Journal of the Operational Research Society

ISSN: 0160-5682 (Print) 1476-9360 (Online) Journal homepage: www.tandfonline.com/journals/tjor20

Examination of risks in circular supply chains using transition management lens: towards a circular economy in emerging markets

Divya Choudhary, Ajay Kumar, Yeming Gong & Thanos Papadopoulos

JOURNAL OF THE OPERATIONAL RESEARCH SOCIETY
https://doi.org/10.1080/01605682.2025.2459252

RESEARCH ARTICLE

OPEN ACCESS Check for updates

Examination of risks in circular supply chains using transition management lens: towards a circular economy in emerging markets

Divya Choudhary[a], Ajay Kumar[b], Yeming Gong[b] and Thanos Papadopoulos[c]

[a]Indian Institute of Management (IIM) Lucknow, Lucknow, India; [b]EMLYON Business School, Lyon, France; [c]Kent Business School, Canterbury, United Kingdom

ABSTRACT

We perform a multidimensional and integrated investigation of risks associated with circular supply chains (CSC), drawing on Transition Management Theory (TMT). This research focuses on e-waste from the Indian electronics industry, a waste stream with significant recovery potential and one of the fastest-growing in emerging economies. Drawing on TMT, the study (i) institutionalises risk management activities in circular systems to operationalise the transition towards CE; (ii) quantifies CSC risks at operational, tactical, and strategic levels and measure the total risk exposure of CSCs; (iii) comprehensively cogitates the operational, socio-environmental, and financial implications of CSCs risks and (iv) considers uncertainty in operations research (OR) models by applying a fuzzy set theory, evidential reasoning algorithm, and expected utility theory based model to evaluate and profile the CSCs risks. The proposed model contributes to the application of decision analysis and risk analysis approaches in the sustainability domain and can efficiently model uncertain, subjective, and incomplete data. Our findings reveal that customers' reluctance to purchase reprocessed products represents the most critical challenge to the effectiveness of CSCs. Furthermore, contrary to conventional perspectives, organizations are strategically shifting toward adopting circular practices. However, they often lack the practical means and resources to implement these strategies effectively.

ARTICLE HISTORY
Received 7 June 2024
Accepted 21 January 2025

KEYWORDS
Circular supply chains; evidential reasoning algorithm (ERA); expected utility theory; risk quantification; transition management theory

1. Introduction

The worldwide efforts to address the climate emergency and reduce global warming have greatly intensified over the last decade (Hosseini-Motlagh et al., 2022; Van Wassenhove, 2019). Immediate actions are required to attain net zero emissions to achieve the target of keeping global temperature rise within 2 degrees Celsius (Haque & Ntim, 2020; Stern & Valero, 2021). Material management activities have emerged as a major contributor to GHG emissions and account for about 45% of current emissions, which is expected to increase up to 66% in OECD countries by 2060 (Ellen MacArthur Foundation, 2021; Hailemariam & Erdiaw-Kwasie, 2023; OECD, 2020). Along these lines, Circular Economy (CE) is evolving as a promising solution towards attaining a net zero economy (Centobelli et al., 2020; Esposito et al., 2018; Trapp et al., 2021). CE aims to minimise resource inputs, emissions, waste, and energy consumption by keeping the products and materials in the economy as long as possible (Agrawal et al., 2021; Kouhizadeh et al., 2020; Zanjirani Farahani et al., 2022). CSCs utilise the CE principles to take back end-of-life, end-of-use, defective and obsolete products and turn those into resources through reuse, recycling, remanufacturing, refurbishing, and cannibalisation (Frishammar & Parida, 2019; Reyhani Yamchi et al., 2023; Zanjirani Farahani et al., 2022). CSCs can handle their returns and also returns of other supply chain operations and are considered the backbone of CE systems.

Although frameworks such as ReSolve are available in the literature to assist, transition towards CSCs can be turbulent due to multifunctional context and adjustments involved and resultantly, companies can get exposed to various risks in this process (de Sousa Jabbour et al., 2018; Frishammar & Parida, 2019; Taddei et al., 2022). These risks could potentially trigger unwanted consequences for CSCs, including operational disruptions, economic losses, inefficient material recovery, reputational damage, and stakeholder backlash, among others (Ethirajan et al., 2021; Ketzenberg et al., 2006; Masi et al., 2018). Hence, it is necessary to understand

CONTACT Thanos Papadopoulos a.papadopoulos@kent.ac.uk Kent Business School, Canterbury, United Kingdom
Supplemental data for this article can be accessed online at https://doi.org/10.1080/01605682.2025.2459252.

and address the risks of CSCs for the successful transition towards CE (Choudhary et al., 2022; De Lima & Seuring, 2023). Accordingly, this study seeks to make novel contributions to existent literature by investigating the risks associated with CSCs to attain the goal of a net zero economy.

The transition towards CE is complex and multifaceted, requiring adaptations at different levels that expose organisations to risks at the company-wide (transition sphere) level, functional (transition schema) level, and individual (transition agents) level (Bertassini et al., 2021; Genovese et al., 2017; Savaskan & Van Wassenhove, 2006). Hence, our extensive analysis draws insights from the multidimensional transition management theory (TMT) to understand and investigate the risks associated with CSCs. The transition management perspective views the concept of "transition" as a structural change involving multiphase multilevel processes in complex systems (Loorbach, 2010; Rotmans & Loorbach, 2009). From the lens of TMT, a transition consists of four phases: (a) organising the transition sphere by developing long-term goals; (b) Building a transition schema by structuring transition pathways; (c) Executing the transition by mobilising the actors; *d) Evaluating and learning from the transition experiment and incorporating necessary adjustments (Gennari, 2023; Kumar, 2021). Accordingly, based on TMT, this study seeks to institutionalise risks present in the sphere of CSCs into strategic, tactical, and operational umbrellas to analytically facilitate the shift towards CE.

A very limited number of studies have explored the risks associated with CE practices. However, none has investigated them in a multidimensional and integrated manner as we do in the present research. The existing studies arguably have certain limitations. First, the risks considered in most past studies are not concise, and some critical risks specific to circular models are not captured. For instance, majority of the studies have not considered marginal value of time risk, decision making risk and secondary product quality risk. Thereby, the findings may be misleading (Choudhary & Kumar, 2024; De Lima & Seuring, 2023; Panjehfouladgaran & Lim, 2020). Second, the existing studies have performed an one-directional assessment of risks and have not considered different facets of risk analysis thus, results might be spurious. Third, majority of existing studies have not drawn from any theoretical lens to understand and analyse the risks associated with CE practices. As the transition towards CE is a complex multidimensional process, TMT seems one of the most appropriate lenses for explaining and understanding the risks present in CSCs but, it is still missing in the literature (Gennari, 2023; Shankar et al., 2019). Fourth, most of the models used for risk evaluation in the CE literature are not sufficient to capture the intricacies and uncertainties involved with CSC risks (Wang et al., 2006). Majority of traditional risk assessment approaches such as AHP, TOPSIS, FMEA etc. cannot handle ignorance and incompleteness in the data and involves averaging of scores on different aspects leading to information loss and imprecise results (Choudhary et al., 2020). Arguably, it has hindered managerial and theoretical implications. Finally, although e-returns are emerging as one of the most significant growing waste streams, existing research has explored CE risks, primarily in the manufacturing sector and PET recycling, not sufficiently in e-returns (Islam & Huda, 2018; Mazahir et al., 2019).

The present study seeks to address the mentioned limitations and gaps in the literature by answering the following research questions:

1. How to operationalise the transition towards CE using the Lens of Transition Management theory (TMT)?
2. What are the most critical risks associated with CSCs in the electronic sector?

This study makes several novel contributions to the existing literature while addressing the posited research questions. It advances beyond current knowledge by offering a multidimensional and integrated investigation of risks associated with Circular Supply Chains (CSCs) to support the transition towards a Circular Economy (CE), using Transition Management Theory (TMT). The research identifies and categorizes a broad spectrum of risks specific to CSCs, proposing a comprehensive taxonomy through the lens of the Transition Framework. Additionally, the study addresses a gap highlighted by Petropoulos et al. (2024) concerning the insufficient consideration of societal aspects. It performs a thorough, multilevel analysis of risks, incorporating operational, socio-environmental, and financial perspectives at operational, tactical, and strategic levels. Another significant contribution is the application of insights from the TMT to institutionalize risk management activities within CSC systems as a necessary element for the shift towards a CE. This research is the first to profile CSC risks, quantify them at various levels, and assess the overall risk exposure of CSCs comprehensively.

The majority of traditional risk analysis approaches in the literature cannot efficiently handle the issues of subjectivity, vagueness, and incomplete information together in a problem (Choudhary et al., 2020; Tian et al., 2020; Yang et al., 2009). Petropoulos et al. (2024) also pointed the same in their review article and suggested that more research need to consider uncertainty in OR models. We attempt to address this gap in the literature by developing a fuzzy set theory, evidential reasoning and expected utility theory (FST-ER-EUT) based model to efficiently capture the uncertainties and subjectivity associated with risk modelling. ER approach is developed based on the Dempster-Shafer theory with its roots in artificial intelligence and can efficiently model the uncertainty in data (Liu et al., 2011; Wan et al., 2024). FST can also capture the vagueness and uncertainty in data while ER algorithm is also suitable to handle incomplete and subjective information (Jia et al., 2016; John et al., 2014; Wang et al., 2006; Wu et al., 2017; Zhang & Liao, 2023). The ERA output is in the form of belief degree structures that are converted into crisp risk scores using the EUT to quantify, compare, and profile risks (Choudhary et al., 2020; Fu et al., 2019; Fulzele & Shankar, 2023). In line with Petropoulos et al. (2024), the proposed model contributes to the application of decision analysis and risk analysis approaches in the sustainability domain and this represents one of the first attempts to implement this model in the CE domain.

For analysis purposes, the study has taken a sample of firms from the Indian electronics sector. Exponentially growing e-waste poses a serious challenge in the path of net zero and the issue is even larger in developing economies such as India. After China and the US, India has emerged as the largest contributor to e-waste. The amount of e-waste generated in India is approximately 1.71 million metric tons annually, growing 10 per cent yearly (Agrawal et al., 2014). Only less that 10% of e-waste is handled by formalised channels in India (Baldé et al., 2022; Esposito et al., 2018). E-waste contains hazardous elements such as lead, asbestos, mercury etc. and improper handling of e-waste can release these toxic substances posing serious threats to health and ecosystem (Islam & Huda, 2018). Accordingly, it is imperative to investigate the CSC risks in the context of Electronics sector to facilitate the adoption of circular practices in developing countries such as India. The remaining parts of the paper are arranged as follows: Section 2 details the background to the study; Section 3 clearly outlines the methodology used; Section 4 illustrates the application of the model for risk analysis; Section 5 includes results and discussion; and lastly, Section 6 offers conclusion and implications.

2. Background

This research seeks to understand and examine the risks associated with CSCs from the lens of Transition Management theory to facilitate the transition towards CE systems. A comprehensive background literature on the related topics is discussed in this section.

2.1. Circular supply chains: Transition towards CE

The diminishing availability of resources, overflowing landfill sites, as well as the growing rate of product returns and the introduction of extended producer responsibility legislation together are making it imperative for organisations to close the SC loops (Agrawal et al., 2021; Haque & Ntim, 2020; Liu et al., 2023; Trapp et al., 2021). CSCs involve managing returns of linear supply chains of different sectors to retrieve the residual value (Ethirajan et al., 2021; Geissdoerfer et al., 2017; Hailemariam & Erdiaw-Kwasie, 2023). Successful handling of returns can offer a competitive advantage to companies by benefiting the environment and society as well as their balance sheets through optimum utilisation of resources (Grafström & Aasma, 2021; Hosseini-Motlagh et al., 2022; Mazahir et al., 2019; Savaskan & Van Wassenhove, 2006). Hence, CSCs go well beyond simply dealing with legal and environmental duties and provide benefits by lowering expenses, raising more revenue, ensuring consumer loyalty, and increasing value (Abbey et al., 2015; Govindan et al., 2015; Zhang et al., 2021)

Regardless of benefits, transforming a linear SC into a circular is a complex task owing to the multifunctional context and involvement of numerous activities and processes (Choudhary & Kumar, 2024; Frishammar & Parida, 2019; Guide & Van Wassenhove, 2009; Münch et al., 2022). The movement of product returns is far less structured than forward supply chains and exposes CSCs to various uncertainties with time and amount of returns, residual value, and reprocessing option selection etc. (Bertassini et al., 2021; Guide et al., 2006; Ketzenberg et al., 2006). These uncertainties can trigger unwanted events, thereby exposing the circular systems to numerous risks (De Lima & Seuring, 2023; Dulia et al., 2021; Frishammar & Parida, 2019; Shankar et al., 2018). In most cases, returns lose the majority of their strategic value in return channels, especially in the electronics sector, because of these risks and ambiguities (Guide & Van Wassenhove, 2009; Zanjirani Farahani et al., 2022). Hence, to attain the desired net-zero goal, it is necessary to minimise the vulnerability of CSCs to these risks (Choudhary et al., 2021; De Oliveira et al., 2021).

A significant quantity of research has been conducted in the context of CE. The majority of studies have focused on aspects related to drivers and enablers, impediments, technology, operational efficiency, and sustainability (Choudhary et al. (2022); Govindan et al. (2015); Sassanelli et al. (2019)). However, the risk management avenues in the context of CE are relatively unexplored and neglected in the literature, which this research seeks to address. Only a handful of studies have investigated CE related risks. An overview of articles addressing risk aspects in the context of CE-led supply chains and operations is presented in Table 1A in Supplementary Appendix.

Based on the review, summarily, following are the gaps present in the extant literature:

a. Lack of studies focussing on operationalising the transition towards CE;
b. Comprehensive multidimensional analysis and profiling of risks in the context of CSCs is missing in the literature;
c. Studies deriving insights from a theoretical lens to understand CSC risks are virtually non-existent with no studies using the lens of transition management theory in this context; and
d. Dearth of attention towards management of CSC risks in the electronic sector.

In every sphere, deliberate and continuous attention to managing risks are imperative to avoid the associated consequences and attain the desired goals. Similarly, to effectively integrate CE practices in supply chains and achieve a high socio-environmental and economic performance, risk exposure of CSCs needs to be optimized and managed. CSCs are quite complicated and vulnerable to various risks due to uncertainties associated with returns and multifaceted operations. It is important to identify and analyse the risks associated with CSCs to attain circular goals, which is lacking in the extant literature. Hence, this study seeks to address the mentioned gaps in the literature by comprehensively investigating the risks present in CSC using the lens of Transition Management theory in the Indian Electronics sector.

2.2. Risks in CSCs: A transition management perspective

Transition Management is an all-encompassing multidimensional theory that provides the basis for managing and understanding shifts in complex systems. Transition is a process where a complex system adapts to changing external and internal circumstances to arrive at a different state with a higher order of complexity. The interactions among other aspects of the economy, society, ecology, and technology during transitions increase complexity and unpredictability. Transition management theory attempts to coordinate and structure the networks of actors that play a role in transition, thereby influencing the direction and speed of transitions through different shifts.

Although every transition is unique in terms of actors, contexts, issues, and solutions, according to the transition management theory, there are four major transition stages: strategic, tactical, operational, and reflexive. The strategic stage involves developing the transition arena where actors with diverse backgrounds and perceptions are involved in problem discussions to determine the directions for integrated solutions. It includes creating structures for long-term planning and developing guiding principles for attaining the envisaged transition. In the tactical stage, the transition views of the future assimilated in the strategic step are developed into transition agendas, translating into different paths towards the envisioned direction. Strategies and policies are fine-tuned in line with the transition vision and transformed into actions. Based on the transition vision and pathways, in the operational stage, activities are derived to contribute towards overall transition goals. The steps should support overall transition objectives and also reinforce other efforts. Lastly, continuous monitoring and evaluation of the transition arena, pathways, and actions are significant aspects of transition management and constitute the reflexive stage.

Summarily, the primary concept behind transition management theory is to understand and facilitate complex shifts by developing a transition vision (strategic), which is transformed into different transition pathways (tactical) that are translated into various actions (operational) to attain the envisaged transition. In this line, transition management provides an appropriate lens to understand a complex shift from a traditional linear economy to a circular economy. Hence, this research draws from the transition management framework to understand and examine the risks at various stages of CSCs to ensure an organised and structured shift towards CE.

Risk is an uncertain event that poses a threat of injury, damage, loss, liability, or other negative consequences. Risks can be measured using probability of occurrence and potential impact. On the other hand, uncertainty is basically unmeasurable. It implies that we know about the events that might occur in future but cannot assign a probability to these events as we cannot predict their occurrence. However, in case of risks, we can predict the possible occurrence of events and assign probabilities. For instance, a shopkeeper informing you will get a product within 2 days is uncertainty while notifying that there is a 95% chance you will get the product is a risk. The risk management process comprises four steps: identification, evaluation, mitigation, and monitoring of risks. The first step involves identifying hazards inherent in a given system to create visibility. The next step is evaluating and quantifying identified risks to predict the associated consequences and severities. In the mitigation stage, companies focus on detecting and mitigating risks proficiently. Finally, companies construct and maintain a risk monitoring system that emerges as an integral component of the company's ethos. A framework integrating the risk management steps into the CSC sphere using the lens of Transition Management theory is presented in Figure 1.

The identification of risks anticipates potential future threats and provides an understanding about various disruptions that could hinder organizational vision. Similar to transition pathways, the evaluation stage offers ways to attain organizational vision by uncovering the most critical risks that can cause serious disruptions. Risk mitigation stage corresponds to taking actions by implementing different strategies to address the critical risks. Lastly, the risk monitoring stage includes keeping a continuous track of existent threats along with new and emerging risks to facilitate risk control. Accordingly, it is strategically necessary for organisations to identify the risks present in CSCs to enable the swift transition towards CE.

In line with the proposed framework, the study initially seeks to identify and propose a taxonomy of risks associated with CSCs using the insights from the transition management framework. With this in mind, a detailed review of literature related to CSC and CE is performed, and twenty-four risks are identified and categorised into strategic, tactical, and operational groups. Next, three experts from the electronic industry are selected based on purposiveness sampling to check for the appropriateness and significance of identified risks in the CSC context. One of the experts held a doctoral degree in managing e-returns and is working as a senior consultant in a multinational organization in the electronics sector with an experience of about 8 years. The other two experts are working as chief operations officer and senior manager in the electronics sector with an experience of 13 and 11 years, respectively. All the experts have a clear understanding of risk concepts and sufficient knowledge about electronic returns as they are dealing with batteries, mobile phones, laptops, TVs and other e-returns.

Multiple rounds of detailed discussions with each expert were conducted for finalising the risks. In the initial round, each expert provided their opinion about the relevance of identified risk. For few risks, consensus was not attained and a second round of discussion was performed to attain an agreement. The risks for which consensus was not achieved, viewpoint of the majority was taken into

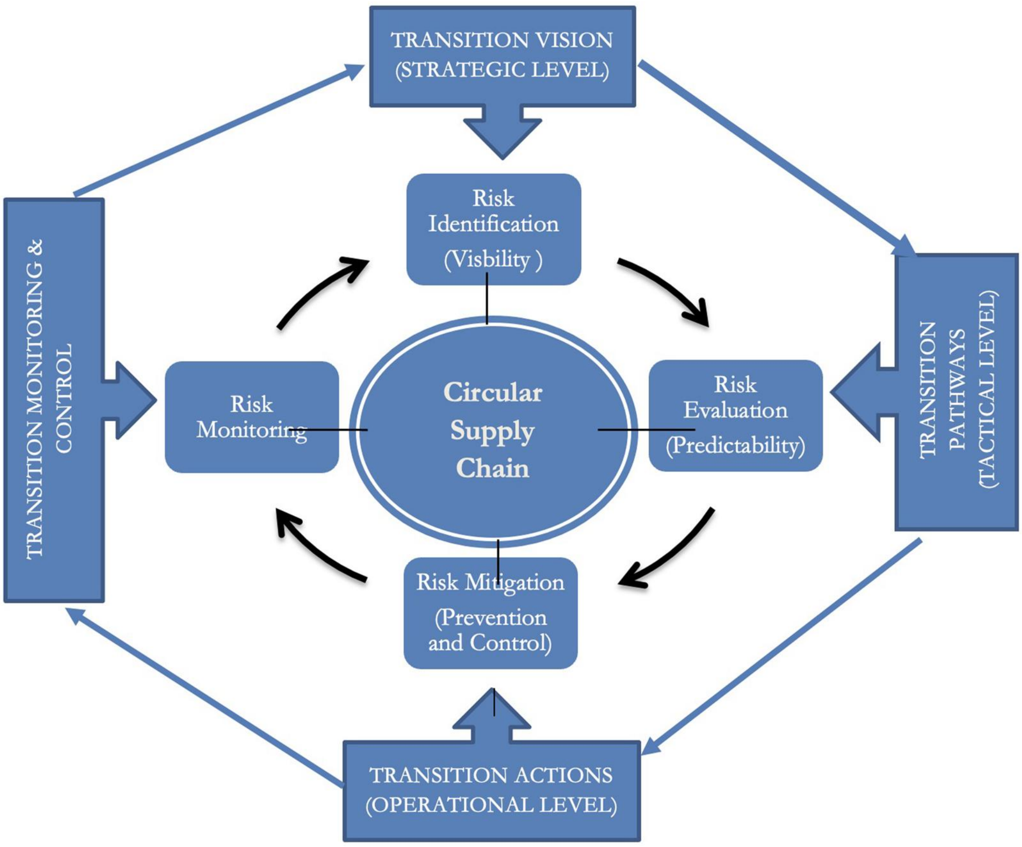

Figure 1. A risk management framework for CSCs based on TM theory.

consideration. Finally, eighteen risks were selected and categorized as shown in Table 1 and the final list was presented to experts for their approval. The finalised risks comprehensively covers various aspects and are quite specific to the CSC context. A brief description of the risks and corresponding references are provided in Table 2A in Supplementary Appendix.

Next, the study addresses the gaps in the existing literature by developing a mathematically robust model to quantify and profile the CSC risks inclusively while considering economic, operational, and socio-environmental impacts.

Table 1. Risks in CSCs.

Transition management lens	RISKS in CSCs
Operational level	Inaccurate forecast risk [R1]
	Technical expertise risk [R2]
	Marginal value of time risk [R3]
	Information accessibility risk [R4]
	Return handling risk [R5]
	Recovery risk [R6]
	Reprocessed quality risk [R7]
Tactical level	Network design risk [R8]
	Decision-making risk [R9]
	Facility risk [R10]
	Reprocessing technology risk [R11]
	Communication coordination risk [R12]
	Inventory management risk [R13]
Strategic level	Acceptance risk [R14]
	Market risk [R15]
	Return on investment risk [R16]
	Lack of awareness risk [R17]
	Commitment risk [R18]

3. Methodology

This paper proposes a flexible and robust integrated methodology combining FST, ERA, and EUT to quantify and profile the risks associated with CSCs. Most of the conventional risk analysis approaches presented in the literature have limitations, including information loss, subjectivity, imprecise results, and inefficiency in dealing with uncertain and incomplete information (Choudhary et al., 2020; Fu et al., 2019; John et al., 2014; Zhang & Liao, 2023). The proposed approach overcomes these limitations in following ways. First, FST is capable of handling uncertain information and finding rationality in the ambiguousness of human decisions (Fulzele & Shankar, 2023; Jia et al., 2016; Wang et al., 2006; Wu et al., 2017). Subsequently, the ERA allows incompleteness in the information and efficiently models the inevitable subjectivity in expert inputs (Chen et al., 2014; Fang et al., 2021; Liu et al., 2011; Tian et al., 2020; Yang, 2001; Zhang et al., 2021). Second, it uses a pragmatic way of representing the linguistic assessment of each attribute as a distributed assessment using belief degree structures to avoid information loss. Third, instead of using averaging, ERA applies the evidence combination rule from Dempster–Shafer (D–S) theory to synthesize linguistic assessments, thus provides reliable inferences. The proposed model has been used in reverse auction (Zhang & Liao, 2023); risk assessment in freight transportation and sea port operations (Choudhary et al., 2020; John et al., 2014); performance measurement (Fulzele & Shankar, 2023) and equity financing (Wan et al., 2024). However, the application of the proposed approach in the CSC domain is one of the first attempts of its kind. The methodological steps are described in detail as follows.

3.1. Step 1: Linguistic assessment of risks

Linguistic variables are utilized in situations that are complex and vague, in which conventional quantitative expressions are unable to offer clear explanations (Liu et al., 2011). These variables can describe ambiguous and ill-defined states using words and sentences in natural language, which is easier to use by decision makers (Li & Wei, 2019). Hence, in most cases where quantitative information about risk events are unavailable, risk assessments are performed using linguistic variables (Liu et al., 2011). The evaluation of risks is primarily done across two facets: impact (I); and probability of occurrence (P) (Heckmann et al., 2015). In this case, the risk impact is examined across three aspects, namely, operational impact (OI); environmental & safety impact (E&SI); and financial impact (FI). To linguistically evaluate the P & I aspects of risks, experts can utilize the five-point linguistic scale, very low (VL), low (L), Medium (M), High (H) & Very High (VH), depicted in Table 2 (Choudhary et al., 2020). Based on P and I, the severity (S) of risks can then be computed based on the equation given below (Schlegel & Trent, 2014).

$$S = P \times I \tag{1}$$

I represent overall impact calculated as the average of OI, E&SI, and FI.

3.2. Step 2: Calculation of fuzzy severities using FST

In this step, linguistic assessments provided in the previous steps are transformed into the corresponding triangular fuzzy numbers using the scale presented in Table 2 and Figure 2. The qualitative variables are represented by a curve known as “membership function,” explaining the mapping of each point in the input space at a membership value ranging between 0 and 1 (Zadeh, 1965). Various membership functions are applicable depending on the circumstances. Here, triangular fuzzy numbers (TFNs) have been applied on the strength their computational simplicity and user-friendliness (Yang et al., 2009).

Table 2. Conversion of linguistic terms into corresponding triangular membership functions.

		Impacts			
Scale	Probability of occurrence (P)	OI	E&SI	FI	Triangular fuzzy membership function
1	VL	VL	VL	VL	(0, 0, 0.25)
2	L	L	L	L	(0, 0.25, 0.50)
3	M	M	M	M	(0.25, 0.50, 0.75)
4	H	H	H	H	(0.50, 0.75, 0.10)
5	VH	VH	VH	VH	(0.75, 1, 1)

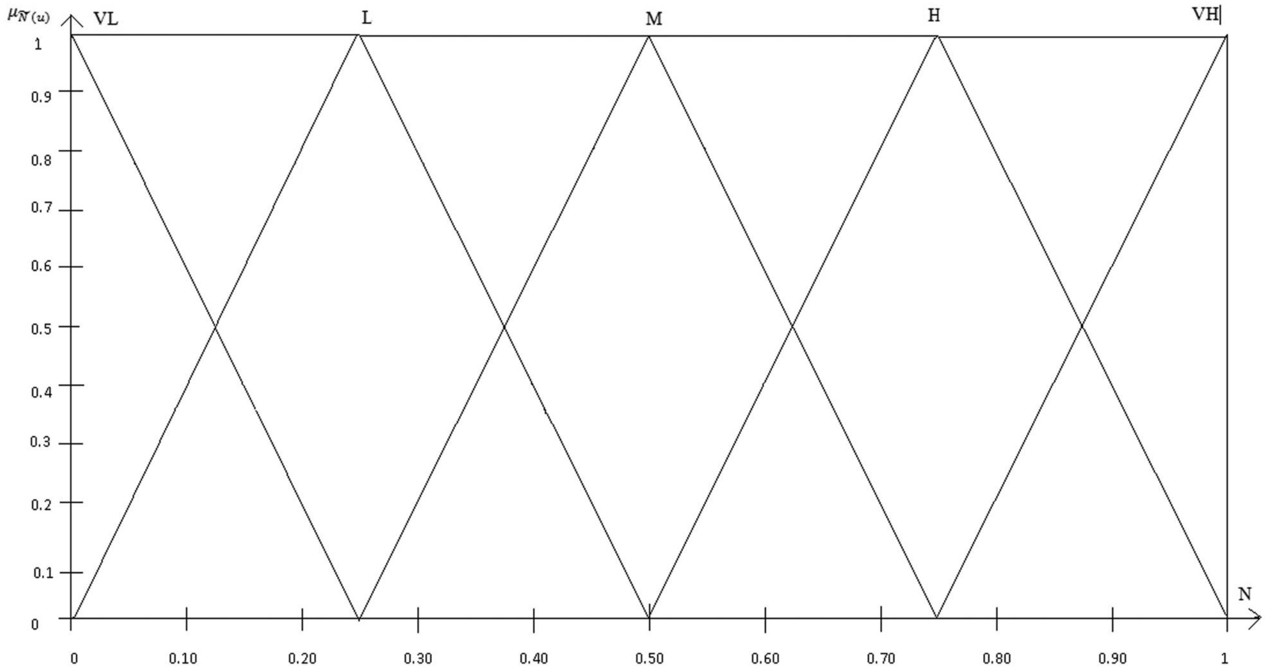

Figure 2. Fuzzy triangular membership function (Yang, 2001).

In the fuzzy environment, the obtained assessments for a risk, R can be represented as: $\tilde{P} = \mathrm{TFN}_{(\mathrm{P})} = (x_P,\ y_P, z_P)$; $\tilde{OI} = \mathrm{TFN}_{(\mathrm{OI})} = (x_{OI},\ y_{OI}, z_{OI})$, $E\tilde{\&}SI = \mathrm{TFN}_{(\mathrm{E\&SI})} = (x_{ESI},\ y_{ESI}, z_{ESI})$ and $\tilde{FI} = \mathrm{TFN}_{(\mathrm{FI})} = (x_{FI},\ y_{FI}, z_{FI})$. The overall impact $\tilde{I} = \mathrm{TFN}_{(\mathrm{I})} = (x_I,\ y_I, z_I)$ can be calculated by taking the average of $\tilde{OI}$, $E\tilde{\&}SI$ and $\tilde{FI}$ as shown in Equation (2). Next, the fuzzy severity, $\tilde{S}$ for each risk can be computed using Equation (1), as presented in Equation (3).

$$\tilde{I} = \mathrm{Avg.}\left(\tilde{OI}, E\tilde{\&}SI \text{ and } \tilde{FI}\right) = \left(\frac{x_{OI}+x_{ESI}+x_{FI}}{3}, \frac{y_{OI}+y_{ESI}+y_{FI}}{3}, \frac{z_{OI}+z_{ESI}+z_{FI}}{3}\right) \tag{2}$$

$$\tilde{S} = \tilde{P} \otimes \tilde{I} = (x_P * x_I, y_P * y_I, z_P * z_I) \tag{3}$$

Furthermore, on the basis of Equations (2) and (3), FST may be deployed to classify risks as outlined in Table 3. The centroid value, K is calculated as follows:

$$\mathrm{K} = \frac{1}{3}\ (x + y + z) \tag{4}$$

3.3. Step 3: Transformation of fuzzy severities into belief degree structures

A belief degree refers to a measure of the extent to which a decision is considered true: it can be 100% or less. In this step, the fuzzy severities computed in the previous step are converted into corresponding belief degree structures with a similar set of

Table 3. Explanation of qualitative scale applied for analyzing risks.

	Evaluation aspects			
Linguistic terms	Probability of occurrence (P)	Overall impact (I)	Membership function	Centroid values (K)
Very low severity risk (VL)	Very low (0, 0, 0.25)	Very low (0, 0, 0.25)	(0.0, 0.0, 0.0625)	0.020
Low severity risk (L)	Low (0, 0.25, 0.50)	Low (0, 0.25, 0.50)	(0.00, 0.0625, 0.25)	0.104
Medium severity risk M)	Medium(0.25, 0.50, 0.75)	Medium(0.25, 0.50, 0.75)	(0.0625, 0.25, 0.5625)	0.292
High severity risk (H)	High (0.50, 0.75, 1)	High (0.50, 0.75, 1)	(0.25, 0.5625, 1.00)	0.604
Very high severity risk (VH)	Very high (0.75, 1, 1)	Very high (0.75, 1, 1)	(0.5625, 1.00, 1.00)	0.854

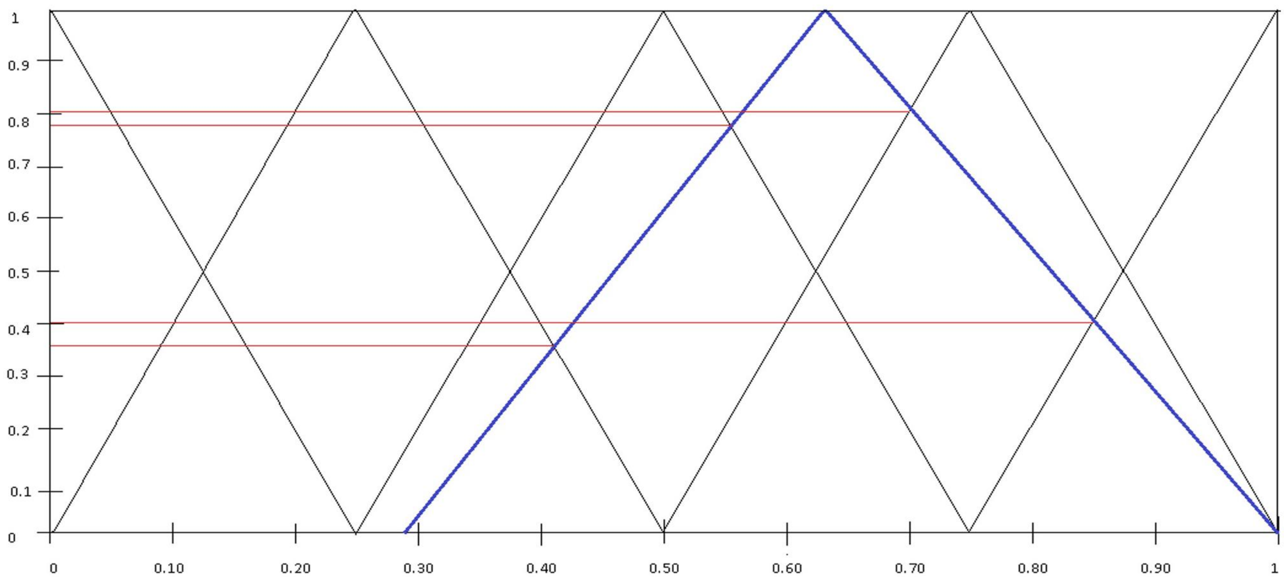

Figure 3. Example of transformation of fuzzy severity, $\tilde{S}$ into 5 non-normalized grades.

Table 4. Illustration of conversion of $\tilde{S}$ into the corresponding belief degree structure.

Fuzzy severity $\tilde{S}$ 0.29, 0.63, 1.00					
Grade	VL	L	M	H	VH
BDS	0.00	0.36	0.78	0.80	0.40
$BDS_{\tilde{S}}$	0.00	0.15	0.33	0.34	0.17

evaluation grades for all risks. For illustration purposes, suppose fuzzy severity, $\tilde{S}$ = (0.29, 0.63, 1.00). To transform $\tilde{S}$ into the corresponding belief degree structure constituting a normalized fuzzy set defined in the five linguistic terms, the following steps need to be followed (Choudhary et al., 2020; Zhang et al., 2021):

- The computed triangular fuzzy severity, $\tilde{S}$ is mapped over the triangular fuzzy membership function (TFN_R), which has five grades (VL, L, M, H, and VH) described in the broad discourse on risk based on Figure 2. The thick lines in Figure 3 represent the triangle obtained by the mapping of $\tilde{S}$.
- The points where the linguistic term of TFN_R are intersected by the newly-mapped triangle representing $\tilde{S}$ are identified and marked in Figure 3.
- If triangle representing $\tilde{S}$ intersects a linguistic term of TFN_R at more than one point, the maximum value is taken.
- Courtesy of intersecting points decided in Figure 3, a belief degree structure (BDS) is established to define five non-normalized grades, which are the intersection points of $\tilde{S}$ and TFN_R as shown in Table 4.
- Finally, the non-normalized grades are normalized to attain the belief degree structure representing $\tilde{S}$ as shown in Table 4.

3.4. Step 4: Aggregation of belief degree structures using the ERA

During this step, the ERA is applied to synthesize the expert evaluations gathered as BDSs in the previous step with respect to each of the selected risks. The development of the ERA here is founded on the Dempster–Shafer theory. The mathematical foundations of the ERA utilised to integrate varying BDSs are explained below (Yang, 2001; Wang et al., 2006).

Suppose D correspond a class of five linguistic risk evaluation terms gleaned from the aggregation of a pair of subclasses D_1 and D_2 given by two different experts, then D, D_1 and D_2 can each be represented as follows:

$$\begin{aligned} D &= \left(\beta^1\text{“VL”},\ \beta^2\text{“L”},\ \beta^3\text{“M”},\ \beta^4\text{“H”},\ \beta^5\text{“VH”}\right) \\ D_1 &= \left(\beta_1^1\text{“VL”},\ \beta_1^2\text{“L”}, \beta_1^3\text{“M”},\ \beta_1^4\text{“H”},\ \beta_1^5\text{“VH”}\right) \\ D_2 &= \left(\beta_2^1\text{“VL”},\ \beta_2^2\text{“L”},\ \beta_2^3\text{“M”},\ \beta_2^4\text{“H”},\ \beta_2^5\text{“VH”}\right) \end{aligned}$$

Suppose w_1 and w_2 are the normalized relative weights of the two experts partaking in the analysis and $w_1 + w_2 = 1$. Furthermore, assume P_i^n ($n = 1$, 2, 3, 4 and 5; $i = 1$ or 2) represents the extent to which i^{th} subset (D_i) supports the hypothesis that severity has been evaluated in accordance with the five linguistic terms. Then it is possible that P_1^n and P_2^n be determined as:

$$P_1^n = w_1 \times \beta_1^n \tag{5a}$$

$$P_2^n = w_2 \times \beta_2^n \tag{5b}$$

Let B_1 and B_2 are the lingering degree of belief values unassigned for P_1^n and P_2^n ($n = 1$, 2, 3, 4 and 5). In that case, B_1 and B_2 can be yielded as follows

(Liu et al., 2011):

$$B_1 = \overline{B}_1 + \tilde{B}_1 \quad (6a)$$

$$B_2 = \overline{B}_2 + \tilde{B}_2 \quad (6b)$$

Where, $\overline{B}_m$ (m = 1 or 2) represents the degree to which the other expert may partake in the evaluation, $\tilde{B}_m$ (m = 1 or 2) presents the probable incompleteness in the subsets D_1 and D_2. It is possible for these to be conveyed as follows:

$$\overline{B}_1 = 1 - w_1 = w_2 \quad (7a)$$

$$\overline{B}_2 = 1 - w_2 = w_1 \quad (7b)$$

$$\tilde{B}_1 = w_1 \left(1 - \sum_{n=1}^{5} \beta_1^n \right) \quad (8a)$$

$$\tilde{B}_2 = w_2 \left(1 - \sum_{n=1}^{5} \beta_2^n \right) \quad (8b)$$

Suppose $\beta^{n'}$ ($n = 1, 2, 3, 4$ and 5) is the non-normalized degree of belief corresponding to the risk assessments under each of the five linguistic variables obtained by combining the inputs of Organizations 1 and 2. Moreover, consider that the remaining non-normalized unassigned belief degree is represented by B'_U. The recursive ERA can be presented as follows (Yang et al., 2009):

$$\beta^{n'} = K\,(P_1^n P_2^n + P_1^n B_2 + P_2^n B_1) \quad (9a)$$

$$\overline{B}'_U = K\,(\overline{B}_1 \overline{B}_2) \quad (9b)$$

$$\tilde{B}'_U = K\,(\tilde{B}_1 \tilde{B}_2 + \tilde{B}_1 B_2 + B_1 \tilde{B}_2) \quad (9c)$$

$$K = \left[1 - \sum_{j=1}^{5} \sum_{\substack{l=1 \\ l \neq j}}^{5} P_1^j P_2^l \right]^{-1} \quad (10)$$

Furthermore, the combined degree of belief, β^n derived by combining the assessments provided by the experts for each risk issue and the unassigned belief degree, β_U representing the overall incompleteness in assessment are measured in the following way (Wang et al., 2006):

$$\beta^n = \beta^{n'} / (1 - \overline{B}'_U)\ (n = 1, 2, 3, 4 \text{ or } 5) \quad (11a)$$

$$\beta_U = \tilde{B}'_U / (1 - \overline{B}'_U) \quad (11b)$$

The process outlined above is relevant to the combination of two subsets only. If more subsets need to be synthesized, the outcome of the aggregation of any two subsets can then be combined with another subset in accordance with the algorithm's steps outlined previously.

3.5. Step 5: Computation of crisp risk scores using expected utility theory (EUT)

This step involves converting aggregated belief structures obtained as outputs of the ERA in the previous step into corresponding crisp scores. To compute the same, the utility of each evaluation term needs to be calculated. The utilities of evaluation terms are assumed to be equidistantly distributed in the normalized utility space and can be calculated as follows (John et al., 2014):

$$u(E_n) = (H_n - 1) \,/\, (H_N - 1)\ (n = 1, 2, \ldots, N) \quad (12)$$

H_n is the rating of the evaluation term being examined (E_n) and H_N is the rating of the most preferred linguistic evaluation grade (E_N). The aggregated belief degree structure for a risk obtained by combining expert decisions can be represented as:

$$BDS_{\tilde{S}} = \{(E_n, \beta_n),\ n = 1, 2, 3, \ldots\ldots, N\} \quad (13)$$

Where, β_n represents the degree of belief that the risk severity level is assessed to the corresponding evaluation grade E_n. In this case, the utility of $BDS_{\tilde{S}}$ can be calculated as follows (Choudhary et al., 2020):

$$u(BDS_{\tilde{S}}) = \sum_{n=1}^{N} \beta_n\ u(E_n) \quad (14)$$

The $u(BDS_{\tilde{S}})$ calculated above is equivalent to the corresponding risk scores.

4. Application of the FST-ERA-EUT based model for risk quantification in CSCs: A multi-case approach

This section illustrates applying the described approach in a real-world scenario to quantify and profile the CSC risks identified in Table 1.

4.1. Data collection

The analysis in this study is based on real-world data gathered from the electronics industry through semi-structured interviews. We have considered the electronics sector for the research as e-waste constitutes the fastest-growing waste stream with huge potential for value recovery (Baldé et al., 2022; Mazahir et al., 2019). E-waste is increasing at a rate of 3–5% per year in the EU alone, and e-waste generated on average is five times more than that caused by end-of-life vehicles (Islam & Huda, 2018). It is expected that e-waste will increase to 110 MT by 2050, and according to reports, only 20% of returns are recycled (Baldé et al., 2022; Esposito et al., 2018). Further, e-waste has huge recovery potential for elements such as copper, aluminium, gold and silver among others. Estimates show that a ton of waste circuit boards contains 30–40 times more residual copper than a ton of copper ore (Esposito et al., 2018). Hence, there is a huge potential for implementing CE practices in the electronics sector, especially in emerging economies such as India. Recently, there is a lot of focus in India to handle the increasing e-waste and also a policy has been introduced in 2022 to formalise the e-waste recycling sector in India.

For this study, three established multinational organisations from the Indian electronics sector were selected. Small scale players are not selected because they do not have a comprehensive view of entire CSC and have limited expertise in risk management. The selected organisations are involved in formalised CSC practices and seek to efficiently manage the returns of numerous electronic products such as mobile phones, laptops, washing machines, TVs, and refrigerators. Within these organisations, appropriate experts for the study were identified using purposive sampling based on their professional responsibilities and recommendations. In purposive sampling, respondents are selected based on their appropriateness and ability to yield useful information. The benefit of using purposive sampling is the better alignment of the sample with the objective of the study, which enhances the trustworthiness and reliability of data and results (Campbell et al., 2020). Two aspects were primarily taken into account while selecting experts. First, they must have been actively involved in handling returns and other CSC operations in their organisation. Second, they needed to be proficient in risk management concepts and have practical exposure to taking risks in the industry.

Semi-structured interviews were conducted with each identified expert. Seventeen semi-structured interviews were conducted, including six experts from Organisation 1 (O1), five experts from Organisation 2 (O2), and six experts from Organisation 3 (O3). The details about the background and experience of experts are provided in Table 5. In the semi-structured interviews, the scope of the study was first explained, followed by a detailed description of each identified risk. Then, the experts were requested to judge the relevance of all identified risks in the CSC context and to linguistically evaluate the probability of occurrence (P), operational impact (OI), environmental& safety impact (E&SI), and financial impact (FI) of each risk by applying the scale presented in Table 2 in the methodology section. All the identified risks were found to be relevant by all experts. In order to reduce the biases in expert judgements, multiple discussions were carried out with the experts within each organization. Instead of taking averages, we tried to eliminate differences in expert opinions to arrive at a single consensus–based input corresponding to each organisation. The majority's opinion was considered for the few relationships where an agreement could not be reached. Further, to address the subjectivity and enhance the reliability of results, the inputs are converted to belief degree structures, which are finally combined together through ERA.

4.2. Application of the proposed model for risk evaluation

Based on the steps explained in the previous section, the analysis was performed as follows:

Step 1: The linguistic assessments obtained from the experts corresponding to the three organisations are presented in Table 6.

Step 2: The linguistic assessments were transformed into corresponding triangular fuzzy numbers based on Table 2. Furthermore, based on OI, E&SI, and FI, the overall Impact, I was computed using Equation (2). Finally, fuzzy severities were calculated for each risk using Equation (3) and are presented in Table 3A in Supplementary Appendix.

Step 3: The fuzzy severities obtained for each risk in the previous step were converted into the corresponding belief degree structures, as explained in Step 3 in Methodology. The results obtained are presented in Table 3A in Supplementary Appendix.

Step 4: The risk assessments obtained in the form of belief degree structures based on the inputs from the three organisations were aggregated together for each risk by applying the ERA using Equations (5)–(11). The output of the ERA is shown in Table 7.

Step 5: The aggregated belief degree structures are then transformed into corresponding crisp values known as risk scores (RSs) using EUT based on Equations (12)–(14) as explained in Table 8. Based

Table 5. Information about experts.

Experts	Designation	Experience	Experts	Designation	Experience
Expert 1	Manager	11 years	Expert 10	Technical Consultant	5 Years
Expert 2	Director	16 years	Expert 11	Senior Manager	12 Years
Expert 3	Senior Consultant	9 years	Expert 12	General Manager	13 Years
Expert 4	Senior Consultant	7 years	Expert 13	Assistant General Manager	9 Years
Expert 5	Business Analyst	5 years	Expert 14	Consultant	8 Years
Expert 6	Risk Consultant	10 years	Expert 15	Consultant	9 Years
Expert 7	Chief Operations Officer	17 years	Expert 16	Technical Analyst	7 Years
Expert 8	Assistant Manager	4 years	Expert 17	Technical Analyst	6 Years
Expert 9	Operations Manager	9 years			

Table 6. Assessment of risks in linguistic terms.

		Organization1				Organisation 2				Organisation 3			
Transition management lens	Risks	P	OI	E&SI	FI	P	OI	E&SI	FI	P	OI	E&SI	FI
Operational level	R1	H	H	M	VH	H	H	L	VH	M	H	L	H
	R2	VH	H	H	H	H	M	M	H	H	M	M	M
	R3	VH	H	H	H	VH	M	H	VH	H	L	L	H
	R4	H	H	M	L	H	H	H	VH	L	H	H	L
	R5	M	M	M	L	M	H	H	M	L	L	H	L
	R6	M	M	M	L	M	VH	VH	VH	M	H	H	L
	R7	H	H	M	L	H	H	L	VH	M	M	M	M
Tactical level	R8	H	H	M	L	H	H	M	H	H	H	H	H
	R9	H	H	M	VH	H	VH	M	VH	M	L	H	H
	R10	H	H	M	L	M	VH	H	H	L	H	H	L
	R11	M	M	M	L	M	VH	L	M	H	M	M	M
	R12	VH	H	H	H	H	L	L	H	H	H	H	H
	R13	VH	H	H	H	H	VH	VH	VH	H	L	H	L
Strategic level	R14	H	H	M	L	M	H	M	H	M	M	M	L
	R15	VH	H	H	H	H	VH	L	VH	H	H	M	H
	R16	M	M	M	L	M	M	VL	H	H	H	M	H
	R17	H	H	M	L	H	VL	VL	VH	H	H	H	H
	R18	M	M	M	L	H	M	L	VH	H	H	H	H

Table 7. Risk scores and profiling of risks.

		Aggregated assessment via ERA (α_n)							
TM LENS	Risks	VL	L	M	H	VH	RSS	Rank	Profiling
Operational lens	R1	0.064	0.379	0.163	0.319	0.075	0.490	7	High
	R2	0.053	0.239	0.389	0.297	0.022	0.499	6	High
	R3	0.033	0.206	0.456	0.154	0.151	0.545	3	High
	R4	0.100	0.294	0.320	0.207	0.078	0.467	9	High
	R5	0.242	0.459	0.236	0.063	0.000	0.280	18	Medium
	R6	0.142	0.523	0.117	0.218	0.000	0.353	14	Medium
	R7	0.146	0.291	0.222	0.292	0.049	0.452	10	High
Tactical lens	R8	0.038	0.268	0.325	0.276	0.092	0.529	5	High
	R9	0.034	0.231	0.377	0.269	0.089	0.537	4	High
	R10	0.133	0.341	0.296	0.112	0.117	0.435	11	Medium
	R11	0.173	0.466	0.298	0.063	0.000	0.313	16	Medium
	R12	0.074	0.265	0.353	0.279	0.030	0.482	8	High
	R13	0.032	0.166	0.337	0.465	0.000	0.559	2	High
Strategic lens	R14	0.151	0.435	0.311	0.104	0.000	0.342	15	Medium
	R15	0.010	0.212	0.275	0.435	0.069	0.585	1	High
	R16	0.195	0.520	0.168	0.083	0.034	0.310	17	Medium
	R17	0.205	0.117	0.543	0.105	0.030	0.410	13	Medium
	R18	0.091	0.332	0.383	0.163	0.031	0.428	12	Medium

Table 8. Obtaining the risk scores using EUT.

E_n	Very high	High	Medium	Low	Very low
H_n	5	4	3	2	1
$u(E_n)$	$\frac{(5-1)}{(5-1)} = 1$	$\frac{(4-1)}{(5-1)} = 0.75$	$\frac{(3-1)}{(5-1)} = 0.5$	$\frac{(2-1)}{(5-1)} = 0.25$	$\frac{(1-1)}{(5-1)} = 0$
β_n	0.075	0.319	0.163	0.379	0.064
$\beta_n \; x \; u(E_n)$	0.075	0.239	0.082	0.095	0

Table 9. Quantification of risks at CSC levels.

	Aggregated assessment via ERA (α_n)						
CSC levels	VL	L	M	H	VH	RSS	Profiling
Operational level	0.103	0.357	0.273	0.218	0.048	0.4376	Medium
Tactical level	0.074	0.293	0.343	0.241	0.048	0.4739	High
Strategic level	0.122	0.332	0.348	0.169	0.029	0.4132	Medium
Aggregated risk exposure	0.092	0.337	0.330	0.203	0.037	0.4395	Medium

on the computed RSs and centroid values in Table 3, the risks are profiled into VL, L, M, H, & VH categories. The calculated results are given in Table 7.

Step 6: Finally, the aggregated belief degree structures obtained for each risk, as shown in Table 7, are further combined under each category to quantify the dangers at operational, tactical, and strategic levels in CSCs. The results obtained are shown below in Table 9.

Quantifying risks at individual, unconditional and holistic levels could provide insights into managing the transition towards CE by addressing the critical risks associated with CSCs.

5. Results & discussion

According to the proposed framework, risk management is essential to establish visibility and predictability across CSCs to transition towards CE effectively. The study applies a transition management framework to identify and categorise risks present at different levels of CSCs. An integrated model based on FST, ERA, and EUT is developed to quantify and profile the hazards and measure the risk exposure of CSCs considering OI, FI and SEI. The results obtained (Table 7) based on the analysis of data collected from the electronics industry show that all identified risks pose a serious threat towards CE transition. All bets are profiled into either medium- or high-priority categories, and none fall into the low-priority zone. The priority order of risks is graphically depicted in Figure 4.

Following results (Table 7), the first ten risks in Figure 4, namely, R15, R13, R3, R9, R8, R2, R1, R12, R4 and R7 are categorised as high-priority risks. The next eight risks are medium-priority risks. The overall risk exposure of CSCs in the electronics sector is found to be 43.95%, which is at the boundary line of being high. The risks measured at the operational and strategic levels of CSCs are found to be 43.76 and 41.32%, which fall in the medium priority level. In contrast, the susceptibility to risks at the tactical level is assessed as 47.39%, equivalent to high priority. Hence, it can be inferred from the results that the transition towards CE faces a major challenge at the tactical level in determining the appropriate pathways for shifting to CSCs. It implies that organizations are facing more disruptions in the implementation of circular practices in comparison to the development of circular strategies. The findings align with the existing studies, which acknowledge this gap in CE literature and state that while CE literature is rich in approaches and concepts, investigation of pragmatic implementation methods is lacking (Frishammar & Parida, 2019). With this in mind, the study has investigated the potential disruptions that can obstruct the implementation of circular business models and, if addressed, could facilitate the smooth transition towards CE.

Market risk [R15] is found to be the highest priority risk in CSCs in the Indian electronic sector. It indicates that organisations are facing a major challenge in circular electronic supply chains due to the poor perception of the customer base regarding secondary products. It further increases in case of third-party reprocessing due to the de-branded version of secondary products (Agrawal et al., 2015). This is because of uncertainty about the quality of refurbished and remanufactured products [R7] and a lack of knowledge among customers about secondary products (Choudhary et al., 2022). The findings align with (Abbey et al., 2015), which indicates that consumers often perceive remanufactured products as of less value than original products. Further, similar results are obtained in the manufacturing sector, where quality degradation in recycled products is the most critical threat (Dulia et al., 2021). The government needs to set some quality standards for reprocessed products to build customer trust. Furthermore, organisations should create greater awareness about their secondary products and offer substantial discounts to attract a broader consumer base.

Next, R13 is in the high-priority category, the highest-priority risk in the plastic recycling industry (Senthil et al., 2018). Proper communication and transparency among all stakeholders are pertinent to

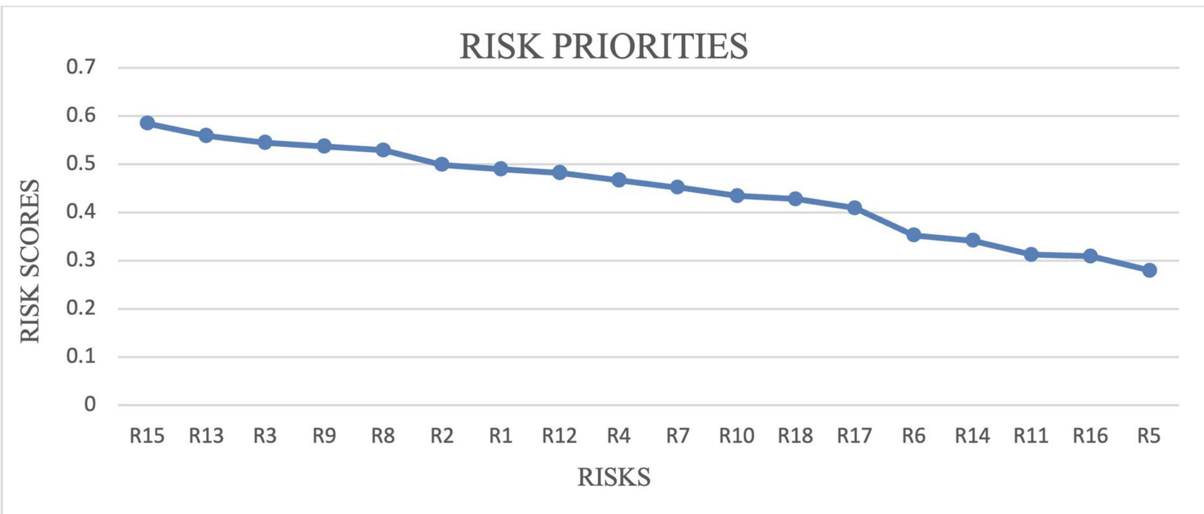

Figure 4. Risk priority order.

managing returned product inventories (Zanjirani Farahani et al., 2022). Other critical risks posing a serious threat in the electronic CSCs are R3 and R9 also indicated that most products lose 45% of their value due to delays in recovery. Furthermore, it is evident from several studies that selecting an appropriate product recovery option is one of the most critical issues in a CE (Guide & Van Wassenhove, 2009; Choudhary et al., 2022). The adoption of advanced IT- and AI-based tools could significantly reduce time wastage in the return channels and can facilitate accurate decision-making in CSCs (Lopes de Sousa Jabbour et al., 2019; Chen et al., 2020; Saide & Sheng, 2024). Inefficient design of collection routes, collection point locations, and inaccurate forecasts lead to R1 and R8, which can significantly hinder circular operations. Understanding the product's life-cycle and market coupled with proper mechanism for product take-back is necessary to reduce such disruptions. Another critical issue is the unavailability of a workforce with the required technical proficiency in CSCs, resulting in R2. Government and educational institutions need to start certified programs in the related area to create awareness and develop skilled workers in the CE field. Furthermore, organisations must conduct regular training programs to keep their employees up-to-date with recent trends and technologies. The last two risks in the high-priority category, R12 and R4, primarily arise due to a lack of transparency or a proper returns management system in CSCs. Analysis conducted by Ethirajan et al. (2021) showed similar results and suggested that transparency-related issues are the main driving risks in a CE.

Other critical risks in CSCs in the medium-priority category are R10, R18, R17, R6, R14, R11, R16, and R5. In most organisations, there are insufficient initiatives for circular practices, which results in R18. This is largely due to a lack of industry incentives and tax benefits for circular businesses (Dulia et al., 2021). Furthermore, policymakers must proactively create awareness among business entities about the necessity and significance of CE and provide implementation support and guidance to promote the adoption of circular business models. Such practices will assist in the mitigation of CSC risks, including R17 and R16. Organisations need to carefully execute the transition towards CSCs by building their employees' required skills and performance incentives to tackle R14. Insufficient knowledge about returned products and inappropriate reprocessing methods can result in R6 (Choudhary et al., 2022). Moreover, integrating Industry 4.0 with CSCs can overcome such threats and reduce potential disruptions due to R11 and R5 (Liu et al., 2023; Seles et al., 2022).

The analysis in this paper combines CE, transition management theory and risk management literature in an objective framework. It is among the first studies to capture the operational, socio-environmental, and financial implications of risks in CSCs. Sustainability and risk related problems are significantly complex and include a lot of uncertainty (Petropoulos et al., 2024). Further, most of the times decision makers involved in these issues have conflicting beliefs and world-views. In view of these characteristics, we have developed an integrated analytical model based on fuzzy set theory, evidential reasoning algorithm and expected utility theory has been developed for risk evaluation and profiling. The proposed approach can tackle the mentioned aspects along with the subjectivity and incompleteness in the data. The FST-ERA-EUT based approach provides a prototype model that can be applied to solve different types of sustainability related problems as it is efficient to handle uncertain and complex scenarios.

The investigation shows that societal aspects play a pivotal role in the transition towards CE as lack of customer confidence in secondary products emerges as the most critical issue in CSCs. Further, the results highlight that there is a need to strengthen the tactical aspects of CSCs as the tactical level risk exposure is the highest. Organizations have the willingness and vision to adopt circular business models but, they face disruptions in the actual implementation of circular practices in supply chain contexts. The identified potential disruptions from the tactical lens can guide the managers in formulating operational pathways for the execution of CE practices in supply chains. The outcomes could assist in uncovering the most severe risks that require utmost attention and resources. Accordingly, strategies could be developed to tackle these serious potential disruptions in CSCs, which would facilitate the transition towards CE. For better understanding and validation, findings are also discussed with three experts working at senior management positions with an experience of 17–20 years in the electronics sector. In line with the findings, experts stated that a growing number of companies in the electronics sector are planning and strategizing to adopt circular practices but are facing major issues in the execution phase. They mentioned that return channels are unstructured in most cases and underlined the importance of managing the identified risks in CSCs for transitioning towards CE. They suggested that the adoption of upcoming Industry 4.0 technologies could address majority of potential risks in CSCs and provide a structure and efficiency for circular operations.

6. Sensitivity analysis

A sensitivity analysis is performed on the risk scores obtained as an output of FST-ERA-EUT based model. Some changes are made in the values of belief degrees associated with linguistic terms, which are the model inputs and the corresponding impact on the output i.e. risk scores is analysed. To validate the inference reasoning and robustness of the approach, the developed model should ensue following axioms (John et al., 2014; Yang et al., 2009):

Axiom 1: A minor decrease in the model input i.e. belief degree associated with linguistic terms should surely cause a decrease in the risk score, which is the model output.
Axiom 2: A minor increase in the model input i.e. belief degree associated with linguistic terms should surely cause an increase in the risk score, which is the model output.
Axiom 3: If the belief degrees associated with the highest utility linguistic term are reduced by a and b, such that $1 > a > b$ and simultaneously the belief degrees associated with the least utility term are increased by a and b, then the utility value calculated for the model's output, that is, U_a and U_b, respectively, are in the order $U_b > U_a$.

Accordingly, the belief degrees associated with the highest utility linguistic term are reduced by 10, 20 and 30% and corresponding risk scores are computed as shown below in Table 10. It can be observed from Table 10 that the model outputs are in accordance with Axiom 1, 2 and 3. Hence it can be inferred that the results obtained using the proposed approach are consistent and reliable.

Table 10. Sensitivity analysis by reducing belief degrees by 10, 20 and 30%.

TM lens	Risks	Risk scores	10%	20%	30%
Operational lens	R1	0.490	0.3967	0.3218	0.2468
	R2	0.499	0.4185	0.3435	0.2685
	R3	0.545	0.4460	0.3583	0.2833
	R4	0.467	0.3727	0.2978	0.2265
	R5	0.280	0.2143	0.1643	0.1145
	R6	0.353	0.2778	0.2027	0.1482
	R7	0.452	0.3645	0.2895	0.2145
Tactical lens	R8	0.529	0.4310	0.3560	0.2810
	R9	0.537	0.4397	0.3648	0.2898
	R10	0.435	0.3347	0.2555	0.1983
	R11	0.313	0.2470	0.1983	0.1470
	R12	0.482	0.3995	0.3245	0.2495
	R13	0.559	0.4838	0.4088	0.3337
Strategic lens	R14	0.342	0.2670	0.2160	0.2660
	R15	0.585	0.4928	0.4178	0.3428
	R16	0.310	0.2268	0.1725	0.1263
	R17	0.410	0.3270	0.2682	0.2183
	R18	0.428	0.3450	0.2715	0.2215

7. Implications

7.1. Theoretical implications

The study adds value to the CE literature by answering two significant research questions related to CSCs. The primary contribution of this research is that it is the initial study to examine and quantify the complexities of risks present at various levels of CSCs using a theoretical lens of Transition Management. A framework based on risk management and transition management theories has been proposed to operationalise the shift towards CE for attaining net-zero economies. Secondly, our work surmounts the limitations of existing studies. Some of the previous studies have addressed discrete elements of risks in the CE context; this is the first scholarship to investigate the risk elements systematically and synchronizes the financial, socio-environment and operational dimensions. Third, the analysis quantifies the susceptibility of CSCs to hazards at the strategic, tactical and operational levels apart from the total risk exposure. It is discovered that, unlike the conventional perspective, organisations are strategically moving towards adopting circular practices; however, they are lacking the means to implement these pragmatically. The published studies affirm the results (Esposito et al., 2018; Hailemariam & Erdiaw-Kwasie, 2023). Fourthly, the appropriateness and applicability of developed FST-ERA-EUT based model has been demonstrated for risk analysis. Unlike majority of the models in the literature that are developed for a specific context, the proposed model is generic and can be adapted to any business scenario for risk examination.

7.2. Managerial and policy implications

The findings offer several significant insights for managers and policymakers. The research provides a roadmap to managers for creating visibility and predictability in CSCs through identification and quantification of risks. It would further assist in institutionalising the circular practices in supply chains and transition towards a CE. Second, the assessment and profiling of risks informs the managers about the severity of potential disruptions and supports the formulation of proactive mitigation strategies. The results show that ten risks, including market risk, inventory management risk, marginal value of time, and decision-making risks, among others, pose the most serious threat to CSCs and, if efficiently tackled, can facilitate the smooth transition towards CE. Managers need to provide smart discounting and quality assurance through branding to capture the customer base for secondary products, as market risk is the most critical threat to return channels (Atasu et al., 2008). It has been found that secondary products with an associated brand value are more attractive to customers (Agrawal et al., 2015). Third, the performed profiling of risks will assist managers in striking a balance between the operational performance and socio-environmental benefits of CSCs. The profiling of risks is done considering the associated financial, operational and socio-environmental implications. Hence, addressing the risks in the high priority zone could facilitate in enhancing the operational and socio-environmental performance of CSCs simultaneously. It will enable CSC operations to function better and attain desired sustainability objectives. Finally, the findings indicate that CSCs face the highest disruption at the tactical level due to unstructured transition pathways towards CE. One of the solutions includes employing upcoming digital technologies and I4.0 tools as a means to streamline and integrate return channels for transforming towards CE (Kazancoglu et al., 2022; Liu et al., 2023; Saide & Sheng, 2024; Seles et al., 2022). The technology adoption will resolve major concerns related to customer perception, delay management, recovery efficiency, reprocessing option selection and transparency, among others in CSCs (Bertassini et al., 2021; Kouhizadeh et al., 2020; Zanjirani Farahani et al., 2022). It will lead to the better administration of returns and extenuation of the most critical risks in CSCs. Further, top management needs to focus on upscaling the managerial expertise to guide the transition in the right direction towards CE.

The research also provides implications for policymakers. There is a need for government interventions to set clear goals and targets regarding CE adoption and tighten regulation compliance to compel organisations to transform their linear business structures. Higher tax subsidies and funding and creating awareness can further encourage adopting circular practices among organisations. Policymakers need to nudge educational institutions towards creating awareness and expertise in circular business models through course curriculums and specialised programs. Specialised certification programs and government-sponsored training programs can sensitise the masses and develop skilled human resources in CSC domains. Lastly, the government needs to set some quality standards for reprocessed products to change consumer perception and increase the market base of secondary effects.

8. Summary & key contributions

The growing popularity of sustainable practices and increasing anxieties about attaining a net zero economy have influenced the proliferation of CE practices in the last decade (Münch et al., 2022). The attainment of net zero and circular goals essentially requires the transformation of linear supply chains to circular supply chains. However, attaining the circular loop faces disruptions due to numerous risks and uncertainties in the return channels. These risks can have severe environmental and safety implications besides operational and financial consequences in a CSC. In this study, we have attempted to address this lacuna by comprehensively investigating the risks associated with CSCs to control the possible disruptions in the path towards CE and net zero. Drawing on the Transition Management theory, this is among the initial research to identify, quantify, and profile risks present in CSCs considering sustainability and operational implications. The research has considered e-waste in the Indian electronics industry, which has huge recovery potential and is the fastest-growing waste stream, especially in emerging economies.

CE avenues are relatively immature and unclear for e-waste management in developing economies, and the related uncertainties and risks are still unaddressed in the extant literature The present research has addressed this gap in the literature by identifying a comprehensive list of eighteen risks specific to CSCs. Using insights from TMT, the identified risks are categorised operational, tactical and strategic umbrellas. The study has developed a novel integrated methodology based on FST, ERA, and EUT for risk assessment and profiling. This is one of the first applications of the proposed approach in the domain of CE. The FST-ERA-EUT-based model is more accurate than conventional approaches in processing linguistic information with substantial subjectivity and uncertainty. The proposed model contributes to the decision analysis and risk analysis domains of OR and addresses the gap highlighted by Petropoulos et al., 2024.

The risk exposure of CSCs in the electronic sector is computed to be 43.95% that almost falls in the high priority zone. The analysis showed that all the identified risks in the operational, tactical and strategic categories are primarily in the medium and high-priority zones. None of the risks are in the low priority zone. It implies that all these risks can have severe financial, operational and socio-environmental repercussions on CSCs and, hence, need to be tackled effectively for a smooth transition towards CE. It is found that customers' reluctance to purchase reprocessed products poses the most critical threat to CSCs, which is consistent with some of the prior studies. For example, (Abbey et al., 2015; Agrawal et al., 2015) highlighted that customers often perceive remanufactured products as degraded compared to fresh products, especially in the involvement of third-party remanufacturing. Both the policy makers and managers need to work in sync to ensure the the quality and reliability of secondary products in the electronics sector. Under the transition management framework, it is discovered that the tactical level has the highest proneness to disruptions (high priority level), followed by operational and strategic levels. The results show that more emphasis should be towards development of resilient means for the implementation of circular practices and increasing the social acceptance of secondary products especially in the electronics sector. Adoption of upcoming analytical and digital tools and technologies could reduce the risk exposure of CSCs and provide a smooth pathway for the transition towards CE.

8.1. Limitations & future research

The study is confined to organisations indulged in CSC practices in the electronics sector in a developing economy. We call for more cross-country and cross-sector studies to better understand other industries and developed economies. It would also be interesting to investigate the consumer's perception of secondary products in other sectors. Second, the research on CE risks is in its infancy. Although we have conscientiously identified risks in the context of CSCs through literature review and expert inputs, there is a possibility of considering more risks. Accordingly, future studies can expand the risks and apply the proposed model to check the consistency of results. Furthermore, we have considered the implications of risks in the context of financial, operational and socio-environment aspects. Other perspectives, including governance, could be taken into account by future studies. Also, prospective research could identify and analyse the strategies to mitigate the identified risks. Lastly, the developed model is generic in nature and not context specific hence, can be applied for risk assessment in any sector. It can be extended to measure the risk exposure of any supply chain or organization as well. Further, the proposed approach can be adapted for information aggregation in different context in any industry.

Acknowledgment

No funding was received.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Abbey, J. D., Meloy, M. G., Guide, V. D. R., Jr., & Atalay, S. (2015). Remanufactured products in closed-loop supply chains for consumer goods. *Production and Operations Management*, *24*(3), 488–503. https://doi.org/10.1111/poms.12238

Agrawal, V., Atasu, A., & Ülkü, S. (2021). Leasing, modularity, and the circular economy. *Management Science*, *67*(11), 6782–802.

Agrawal, V. V., Atasu, A., & van Ittersum, K. (2015). Remanufacturing, third-party competition, and consumers' perceived value of new products. *Management Science*, *61*(1), 60–72. https://doi.org/10.1287/mnsc.2014.2099

Agrawal, S., K. Singh, R., & Murtaza, Q. (2014). Forecasting product returns for recycling in Indian electronics industry. *Journal of Advances in Management Research*, *11*(1), 102–114. https://doi.org/10.1108/JAMR-02-2013-0013

Atasu, A., Sarvary, M., & Van Wassenhove, L. N. (2008). Remanufacturing as a marketing strategy. *Management Science*, *54*(10), 1731–1746. https://doi.org/10.1287/mnsc.1080.0893

Baldé, K., D'angelo, E., Luda, V., Deubzer, O., & Kühr, R. (2022). *Global transboundary e-waste flows monitor 2022*. United Nations Institute for Training and Research (UNITAR) [Preprint]. https://ewastemonitor.info/wp-content/uploads/2022/06/Global-TBM_webversion_june_2_pages.pdf

Bertassini, A. C., Ometto, A. R., Severengiz, S., & Gerolamo, M. C. (2021). Circular economy and sustainability: The role of organisational behaviour in the transition journey. *Business Strategy and the Environment*, *30*(7), 3160–3193. https://doi.org/10.1002/bse.2796

Campbell, S., Greenwood, M., Prior, S., Shearer, T., Walkem, K., Young, S., Bywaters, D., & Walker, K. (2020). Purposive sampling: Complex or simple? Research case examples. *Journal of Research in Nursing*, *25*(8), 652–661. https://doi.org/10.1177/1744987120927206

Centobelli, P., Cerchione, R., & Esposito, E. (2020). Pursuing supply chain sustainable development goals through adopting green practices and enabling technologies: A cross-country analysis of LSPs. *Technological Forecasting and Social Change*, *153*, 119920. https://doi.org/10.1016/j.techfore.2020.119920

Chen, L. H., Hung, P., & Ma, H. W. (2020). Integrating circular business models and development tools in the circular economy transition process: A firm-level framework. *Business Strategy and the Environment*, *29*(5), 1887–1898. https://doi.org/10.1002/bse.2477

Chen, Y., Shu, L., & Burbey, T. J. (2014). An integrated risk assessment model of township-scaled land subsidence based on an evidential reasoning algorithm and fuzzy set theory. *Risk Analysis*, *34*(4), 656–669. https://doi.org/10.1111/risa.12182

Chopra, S., & Sodhi, M. S. (2014). Reducing the risk of supply chain disruptions. *MIT Sloan Management Review*, *55*(3), 73–80.

Choudhary, D., Choudhary, A., Shankar, R., & Hicks, C. (2021). Evaluating the risk exposure of sustainable freight transportation: A two-phase solution approach. *Annals of Operations Research*, 1-35. https://doi.org/10.1007/s10479-021-03992-7

Choudhary, D., & Kumar, R. (2024). Risk investigation in circular economy: A hierarchical decision model approach. *International Journal of Logistics Research and Applications*, *27*(1), 103–128. https://doi.org/10.1080/13675567.2021.2014430
Choudhary, D., Qaiser, F. H., Choudhary, A., & Fernandes, K. (2022). A model for managing returns in a circular economy context: A case study from the Indian electronics industry. *International Journal of Production Economics*, *249*, 108505. https://doi.org/10.1016/j.ijpe.2022.108505
Choudhary, D., Shankar, R., & Choudhary, A. (2020). An integrated approach for modeling sustainability risks in freight transportation systems. *Risk Analysis*, *40*(4), 858–883. https://doi.org/10.1111/risa.13435
De Lima, F. A., & Seuring, S. (2023). A Delphi study examining risk and uncertainty management in circular supply chains. *International Journal of Production Economics*, *258*(April 2022), 108810. https://doi.org/10.1016/j.ijpe.2023.108810
De Oliveira, U. R., Aparecida Neto, L., Abreu, P. A. F., & Fernandes, V. A. (2021). Risk management applied to the reverse logistics of solid waste. *Journal of Cleaner Production*, *296*, 126517. https://doi.org/10.1016/j.jclepro.2021.126517
de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Foropon, C., & Godinho Filho, M. (2018). When titans meet – can Industry 4.0 revolutionise the environmentally sustainable manufacturing wave? The role of critical success factors. *Technological Forecasting and Social Change*, *132*(January), 18–25. https://doi.org/10.1016/j.techfore.2018.01.017
Dulia, E. F., Ali, S. M., Garshasbi, M., & Kabir, G. (2021). Admitting risks towards circular economy practices and strategies: An empirical test from supply chain perspective. *Journal of Cleaner Production*, *317*, 128420. https://doi.org/10.1016/j.jclepro.2021.128420
Ellen MacArthur Foundation. (2021). How the circular economy tackles climate change 2021. *Ellen MacArthur Foundation*, *3*(26 September), 1–71.
Esposito, M., Tse, T., & Soufani, K. (2018). Introducing a circular economy: New thinking with new managerial and policy implications. *California Management Review*, *60*(3), 5–19. https://doi.org/10.1177/0008125618764691
Ethirajan, M., Arasu M, T., Kandasamy, J., K.e.k, V., Nadeem, S. P., & Kumar, A. (2021). Analysing the risks of adopting circular economy initiatives in manufacturing supply chains. *Business Strategy and the Environment*, *30*(1), 204–236. https://doi.org/10.1002/bse.2617
Fang, R., Liao, H., Yang, J. B., & Xu, D. L. (2021). Generalised probabilistic linguistic evidential reasoning approach for multi-criteria decision-making under uncertainty. *Journal of the Operational Research Society*, *72*(1), 130–144. https://doi.org/10.1080/01605682.2019.1654415
Frishammar, J., & Parida, V. (2019). Circular business model transformation: A roadmap for incumbent firms. *California Management Review*, *61*(2), 5–29. https://doi.org/10.1177/0008125618811926
Fu, C., Chang, W., Xue, M., & Yang, S. (2019). Multiple criteria group decision making with belief distributions and distributed preference relations. *European Journal of Operational Research*, *273*(2), 623–633. https://doi.org/10.1016/j.ejor.2018.08.012
Fulzele, V., & Shankar, R. (2023). Performance measurement of sustainable freight transportation: A consensus model and FERA approach. *Annals of Operations Research*, *324*(1–2), 501–542. https://doi.org/10.1007/s10479-020-03876-2
Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The circular economy – a new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048
Gennari, F. (2023). The transition towards a circular economy. A framework for SMEs. *Journal of Management and Governance*, *27*(4), 1423–1457. https://doi.org/10.1007/s10997-022-09653-6
Genovese, A., Acquaye, A. A., Figueroa, A., & Koh, S. C. L. (2017). Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications. *Omega*, *66*, 344–357. https://doi.org/10.1016/j.omega.2015.05.015
Govindan, K., Soleimani, H., & Kannan, D. (2015). Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future. *European Journal of Operational Research*, *240*(3), 603–626. https://doi.org/10.1016/j.ejor.2014.07.012
Grafström, J., & Aasma, S. (2021). Breaking circular economy barriers. *Journal of Cleaner Production*, *292*, 126002. https://doi.org/10.1016/j.jclepro.2021.126002
Guide, V. D. R., Jr., Souza, G. C., Van Wassenhove, L. N., & Blackburn, J. D. (2006). Time value of commercial product returns. *Management Science*, *52*(8), 1200–1214. https://doi.org/10.1287/mnsc.1060.0522
Guide, V. D. R., & Van Wassenhove, L. N. (2009). The evolution of closed-loop supply chain research. *Operations Research*, *57*(1), 10–18. https://doi.org/10.1287/opre.1080.0628
Hailemariam, A., & Erdiaw-Kwasie, M. O. (2023). Towards a circular economy: Implications for emission reduction and environmental sustainability. *Business Strategy and the Environment*, *32*(4), 1951–1965. https://doi.org/10.1002/bse.3229
Haque, F., & Ntim, C. G. (2020). Executive compensation, sustainable compensation policy, carbon performance and market value. *British Journal of Management*, *31*(3), 525–546. https://doi.org/10.1111/1467-8551.12395
Heckmann, I., Comes, T., & Nickel, S. (2015). A critical review on supply chain risk – definition, measure and modeling. *Omega*, *52*, 119–132. https://doi.org/10.1016/j.omega.2014.10.004
Hosseini-Motlagh, S. M., Nematollahi, M., & Ebrahimi, S. (2022). Tri-party reverse supply chain coordination with competitive product acquisition process. *Journal of the Operational Research Society*, *73*(2), 382–393. https://doi.org/10.1080/01605682.2020.1824550
Islam, M. T., & Huda, N. (2018). Reverse logistics and closed-loop supply chain of Waste Electrical and Electronic Equipment (WEEE)/E-waste: A comprehensive literature review. *Resources, Conservation and Recycling*, *137*(May), 48–75. https://doi.org/10.1016/j.resconrec.2018.05.026
Jia, W., Liu, Z., Lin, Z., Qiu, C., & Tan, J. (2016). Quantification for the importance degree of engineering characteristics with a multilevel hierarchical structure in QFD. *International Journal of Production Research*, *54*(6), 1627–1649. https://doi.org/10.1080/00207543.2015.1041574
John, A., Paraskevadakis, D., Bury, A., Yang, Z., Riahi, R., & Wang, J. (2014). An integrated fuzzy risk assessment

for seaport operations. *Safety Science*, *68*, 180–194. https://doi.org/10.1016/j.ssci.2014.04.001

Kazancoglu, I., Kazancoglu, Y., Kahraman, A., Yarimoglu, E., & Soni, G. (2022). 'Investigating barriers to circular supply chain in the textile industry from Stakeholders' perspective. *International Journal of Logistics Research and Applications*, *25*(4–5), 521–548. https://doi.org/10.1080/13675567.2020.1846694

Ketzenberg, M. E., van der Laan, E., & Teunter, R. H. (2006). Value of information in closed loop supply chains. *Production and Operations Management*, *15*(3), 393–406. https://doi.org/10.1111/j.1937-5956.2006.tb00253.x

Kouhizadeh, M., Zhu, Q., & Sarkis, J. (2020). Blockchain and the circular economy: Potential tensions and critical reflections from practice. *Production Planning & Control*, *31*(11–12), 950–966. https://doi.org/10.1080/09537287.2019.1695925

Kumar, A. (2021). Transition management theory-based policy framework for analysing environmentally responsible freight transport practices. *Journal of Cleaner Production*, *294*, 126209. https://doi.org/10.1016/j.jclepro.2021.126209

Li, P., & Wei, C. (2019). An emergency decision-making method based on D-S evidence theory for probabilistic linguistic term sets. *International Journal of Disaster Risk Reduction*, *37*, 101178.https://doi.org/10.1016/j.ijdrr.2019.101178

Liu, H.-C., Liu, L., Bian, Q.-H., Lin, Q.-L., Dong, N., & Xu, P.-C. (2011). Failure mode and effects analysis using fuzzy evidential reasoning approach and grey theory. *Expert Systems with Applications*, *38*(4), 4403–4415. https://doi.org/10.1016/j.eswa.2010.09.110

Liu, L., Song, W., & Liu, Y. (2023). Leveraging digital capabilities toward a circular economy: Reinforcing sustainable supply chain management with Industry 4.0 technologies. *Computers & Industrial Engineering*, *178*, 109113. https://doi.org/10.1016/j.cie.2023.109113

Loorbach, D. (2010). Transition management for sustainable development: A prescriptive, complexity-based governance framework. *Governance*, *23*(1), 161–183. https://doi.org/10.1111/j.1468-0491.2009.01471.x

Lopes de Sousa Jabbour, A. B., Rojas Luiz, J. V., Rojas Luiz, O., Jabbour, C. J. C., Ndubisi, N. O., Caldeira de Oliveira, J. H., & Junior, F. H. (2019). Circular economy business models and operations management. *Journal of Cleaner Production*, *235*, 1525–1539. https://doi.org/10.1016/j.jclepro.2019.06.349

Masi, D., Kumar, V., Garza-Reyes, J. A., & Godsell, J. (2018). Towards a more circular economy: Exploring the awareness, practices, and barriers from a focal firm perspective. *Production Planning & Control*, *29*(6), 539–550. https://doi.org/10.1080/09537287.2018.1449246

Mazahir, S., Verter, V., Boyaci, T., & Van Wassenhove, L. N. (2019). Did Europe move in the right direction on e-waste legislation? *Production and Operations Management*, *28*(1), 121–139. https://doi.org/10.1111/poms.12894

Münch, C., Benz, L. A., & Hartmann, E. (2022). Exploring the circular economy paradigm: A natural resource-based view on supplier selection criteria. *Journal of Purchasing and Supply Management*, *28*(4), 100793. https://doi.org/10.1016/j.pursup.2022.100793

Panjehfouladgaran, H., & Lim, S. F. W. T. (2020). Reverse logistics risk management: Identification, clustering and risk mitigation strategies. *Management Decision*, *58*(7), 1449–1474. https://doi.org/10.1108/MD-01-2018-0010

Petropoulos, F., Laporte, G., Aktas, E., Alumur, S. A., Archetti, C., Ayhan, H., Battarra, M., Bennell, J. A., Bourjolly, J.-M., Boylan, J. E., Breton, M., Canca, D., Charlin, L., Chen, B., Cicek, C. T., Cox, L. A., Jr, Currie, C. S. M., Demeulemeester, E., Ding, L., Disney, S. M., Ehrgott, M., … Zhao, X. (2024). Operational research: Methods and applications. *Journal of the Operational Research Society*, *75*(3), 423–617. https://doi.org/10.1080/01605682.2023.2253852

Reyhani Yamchi, H., Jabarzadeh, Y., Govindan, K., & Amoozad Mahdiraji, H. (2024). A triple bottom line approach for designing a sustainable closed-loop supply chain network in fruit industry: A metaheuristic solution approach. *Journal of the Operational Research Society*, *75*(10), 1925–1948. https://doi.org/10.1080/01605682.2023.2286318

Rotmans, J., & Loorbach, D. (2009). Complexity and transition management. *Journal of Industrial Ecology*, *13*(2), 184–196. https://doi.org/10.1111/j.1530-9290.2009.00116.x

Saide, S., & Sheng, M. L. (2024). ICT team dual-innovations in the microlevel of circular supply chain management: Explicit-tacit knowledge, exchange ideology, and leadership support. *IEEE Transactions on Engineering Management*, *71*, 12124–12137. https://doi.org/10.1109/TEM.2022.3166763

Sassanelli, C., Rosa, P., Rocca, R., & Terzi, S. (2019). Circular economy performance assessment methods: A systematic literature review. *Journal of Cleaner Production*, *229*, 440–453. https://doi.org/10.1016/j.jclepro.2019.05.019

Savaskan, R. C., & Van Wassenhove, L. N. (2006). Reverse channel design: The case of competing retailers. *Management Science*, *52*(1), 1–14. https://doi.org/10.1287/mnsc.1050.0454

Schlegel, G. L., & Trent, R. J. (2014). *Supply chain risk management: An emerging discipline*. CRC Press.

Seles, B. M. R. P., Mascarenhas, J., Lopes de Sousa Jabbour, A. B., & Trevisan, A. H. (2022). Smoothing the circular economy transition: The role of resources and capabilities enablers. *Business Strategy and the Environment*, *31*(4), 1814–1837. https://doi.org/10.1002/bse.2985

Senthil, S., Murugananthan, K., & Ramesh, A. (2018). Analysis and prioritisation of risks in a reverse logistics network using hybrid multi-criteria decision making methods. *Journal of Cleaner Production*, *179*, 716–730. https://doi.org/10.1016/j.jclepro.2017.12.095

Shankar, R., Choudhary, D., & Jharkharia, S. (2018). An integrated risk assessment model: A case of sustainable freight transportation systems. *Transportation Research Part D: Transport and Environment*, *63*, 662–676. https://doi.org/10.1016/j.trd.2018.07.003

Shankar, R., Pathak, D. K., & Choudhary, D. (2019). Decarbonising freight transportation: An integrated EFA-TISM approach to model enablers of dedicated freight corridors. *Technological Forecasting and Social Change*, *143*, 85–100. https://doi.org/10.1016/j.techfore.2019.03.010

Stern, N., & Valero, A. (2021). Research policy, Chris Freeman special issue innovation, growth and the transition to net-zero emissions. *Research Policy*, *50*(9), 104293. https://doi.org/10.1016/j.respol.2021.104293

Taddei, E., Sassanelli, C., Rosa, P., & Terzi, S. (2022). Circular supply chains in the era of industry 4.0: A systematic literature review. *Computers & Industrial*

Engineering, *170*, 108268. https://doi.org/10.1016/j.cie.2022.108268

Tian, Z. P., Nie, R. X., & Wang, J. Q. (2020). Probabilistic linguistic multi-criteria decision-making based on evidential reasoning and combined ranking methods considering decision-makers' psychological preferences. *Journal of the Operational Research Society*, *71*(5), 700–717. https://doi.org/10.1080/01605682.2019.1632752

Trapp, A. C., Konrad, R. A., Sarkis, J., & Zeng, A. Z. (2021). Closing the loop: Forging high-quality agile virtual enterprises in a reverse supply chain via solution portfolios. *Journal of the Operational Research Society*, *72*(4), 908–922. https://doi.org/10.1080/01605682.2019.1707721

Van Wassenhove, L. N. (2019). Sustainable innovation: Pushing the boundaries of traditional operations management. *Production and Operations Management*, *28*(12), 2930–2945. https://doi.org/10.1111/poms.13114

Wan, X., Teng, Z., Zhang, Z., Liu, X., & Du, Z. (2024). Equity financing risk assessment based on PLTS-ER approach in marine ranching from the ecological and circular economy perspectives. *Annals of Operations Research*, *342*(1), 875–920. https://doi.org/10.1007/s10479-023-05222-8

Wang, Y. M., Yang, J. B., & Xu, D. L. (2006). Environmental impact assessment using the evidential reasoning approach. *European Journal of Operational Research*, *174*(3), 1885–1913. https://doi.org/10.1016/j.ejor.2004.09.059

Wu, B., Yan, X., Wang, Y., & Soares, C. G. (2017). An evidential reasoning-based CREAM to human reliability analysis in maritime accident process. *Risk Analysis*, *37*(10), 1936–1957. https://doi.org/10.1111/risa.12757

Yang, J. B. (2001). Rule and utility based evidential reasoning approach for multiattribute decision analysis under uncertainties. *European Journal of Operational Research*, *131*(1), 31–61. https://doi.org/10.1016/S0377-2217(99)00441-5

Yang, Z. L., Wang, J., Bonsall, S., & Fang, Q. G. (2009). Use of fuzzy evidential reasoning in maritime security assessment. *Risk Analysis*, *29*(1), 95–120. https://doi.org/10.1111/j.1539-6924.2008.01158.x

Zadeh, L. A. (1965). Fuzzy sets. *Information and Control*, *8*(3), 338–353. https://doi.org/10.1016/S0019-9958(65)90241-X

Zanjirani Farahani, R., Asgari, N., & Van Wassenhove, L. N. (2022). Fast fashion, charities, and the circular economy: Challenges for operations management. *Production and Operations Management*, *31*(3), 1089–1114. https://doi.org/10.1111/poms.13596

Zhang, Z., & Liao, H. (2023). An evidential reasoning-based stochastic multi-attribute acceptability analysis method for uncertain and heterogeneous multi-attribute reverse auction. *Journal of the Operational Research Society*, *74*(1), 239–257. https://doi.org/10.1080/01605682.2022.2035271

Zhang, Y., Montenegro-Marin, C. E., & Díaz, V. G. (2021). Holistic cognitive conflict chain management framework in supply chain management. *Environmental Impact Assessment Review*, *88*, 106564. https://doi.org/10.1016/j.eiar.2021.106564

Zhang, A., Wang, J. X., Farooque, M., Wang, Y., & Choi, T.-M. (2021). Multidimensional circular supply chain management: A comparative review of the state-of-the-art practices and research. *Transportation Research Part E: Logistics and Transportation Review*, *155*, 102509. https://doi.org/10.1016/j.tre.2021.102509