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Risks in circular business models innovation: A cross-industrial case study for composite materials

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Abstract

Circular business models (CBMs) are key enablers to implement circular economy (CE), yet they entail risks, which often discourage organisations. This work aims to explore the main risk factors perceived by the manufacturing industry in transitioning to CBMs to enable the development of appropriate risk management strategies. A cross-industrial multiple-case study research design was used to explore risk factors across seven organisations planning the transition to CBMs for composite-based products and involving three different CBM types—'Circular Supplies', 'Product Life Extension' and 'Hybrid'. Results evidenced that risks are multi-disciplinary but are not equally perceived across different CBM types. Customers' perceptions of CE products, economic cycle and take-back systems were prevalent across all CBMs. Supply and technological risks were prioritised for 'Circular Supplies' CBM, whereas political and regulatory risks for 'Product Life Extension' CBM. This research contributes to the CE field by evaluating and prioritising the perceived risk factors in transitioning to CBMs and first disaggregating such risk factors according to CBM types. Critical risk patterns identified across different industries and CBM types enable mitigating actions to be prioritised.

KEYWORDS

business model innovation, circular business model, circular economy, composite materials, risk assessment

1 | INTRODUCTION

Traditional economic systems are built on a linear model whereby resources are consumed to create products that, once no longer needed by a consumer, are disposed of as waste (Henry et al., 2020). Finite resources depletion is part of this economic cycle (Lüdeke-Freund et al., 2019), which puts pressure on planetary boundaries (Persson et al., 2022). Shifting away from this linear model is essential to reduce environmental pressures, and considering wastes as a resource can break the link between economic growth and resources consumption (De Angelis, 2022). This means embracing a circular economy (CE) approach, 'an industrial system that is restorative or regenerative by intention and design' (Kirchherr et al., 2017). Circular systems include recycling, remanufacturing, reusing or repairing activities as well as narrowing, slowing or closing the loop for energy and material use (Geissdoerfer et al., 2017; Lieder & Rashid, 2016).

Fully embracing the CE involves not just changing organisations' production systems or packaging materials but also business model (BM) types (Henry et al., 2020). Adopting circular business models (CBMs) means that new ways to generate value are pursued as well as making operational changes to include circular activities such as reverse logistics, remanufacturing products or components and using recycled content (Hussain & Malik, 2020). New ways to use products can also be established (Selvefors et al., 2019). The transition to CBMs presents challenges and potential risks that slow the pace of investment in innovative CBMs and their uptake in the manufacturing sector (Linder & Williander, 2017). In the literature, there is a lack of analysis of the risks associated with the uptake of CBMs as well as an evaluation of whether risks can be influenced by CBM types.

This work thus aims to understand the main risk factors perceived by the manufacturing industry in transitioning to CBMs, focusing on organisations that are currently designing and/or planning the transition towards CBMs. This is achieved by exploring cross-industrial case studies for composite materials and investigating different CBM types to identify the extent to which risks are linked to organisations' CBM types and if key risks are common across all CBM types. Risk identification is fundamental for effective risk management strategies that can promote CBM uptake and integration.

This paper is structured as follows. Section 2 reviews the literature to identify risk factors specific to the CE and BM innovation. Section 3 illustrates the research design including the multiple-case study methodology adopted, while an overview about the case studies is introduced in Section 4. Section 5 presents the results focusing on the cross-case analysis and identification of the key risk factors. Section 6 discusses the case study analysis findings. Finally, Section 7 concludes this paper, outlining potential future research directions.

2 | LITERATURE REVIEW

Circular BM innovation involves two different activities: firstly, introducing the CE principles to the organisation and beginning the transition and integration into business practices; secondly, changing the BM, either for the business as a whole or at a product-specific level (Geissdoerfer et al., 2018; Urbinati et al., 2017). Therefore, it is important to consider business risks in terms of these two different activities. Following an introduction about CBM innovation in Section 2.1, CE risk factors are outlined in Section 2.2, while BM innovation risk factors are listed in Section 2.3, leading to the research gap (Section 2.4).

2.1 | Circular business model innovation

Adopting CBMs involves businesses updating their BM, which requires a process of change or innovation within an organisation. This change can be through radical shifts that impact the whole business or smaller, incremental changes to parts of the BM (Demil & Lecocq, 2010; Geissdoerfer et al., 2020). This business model innovation (BMI) process involves offering a new service or product proposition to the market (Mitchell & Bruckner Coles, 2004).

CBMs relate to the extension of product value throughout the product lifecycle through repair, remanufacturing, refurbishment, maintenance or reuse processes (Copani & Behnam, 2020; Linder & Williander, 2017; Lüdeke-Freund et al., 2019). CBMs have been categorised in a variety of different ways in the literature. Bocken et al. (2016) developed a two-level hierarchical classification of CBMs, with the first level being the CBM approach, which can either be to slow the resource loop, with a focus on the product level (Lüdeke-Freund et al., 2019), or to close the resource loop, with a focus on the material level (Lüdeke-Freund et al., 2019), and the second level being the CBM strategy. Access and performance models, extending product value, classic long-life model and encouraging sufficiency are among the CBM strategies that belong to BM strategies for slowing loops, whereas extending resource value and industrial symbiosis are CBM strategies classified as functional to closing loops (Bocken et al., 2016). Slowing-the-loop strategies typically have less environmental benefit than closed-loop approaches (Taps et al., 2013). Lüdeke-Freund et al. (2019), while also referring to slowing and closing the resource loop, identified six patterns for CBMs. Repair and maintenance, reuse and redistribution, refurbishment and remanufacturing are the three identified patterns seeking to retain product value by slowing resources loop, while recycling, cascading and repurposing as well as organic feedstock are the three identified patterns that contribute to closing the resources loop by retaining the material value (Lüdeke-Freund et al., 2019).

Another CBM classification is proposed by Vermunt et al. (2019), who distinguish among four types of CBM, namely product-as-a-service (PSS), product life extension (PLE), resource recovery (RR) and circular supplies (CS). PSS models emphasise the value proposition to the customer, combining tangible products with intangible services in order to fulfil final customer needs (Tukker, 2015). PSS models enable the producer to control product returns through take-back systems (Sundin et al., 2008), as well as being able to offer longer product life, adding value at the customer level (Lewandowski, 2016). PLE models instead aim to extend the lifecycle of products, 'exploiting the residual value of used products', through reuse or product reclaim strategies, such as repairing, refurbishing or remanufacturing (Vermunt et al., 2019). RR models shift value retention from product to material level, aiming to exploit 'the residual value of resources' and transform them to generate value in new forms (Vermunt et al., 2019). Finally, CS model also focuses on the material level, aiming to reduce dependency on virgin raw materials through circular procurement (Vermunt et al., 2019).

While several categorisations of CBMs have been proposed, achieving more sustainable production relies on this change to more circular practices; however, the innovation and transition process to CBMs is far from simple or risk-free and pose many uncertainties that businesses must overcome (Tuni et al., 2023).

2.2 | Circular economy risk factors

The CE is an 'economic system that is based on business models which replace the "end-of-life" concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes', which aims to contribute to sustainable development for current and future generations (Kirchherr et al., 2017). Interested readers can refer to Batista et al. (2023), Geissdoerfer et al. (2017), Ghisellini et al. (2016) and Lieder and Rashid (2016) for an in-depth description of the CE. Multiple aspects of the transition towards the CE have been investigated in the literature, including barriers (Galvão Araujo et al., 2022; Geissdoerfer et al., 2023; Kirchherr et al., 2018), drivers (Geissdoerfer et al., 2023; Gusmerotti et al., 2019) and success factors (Rocca et al., 2022); however, the risk factors linked to the CE transition process have not been systematically evaluated.

Yang and Li (2010) first identified CE risks, highlighting organisational risks due to conflicts and lack of alignment between organisations leading to increased costs, as well as control system risks, which are linked to the complexity of controlling and monitoring complex and circular processes along reverse supply chains.

Supply risks were identified by Choudhary and Kumar (2021), Yang and Li (2010) and Yazdani et al. (2019): these included product returns forecast, gate keeping, environmental, logistical and infrastructural risks as well as uncertainties regarding the quality of returned products (Golinska & Kawa, 2011; Urbinati et al., 2021). Moreover, take-back systems require to be flexible (Chakraborty et al., 2019), to adapt to the market's evolution and guarantee the availability of parts that become part of the circular system—either being reused, recycled or remanufactured, in order to avoid supply shortages (Shao et al., 2020; Urbinati et al., 2021).

Risks were also found on the demand side, due to external factors driven by customers, competitors and volatility in the market (Yang & Li, 2010). The acceptability of products in the market is a major risk (Choudhary & Kumar, 2021; Guldmann & Huulgaard, 2020), as customers may not prefer to purchase remanufactured products due to perceived quality risks (Arena et al., 2021).

Product quality concerns are further observed throughout the products' lifecycle. Insufficient skills of human resources in the repair and remanufacturing operations, which are particularly labour-intensive, can affect the quality of circular products (Kazancoglu et al., 2021), whereas the durability of circular products and their performance over products' life span were identified among risks related to the use phase of products (Dulia et al., 2021; Kazancoglu et al., 2021).

External risks such as macro-political climate and policy risks were also highlighted (Dulia et al., 2021; Yazdani et al., 2019). Policy risks relate to a lack of clear objectives and targets to support the CE as well as ineffective recycling policies and standards to drive change (Govindan & Hasanagic, 2018), with recovery regulations, quality standards requirements and handling of returns policies varying across different countries (Choudhary & Kumar, 2021). Regulatory risks can have a knock-on impact on operational, capital, production and maintenance costs as well as on businesses' technical knowledge (Gatzert & Kosub, 2016).

Finally, several authors found financial factors critical for the development of the CE, mentioning risk factors such as limited funding, upfront technology costs, low financial returns, unattractive investment payback period and higher costs for recycled materials (Choudhary & Kumar, 2021; Dulia et al., 2021; Govindan & Hasanagic, 2018; Guldmann & Huulgaard, 2020; Kazancoglu et al., 2021; Leisen et al., 2019). Ethirajan et al. (2021) emphasised links between risk categories, identifying a cascading effect of financial, operational and reputational risks on the supply chain, thus first inferring interrelationships among risks.

2.3 | Innovative business model risk factors

CBMs are a form of innovative BMs, as they implement new conceptual logic to create, deliver and capture value. BMI requires change in multiple companies' business variables concurrently and, as such, uncertainties and risks are inherent in this process (Brillinger et al., 2020). The risks associated with innovation can be linked to complexity, where there is a need for modularity or increased business integration (Brillinger et al., 2020).

Risks can be internal or external (Brillinger et al., 2020; Vermunt et al., 2019). Internal risks include financial and technical areas, whereas external risks range across markets, supply chains and customers with political and regulatory risks also falling into this category and potentially being a deciding factor in the financial viability of a BMI (Brillinger et al., 2020; Vermunt et al., 2019). Regulatory change can stimulate markets (e.g. the energy sector), introduce new actors who meet environmental criteria or remove some BMs, e.g. through taxation impacts (Gatzert & Kosub, 2016; Leisen et al., 2019). Regulatory risks can have a cascading effect on other elements of BMs creating potential additional risks, such as increased capital, operational, production and maintenance costs as well as technological, know-how, human resources and market risks (Gatzert & Kosub, 2016). These risks need to be holistically evaluated to inform decisions about the development of innovative BMs (Brillinger et al., 2020).

2.4 | Research gap

The identification and evaluation of CE (Section 2.2) and BMI (Section 2.3) risk factors have been predominantly carried out in isolation from each other, thus lacking a joint analysis at the intersection of the two areas regarding risk factors specific to transitioning from linear to circular BMs. The sole exception is Tuni et al. (2023), who assessed risks for CBMs using a fuzzy Delphi method but did not distinguish different CBM types, thus obtaining an aggregated overview of the risks. This work expands the understanding of risk factors for CBMs, by exploring their significance for different CBM types and exploring whether different perceived risk factors correspond to alternative CBMs.

3 | METHODOLOGY

3.1 | Research design

The research design, illustrated in Figure 1, kicked-off with the definition of the research aim, outlined in Section 1, which informed the selection of multiple case studies as the research methodology to understand the main risk factors perceived by the manufacturing industry in transitioning to CBMs. Within-case analysis was carried out first to identify risk factors for each case study, followed by a cross-case analysis to prioritise risk factors by CBM type.

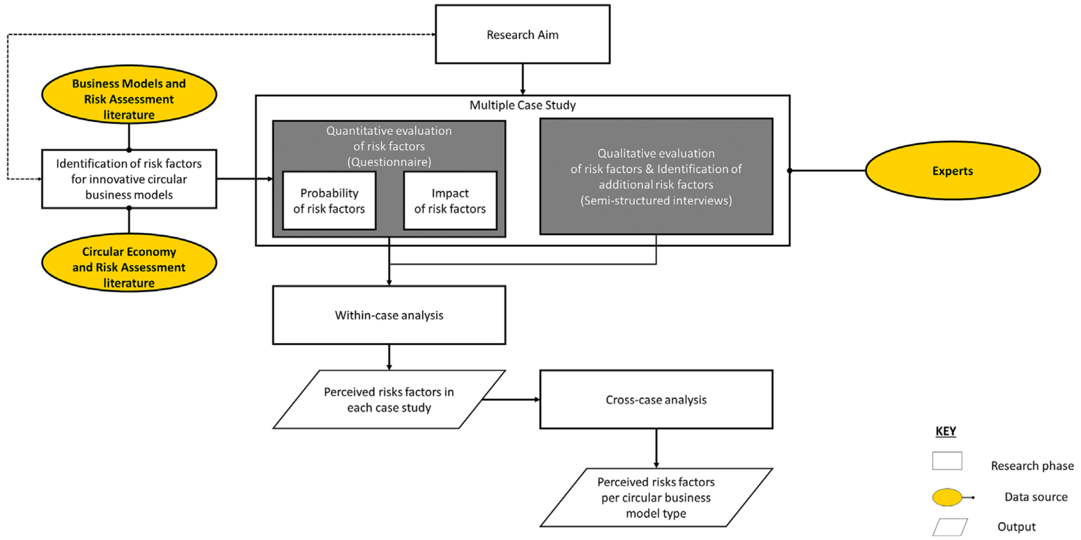

FIGURE 1 Research design.

TABLE 1 Actions taken to ensure research quality.

	Research phase		
Criterion	**Design**	**Data collection**	**Data analysis**
Construct validity	• Development of interview guidelines based on reviewed literature • Adoption of constructs from previous works in the fields of risk assessment, BMs and CE	• Multiple sources of information: questionnaire, semi-structured interviews and secondary data about organisations (reports and websites) • Anonymity assured	• Data triangulation based on independent sources • Key informants reviewed draft case study report with feedbacks
External validity	• Comparative multiple-case study design with case studies belonging to different industries and countries • Literal and theoretical replication logic across case studies	• Gathering data on the case context	• Triangulation of data • Consideration of case context • Pattern matching rather than statistical projections employed
Internal validity		• Iterative data gathering • Structured data coding	• Inclusion of multiple data/ information sources • Data triangulation based on independent sources • Key informants reviewed draft case study report with feedbacks • Pattern matching among cases
Reliability	• Development and application of case study protocol • Development and application of case studies database	• Shared questionnaire for all organisations	• Most senior author not being involved during the data collection phase

Existing research at the intersection of CBMs and risk management is immature; therefore, an exploratory case study approach was deemed appropriate to identify risk perceptions in the transition from linear BMs to CBMs and to determine how the choice of the CBM type may affect these risk perceptions. A case study is an 'empirical enquiry that investigates a contemporary phenomenon within its real life context' (Yin, 2003). Accordingly, case study research methodology was selected as the research focuses on a contemporary phenomenon, i.e. the perceived risk factors by organisations for the transition to CBMs, which does not require the control of behavioural events and arises in a real-life context (Yin, 2003).

A holistic multiple-case study design was selected, with the unit of analysis being the individual organisations planning the transition to CBMs for their composite materials products. The multiple-case study design allows to compare different case studies through a cross-case analysis, thus strengthening the external validity of the study thanks to the replication logic (Gong et al., 2018). Literal replication was employed to determine a set of common conditions across case studies, i.e. CBMs applied to products manufactured with the same material and hence exploiting similar technologies along the reverse supply chains, while theoretical replication was employed to identify different conditions across case studies, most noticeably the planned CBM type, in order to investigate how alternative CBMs can affect the perceived risk factors for the transition from linear to circular BMs.

At the research design stage, a case study protocol, including the development of interview guidelines, was established and a case study database was created. Moreover, additional actions were planned for the subsequent phases of data collection and data analysis to ensure the research quality against the four criteria defined by Yin (2003): construct validity, internal validity, external validity and reliability (Table 1).

3.2 | Case studies selection

Purposive sampling was used to select the case studies, as it allows to select relevant cases for the research objectives (Creswell, 2014). Relevant cases in this instance were organisations that are currently designing and/or are involved in planning the transition towards CBMs but have not yet reached implementation stage, because the research focused on perceived risks that affect the decision to start the transition, rather than those encountered during the CBM transition.

The research is grounded in the specific case of composite materials, used in product manufacturing, thus focusing on a homogeneous sub-group of manufacturing companies, which display similarity in terms of the materials used for their final products (Saunders et al., 2008). This choice allowed greater depth in the study and limited the influence of additional non-CBM-type contextual variables, thus achieving literal replication across case studies (Yin, 2003). It also enhanced the robustness of the cross-case analysis by limiting potential biases from material-specific characteristics and available technologies for recycling and/or remanufacturing for different materials. Moreover, the composite industry is a relevant case of transition towards CBMs (Tuni et al., 2023), given the cross-industrial and extensive use of composites and the challenges associated with their end-of-life management (Naqvi et al., 2018). The management of composites at the end-of-life is currently costly from an environmental and economic point of view, and while composites are an advantageous material from a manufacturing perspective, offering lightweight and strong material for use in a variety of industries, landfilling remains the predominant end-of-life option, as alternative options remain economically costly (Rybicka et al., 2016). Alternative composite end-of-life management is a major challenge for the manufacturing industry (Rybicka et al., 2016), given the environmental impacts and increasing costs of landfilling plus the political and social pressures towards a circular approach.

A heterogeneous sub-group of representative organisations was selected among companies manufacturing composite products, i.e. selected organisations belong to different industries, in line with the cross-industrial application of composite materials. Organisations also differ in terms of CBM features, thus meeting the criteria for theoretical replication, as explicated in Section 3.1, and allowing the identification of patterns and key themes for CBM transition in the composite material sector, based on CBM type (Saunders et al., 2008). This approach limits the number of case studies required to obtain comprehensive insights (Sauer et al., 2022).

Finally, the organisations in the study were concerned about environmental sustainability across their supply chain and were motivated to improve their environmental performance through the implementation of CBMs, thus were committed to the study (Dou et al., 2017; Grimm et al., 2016; Tuni & Rentizelas, 2022).

3.3 | Data collection and analysis

Data and information were collected and documented according to the case study protocol. First, archival data about the organisations were collected through secondary sources including company websites, internal company documents and publicly available reports. This secondary evidence was particularly useful to enhance the understanding of the context of each case. Second, a standardised online questionnaire was circulated among the organisations to assess the probability and impact of CBM risk factors using a 5-point linguistic scale. The list of risk factors was retrieved from Tuni et al. (2023). Probability was defined as the likelihood that a risk factor will occur during a specific time frame (Leisen et al., 2019; Yazdani et al., 2019), while impact was defined as the severity of the financial effect should the risk factor occur within the specified time frame (Leisen et al., 2019; Yazdani et al., 2019). The time frame for the risk assessment was defined as 5 years, in line with Leisen et al. (2019). The linguistic judgements provided from the organisations were then quantified according to the values displayed in Table 2. The risk score was then determined by multiplying the probability and impact values for each risk factor.

Third, the quantitative data were complemented by at least two rounds of interviews with each organisation, in order to capture qualitative information. Interviews are particularly suitable to collect 'rich, empirical data when the phenomenon of interest is highly episodic and infrequent' (Jia et al., 2018), as is the case of BM innovation, and allow interviewees to elaborate on emerging issues 'through examples, illustrations and insights' (Grimm et al., 2022). Focused interviews, combining an open-ended and conversational nature with questions derived from the case study protocol (Yin, 2003), were conducted by one or more of the co-authors. The most senior author was not involved in the data collection to enable a more independent point of view during data analysis and to enhance the reliability of data interpretation (Grimm et al., 2016). A total of 16 interviews were conducted. All interviews were conducted online. The average length of the interviews was 60 min. Whenever possible, more than one respondent per organisation was interviewed in order to avoid single informant bias.

TABLE 2 Definition of the linguistic scale, adapted from Hallikas et al. (2004) and Tuni et al. (2023).

Linguistic scale[a]	Probability	Impact	Score
Very low	Very unlikely: Very rare event	No impact: Insignificant financial impact for the whole organisation	1
Low	Unlikely: Indirect evidence of event	Minor impact: Isolated small financial losses	2
Medium	Moderate: Direct evidence of event	Medium impact: Short-term financial difficulties	3
High	Probable: Strong direct evidence of event	Serious impact: Long-term financial difficulties	4
Very high	Very probable: Event is expected	Catastrophic impact. Business discontinued	5

[a]Option "Not able to evaluate" was available to respondents, which corresponds to a 0 score.

Open-coding was applied to the risk factors identified during the interviews to identify additional risk factors, which were not part of the questionnaire. Subsequently, these first-order codes were refined incrementally and iteratively (Foerstl et al., 2010). Axial coding was then applied to delete and merge codes, generating more abstract codes aiming to increasingly draw comparison with the existing literature (Saunders et al., 2008; Wilhelm, Blome, Bhakoo, & Paulraj, 2016). Axial coding also enabled an initial comparison across different cases (Meinlschmidt et al., 2018). Data from the three different sources were tabularised into spreadsheets (Grimm et al., 2016; Yin, 2003) in order to structure the available information (Foerstl et al., 2010) and finally triangulated to obtain a nuanced understanding of the phenomenon (Sauer et al., 2022).

In line with Jia et al. (2018), within-case analysis was first conducted to summarise the key results as objectively as possible for each case. An initial draft case study report for each case study was submitted to key informants to check the accuracy of information and incorporate adjustments when required, thus strengthening the research construct validity. Cross-case analysis followed to look for key themes and detect communalities and differences in patterns of risk factors perceived across the cases (Foerstl et al., 2010). Data coding enabled data quantity reduction and its presentation for ease and effectiveness of comparative analysis (Jia et al., 2018). An inductive data analysis process was employed to organise the data into increasingly more abstract units of information through an iterative bottom-up process until a comprehensive set of themes was defined (Creswell, 2014). Concurrently, possible explanations for emerging patterns were iteratively built while collecting and analysing data (Saunders et al., 2008; Yin, 2003).

4 | CASE STUDIES OVERVIEW

This section provides an overview and context of the case study organisations, which are all based in Europe.

Company *Alpha–Sport* is an Austrian leading global manufacturer and marketer of premium sports equipment, which uses composite materials for structural parts in the production of both winter sports equipment and rackets. *Alpha* aims to extend the resource value and its CBM can be classified as 'Circular Supplies', as *Alpha* plans to partially replace virgin material with circular material obtained from internal production waste. This would be treated externally by a specialised recycling company, as *Alpha* lacks recycling skills internally.

Company *Beta–Home Furnishing*, based in France, is the European leader in the production of shower enclosures and whirlpool baths, producing over one million shower enclosures a year. *Beta* also aims to extend the resource value, and its CBM can be classified as 'Hybrid', combining elements of 'Resource Recovery' and 'Circular Supplies'. *Beta* aims to replace virgin glass fibre with recycled glass fibre. The material is to be recycled internally, initially exploiting the production waste, hence 'Circular Supplies', and later expanding to glass fibres obtained from end-of-life (EOL) products from the home furnishing industry as well as from different industries, hence 'Resource Recovery'.

Company *Gamma–Home Furnishing* is an Italian SME manufacturing a variety of products both for the construction sector, such as laminates in polyester thermoset resin reinforced with glass fibres, and for the office furnishing sector, such as desk tops and table tops. *Gamma*'s CBM is a very innovative 'Hybrid' CBM primarily based on a 'Product-as-a-service' CBM, with secondary elements of 'Resource Recovery' and 'Circular Supplies' CBM. The table tops produced by *Gamma* are to be assembled by its direct customer in the final product, which is then leased to the final customer, typically large organisations with extensive office spaces. *Gamma* and its assembly partner are going to work together on regularly updating the offering for final customer. Returned table tops are going to be recovered and its fibres internally recycled by *Gamma* to produce new table tops.

Company *Delta–Automotive* is a Spanish organisation active in the automotive industry, offering stamping dies manufacturing services and manufacturing serial automotive products such as pedal modules, parking brakes and gear shift levers. Company *Epsilon–Automotive* also manufactures components for the automotive industry and is a leader among plastic component suppliers in the industry. Based in Spain, it supplies the most important automotive OEMs worldwide. Both *Delta* and *Epsilon* seek to extend the resource value by exploiting a pure

'Circular Supplies' CBM, replacing virgin supplies with recycled supplies.

Company *Zeta–Automotive* is a German automotive engineering specialist for vehicle development and plant realisation, which develops production-ready solutions for automobiles and commercial vehicles in high- and low-volume production. Company *Eta–Aerospace* is also based in Germany and operates in the aerospace industry, offering know-how in the field of high-performance fibre composites, allowing for manufacturing from prototypes and samples up to delicate flight hardware. Both *Zeta* and *Eta* aim to extend the product value, thus planning a 'Product Life Extension' CBM to exploit the residual value of the EOL products, by repairing and remanufacturing the products before reselling them. Table 3 summarises the main pieces of information about organisations involved in the study, including who is responsible for supplying the EOL material/product and for carrying out the R-activities according to the 9Rs framework (Kirchherr et al., 2017). Finally, Table 3 details the key informants within each organisation.

5 | RESULTS

The perceived risk factors for the transition from linear BMs to CBMs were predominantly captured by two sources of evidence. First, the quantitative risk scores emerging from the questionnaire, displayed in Table 4, were calculated by multiplying the probability and impact of each risk factor. Second, the quantitative scores were complemented by qualitative evidence emerging from the interviews in the form of rich and empirical information (Jia et al., 2018).

Following a within-case analysis, which investigated the main perceived risk factors for each case study, while considering the level of supply chain vertical integration (Section 5.1), the two sources of information were combined to identify convergent lines of inquiry (Ashby, 2014). A cross-case analysis (Section 5.2) was performed to identify commonalities and differences in the patterns of perceived CBM transition risks across the different cases studied (Foerstl et al., 2010; Grimm et al., 2016). Based on the existing literature on CBMs and on the themes emerging from the data (Wilhelm, Blome, Wieck, & Xiao, 2016), the case studies were analysed and compared on the basis of the CBM type as detailed in Vermunt et al. (2019).

5.1 | Within-case analysis: Circular supply chain analysis

Within-case analysis was first conducted to summarise the key results for each case study. The initial analysis was guided from the level of vertical integration of circular supply chains, considering two variables, namely the origin of the material and the main actors involved in recycling and/or remanufacturing activities. The extent to which such variables are internally controlled from the organisation or are dependent on external partners can provide initial insights on the perceived risk factors for CBM transition.

Company *Alpha–Sport* chose to outsource the recycling activities, albeit using scrap from internal production processes as the low quantities involved did not justify an investment to set up recycling activities internally. Nevertheless, the circular supply chain structure, where the recycling is simply outsourced to a third party, is susceptible to increased outsourcing and logistics costs, impacting the overall cost structure of the CBM. The availability of a partner such as a recycling company in close proximity of *Alpha* is necessary for the value creation of the CBM and key to ensure the financial and operational viability of the 'Circular Supplies' CBM. Moreover, the organisation stressed that changes to the production machineries are required to use the recycled material, thus impacting key production activities; however, the magnitude of such changes is still difficult to estimate as the company lacks experience in manufacturing with recycled fibres.

Company *Beta–Home Furnishing* initially chose to limit the scope of its circular initiatives to materials of internal origin for quality concerns following preliminary material testing, as quality of fibres and weight of granules depend on the application of the original product and on the industry. Materials originating from different sectors, i.e. nautical, posed technical challenges in the production process, which determined the choice from company *Beta*. The organisation is seeking to expand its recycling operations also with externally sourced materials following additional research and development; however, the supplier quality risk remains a significant barrier to this expansion, as additional key supply partners need to be engaged.

Company *Gamma–Home furnishing*, despite only recycling materials from internal origin, i.e. table tops, and performing internally recycling processing, questioned the availability of supply as leasing is not yet fully established in the furnishing industry and is new to the company, which lacks experience on the servitization of the offering and the associated value proposition. The flow of returned products remains thus uncertain and is perceived as a potential bottleneck limiting the production capacity for table tops made of recycled material due to lack of materials. Additionally, the transition phase until the first batch of table tops is returned would necessarily rely still on virgin material. Finally, an additional risk factor was linked to the production cost for the grinding activities required to recycle fibres, due to growing electricity costs, which can impact the cost structure of the CBM.

Companies *Delta–Automotive* and *Epsilon–Automotive* planned their CBM with a complete externalisation of the circular supply chain, both for the material origin and for the recycling activities. This choice exposes the organisations to financial risks, in particular regarding the cost structure of their 'Circular Supplies' CBM. On the supply side, company *Delta–Automotive* identified a major source of risk in the potential increase of recycled carbon fibres costs, as this is sourced externally and, on the market side, the automotive market does not allow 'any flexibility for selling the product at a higher price' as the price is determined proportionally to the industrial costs. Moreover, additional risk factors were identified in the structure of the externalised supply chain, as *Delta–Automotive* highlighted the lack of skilled partners able to scale-up the production of recycled carbon fibres, with pyrolysis stage being particularly critical. The concern for the

TABLE 3 Profiles of organisations.

Organisation code	Employees	Turnover [M€]	Country	Industry	CBM strategy (Bocken et al., 2016)	CBM type (Vermunt et al., 2019)	Material/product origin	Rs activity	Key informant	Years of experience (organisation)	Years of experience (industry)
Alpha	600	400	Austria	Sport	Extending resource value	Circular supplies	Internal	External	Project manager/leader	25	25
Beta	793	160	France	Home furnishing	Extending resource value	Hybrid[a]	Internal	Internal	R&D manager	7	30
Gamma	33	10	Italy	Home furnishing	Access and performance model	Hybrid[b]	Internal[c]	Internal	Operations manager	21	21
Delta	1448	187	Spain	Automotive	Extending resource value	Circular supplies	External	External	Senior engineer	6	18
Epsilon	2000	212	Spain	Automotive	Extending resource value	Circular supplies	External	External	Project manager/leader	20	20
Zeta	8000	687	Germany	Automotive	Extending product value	Product life extension	Internal[c]	External and internal	Project manager/leader	3	6
Eta	94	11	Germany	Aerospace	Extending product value	Product life extension	Internal[c]	External and internal	Project manager/leader	4	10

[a]Hybrid CBM, including elements of circular supplies and resource recovery.
[b]Hybrid CBM, including elements of circular supplies, resource recovery and product-as-a-service.
[c]In collaboration with customer.

TABLE 4 Questionnaire risk scores.

Risk category	Risk factor	Risk factor definition	Alpha (Circular supplies)	Beta (Hybrid)	Gamma (Hybrid)	Delta (Circular supplies)	Epsilon (Circular supplies)	Zeta (Product life extension)	Eta (Product life extension)
Market	Consumer perception (quality)	Resistance of end-users towards CE products due to customer perception about inferior quality compared to new products, resulting in low public acceptance and low market penetration	9	6*	3*	16*	9*	12*	8*
	Customer perception (ownership)	Resistance of end-users towards CE products due to preference of customers for ownership rather than access to service resulting in low public acceptance of products (applicable only to non-ownership business models)	0	6	0	16	20	9	4
	Market forecast	Demand risk, namely the uncertainty about the market size	9	9	4	9	20*	4*	6*
	Economic cycle	Risk in the business environment/market due to adverse economic cycle and/or uncertain financial stability, resulting in low demand for products at the global level	12*	9*	16*	25*	16*	4*	6*
Supply	Supply availability	Limited and/or not timely availability of recycled materials to support demand of CE final products	1	4	12*	25*	9*	8	1
	Logistics	Risk associated with changes in the supply network and transportation determining an increase of the logistic costs	0*	12	6	16	12	8*	12*
	Supplier quality	Supplier quality risk, resulting in quality criteria for the input materials not being achieved	1	4*	4	25*	12	4	8
	Take-back systems	Lack of structured take-back systems, including the lack of accurate information about the tracking of materials in the reverse supply chain	0	4*	12*	16*	5*	4*	16*
Finance	Lifecycle revenues	Lifecycle risk and uncertainty factors related to a possible uncalculated change of revenues due to price volatility of the final product resulting in lower than expected revenues	4	2	9	16	0	16	6
	Capital costs	Risk associated with high up-front investment costs and capital costs required to create and deliver the value proposition of the innovative business models, including costs for production plants and inventory costs	4*	16	9	9	1*	12*	12*
	Recycled material costs	Unforecasted increase of recycled material cost, affecting the economic viability of using recycled materials	9	9*	1	16*	0*	16	0

(Continues)

TABLE 4 (Continued)

Risk category	Risk factor	Risk factor definition	Alpha (Circular supplies)	Beta (Hybrid)	Gamma (Hybrid)	Delta (Circular supplies)	Epsilon (Circular supplies)	Zeta (Product life extension)	Eta (Product life extension)
	Virgin material costs	Unforecasted decrease of virgin materials cost, affecting the economic viability of using recycled materials	1	1	1	25	15	2	1
	Production costs	Increased production costs, including increased costs for energy and maintenance within the production plant	9	6	1*	25	15	2	1
	Financial resources	Factors impacting the capability to finance the CE business model, including access to finance	9	12	4	16	9	9	6
Political and regulatory	Regulatory standards	Lack of standards for CE products, potentially affecting compatibility, quality and sustainable branding	1	4	12	9	6	12*	12*
	Legal and regulatory	Commitment of regulatory and legal circumstances, including the ineffectiveness of existing laws and/or their insufficient implementation	9*	1*	6	9	0	20	12
	Public policy and institutional	Risk arising from adverse changes in policy support schemes or regulations, including economic incentives to shift from linear economy to CE, and/or uncertainty regarding changes in government policies	4	1	12	9	9	6	4
	Taxation	Risk arising from adverse changes in the taxation regulations, including declining or eliminated tax advantages for green products, and/or uncertainty regarding changes to the fiscal policies	4	16	6	9	0	4	4
	Non-ownership business models	Legal issues emerging for non-ownership business models as service providers cannot legally retain ownership of a sold product	0	0	9	9	0	12	1
	Intellectual property	Risks associated with the drainage of Intellectual Property (IP) or know-how, including sensitive data on the organisation's partners	4	8	3	4	1	4	1
Technical	Human resources	Risks related to the lack of qualified human resources required to realise the CBM	4	6	12	9	6	1	3
	Quality	Risks related to the quality of the final CE products, such as gaps in expected vs. delivered performance, durability and functionality throughout lifecycle of the CE product	9	8	4	25*	12*	12	3

TABLE 4 (Continued)

Risk category	Risk factor	Risk factor definition	Alpha (Circular supplies)	Beta (Hybrid)	Gamma (Hybrid)	Delta (Circular supplies)	Epsilon (Circular supplies)	Zeta (Product life extension)	Eta (Product life extension)
	Technology	All risk and uncertainty factors that are linked to the use of technologies that are new or still in a premature state, highly complex, or for which the company lacks experience, potentially leading to lower than expected technological efficiency	12	9	9	16*	9*	4	12
Other	Covid-19 pandemic	Risk arising from the Covid-19 pandemic, including major supply chain disruptions, supplier failure and/or customer solvency	0	15	12	16	12	3	6

*Risk factor highlighted during the semi-structured interviews.

value creation along the supply chain was also shared by *Epsilon–Automotive* that confirmed that take-back systems for a reverse carbon fibre supply chain are not entirely established at the technological readiness level required for a full commercial exploitation. This was indirectly confirmed by *Delta–Automotive*, which lamented the lack of a sizeable and reliable partner organisation able to take responsibility for all activities in the reverse supply chain, hence requiring *Delta* to manage a complex reverse supply chain. This was perceived as additional risk factors by *Delta*, due to the immaturity of such reverse supply chains.

Companies *Zeta–Automotive* also confirmed during the interviews the risks arising due to a limited visibility of the reverse supply chain, as they would be responsible solely for the disassembly of a subassembly of the vehicle, while a third party would be in charge of the disassembly of the vehicle, on behalf of the focal company. Information such as costing of vehicle disassembly, availability of subassemblies and location of vehicle disassembly plants are key to transition towards a fully circular supply chain. Company *Eta–Aerospace* also highlighted as a major risk the lack of visibility over the downstream part of the supply chain, which is managed from the focal company. This turns into the upstream part of a reverse supply chain, and the lack of visibility and traceability over materials can significantly hamper the viability of the CBM. Both *Zeta* and *Eta* ultimately stressed risks connected to key circular activities required to create value for the CBM, as these activities will be carried out by partners in a complex circular network structure, which is yet to be shaped. Such activities do not only include the physical activities but also the associated information flow. A secondary risk factor was the logistic costs associated to the reverse supply chain, which can affect the cost structure of the CBM, although these are expected to decrease over time, as remanufacturing and repair centres become more widespread.

5.2 | Circular business model type analysis

The cross-case analysis was guided from the selected CBM by organisations for the CE transition. The analysis of the results identified key patterns and themes, by first highlighting risk factors that are perceived irrespective of the CBM chosen and second identifying risk factors that were perceived particularly with a specific CBM.

Market risk factors were evaluated similarly across all organisations involved in the study. Interviewees particularly emphasised the economic cycle as a major source of risks, highlighting that it 'may not be the most convenient moment to introduce such a significant change to our business' (*Gamma–Home Furnishing*). Organisations demonstrated awareness that sustainability is going to increasingly become a competitive leverage; however, this is not perceived as a short-term urgency yet. As a result, a more favourable economic trend is seen as an enabler for BMI. The option to further delay the transition to CBM was particularly stressed by organisations that highlighted concerns regarding the capital costs (*Alpha*, *Beta*, *Epsilon*, *Zeta*, *Eta*). Organisations would incur in increased short-term costs coupled to an overall negative economic outlook, which often discourages organisations to transition to circular supply chains (Dulia et al., 2021). Another common risk factor, with the only exception of *Alpha*, is the customer perception of CE products, which are often considered of inferior quality or lacking safety, especially in more immature markets. The additional sustainable dimension offered by CBM is not perceived sufficient to counterbalance potential diminishing value offered to customers on other dimension, particularly on products' performance, as products made with recycled materials currently compete against products made with virgin materials and are expected to reach similar performance standards (Kazancoglu et al., 2021).

The supply side is also considered a significant risk across different CBMs, with respect to the lack of structured take-back systems being recognised as a major risk for the CBM transition, irrespective of the selected CBMs, in line with Tuni et al. (2023), Dulia et al. (2021) and Choudhary and Kumar (2021). The main consequence of the lack of accurate information about the tracking of materials in the reverse supply chain is the impossibility to accurately plan production due to uncertainties related to the amount and timing of returns. This risk is further exacerbated by the limited experience of organisations in managing sub-suppliers in circular supply chain (Dulia et al., 2021) and the lack of historical data (Ethirajan et al., 2021). The 'Take-back systems' risk was stressed by all interviewees, with the only exception of *Alpha–Sport*, although the reliance of *Alpha–Sport* solely on internal materials with a simple reverse SC structure mitigates this risk for the organisation, as the recycler acts simply as an outsourcing company for *Alpha–Sport*. The identification of key partners to manage reverse material and information flow is thus crucial to strengthen the value creation of CBMs and to lower risks associated with the transition to all types of CBMs.

Other supply risks are instead CBM-specific, as both 'Circular Supplies' and 'Hybrid' CBMs mentioned supply availability and supplier quality among the key risk factors, ultimately impacting the value creation of the CBMs. The supply availability risk, described as a knock-on effect of the lack of structured take-back systems, is further exacerbated for the 'Circular Supplies' BM in instances where the organisation does not have full control of the origin of the supplies, either because they are intended to be purchased on the market (*Delta–Automotive* and *Epsilon–Automotive*) or because the return of the product requires a multi-tier cooperation, i.e. involving both the customer and the final consumer, as in the case of *Gamma–Home Furnishing*. *Delta*, *Epsilon* and *Gamma* evidenced that the delay of supplies may lead to halt companies' operations, in line with Ethirajan et al. (2021). Moreover, the reliance on the market for purchasing recycled material further increases the risk related to supplier quality, as evidenced by *Delta–Automotive* and *Epsilon–Automotive*, demonstrating that the lack of an established market at an industrial scale for such materials presents significant risks for the upstream circular supply chain, as organisations lack experienced partners to trust. The lack of a mature market for recycled composites determines that emerging recycled materials market need to compete with existing markets, as observed by Kazancoglu et al. (2021), and match virgin material quality standards, at least until the market becomes further segmented.

The varying quality of the input materials cascades down to the quality of the final products and the technical risks, with a particular focus on the technological risks, particularly in terms of 'the amount of recycled material to be used' in the final product to maintain the quality standards required from automotive focal companies (*Epsilon–Automotive*). The technical performance of recycled fibres is typically inferior to the virgin material (*Delta*, *Epsilon*), requiring an update in the product design to preserve the quality of the final product. Differently from existing evidence consistently ranking the quality of recycled products throughout their lifecycle among top risks (Dulia et al., 2021; Kazancoglu et al., 2021), this work limits the perceived quality risks to 'Circular Supplies' CBMs, highlighting that an increased control or collaboration along the circular supply chain may concurrently lower supply and quality risk factors. Moreover, human resources were not perceived as a major risk in terms of quality in the transition to CBMs, in contrast to Kazancoglu et al. (2021) and Choudhary and Kumar (2021).

Capital costs risk as well as political and regulatory risks appear instead more significant for the 'Product Life Extension' CBM, as confirmed both by the risk scores from the questionnaire and the evidence collected through interviews. Both *Zeta* and *Eta* emphasised the size of the investment and the financial resources required to build both the remanufacturing and repairing infrastructure required to establish the intended CBM, which affect the CBM's value capture due to increased costs. Considering the nature of the automotive and aerospace industries, these investments are deemed strategic as they impact the long-term production capacities of organisations. Capital costs were assessed less important for other CBM types, although the investment required to amend the production processes was mentioned both by *Alpha* and *Epsilon*, albeit with lower risk scores recorded from the questionnaire. This finding further dissects existing evidence of upfront capital costs being a major risk for the transition towards circular supply chain (Dulia et al., 2021), as the capital costs risk perception is linked to CBM requiring assets to be fixed for a longer time span.

Moreover, another risk factor particularly significant to the 'Product Life Extension' CBM is the lack of an existing regulatory framework, as already evidenced by Dulia et al. (2021), and of a regulatory standard to enable a multi-actor supply chain based on remanufacturing and repair. This was deemed critical especially by company *Zeta–Automotive*, which stressed that a stronger legislative framework is required due to some specific features of the industry. These include the long-term planning horizon of the automotive sector for key subassemblies, such as vehicle platforms, and the fact that multiple actors, such as focal company, OEM, dismantler and logistics providers, need to be involved. This calls for simplified processes exploiting modularisation along the reverse supply chain (*Zeta–Automotive*), which require standards, yet to be regulated, to enable collaboration in the circular supply chain and lower trust issues and uncertainties.

Finally, open-coding was applied to the risk factors identified during the interviews to identify additional risk factors, which were not part of the questionnaire. This process led to the identification of two additional risk factors specific to the 'Product Life Extension' CBM, which emerged during the interviews with company *Zeta–Automotive* and *Eta–Aerospace*, namely product cannibalisation and lack of product innovation. Both companies stressed that shifting towards a 'Product Life Extension' CBM will progressively transform the organisation into a 'remanufacturer' in the long term, as products in high-end applications can be continuously repaired and remanufactured for up to 30 years, according to the interviewees. This could affect the sale of new products and associated revenues, as part of their market would be taken from repaired and remanufactured products. Increased market segmentation may be required to lower this risk and to target different customers for CE products compared to the customer segments targeted with linear BMs, thus updating the value proposition. The extended product lifetime was considered a potential threat also to product innovation, as it would be unclear when it is the 'moment to phase out the old platforms' and to introduce new products with enhanced characteristics (*Zeta–Automotive*). Long-term return policies were previously identified as a risk bounded to design (Kazancoglu et al., 2021), whereas interviewees expanded the potential implications of this risk to the broader product innovation.

The cross-case analysis enabled the comparison of risk factors across different CBMs and an initial identification of the main CBM-specific risk factors, as illustrated in Figure 2. Market risks, such as customer perception and economic cycle, were equally prioritised across different CBM types, being mentioned as reasons to delay the uptake of CBMs. Similarly, the lack of structured take-back systems was also prioritised for all CBMs. The lack of accurate information about the tracking of materials in the reverse supply chain was particularly identified as a critical risk for production planning, impacting the value creation of CBMs.

Other risk factors were instead prioritised for specific CBMs. Both supplier quality and supply availability risk factors were prioritised for 'Circular Supplies' CBM type, largely due to the high dependence of buyers on critical circular suppliers for their purchases. Moreover, technological risk factors were also highlighted for 'Circular Supplies' CBM, being linked to the challenges in process re-design due to varying quality of the input material. Political and regulatory risks were instead prioritised for 'Product Life Extensions' CBM, as this CBM requires a longer planning horizon, which calls for increased certainty on the overall legislative framework and clear standards to enable multi-tier circular supply chains. Moreover, cannibalisation and lack of product innovation were also identified as 'Product Life Extension'-specific CBM, which will require further investigation from future research.

6 | DISCUSSION

6.1 | Theoretical implications

This research contributes to the CE literature in three ways. First, it increases the understanding of the main risk factors perceived by the manufacturing industry in the transition to CBMs, with a joint analysis of risk factors linked to the CE and to BMI. This study combines the focus on a specific application context, i.e. composite materials with similar technological challenges due to a focus on a particular material type, with a cross-industrial approach. This allowed a more in-depth investigation, increasing the level of granularity compared to generic CE-approaches, by highlighting that the immaturity of circular approaches for composite materials determines a significant perceived risk in terms of take-back systems and customers' perception of CE products. Moreover, by removing contextual variables such as challenges associated with different materials, it enabled a cross-industrial analysis of perceived risk factors, which determined a new understanding about common patterns across different industries and CBM types.

Second, this work first disaggregates the risk factors according to different CBM types, identifying factors whose perception is linked to the organisations' selected CBM. Few risk factors, such as customer perception, economic cycle and the lack of structured take-back systems, are equally prioritised across different CBM types, whereas multiple risk factors are prioritised for specific CBMs. The disaggregated evaluation of risk factors across different CBMs permitted initial conclusions about CBM-specific risk factors to be drawn, unpacking the risk factors previously identified in the literature and providing more in-depth information about the perceived risk factors for specific CBMs. The findings of this explorative study have provided a strong basis upon which further new research can build to advance the field.

Third, this study advances extant literature on CBM risk factors as the in-depth knowledge acquired through the semi-structured interviews contributes towards a strong foundation in the state of art

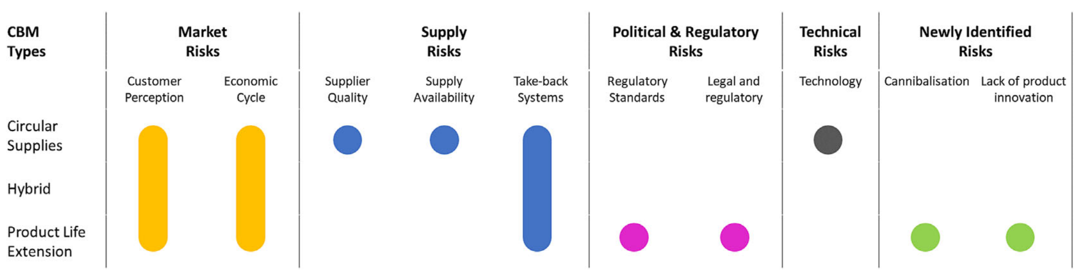

FIGURE 2 Prioritised risk factors by circular business model type.

understanding of the concept. Additional risk factors were identified specifically for 'Product Life Extension' CBM, highlighting the perceived risk of a cascading effect from the establishment of the CBM towards product cannibalisation and ultimately the lack of product innovation. The slowing down resource loop approach coupled with repairing strategy for products with a long lifecycle can limit the ability of companies to establish innovative features to the products. Strategies to maintain the EOL product at the product level without disassembly, i.e. repair, are considered environmentally favourable compared to strategies that exploit only the residual value of materials, such as recycling (Kirchherr et al., 2017); however, they introduce additional risk factors that organisations need to leverage effectively to maintain the economic viability of CBMs in the long-term.

6.2 | Managerial implications

CBMs have the potential to increase revenues by exploiting new markets and customers, limiting costs by reducing the quantity and types of production materials, shortening the supply chain and reducing its complexity to increase industrial resilience as well as strengthening business' relationship with customers. However, CBM implementation carries several risks. This demands identification of potential risk factors and the extent of their potential impact for given CBMs so that appropriate mitigating measures can be developed to drive programmes.

Some risks, such as customer perception of product quality, and supply risks were generic to all CBM types analysed, while other risks, such as technical as well as political and regulatory risks, were more significant for certain CBM types. In particular, for 'Product Life Extension' CBM, legislative risks are more complex to navigate as the legislation on involved regulatory standards will cover multiple aspects such as product ownership, boundaries of waste definition on when an EOL product is or is not treated as waste, in addition to the existence of the broader legislative drivers to create the market incentive for change.

From a managerial perspective, CBM risks can also be looked at in terms of internal and external risks. Internal risks cover aspects such as changes to production processes to handle recycled materials and product design variations, which can incur production system change costs. External risks are those related to the upstream supply chain, material quality and customer perceptions as well as legislative risks. Organisations must thus consider the risks associated with their CBM as well as their capabilities in order to prioritise risk mitigation and to proceed with CBM implementation.

External risks are likely to be more complex to manage, e.g. legislative risks can be difficult to mitigate and involve being forward-looking and anticipating potential impacts as well as working with the relevant policy organisations to understand the business implications and feed into the policy-making process itself, where relevant. Other external risks relating to recycled material supply or product take-back involve the organisation taking control of the risk and working with external partners to reduce it. The level of control that organisations can exert over the sources of risk will affect the extent of and perception of risk associated with particular CBM and thus the willingness to engage in them since lack of control increases uncertainty and vulnerability and therefore the level of flexibility that would be required from the organisation involved. For example, a CBM that requires subcontracting as part of the process will be partly dependant on the performance of the third party actor. Successful implementation of CBM in such instances may require introduction of methods to reduce actual and perceived risks. This would include for example practices that would engender uniformity in standard and expectations as well as coordination between the organisation and the third party. This call for working more closely with suppliers could develop an increased vertical integration along the circular supply chain to facilitate access to key recycled materials and activities for the CBM development. Other business-led activities could include changing procurement requirements and product specifications, to reduce the risk of poor material quality or material availability. For the majority of analysed CBMs, reducing material quality risk is identified as important, and this could involve companies establishing their own take-back systems or working with the waste and recycling sector more closely on market quality requirements.

Internal risks are inherently easier to control; however, there can be cost implications associated with any required capital investment changes to equipment or increasing technical knowledge of key design and production staff, costs which must then be built into the CBM cost structure. Regardless of the CBM type, the success of CBMs involves taking management responsibility for reducing the risks identified and working externally with circular supply chains in a more collaborative way to establish new partnerships and widen the value chain.

7 | CONCLUSIONS

This work aimed to understand the main risk factors that are perceived by the manufacturing industry in the transition to CBMs. A multiple-case study research design was used to explore perceived risk factors across seven European organisations active in different industries and currently planning the transition to CBMs for their composite-based products. Results showed a prevalence of market (customer perception and economic cycle) and supply (take-back systems) risk factors across all CBMs, while limited emphasis was given to financial risk factors. Other risk factors were particularly relevant for specific CBM types, such as political and regulatory risks for 'Product Life Extension' CBM as well as technical, supply availability and supply quality risks for 'Circular Supplies' CBM. These risks were magnified in circular supply chains displaying lower vertical integration and relying on third parties both for material supply and for carrying out Rs activities.

As with every piece of research, this study is not without limitations. Some limitations are embedded in the methodology adopted.

This work adopted multiple sources of data for the identification of the risk factors, combining structured information collected through the questionnaire with open-ended data collected through the interviews. Nevertheless, some risk factors may have been overlooked. Additionally, the main source of data, semi-structured interviews, is not bias-free, as interviews rely on the opinions of experts, which contain some subjectivity. Furthermore, all organisations involved in this study planned the circular transition for products made of composite materials, despite being active in different industrial sectors. As such, the findings presented in this work cannot be analytically generalised without adequate replication in one or more different industrial settings in order to further strengthen the results (Yin, 2003). Future research may replicate this study to non-composite materials industrial contexts in order to distinguish risk factors specific to composite materials and those applicable across a wider variety of industrial sectors.

The main output from this work is an accurate analysis of risk factors for CBM transition. This has provided a strong foundation for further in-depth analysis to enhance academic understanding and industrial practice in this novel field. Examples of such research work include identifying the most suitable risk management strategies to tackle the identified risks and thereby facilitate successful establishment of CBMs or complementing the findings from this current study using quantitative methods to capture the economic quantification of risk factors. In the latter case, bow-tie analysis could be used to perform an economic assessment of innovative CBMs, while considering the uncertainties associated with risk factors and risk management strategies. Quantitative approaches could be further enhanced by stochastic methods, such as Monte Carlo or Markov chains. Finally, future research may also compare the results of this work, i.e. risks perceived by organisations ex-ante, with risks that emerge after the transition to CBMs is completed, adopting a longitudinal approach. Nevertheless, this work is paramount in order to achieve circularity, which is vital for industrial sustainability and global environmental preservation.

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