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Enabling the Circular Economy: An Exploratory Study on Intellectual Property Challenges in Innovation Ecosystems

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ABSTRACT

This paper explores circular economy related intellectual property (CEIP) challenges that actors in circular economy innovation ecosystems (CEIEs) face. Findings from a literature review are combined with empirical evidence from semi-structured interviews with different actors in CEIEs, including original equipment manufacturers as well as end-of-life solution providers of different company sizes and manufacturing industries. The main contributions of this paper to the literature are: (i) a preliminary framework to better understand IP challenges in CEIEs, (ii) a CEIP challenges framework which extends findings from the literature by categorising CEIP challenges mentioned in the conducted interviews and (iii) a visual mapping of CEIP challenges in the aerospace industry.

1. Introduction

Enabling the circular economy (CE) can lead to significant benefits both for the environment and economy (Pieroni et al., 2021; Scheel et al., 2020; Ranta et al., 2018; Kirchherr et al., 2017). Next to significant reductions in greenhouse gas emissions (Gallego-Schmid et al., 2020; Christis et al., 2019; Liu et al., 2018), annual business opportunities are estimated to range between €1.8 trillion in Europe (MacArthur et al., 2015) and $4.5 trillion globally by 2030 (Esposito et al., 2018). Despite these benefits, to date economies worldwide are employing linear principles (Patwa et al., 2021; Brydges, 2021; Velenturf and Purnell, 2021; Sanyé-Mengual et al., 2019). One of the reasons for this is related to intellectual property (IP) (Eppinger et al., 2021) which includes both formal IP such as patents and informal IP like trade secrets (Hall et al., 2013). Investigating the economy at micro level gives a first glimpse into IP challenges (which we define as tensions, risks and uncertainties related to IP) that hinder the implementation of the CE. An example can be found in the automotive industry. In the European Union (EU) the European Commission estimates vehicles to be responsible for about 7-8 million tonnes of waste on a yearly basis (Takhar, 2019). Therefore, as of January 1, 2015, the Directive 2005/64/EC provides that all vehicles must be manufactured with at least 85 percent recyclable and 95 percent reusable or recoverable material (European Commission, 2022). To cope with this ruling, for instance German car manufacturer BMW Group has its own recycling and dismantling centre. There, the original equipment manufacturer (OEM) researches and develops materials, tools and processes specifically tailored to recycling and disassembly (BMW Group, 2009). All of this is potentially related to the development of IP owned by BMW Group and as such may be legally protected (Wiens, 2014). However, so far using these innovations the OEM itself is recycling only a few thousand vehicles per year as compared to millions in sales (Wiens, 2014; Hepe, 2021). To scale the end-of-life (EOL) procedure for the remaining vehicles, it is necessary that independent recyclers, refurbishers and repairers (which we collectively refer to as EOL solution providers) world-wide get access to IP from OEMs like BMW Group or at least have freedom to operate to develop their own dis- and reassembly tools. For instance, technicians require access to diagnostic codes, circuit schematics, replacement parts or proprietary tools to successfully reuse and repurpose the items (Wiens, 2014). If the OEM neglects to share the IP or only shares it under too strict licensing clauses, third parties are running into the risk of infringing the original owner's IP rights (IPRs) (Holgersson, 2018). In 2014 for example Canon Inc. successfully sued an EOL solution provider from the United Kingdom (UK) for patent infringement (Canon Inc., 2014). In this case, the infringement related to the sales of remanufactured toner cartridges which reused Canon Inc.'s original components (Hartwell and Marco, 2016). To highlight another "David versus Goliath" case: In 2020 the Supreme Court of Norway decided in favour of Apple Inc., that a small EOL solution provider from Norway who imported allegedly refurbished screens bearing the Apple logo violated Norway's Trademark law (Svensson-Hoglund et al., 2021; Velden, 2020). A decision which is considered to be representative and thus, according to Velden (2020, p. 1) displays a "heavy defeat for electronics repair around the world". These examples illustrate how IP can be a hinderance for third parties to engage in activities related to the CE. At the same time, for a CE to thrive these third parties should be included in the innovation ecosystem (IE) to achieve the

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required economies of scale (Wiens, 2014). To make the CE transition become a reality it is therefore necessary that multiple actors in IEs do not work against each other but instead collaborate (Brown et al., 2020; Zufall et al., 2020; Hansen and Revellio, 2020; Hockerts and Wüstenhagen, 2010). In this regard, the literature reveals several research gaps. While the literature provides a good basis for different IP challenges in a collaborative innovation setting, those that identify IP challenges specific to the CE context is limited. Besides, few IP challenges in the literature are sufficiently supported with empirical evidence. And finally, a structured overview of these IP challenges is lacking. This paper aims to address these gaps. It explores IP challenges that slow down or even prevent the successful transition from linear to circular economic systems with closed loops. Because of the exploratory nature of this study, findings from a literature review about generic IP challenges are combined with empirical evidence from semi-structured interviews to determine circular specific ones. The research is guided by the following question: *What IP challenges do actors in circular economy innovation ecosystems (CEIE) face?* We build on the definition of an IE provided by Granstrand and Holgersson (2020) and define a CEIE as the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors contributing to the CE.

The contributions of this paper to the literature are threefold: (i) a preliminary framework to better understand IP challenges in CEIEs, (ii) a CEIP challenges framework which extends findings from the literature by categorising CEIP challenges mentioned in the conducted interviews and (iii) a visual mapping of CEIP challenges in the aerospace industry.

The remainder of this paper is structured as follows. Section 2 presents the status quo in the literature. Section 3 in turn explains the methodology. Then, Section 4 presents the findings from the collected interview data according to the research question, before Section 5 concludes.

2. Literature review

2.1 The evolution of ecosystems and the bridge to CEIEs

The concept of "ecosystems" goes back to Moore (1993, 1996) who applied the biological concept of natural ecosystems to the business world. Over time, building on this work various definitions and applications of ecosystems emerged in the literature, among them IEs (see, e.g., Adner, 2006; Adner and Kapoor, 2010; Autio and Thomas, 2014). Relatively recently, Granstrand and Holgersson (2020, p. 3) provided a review of 120 publications on IEs and based on their analysis propose a revised IE definition: "An innovation ecosystem is the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors". Moreover, Adner (2017, p. 42) had offered a definition of ecosystems that is centred around a value proposition: "The ecosystem is defined by the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize".

These two definitions build the bridge between IEs and CEIEs. We argue that in a CEIE the focal value proposition of the ecosystem is the CE. In the eyes of Adner (2017) ecosystems are primarily defined by all things that are necessary and that have to be orchestrated so that the value proposition can be achieved. Hence, achieving the CE requires the different factors within an IE (or in this case a CEIE) mentioned by Granstrand and Holgersson (2020) to work together, e.g., by sharing relevant knowledge in form of IP and jointly developing new CE related technologies.

2.2 IP challenges in the collaborative innovation literature and links to the CE

Risk of knowledge leakage: The risk of knowledge leakage "refers to the loss of knowledge intended to stay within a firm's boundaries" and thus can lead to a competitive disadvantage (Frishammer et al., 2015, p. 85). This involuntary knowledge outflow incurs costs in form of transaction as well as management costs, thereby discouraging firms from engaging in collaborations with external partners (Belitski, 2019; Beers and Zand, 2014). In their exploratory empirical study based on interviews and a survey of 101 firms, Hagedoorn and Zobel (2015) find that especially firms with strong research and development (R&D) capabilities that engage in external knowledge exchange have a high risk of leaking knowledge to external partners. This is strengthened by Frishammer et al. (2015) who argue, based on five case studies of joint R&D projects in large firms in Sweden that knowledge leakage negatively affects the focal firm's effectiveness or efficiency. Paza-Ullah and Eriksson (2017) provide further empirical evidence based on a survey of 186 SMEs that in coopetitive settings knowledge leakage has a negative impact on the otherwise positive relationship between knowledge sharing and performance.

Risk of knowledge spillovers/opportunism: The risk of knowledge spillovers implies "that new knowledge, once generated, may be used by agents other than the innovator" (Samaniego, 2013, p. 1), leading to a situation in which one actor appropriates more value from a collaboration than its counterpart (Holgersson, 2018; Driffield et al., 2014; Chesbrough, 2006). As a result, opportunistic threats arise for firms that share their knowledge during R&D collaborations (Czarnitzki et al., 2015), with the risk of involuntary spillover effects being larger the weaker the IPRs can be enforced (Hagedoorn and Zobel, 2015; Samaniego, 2013). This is true both for cooperative as well as coopetitive settings. In their empirical study, Cassiman and Veugelers (2002) find that cooperations between firms and their suppliers or customers are particularly vulnerable for knowledge spillovers since protection measures in this setting are less effective. Also, in technology-based coopetitions these opportunistic threats can result in coopetitive tensions meaning that the coopetition is jeopardised by mutual assumptions of malicious intentions (Holgersson, 2018; Fernandez et al., 2014). This in turn yields more complex contracts in alliances (Colombo and Piva, 2019) and puts needed novel technologies in the fields of recycling, refurbishment and comparable at risk (Eppinger et al., 2021).

Lack of IP articulation and IP negotiation skills: In their recent European Commission report, Tietze et al. (2021)

interviewed 40 companies involved in open innovation (OI) across seven value chains including CE and report that SMEs find it challenging to specify and articulate their background IP correctly. This induces severe risks in the context of forming collaborations, namely that the background IP could be "claimed by the OI partner as Foreground-IP during an OI project, if not clearly identified and captured before the project start" (Tietze et al., 2021, p. 12). For EOL solution providers it is therefore critical to know their rights when negotiating with OEMs. However, literature provides evidence for a lack of negotiation skills across different settings, such as in technology commercialisation (Kamiyama et al., 2006), university technology transfer (Khadhraoui et al., 2017) or international technology transfer negotiations (Prasad et al., 2012; Rechman, 2009) that are particularly distinct for SMEs in OI projects (Tietze et al., 2021).

Organisational asymmetries and sector-specific IP contract differences: Differences in the strategic orientation, culture and mindset, contract formalities, pace of progress or risk tolerance lead to organisational asymmetries between OI partners that are challenging to overcome (Tietze et al., 2021). These asymmetries are enhanced through divestitures and mergers and acquisitions (M&A) processes, thus raising the question of how to deal with the IP concerned (Holgersson, 2018). On top of that, sector-specific differences regarding patent licensing or language and culture yield further costs of communication and administration (Eppinger et al., 2021).

Lack of effective IP management and strategic thinking about IP: The successful sharing of IP requires a proper IP management, especially in coopetitive settings (Holgersson, 2018; Korhonen et al., 2018; Ritala and Hurmelinna-Laukkanen, 2013). However, according to Hartwell and Marco (2016) managing uncertainties that relate to IP represent a severe challenge in industry-wide implementations of remanufacturing activities. This is underlined by Eppinger et al. (2021, p. 122) who argue that "successfully implementing the CE also requires access to existing IPR assets through technology transfer. Hence, collaboration and cooperation amongst upstream and downstream actors of the same supply chain appear to be critical for a successful CE implementation, wherefore, uncertainties in managing IPR may inhibit CE implementation". A lack of in-house expertise makes it additionally difficult for SMEs to manage their IP in a strategic way, with the problem being larger if collaborations between unequal partners take place (Tietze et al., 2021). Besides, if the top management is not aware of the CE it might not prioritise initiatives in this direction and thus commit fewer resources to R&D for corresponding innovations (Dey et al., 2020; Tura et al., 2019). This challenge is acerbated when environmental consequences of linear economic models are not considered (Ormazabal et al., 2018; Tura et al., 2019).

Uncertainty about IP ownership and lack of available resources: Another challenge related to IP is the uncertainty about IPR ownership (Rimmer, 2011; Dreyfuss, 2000). In the case of recycled components that incur IP from different actors, it is unclear who owns what parts of the component after it has been recycled (Eppinger et al., 2021). The same applies to soft IP in form of data related to certain equipment that is shared and used by multiple users (Eppinger et al., 2021). Besides, new entrants face the challenge of having little IPR assets, capabilities and resources to share their IPRs (Eppinger et al., 2021). Tura et al. (2019) highlight that companies face a lack of information and knowledge, as well as technologies and technical skills. This argumentation is strengthened by Ormazabal et al. (2018) who provide empirical evidence, based on a survey of 95 companies that SMEs, at least in some countries, are missing qualified personnel in environmental management.

Strict IP control mechanisms: To maintain their competitiveness, firms want to protect their IP (Holgersson and Granstrand, 2017; Fu and Zhang, 2011). Hence, instead of sharing the valuable know-how with others incumbent manufacturers may deny access to proprietary IP, thereby slowing down or even preventing the widespread application of circular activities (Eppinger et al., 2021; Hartwell and Marco, 2016). Svensson-Hoglund et al. (2021) point out that in the absence of legal rules OEMs control, through their product designs, in how far third parties are able to participate in circular activities. This is particularly harmful because collaborative product designs are considered important parts of firms' strategies that wish to successfully adopt the CE (Dey et al., 2020). Furthermore, IP holders try to prevent opportunism by establishing license clauses (Holgersson, 2018), patent fences as well as cross licensing agreements (Hackl, 2017; Eppinger et al., 2021), strict terms for end users with end-user-license agreements or conditioned sales contracts (Svensson-Hoglund et al., 2021), eventually forbidding "some types of repairs, disassembly, and use of non-OEM parts" (Svensson-Hoglund et al., 2021, p. 3).

Insufficient public law regimes: Despite an increasing awareness for the CE among politicians, the regulatory framework including the law in force is lagging behind (Ballardini et al., 2021; Eppinger et al., 2021; Lieder and Rashid, 2016). As key reason for this the Western-style IP system is mentioned which prioritises economic incentives over environmental consequences (Ballardini et al., 2021; Ormazabal et al., 2018; Dey et al., 2020; Tura et al., 2019). For example, one of the key laws promoting CE in the EU is the Waste Framework Directive. It requires EU member states "to take measures […] to promote repair and reuse activities" (Ballardini et al., 2021, p. 2). However, its article 9 limits these very activities by clarifying that such acts "should be encouraged 'without prejudice to IP rights'" (Ballardini et al., 2021, p. 3). Another example is the Ecodesign Directive that specifies requirements for energy and material efficiency, off and standby modes, etc., but neither provides guidance on the IPR perspective (Eppinger et al., 2021) nor promotes repairability, refurbishability or reusability of products (Ballardini et al., 2021). On top of that, most regulations are taking place at state or national instead of federal level (Svensson-Hoglund et al., 2021).

Uncertainty about IP law interpretation: Given insufficient public law regimes it is crucial to understand the private law, with a particular focus on IPRs. Here, EOL solution providers face an uncertainty concerning the extent to which they are allowed to perform circular activities without infringing a patented invention (Ang et al., 2021; Ballardini et al., 2021). This fear is justified as IP laws are actually "meant to preventively hinder reconstruction of protected work" (Svensson-Hoglund et al., 2021, p. 3). In fact, refurbishment or remanufacturing could be interpreted as some form of "imitation" in the broader sense. When it comes to a legal suspension in court, the question is usually whether the act can be considered a repair (or maintenance) of the product within its normal lifespan rather than making the patented product (Hartwell and Marco, 2016; Ballardini et al., 2021; Svensson-Hoglund et al., 2021). As soon as the activity is deemed to be a reconstruction or modification it already infringes the patent (Svensson-Hoglund et al., 2021). Indeed, further cases of possible IP infringements are present. To pick three examples: Unauthorised copying of programming codes for repair activities constitutes copyright infringement, the unauthorised spread of information on how to perform repairments is prohibited and the unauthorised import of trademark refurbished spare parts is not allowed (Svensson-Hoglund et al., 2021). Next to the written law, its ambiguous interpretation constitutes a challenge. Often, courts decide in favour of IPR holders and thus discourage EOL solution providers to ultimately take the risk (Hartwell and Marco, 2016; Velden, 2020; Ballardini et al., 2021). The uncertainty is intensified by the circumstance that there are no uniform legal definitions on various terms related to the CE (Hartwell and Marco, 2016). Finally, valid laws such as in the UK build on precedents and as such commonly overrule conclusions of earlier court decisions (Hartwell and Marco, 2016).

2.3 Preliminary framework to study IP challenges in a CEIE

The preliminary framework (Fig. 1) lists the identified IP challenges and sets them into perspective of a CEIE. In its core the framework is based on the illustration of an IE provided by Granstrand and Holgersson (2020). Therefore, it is structured around the same key factors. The frame, however, differs in the sense that it displays a CEIE. Instead of referring to the author's complete breakdown of artifacts, here, they are limited to knowledge/technology in form of IP. The actor's decision whether and how to share this IP with third parties is influenced by different IP factors. These include three out of four key factors mentioned by Granstrand and Holgersson (2020), namely actors, artifacts and institutions, while the last factor (i.e., activities) represents the actual decision. With respect to IP activities, for each IP asset actors decide between in- and outbound sharing or not sharing at all (Chesbrough et al., 2014; Sternkopf et al., 2016). Besides, actors in a CEIE

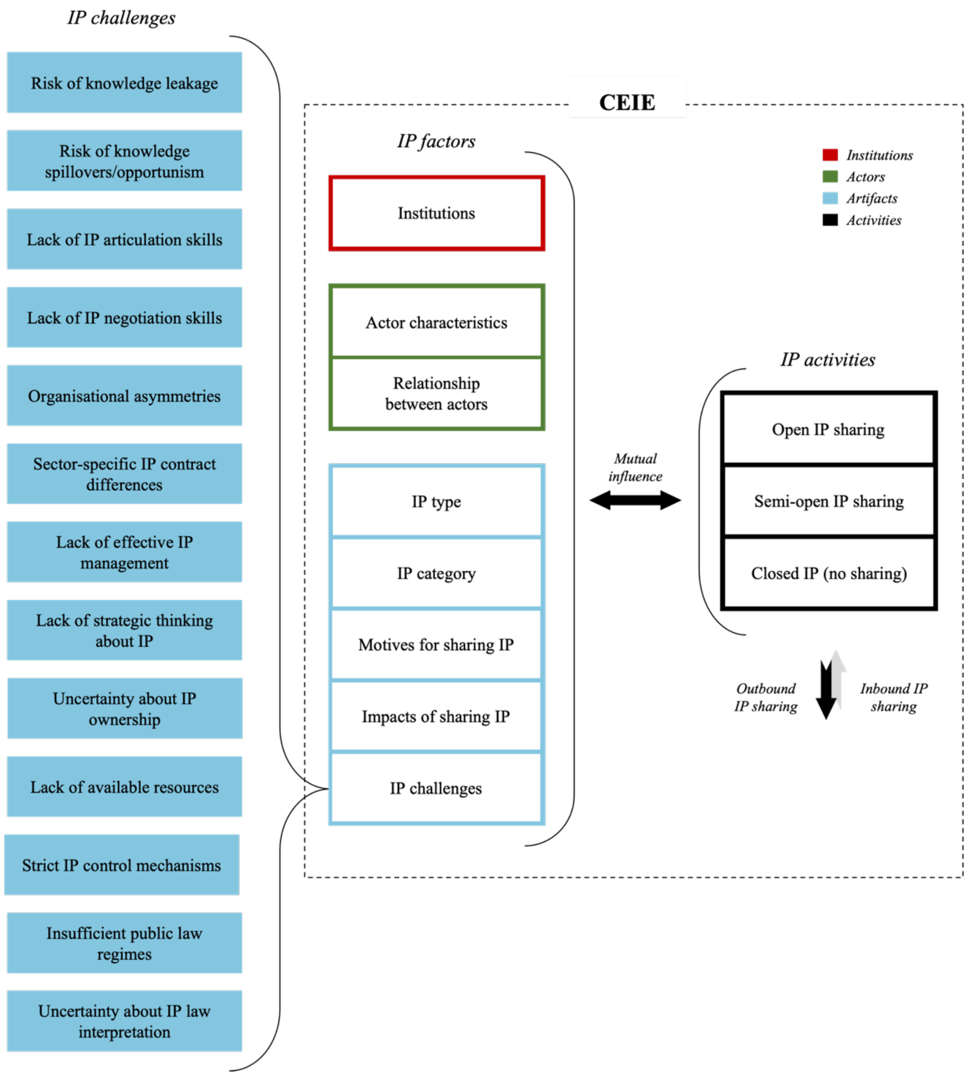

Fig. 1. Preliminary framework to study IP challenges in a CEIE (Source: Own compilation)

have three different IP strategies to choose from along the degree of openness, namely open, semi-open or closed (Vimalnath et al., 2020). Concerning IP factors, institutions determine the playing field for actors in their decision-making (Granstrand and Holgersson, 2020). As part of this, law regimes such as the IP law have significant impact on the actor's incentives (Ballardini et al., 2021). The preliminary framework focuses on actors at the micro level since Eppinger et al. (2021, p. 119) identify "established firms (incumbents) and new entrants (start-ups, or firms that enter a new field)" to play a key role in sustainable technology focused innovation systems. Applying this distinction, actors in a CEIE are characterised as either large corporates, SMEs or start-ups. Besides, the relationship between actors is crucial. Next to the complementary and substitute relations referred to by Granstrand and Holgersson (2020) IP management depends on whether actors are competing, collaborating or coopeting on technology (Holgersson, 2018). With this, technology introduces the last IP related factor, namely artifacts. The question whether to share IP depends on the IP concerned. Next to the IP type including both formal and informal IP (Hall et al., 2013) the distinction between IP categories such as background and foreground IP is considered (Holgersson, 2018). Eventually, motives and impacts of sharing IP such as commercial, societal or environmental are applied (Hernández-Chea et al., 2020).

Finally, a total of 13 IP challenges with possible links to the CE were identified from the literature.

3. Methodology

3.1 Research design and sample selection

To answer the research question, we adopted an exploratory qualitative research design. Specifically, multiple semi-structured interviews with actors in CEIEs were conducted to explore circular economy related intellectual property (CEIP) challenges with empirical evidence. For the sample selection, different selection criteria were defined. These include (i) that the respective company is active in a manufacturing industry, (ii) its business activities enhance the CE, (iii) it owns relevant IP for the CE and (iv) has a track record of collaborations with EOL solution providers (optional). Furthermore, (v) it is located within the EU to ensure at least to some extent comparable political settings. A part of the total sample was selected based on participation in different competitions such as from the European Inventor Award, the World Economic Forum or the European Remanufacturing Network (over the past five years). For the remaining sample, desk research was applied and extended by news articles that revealed IP challenges and known or intended collaborations with complementors or competitors. This search procedure revealed 87 companies representing the total sample.

3.2 Data collection

Overall, 12 semi-structured interviews with 13 interviewees (see Table 1) were conducted virtually, recorded and transcribed using video techniques. Of the 13 interviewees four are active in the aerospace, five in the automotive, three in the furniture and one in the packaging industry. One half of the interviewees represent OEMs, with the other half being EOL solution providers. While the interviewed OEMs typically show a large corporate size, interviewed EOL solution providers consists of large corporates, SMEs as well as start-ups. The average interview length was 64 minutes. The interview questionnaire was developed in four steps. A first draft was created based on the literature review, combined with iterative ideating sessions. This draft was presented to a panel of research experts studying IP and IEs in the contexts of sustainability, CE and emerging technologies, holding different positions at the UK, Germany, Austria, India as well as China. The adjusted version was then tested in a pilot inter-

Table 1
Overview of the interview sample.

Interviewee	Industry	Company type	Company size *	Length
ID1	Aerospace	OEM	Large corporate	53 minutes
ID2	Aerospace	EOL solution provider	Large corporate	69 minutes
ID3	Aerospace	EOL solution provider	Large corporate	81 minutes
ID4	Aerospace	EOL solution provider	Large corporate	47 minutes
ID5	Automotive	OEM	Large corporate	49 minutes
ID6	Automotive	OEM	Large corporate	88 minutes
ID7	Automotive	OEM	Large corporate	61 minutes
ID8	Automotive	EOL solution provider	SME	44 minutes
ID9	Automotive	EOL solution provider	Start-up	126 minutes
ID10, ID11	Furniture	OEM	Large corporate	59 minutes
ID12	Furniture/Textile	OEM	Large corporate	69 minutes
ID13	Packaging	EOL solution provider	Start-up	18 minutes

Notes: * The company size is categorised as follows. Large corporate: ≥ 250 staff headcount and > €50 m. in turnover; SME: ≥ 10 staff headcount and > €2 m. in turnover (European Commission, 2020).

view. Incorporating feedback from this interview the final version evolved, functioning as guidance for the remaining interviews. It includes the following three open-ended interview questions: What IP assets of your company are relevant for the CE? What challenges does your company face with respect to these IP assets? Does your company collaborate with third parties on CE related innovations or technologies and if so, what IP related challenges occur in this context?

3.3 Data analysis and coding

This paper follows a directed approach to content analysis, with the goal to validate and extend the theoretical findings from the literature (Hsieh and Shannon, 2005). Hence the previously identified IP challenges (see Fig. 1) served as starting point to code the primary data which originated from the interview transcripts of the conducted semi-structured interviews. To identify the corresponding sub-codes, parent codes and categories the method used by Jain and Ogden (1999) was adopted. First, the interview transcripts were carefully read to understand the available information. Subsequently a first set of relevant codes was consolidated. Based on this set the coding frame was iteratively developed, meaning that every time a new code emerged the previous sub-codes were reread according to the new structure and if necessary reorganised (Rourke and Anderson, 2004). After several iterations the final set of the coding frame includes 31 sub-codes that are grouped under 12 different parent codes which in turn are cumulated into three categories.

4. Findings

4.1 CEIP challenges framework

The 31 CEIP challenges resulting from the interview data (see Fig. 2) can be categorised according to three levels ranging from a micro to macro perspective, namely intra-organisational, inter-organisational and ecosystem. The first category contains 10 CEIP challenges that occur within organisations. By slowing down intra-organisational processes IP challenges of this category hinder the successful performance of EOL solution providers, thereby contributing to an overall slower transition towards the CE of one specific actor. The second category contains 15 CEIP challenges that occur when different actors in CEIEs interact with each other at an inter-organisational level. This is, for example, the case when large corporates, SMEs and start-ups collaborate in joint research projects for developing CE innovations. Other scenarios are development projects between OEMs and suppliers of different tiers that offer circular solutions or joint ventures between OEMs and EOL solution providers. IP challenges of this category hinder or even prevent the development of CE enhancing innovations and its diffusion into the market by complicating the process of IP sharing between actors. The third category reflects 6 CEIP challenges that affect the whole CEIE, i.e., at an ecosystem level. Consequently, IP challenges of this category make an industry-wide successful transition from a linear towards the CE more difficult. Figure 2 shows the CEIP challenges framework which not only lists the challenges per category but also highlights if they have a mutual influence (meaning they affect each other either positively or negatively) which is indicated by two-sided arrows.

4.1.1 Intra-organisational CEIP challenges

Immature IP cultures: Immature IP cultures hinder the successful performance of EOL solution providers. This stems from different reasons. First and foremost, if IP is not part of the corporate culture, then a corporate-wide awareness for IP is missing, implying an increased risk of unintended IPR infringements. Implementing such awareness is difficult since it does not immediately bring in revenues but costs money. This circumstance is worsened in times of crises such as the Covid-19 pandemic as costs are to be saved throughout the organisation. Moreover, if the importance of IP is not sufficiently recognised, a lack of strategic thinking about IP can be inferred for EOL solution providers. In contrast to OEMs, EOL solution providers tend to follow a defensive instead of offensive IP approach. This means IP decisions are operationally driven instead of following a long-term strategy leading to two consequences. First, this defensive approach increases the amount of time spend on IP issues since decisions must be considered and readjusted on a single case basis. Second, thinking defensively leads to more patent fencing, eventually decreasing possibilities for new CE enhancing technology developments around these patents. Also, lacking processes to retain IP competences resemble a challenge. Whenever brain drain in the organisation occurs and no processes to keep the knowledge are in place, it quickly erodes and new employees must be onboarded again, consuming time and resources. Furthermore, if the corporate structure is complex and internal knowledge management not well organised, identifying what IP is currently available becomes another hurdle. In fact, knowledge management influences the decision-making whether innovations take place in-house or externally and hence is decisive for potential collaborations.

Lack of available resources: During the start-up phase, EOL solution providers tend to have few available resources. This can be both because of the nature of start-ups or immature IP cultures. Interviewee ID9 highlights the extent of this lack: “You can't choose the senior people for each area at the beginning. Because of limited resources we don't have […] a strongly developed legal department, legal counsel or even an IP counsel”. This makes it difficult for start-ups to define their IP and negotiate with large corporates. Making up for the missing IP knowledge is not easy either as start-ups struggle with self-educating themselves about how to deal with IP and make right strategic decisions. Among others, this is because patent management literature often takes the view of large corporates that have sufficient resources available.

Unintended IPR infringements: Unintentionally infringing other actors’ IPRs is a critical challenge for EOL solution providers, slowing down their overall performance. To some extent it results from the previously described CEIP challenges and to some independent of those. One of the reasons can be traced back to an ambiguous interplay between different law regimes and a resulting uncertainty about IP law interpretation. In the aerospace industry, for example a congruent line between aviation and patent law is missing.

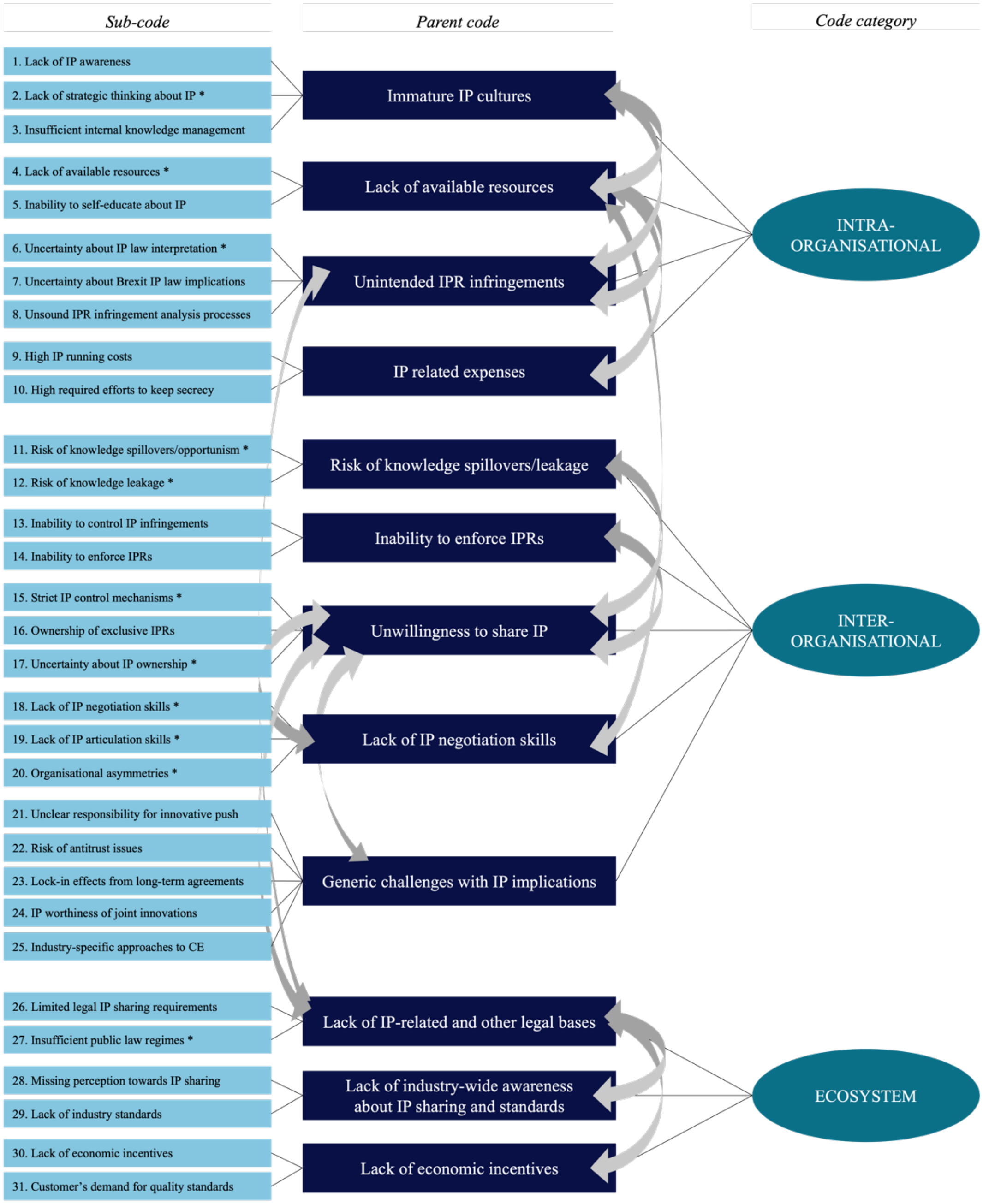

Fig. 2. CEIP challenges framework.

Notes: * IP challenges that were also identified in the reviewed literature.

Interviewee ID2 describes it in the following wording: "That is precisely the trap where you have to be careful […] because you think that under aviation law it is permitted […]. Because there is still patent law that draws this line differently and then you may […] be, while […] still in the process of repair under aviation law, already in the process of manufacturing under patent law and would thus be infringing the patent". Moreover, Brexit has created additional uncertainties about IP law, especially regarding the territorial IP exhaustion principle. IP exhaustion under patent or trademark law means that a patent- or trademark-protected object has been put on the market with the consent of the rights holder, thereby exhausting the IPR. Generally, this principle varies from region to region, with EU-wide IP exhaustion applying in the EU. In other words, if the manufacturer puts a component on the market in the EU, then it may not exercise this right again. In this case the part can circulate within the EU and be resold by others without the manufacturer being able to prevent it. But if the part is now to be sold outside the EU in another country, then it could be that this principle no longer applies. Consequently, it is crucial to have sound IPR infringement analysis processes, which, however, is often not the case. If single items are examined at individual components level instead of following a uniform process, it negatively affects how efficient the actor is working.

IP related expenses: Finally, EOL solution providers struggle with IP related expenses. Drafting and maintaining patents is associated with high costs, especially if a global protection is sought after and external legal advice bought in. This is particularly difficult during the start-up phase, due to the previously mentioned reasons. Hence, as an alternative to patents, secrecy could be an option. However, this is also associated with high efforts to keep the secrecy. As interviewee ID8 highlights: "When we wanted to start a project, we couldn't protect ourselves legally. Because we didn't have the patents yet or they hadn't been granted, we had to keep a very low profile and couldn't build up collaborations properly". Eventually, this keeps start-ups from scaling up.

4.1.2 Inter-organisational CEIP challenges

Risk of knowledge spillovers/leakage: The risk of knowledge spillovers and leakage prevents collaborations. For example, in the aerospace industry OEMs provide maintenance, repair and overhaul (MRO) companies through license agreements with data on how to disassemble an airplane or parts of it and perform repair activities, then reassemble it again. Given that OEMs and MRO companies are partly competing in the aftermarket some IP is sensitive and thus constitutes a source of coopetitive tension, leading to reduced IP access for EOL solution providers. Interviewee ID6 provides another example in the automotive industry: "We are in a dispute with our own waste disposal company for the very first time, because it is the first time that a disposer of ours also becomes a competitor. Our [battery] cells are development cells and […] that's where we run into challenges because our disposal company would look at our development cells which we don't want […]". The OEM receives strictly secret materials from cell manufacturers and is bound to legal agreements that the IP does not leak to competing cell manufacturers. Consequently, the OEM provides series cells to the disposal company to avoid that sensible information is extracted. Using the series instead of development battery cells, however, the EOL solution provider is not able to research as efficiently on new battery recycling technologies as otherwise. Similarly, EOL solution providers weigh the risk of knowledge spillovers with the extent to which they want to scale their business, e.g., by incorporating a license model for recycling processes. In this case, next to the pure patent implementation knowledge, plant operation, maintenance or transport know-how would be provided, too, which further increases the associated risks.

Inability to enforce IPRs: The absence of effective IP control mechanisms is challenging for IPR owners. In the software sector for example it is difficult to know which algorithms competitors or collaborators are using and thus whether IPRs are violated. Ultimately, this intransparency leads to lower incentives for EOL solution providers to collaborate with other actors. Moreover, if innovative start-ups achieve CE related certifications but face uncontrollable brand infringements, it can lead to reputation damages. This can be seen in the following situation: Individuals or companies with similar names claim to sell the original product or remanufactured one including its certifications. If the product is offered from an unknown third party on, e.g., an online platform and customers are purchasing the product from this platform instead of the original website, they are tricked. When the product is not delivered or shows bad quality customers tend to blame the original manufacturer. Finally, the extent to which IP control mechanisms are effective depends on the customer segment that is served. As an example, if in the aerospace industry commercial aircrafts are converted into military aircrafts with governmental customers OEMs are more concerned about enforcing their IPRs.

Unwillingness to share IP: While a lack of IP control mechanisms is challenging, too strict ones also significantly slow down industry-wide progress towards the CE. This has different reasons. To start with, to a certain extent EOL solution providers are dependent on the information provided by OEMs. If the required soft IP is not shared it prevents the successful implementation of closed loops. This is particularly harmful if OEMs leverage their market power. On the one side, because of their business model OEMs accumulate IP from third parties. If this IP is considered their own proprietary information OEMs charge royalty payments in exchange for IP access rights, making it difficult for EOL solution providers to become independent. On the other side, OEMs legally own IPRs and try to expand these. One example from the aerospace industry concerns data ownership from digital twins. During operation, planes are constantly generating data what brings up the question whom this data belongs to: the OEM or the aircraft customer who purchased the aircraft? In this regard, OEMs try to incentivise customers with lower aircraft prices for giving up the data ownership rights. Another example can be found in tender markets. If, for instance, in the furniture industry an OEM develops, e.g., a sit-stand desk with gas springs instead of electrification, it develops an innovation that is relevant for the CE in the sense that it reduces the product's carbon footprint as well as the need for critical materials. However, if the customer who issues a tender for sit-stand desks is not aware of this innovation and no other actor is allowed to use the same material, then the customer will not demand it. Hence, not sharing IP with other actors prevents a diffusion of such innovations into the market. In joint collaborations with suppliers, OEMs often enforce an IP exclusivity right, keeping the innovation similarly out of the market. Assume, for example that in the automotive industry an OEM orders a recyclable floor covering from one of its suppliers and starts a joint development project. In this collaboration the OEM invests money and provides necessary tools, laboratories as well as know-how while the supplier takes care of the implementation. Typically, in this case a development contract is signed upfront according to which the OEM receives an exclusive right for, e.g., three years during which the supplier is not allowed to offer the floor covering to others. Regular development times in this industry are about seven years wherefore without these rights it takes years for competitors to catch up. When the IP is not shared but instead more restricted, this "catch-up" time expands further. Regarding collaborations between EOL solution providers and other actors such as corporates, start-ups or universities an undesired shared ownership of the foreground IP represents yet another challenge. In research projects it is usually required from participating parties to develop something new. The project is then split in multiple work packages and assigned to different parties. If not negotiated otherwise, IP ownership rights belong to all partners in equal shares. This leads to actors preferably picking research projects without co-developers yielding a loss of synergies and fewer innovations in the CEIE. Especially challenging is IP sharing for EOL solution providers that are strongly dependent on their IP for survival. Interviewee ID9 explains: "IP is vital for us as a start-up. […] If we were to give it all away, then we would simply be talked away by the big OEMs with a lot of resources. Consequently, someone else would take it over. So, I can hardly imagine a model, where we would completely share our IP and still be running as well as we are right now".

Lack of IP negotiation skills: To strengthen research collaborations between different actors, it is critical to have solid IP negotiation skills. While this is typically the case for OEMs, it is not for EOL solution providers during the start-up phase. Because of little available resources, they often go into negotiations lacking sophisticated legal advice. Another aspect in this regard comes from the questions of how to articulate IP correctly during negotiations and what IP types to bring into collaborations. Provided that start-ups know about the different types, interviewee ID9 expresses the following concern: "[…] if we know that there is background and foreground IP, is it helpful […] to include background IP every time? How should we deal with foreground IP? […] how do we use this strategically in the best way for us?". This is further enhanced if organisational asymmetries between collaborating actors are present. On top of that, if organisations are subject to change through M&A processes it impacts not only the internal development but also external relationships. For example, it can happen that at the time of contract conclusion the relationship between the supplying entity and the OEM was friendly, but then the supplier gets bought by another company whose relationship to the OEM is not friendly. In this case tensions between these actors can arise, negatively affecting their relationship within the CEIE.

Generic challenges with IP implications: In addition, there are generic challenges with IP implications. First, it is not always clear which actor is responsible for an innovative push towards the CE and who should collaborate in this regard. For the automotive industry, interviewee ID5 explains: "There is a lot of discussion about whether we have to design our vehicles for the circular economy or whether recycling companies will bring it up to a level of innovation in 10 years anyway, where everything can be separated by type, for example". The collaboration between two or more large corporates is furthermore hampered through antitrust issues. If these corporates decide to jointly develop new innovations, it may result in near-monopoly market power and hence requires large sums of provisions. In the automotive industry there are two relatively recent examples that relate to the CE, namely agreements on so-called AdBlue-Tanks for better exhaust gas purification and arrangements concerning the recycling of EOL vehicles. In addition to antitrust issues, collaborations between large corporates are distracted because of complex legal agreements, given that each party has different non-disclosure agreements and development contracts. Also, long-term binding contracts with incumbent suppliers create lock-in effects for OEMs, thereby restricting IP sharing to or from other actors in CEIEs. The typical contract length in, e.g., the aerospace industry ranges between five to ten years or even the airplane's lifespan making a supplier switch difficult. Legally binding agreements that ensure the suppliers exclusive rights for years thus constrain OEMs in pursuing development projects with third parties. OEMs further struggle with knowing every supplier along the supply chain. In the automotive industry, OEMs usually only work together with tier one suppliers but hardly know their respective suppliers. Assume that a tier one supplier supplies the OEM with a seat cover made of textile. In the supply chain there are lower tier suppliers who make the cover, weave the fabric, spin the fibre and make the granulate. If the OEM requests from the tier one supplier that it incorporates a certain share of recyclate, this task would need to be accomplished by the very first lower tier supplier who makes the granulate. Hence it raises the question on behalf of the OEMs how deeply they should be involved in the supply chain and steer innovations? Besides, the extent to which IP is shared and opened to the whole industry depends on how worthy the IP is from an economic perspective. Interviewee ID6 provides a corresponding example: "There was a dismantling device, an excavator that we developed together with someone else […] which was originally planned as a patent. […] This is now patent-free. […]. Whether it is worthwhile for a car dismantling company to buy this excavator […] is the second question. Or do they take the manual labourer who perhaps don't cost as much […]". Finally, the public debate around how much CO_2 corporates are allowed to emit and what secondary raw material quotas must be fulfilled has impacted the topic of recycling. Various products in the automotive industry such as batteries must meet stricter requirements in terms of recycling what increases the need for knowledge exchanges and joint innovations. This, however, is challenging if it requires to work together with actors across different industries that follow other approaches towards implementing the CE.

4.1.3 Ecosystem CEIP challenges

Lack of IP-related and other legal bases: The legal basis influences how CEIE actors behave. Picking up the challenge of too strict IP control mechanisms, on ecosystem level the question is in how far OEMs are legally obliged to provide information? The automotive industry in Europe has an obligation to make IP in form of disassembled information available. For this purpose, the industry created a platform called International Dismantling Information System through which EOL solution providers can identify the components that need to be disassembled. But the car manufacturer must only provide rough information for disassembly and no details for repairing. While access to this detailed level of IP is requested by recycling companies, according to interviewee ID7 OEMs "are resisting this because the data generation is very costly. Any car recycler can receive it in exchange for a license fee. But not everyone would be able to afford to pay for the licenses which a repair shop can certainly do because a repair shop earns money with the repairs. […] it's a little different for car recyclers." (ID7). In addition, insufficient public law regimes or regulations have a significant impact on how fast or slow an industry converges towards achieving the CE. In Europe for example there are differences in how single countries like Italy, Bulgaria or Germany deal with waste disposal. In Germany the tax legislation provides that if you donate something, you need to pay value-added-tax (VAT) for it. One can work around this regulation by scrapping the item concerned since for scrap there is no requirement to pay VAT.

Therefore, various companies are encouraged to scrap returns in order to save costs, indicating a clear lack in the regulations that creates disincentives to engage in circular activities. Relatively recently, Germany introduced the Obhutspflicht (duty of care) as part of its Kreislaufwirtschaftgesetz (Closed Substance Cycle Waste Management Act), written in article 23, paragraph 2, sentence 11. This duty ensures that returning products cannot be just disposed but must be taken care of so that they do not become waste. However, to apply the written law it requires an ordinance that regulates how the law is applied which is not yet confirmed. On top of that, specific to the aerospace industry, EOL solution providers are obliged to provide proof that they have successfully achieved some certifications before they are legally allowed to perform circular activities. In this regard, three certifications stand out. First, an EOL solution provider must be certified as repair station to be allowed to maintain or repair an aircraft. Second, it must be certified as manufacturing company to manufacture aircraft parts themselves. And third, it must be certified as development company to be able to develop own solutions and deviate from solutions developed by OEMs. This procedure prevents some EOL solution providers from performing CE related activities and increases their dependency on OEMs.

Lack of industry-wide awareness about IP sharing and standards: The absence of suitable regulatory frameworks also influences in how far industries are aware of the need to implement the CE. For example, OEMs struggle to share their IP if an industry-wide perception towards IP sharing is missing. Interviewee ID10 underlines this: "Your introduction into the market should be: We've got a great invention. It's about circular economy. This should be the market standard. We've done the development. We can give you instructions, we can give you the manual. We can give you the IP. You just pay us a basic fee and then the whole market can use it. […] But licensing that's not something that's done in our market. […] we're in an old market, so that takes time. […] we're not there yet". Therefore, before the industry-wide appreciation towards IP sharing penetrates, a corresponding mindset change from closed to OI is necessary. Continuing in this regard, a lack of industry standards contributes to the spread of low-quality refurbishment companies that show opportunistic behaviours.

Lack of economic incentives: The final CEIP challenge represent a lack of economic incentives to invest in CE-enhancing innovations. In the automotive industry for example it requires much effort to retain the qualitative requirements for automotive steel from vehicles that were built several years ago. Instead, mostly it is used as structural steel that shows fewer quality requirements, since otherwise it is not economically feasible. Similarly, in the aerospace industry OEMs find it difficult to prioritise circularity within their R&D processes. If from one aircraft generation to the other wings and fuselages are switched from aluminium to carbon-fibre-reinforced plastics, it is more durable and lighter on the one side but less recyclable on the other side. Next to this, the customer's demand for quality standards is another driving force behind the extent to which related innovations are pursued. Comparable to regulations, the perception of quality standards also differs from country to country. In the Chinese market for example, according to interviewee ID6 "recyclate is considered a used material. And everything that is used still has negative connotations in China. That means a 100% recyclate content is something bad". Hence this is decisive for the product designs, thereby negatively affecting the incentives to invest in circular innovations.

4.2 Visual mapping of CEIP challenges: An example of the aerospace industry

Applying the preliminary framework (see Fig. 1), the identified CEIP challenges are visualised for the aerospace industry in Figure 3. In this CEIE six actors are active. These include OEMs that manufacture airplanes which are bought and used by its customers (who are in most cases either airlines or governments), cross-industry suppliers of the OEMs (of different tiers), external part manufacturers, external MRO companies as well as regulatory authorities under which the airplanes are registered. Of these, regulatory authorities provide a set of rules that govern how actors within this CEIE behave. Among others, the authorities decide which parts can be installed on the airplane including OEM parts, Parts Manufacturer Approval (PMA) parts or used serviceable parts that are extracted from airplanes at their EOL. External MRO companies provide labour for MRO work and manufacture PMA as well as used serviceable parts and hence are considered EOL solution providers. The manufacturing of OEM, PMA and used serviceable parts is additionally done by OEM's suppliers and external part manufacturer which, therefore, in some cases are also EOL solution providers. Even though the aftermarket is not the OEM's core business, to a minor extent OEMs are active in the market for used serviceable parts and modifications, besides being major players in the sales and distribution of OEM designed parts. Put together, the different actors have multiple relationships with each other (such as being a supplying and competing entity at the same time) what constitutes a source of CEIP challenges.

From the IP perspective, airplane parts can be differentiated between OEM designed parts (meaning they are designed all the way to the end by the OEM) and vendor designed parts. While the former one constitutes OEM's IP, the latter one refers to supplier's IP but is built to the OEM's requirements and builds on OEM's soft background IP. Of these two, vendor designed parts reflect a significant (possibly major) share of the overall IP used on airplanes. IP that is owned by OEMs mostly refers to parts that relate to the aircraft's structure and are fully designed by the respective OEM like the design of fuselages or swept wings. This formal IP in form of (un)registered designs as well as informal IP in form of data resulting from R&D processes is provided under strict purpose-binding legal agreements to both suppliers who are manufacturing the corresponding parts for the OEM as well as external MRO companies who perform circular activities. Hence at these interfaces various IP challenges emerge like the risks of knowledge spillovers and leakage or unintended IPR infringements. This in turn negatively affects the extent of IP sharing between the actors, e.g., through restricted IP access rights. Designs that are owned by suppliers, on the other side mostly refer to different systems and parts of the aircraft. While OEMs usually provide requirements to suppliers on how efficient the system must be, the actual design is created and owned by the suppliers.

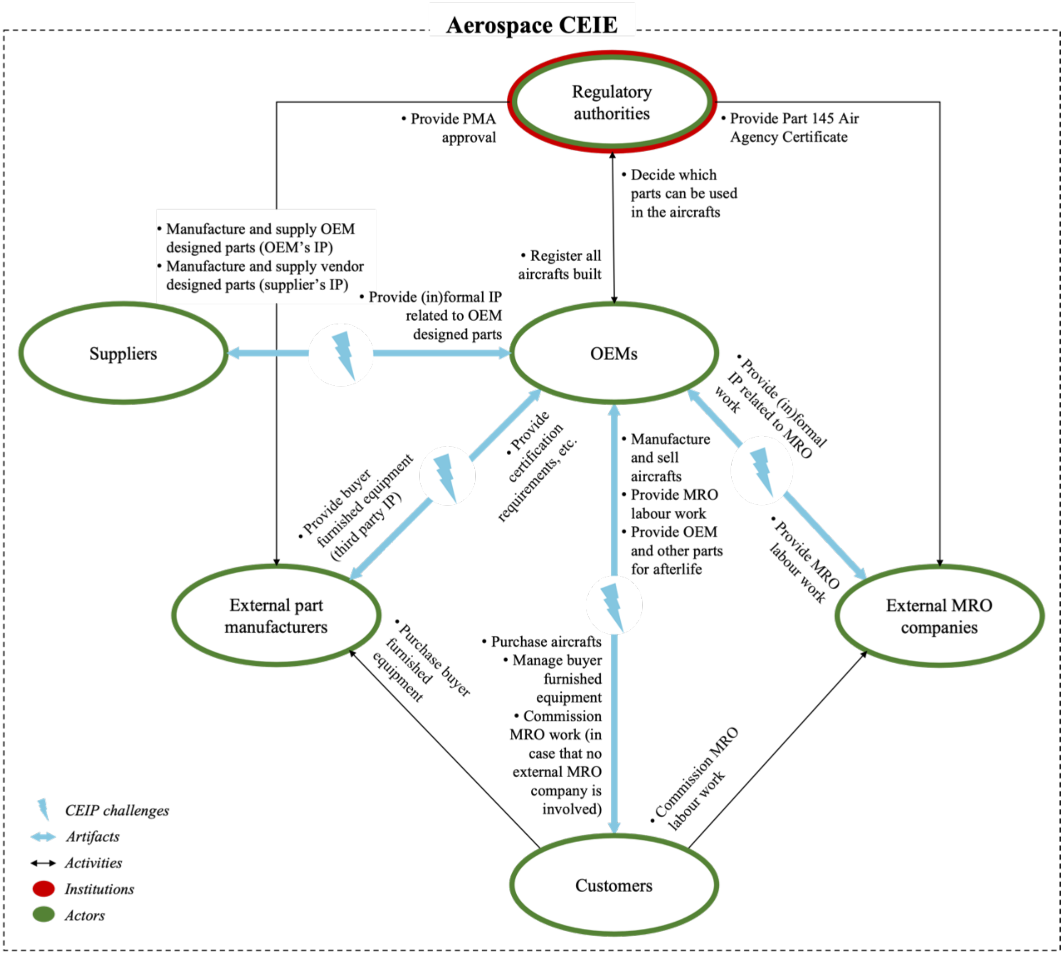

Fig. 3. Visual mapping of CEIP challenges in the aerospace industry.

Consequently, if IP in form of manuals not only for the aircraft's structure but also its systems and parts is required, it must be requested from various third party suppliers. This makes it challenging for EOL solution providers to gain access to all IP to successfully accomplish circular activities.

5. Conclusion

5.1 Summary of the key research findings

This paper explores circular economy related IP (CEIP) challenges that actors in circular economy innovation ecosystems (CEIEs) face. Therefore, exploratory research was conducted in form of a literature review combined with empirical evidence from semi-structured interviews. The key contributions of this paper to the literature are: (i) a preliminary framework to study IP challenges in CEIEs, (ii) the CEIP challenges framework and (iii) a visual mapping of CEIP challenges. Referring to the interview data it can be inferred that 11 out of 13 identified IP challenges from the literature review do not only apply in a generic but also in the CE context. Beyond that, 20 challenges are explored that were not mentioned in the reviewed literature. In total these 31 challenges are aggregated into 12 key CEIP challenges of which four are assigned to the intra-organisational, five to the inter-organisational and three to the ecosystem category. The CEIP challenges shape actors' interactions within CEIEs and thus influence to what extent industries are transforming from linear to circular economic systems with closed loops.

5.2 Limitations of the results

The provided empirical evidence is limited to a small set of semi-structured interviews. This bears four consequences. First, the gathered data is not representative. Second, the number of actors that were interviewed mainly stem from three different industries, implying that generic conclusions can hardly be drawn. Third, only in some cases multiple employees from the same actor were interviewed. Consequently, the responses might not provide the full context or IP challenges might not be regarded holistically. And finally, large corporates represent the majority of the interview sample. Hence biases in the data analysis may occur, according to which the views of SMEs and start-ups are not sufficiently accounted for.

5.3 Future research avenues

For future research, we encourage the use of the developed frameworks as basis to better understand what IP challenges actors in CEIEs face. To further evolve the CEIP challenges framework, we suggest continuing collecting empirical evidence. If actors of a wider range of industries are considered, cross-industry or industry-specific IP challenges can be specified and prioritised. As an incremental next step, targeted solutions should be specified to overcome the identified challenges. This is important because addressing CEIP challenges means that CE related innovations are enhanced and their diffusion into the market is achieved at faster pace, thereby constituting the foundation for enabling the CE.

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