW 1.“We’re looking at our network, and rethinking how we serve the characteristics of different geographic areas" 2.“The Holy Grail for our industry is to create a system that will automatically build a pallet of mixed SKUs that doesn’t damage the product, maximizes the cube of a truck, and gets to the store in an aisle-aligned manner based on the planogram for that store,” 3. “When you look at where you have injuries in a warehouse, the majority are repetitive motion injuries to backs and shoulders; Most of those are the result of lifting. Developing an automatic mixed case palletizing system would eliminate those.” 4. “Like many distributors, we’ve had significant turnover in our warehouses and that’s very inefficient … long-term, we see it as a continuing problem,”
3	Sobey’s, - grocery, retail [$150 M investment] - Retailer R7 (10 year experience with automation equipment supplier M1)	Reason behind automation - improve efficiency;Companies goal - improve cost base while boosting service to stores; a variety of store formats; orders are labor intensive; ability to add SKUs with little impact on operation complexity is important; damage and human errors - virtually eliminated; throughput - up 3–4 times (180 case/hr. to 720 case/hr.); about 10 % more cases on a pallet; building one pallet per CXO-So-1/FM “The reason behind automation was to improve efficiency,” CXO-So-2/ES 1. " … Most goods it ships to stores are in case quantities rather than

(*continued on next page*)

Table A6 (*continued*)

Sl. No.	Source of information	Key insights from CXO interviews
		pallets … this order profile is labour intensive. Order selectors have to travel to multiple locations to build a pallet." Sobeys needed a system that could flexibly service small formats as well as big ones and cut costs. 2."No longer [does] a picker have to drive a pallet jack two miles to pick a convenience store order with fewer cases, which isn't as efficient as if you're picking for a full-service store," 3. "We only control the sequence, not the frequency …. By controlling the sequence, we can build store-friendly pallets" CXO-So-3/MC ". when another store is added to the mix, it's just a matter of programming the system to pick another store. Essentially, automation allows Sobeys to offer a wider product variety than its competitors … " CXO-So-C-4/TP. a problem with conventional DCs is many employees work part time. Turnover can be high. "It takes two to three months before they're building a decent pallet, but this system always produces a perfect pallet: it's cubed, built nice and high, with no overhang."
4	Supervalue- grocery, retail - Retailer R8 (Albertsons, Jewell-Osco, Acme, and Save-a-Lot) (14 year experience with automation equipment supplier M1)	Cubing load better has helped reduce transportation costs; Throughput is improved significantly and order fulfilling accuracy is high; Customers (stores) are amazed; CXO-Su-1/JF 1. "We have a great partnership with (supplier) XX. They have logistics knowledge, not just systems knowledge." CXO-Su-2/BK 1. "We now cube our loads better than in the past and have since seen a reduction in the total number of outbound loads, which has resulted in transportation savings," 2. "They (customers, i.e., stores) see the efficient movement of our products, the smoothness, and how well the system handles the products without any damage. They also see the quality of the loads as they arrive at their back doors. The facility is now meeting our expectations and getting the ROI we need. And it is designed to give us the ability to grow."
5	Berner Group, direct seller, automotive, construction, others. - Retailer R9	Dynamic picking system - that employs totes was implemented; throughput increases by 80 %, error rate (reduced to 0.04 %) and costs decreased; Reduction in no. of shifts (from 1.5 to 1) resulted in reduction in logistic costs. Able to provide high level of service - key for future success. CXO-B-1/HG 1."What used to be considered a rush order is now a standard order for us. ".2."Shipments are becoming increasingly small-scale and order frequency is on the rise – a flexible and highly efficient logistics structure is an absolute must for us in an environment like this … "; 3."We managed to resolve any issues that arose directly and easily with our general contractor XX", CXO-W-2/JG-1." … This joint realisation of the project worked very well because the structures of both partners (buyer and the supplier of equipment) fit together."
6	Boots, health and beauty, retail -Retailer R10 (10-year relationship with Automation equipment supplier M1)	CXO-Bo-1/AP 1."The automated system has improved efficiency throughout the entire supply chain at Boots."2. "We're proud of the partnership that we've developed, and together we will continue to work hard to improve the system and create additional efficiencies in the system and in the service for our customers." Store-friendly presentation is important: reduces stocking time at stores; supply chain wide impact has been observed and helped to compete well; the Dynamic Picking system helped achieve business goals and is continuously being improved; integrating IT was key to success
7	Sustainable networks related secondary data and reports	Largely through research articles, white papers (Ernst and Young, Mckensy, Delloitte) by industry thought leaders. 1. R. Alves, L. Rogge, G. Seinberg, S.Dutta, C. Mork, 2022, "Building supply chain sustainability that can drive revenues and reduce operational risks 2022″, Ernst and Young report on survey of 525 industry executives 2. "Deloitte 2023 CxO Sustainability Report", Jennifer Steinmann, Deloitte Global Sustainability & Climate Practice Leader; report based on interview of 2046 CXOs 3. J. Henrich, J. D. Li, C. Mazuera, and F. Perez, 2022, "Future-proofing the supply chain." McKinsey and Co.

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