Circular and Data Driven Collaborative Design Framework (CADCOD)

Project within: Cirkularitet - FFI - Hösten 2023

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Date: 2024-09-30

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Content

1. Summary

The CADCOD project (Circular and Data Driven Collaborative Design Framework) is the first follow up initiative from the DIPP prestudy (Produktutveckla med hänsyn till Digital Product Passport (Isaksson et al., 2023). The project delivers a framework for the collaborative development approach needed to realize circular and sustainable solutions that build on the increased availability of data expected from Green Deal emerging initiatives.

The Green Deal emerging initiatives, such as the Digital Product Passport and End-of-Life Vehicle regulations, are driving the industry to set ambitious goals and prioritize actions. This pressures the manufacturing industry to design and develop more sustainable and circular solutions. The Digital Product Passport creates an important mechanism for collaborating with stakeholders in the value chain and leveraging sustainability data in the early stages of design. However, there is a need for investigation and definition of roles, responsibilities, incentives, and work practices to engage with stakeholders in the value chain early in the design process.

The CADCOD project's framework includes a set of proposed guidelines and principles, a design methodology with methods and tools, to support value chain collaboration in the development of sustainable and circular solutions. The developed framework was based on requirements extracted from the previous research projects- DIPP (Isaksson et al., 2023), a literature review of 85 articles in the field, and insights extracted from 16 interviews with value chain actors.

The final framework consists of three main themes: Collaboration; Data & information; Sustainable circular ecosystem. Each theme has some categories including principles, guidelines, methods, and tools to choose from. It addresses the need to prepare the automotive industry for co-developed circular solutions that meet the requirements for providing transparency and traceability of sustainability-related product information throughout the product lifecycle and value chain. The CADCOD framework seeks to give guidance in identifying different roles, responsibilities, incentives and working methods in the value chain for different alternative circular scenarios. Furthermore, it is designed to provide support in defining sustainability requirements in the value chain, meet new standards based on Circular Economy, such as (ISO 59010:2024, IDT) and upcoming regulations (such as End of Life Vehicles Regulations), assessing and developing data capabilities. Furthermore, it is expected to reduce the risks for automotive companies and their collaborative partners when defining and implementing collaborations for circular products using Digital Product Passport.

The CADCOD framework was developed in collaboration with Volvo, as an automotive OEM. Although the focus is on the automotive manufacturing industry within the specific

interest in how it may impact product development, it is likely that the findings are relevant also for other industry sectors.

The next phase of this work is a further development and testing of the framework in real cases with an OEM, such as Volvo Group, and their value chain partners. The idea is to develop and demonstrate capabilities, build data for impact measures and to analyse, visualize and compare a traditional- "linear" design solution versus a "circular" design solution.

2. Sammanfattning på svenska

CADCOD-projektet (Circular and Data Driven Collaborative Design Framework) är det första uppföljningsprojektet från den handlingsplan som resulterade från DIPP-förstudien (Produktutveckling med hänsyn till Digital Product Passport (Isaksson et al., 2023). Projektet levererar ett ramverk för samverkan i värdekedjan för utveckling av cirkulära och hållbara lösningar. Ramverket avser nyttja den förväntade ökade tillgången av data som blir resultatet av initiativ inom EU's Green Deal med nya direktiv samt lagstiftning gällande uttjänta fordon. Detta ger påtryckningar på tillverkningsindustrin att designa och utveckla mer hållbara och cirkulära lösningar. Det digitala produktpasset skapar en viktig mekanism för att samarbeta med intressenter i värdekedjan och att kunna nyttja hållbarhetsdata i de tidiga stadierna av designprocessen. Dock finns det ett behov av att undersöka och definiera roller, ansvar, incitament och arbetsmetoder för att engagera intressenter i värdekedjan tidigt i designprocessen.

Projektet har bedrivits som en systematisk forskningsstudie, där en första klargörande studie (intervjuer, workshop och litteraturarbete) tydliggjorde behovet av vilket stöd som krävs vid samverkansutveckling i värdekedjor. Ett ramverk utformades och validerades både mot liknande publicerade ansatser samt i feedbacksessioner med specialister. Huvudsakliga resultat avses publiceras i granskande forum efter avslutat projekt i samråd med industripartners.

CADCOD-projektets förslag på ramverk inkluderar en uppsättning riktlinjer och principer, en designmetodik med förslag på metoder och verktyg för att stödja samarbete i värdekedjan vid utvecklingen av hållbara och cirkulära lösningar. Det utvecklade ramverket baserades på krav hämtade från tidigare forskningsprojekt – DIPP (Isaksson et al., 2023), en litteraturöversikt av 85 artiklar inom området, samt insikter hämtade från 16 intervjuer med aktörer i värdekedjan.

Det slutliga ramverket består av tre huvudteman (i) Samarbete (ii) Data & information, samt (iii) Hållbart cirkulärt ekosystem. Varje tema bygger på kategorier med principer, riktlinjer, metoder och verktyg att välja mellan. Ramverket betonar behovet av att förbereda fordonsindustrin för samutvecklade cirkulära lösningar som uppfyller kraven på att tillhandahålla transparens och spårbarhet av hållbarhetsrelaterad produktinformation

genom produktens livscykel och värdekedja. CADCOD-ramverket avser ge vägledning i att identifiera olika roller, ansvar, incitament och arbetsmetoder i värdekedjan för olika alternativa cirkulära scenarier. Vidare är det utformat för att ge stöd vid definitionen av hållbarhetskrav i värdekedjan, uppfylla nya standarder baserade på cirkulär ekonomi, såsom (ISO 59010:2024, IDT) och kommande regleringar (som regler för uttjänta fordon), samt att bedöma och utveckla datakapacitet. Avsikten är att minska riskerna för fordonstillverkare och deras samarbetspartners vid utveckling av nya cirkulära lösningar som bygger på samarbeten samt ökad tillgänglighet och spårbarhet av data. Avsikten är vidare att såväl strategiska aktiviteter, till exempel handlingsplaner, som mer operativa aktiviteter ska kunna stödjas.

CADCOD-ramverket utvecklades i samarbete med Volvo Group som representant för en OEM i fordonsindustrin. Även om fokus ligger på fordonsindustrin, med ett specifikt intresse för hur det kan påverka produktutveckling, är det troligt att resultaten även är relevanta för andra industrisektorer.

Nästa fas i detta arbete är en vidareutveckling och testning av ramverket i verkliga fall med en OEM, såsom Volvo Group, och deras värdekedjepartners. Idén är att utveckla och demonstrera förmågor, samla data för att mäta påverkan samt att analysera, visualisera och jämföra en traditionell "linjär" designlösning med en "cirkulär" designlösning. I linje med föregående DIPP studie öppnas för i) utveckling och validering av kunskap och specifika metoder och verktyg som behövs nyttjas i samverkansutveckling, ii) demonstration och validering av hur ramverket anpassas och bidrar till att demonstrera nya, cirkulära koncept samt iii) hur nyckelkoncept, definitioner och modeller kan standardiseras i fordonsbranschen och de leverantörspartners som behöver kunna förhålla sig och använda underliggande begrepp, koncept och informationsmodeller.

3. Background

Manufacturing companies need to be prepared to co-design data driven circular products. Volvo Group is already strategically committed to develop and design circular solutions, and solutions complying with science-based targets, where it will be necessary to engage suppliers already in the early design phases. The increased regulatory instruments for transparency and traceability following Digital Product Passport (DPP) (European Commission, 2023) create an important mechanism to co-innovate with suppliers to benefit from such data. The data driven approach directly responds to the increasing requirements of providing transparency and traceability of sustainability-related product information throughout the product life cycle and throughout the value chain. Both market expectations and upcoming regulations, through the End-of-life vehicles Regulation (European Commission, 2024) and the EU New Circular Economy Plan (European Commission, 2020) and specifically the proposed Digital Product Passport (DPP), require new skills and practices and changes the roles of partners in the value chain. The roles, responsibilities, incentives and work practices to engage tight with suppliers early need to be investigated and defined. Results from the DIPP prestudy (Isaksson et al., 2023) pointed out the

necessity for a co-design framework to facilitate an increased interaction and collaboration in the value chain.

At present, vehicle circular passports are proposed for cars, and regulations are expected also in commercial vehicles such as trucks. The End-of-life (ELV) vehicles Regulation is being updated (European Commission, 2024).

In total seven areas were identified in the DIPP prestudy were:

(i) Transparency and ownership of data, where introduction of DPP and Science Based targets successively changes conditions for industry

(ii) Value for Stakeholders in Eco System, where a "win-win" business conditions will change

(iii) Secure storage and transport of data, where several projects and solutions are underway

(iv) Communication and representation, where circular solutions need to be possible to visualize, represent and communicate for shared understanding

(v) Systemic Sustainability Assessment, as data availability and coverage are limited in current practice

(vi) Data Quality, where it's unclear what level of detail is needed, and required for DPP applications

(vii) Standards, where the absence of standards is a hinder to scaling up solutions in multi partner and multi software situations.

An overarching problem is the disruptive nature of established ('linear') practices and the limited experience, available tools, methods and practices for co-design of higher-order circular solutions. Therefore, in CADCOD the focus was to address foremost on (ii), (iv) and (v), according to above.

There is a wide consensus that moving towards a CE, in which resources are continuously utilized and recirculated, requires extended value chain collaboration from upstream suppliers to downstream distributors, consumers, and recycling facilities (Blomsma, et al., 2019a; Brown et al., 2021; Geissdoerfer et al., 2018). A particular challenge for manufacturers is shifting the traditional mindset of maximizing individual benefits to exploring the shared value that the CE can offer for multiple actors (Brown et al., 2020). The realization of collaborative circular value chains, or circular ecosystems, which explore and maximize shared value on a system level, require new types of innovative partnerships that go beyond the conventional supplier-client relationships that most OEMs are used to. The current lack of standards and regulations to steer these types of circular partnerships emphasizes the necessity to develop clear processes and procedures to guide collaborative efforts, build trust between value chain actors, overcome challenges related to data and information sharing, and facilitate inclusive and shared value co-creation. Here, participatory approaches such as co-creation and co-design, design thinking methodologies, and stakeholder workshops can foster inclusive approaches in the development of circular value propositions, to help discover new partners, align stakeholder perspectives and interests regarding circularity, and maximize shared value creation (Blomsma et al., 2019; Geissdoerfer et al., 2016; Hoes et al., 2021). Previous research has developed some prescriptive frameworks and methods to support collaboration and co-creation for circular value chains (Blomsma, et al., 2019; Brown, et

al., 2021; Santa-Maria et al., 2022). However, few of these provide practical guidance in terms of how the frameworks can be operationalized in design and business practice, how to facilitate collaborative processes, and how to mitigate challenges related to data management and exchange throughout the value chain and collaboration.

4. Purpose, research questions and method

The purpose of CADCOD project was: i) to prepare the automotive industry for co-developed circular solutions, ii) to provide transparency and traceability of sustainability-related product information throughout the product life cycle and value chain, iii) to reduce the risks for all partners in the development work when they define and initiate the development of circular products.

The following research questions have guided the research work:
1. What are key factors for the development of collaborative circular value chains?
2. What frameworks and methods currently exist that support collaboration for circular value chains?
3. What are the current processes, needs, and challenges related to value chain collaboration within the context of automotive manufacturers?
4. What framework can support value chain collaboration in the automotive industry to enable the development of sustainable and circular solutions?

The overall research approached was inspired by the Design Research Methodology (DRM) (Blessing & Chakrabarti, 2009), and was organised according to following, see figure 1.
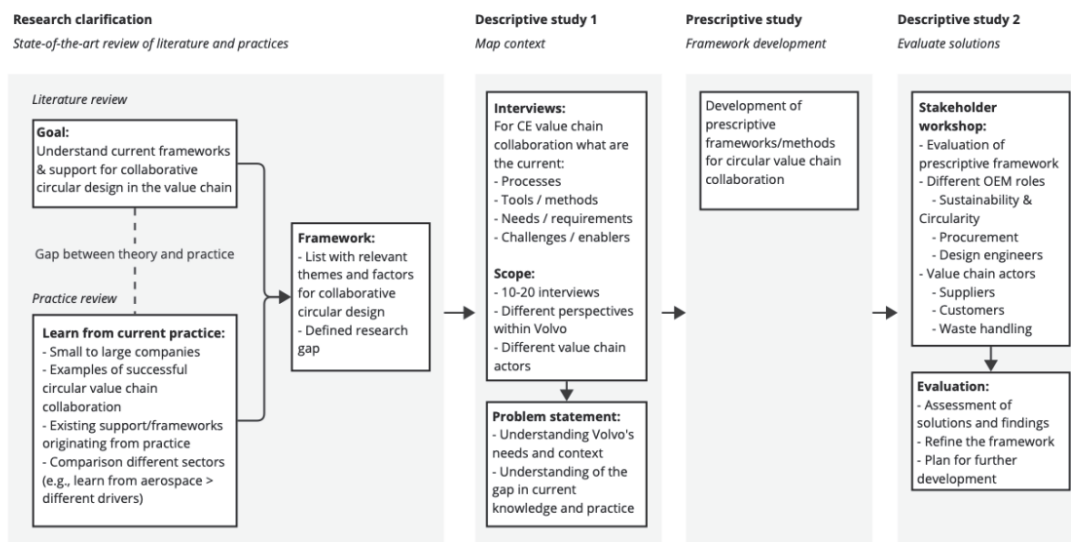
Figure 1. Research approach in the CADCOD project based on the Design Research Methodology.

The following research methods were applied to satisfy the research questions:

Scoping review
- Scoping review (Arksey & O'Malley, 2005) to summarize existing body of works and clarify research gaps and working definitions
- Focused on collaboration for circular value chains through a combination of search strings including: Circular, Sustainability, Value chain, Supply chain, Collaboration, co-design, and co-creation
- Initial screening of 131 articles led to 85 articles being reviewed, categorized by relevance, with 44 highly relevant articles analyzed and read in detail
- Identified factors for collaborative circular value chains were clustered into themes
- 36 prescriptive frameworks from practice were also reviewed through an online search.

Interviews, meetings & workshops
- 16 semi-structured interviews conducted with Volvo Group and other value chain stakeholders (e.g. suppliers, other OEMs, and one recycling company)
- Interviews covered themes like collaboration, sustainability, circularity, and data sharing
- On-site meeting and workshop at Volvo Group to understand current practices regarding sustainability and circularity as well as needs and priorities regarding development of the CADCOD framework

CADCOD framework development
- The CADCOD framework was developed by 4 researchers and feedback from project partners (Volvo Group) and is based on findings from the review and interviews
- Framework provides an overview of relevant themes, principles, guidelines, and tools for the development of collaborative circular value chains

5. Objective

The ideas, objectives and goals of the CADCOD project was to derive a framework that enable value chain partners to co-innovate with OEM's for both closed loop and solutions based on regenerative flows. The goal is to prescribe a Circular Design-framework including a methodology and guidelines, that accounts for increased transparency, traceability and availability of life cycle data. During the CADCOD project, a preliminary consortia and proposal ideas for how to address critical gaps and realization of identified potential was formed.

6. Results and deliverables

6.1 Initial requirements CADCOD framework

An initial list of requirements for the CADCOD framework was created based on insights from earlier projects and stakeholder input. This list outlines the tasks, processes, and expected outcomes related to developing methodologies and guidelines. The requirements are informed by two previous projects: Digital Product Passport (DIPP, 2022-2023) and Digital Sustainability Implementation Package (DSIP, 2021-2023).

Table 1. Overview of initial requirements formulated for the development of the CADCOD framework.

Principle	Description of requirement in relation to capabilities of the CADCOD framework
Mapping stakeholders	Identify relevant and necessary actors to enable circular and sustainable solutions
Mapping values	Identify values and incentives of circular and sustainable solutions for focal company and value chain actors
Mapping internal barriers	Identify hotspots/limitations towards realizing a circular and sustainable solution
Mapping external barriers	Identify what currently limits value chain actors from being part of a circular and sustainable solution with focal company
Mapping needs	Identify needs for changing internal capabilities and processes
	Identify needs of value chain stakeholders
	Identify needs regarding technological developments and changes
	Identify needs regarding data and information management to enable circular and sustainable solutions
	Support analysis of current situation and gaps to steer development needs
Anticipate priorities	Support product planning and setting of priorities
Anticipate legislation	Support current and upcoming legislations regarding CE and sustainability compliance
	Support the coupling of projects and products to relevant legislations and standards
	Map which regulations, legislations, and policies will affect focal company and how
Anticipate capabilities	Support the analysis of what capabilities and organisations will be affected and how
	Support the analysis of responsibilities and roles needed and how to assign responsibilities
Knowledge development	Provide an overview of key concepts regarding sustainability and circular economy to guide development efforts
Stakeholder collaboration	Support communication and collaboration between different value chain actors
Circularity assessment	Visualise and communicate enabling factors and solutions and how they support circularity
	Support assessment of solutions in relation to defined goals
	Integrate goals based upon critical areas defined in the DIPP project and the circular strategies in the R9 framework, to identify consequences for each actor in the value chain
Business model innovation	Support the development and definition of new business models
Guidelines	Provide an overview and examples of tools and methods that are applicable for different purposes
	Integrate methods from DSIP as a base of tools and methods that support sustainable and circular solutions
Roadmap communication & visualization	Support communication of sustainable and circular goals for product development
	Establish a roadmap based upon critical areas in DIPP framework and take into account barriers
	Visualize roadmap enabling analysis of different perspectives
	Include a step-wise approach to realizing the change

6.2 Findings from literature review

An overall analysis of the 85 reviewed articles revealed a steady increase in publications from 2015, with a peak in 2021 after which publications somewhat declined (See figure 2). The left diagram in the same figure shows that most publications were case studies and prescriptive frameworks (e.g., the development of new tools or methods), while

fewer publications focused on reviews, original research, or conceptual papers (e.g. developing theoretical concepts and frameworks).
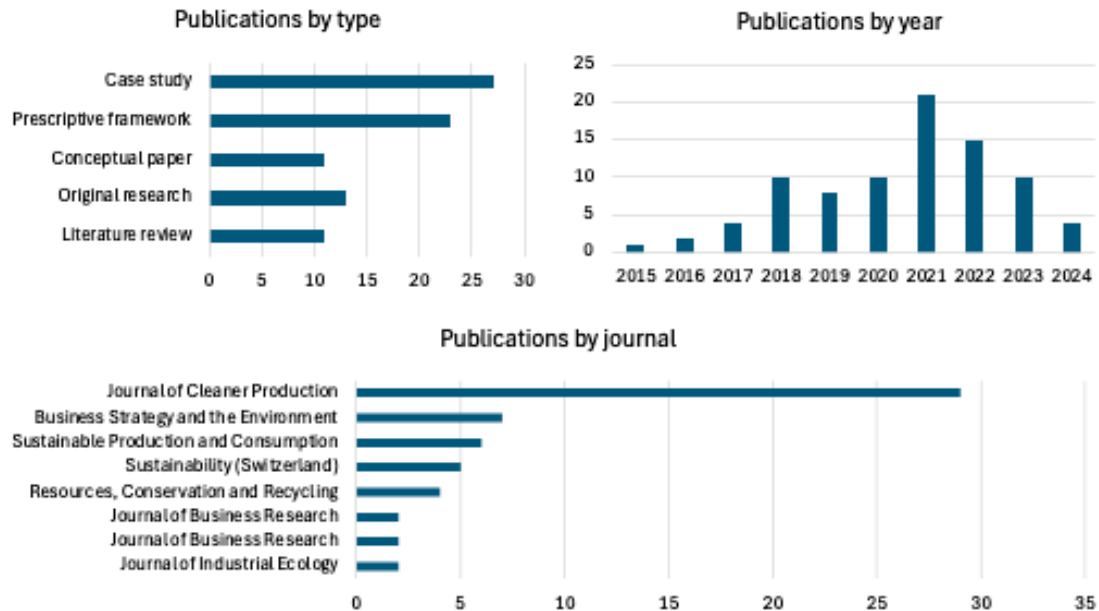
Figure 2. Distribution of publications according to type, year, and journal (occurrences below two were excluded).

From the 85 reviewed articles, key factors for the development of collaborative circular value chains were identified and clustered into themes. The themes identified related to building trust, collaborative governance, collaborative processes, ecosystem orchestration and perspectives, monitoring and evaluation, shared vision building, stakeholder mapping, sustainability leadership, and value mapping. Figure 4 shows a summarized overview of the clustered themes identified in the literature review, other key findings of the review were:

- Circular ecosystems as a novel and recurrent concept that focus on identifying and fostering shared value, management and orchestration of value chain stakeholders, and management and sharing of data flows for circularity
- Research gap identified that limited research addresses the interface of value chain collaboration, novel digital technologies, and data and information exchange and management
- Identified need to investigate the potential of novel technologies and how they improve and enable value chain collaboration for circularity
- Identified need for development of guidelines and support for industry on how to leverage and synergize these technologies to facilitate collaboration in circular ecosystems
- Literature emphasizes importance and challenges of collaborative circular value chains but there was an identified lack of:

- Knowledge about how to foster the conditions and capabilities for successful value chain collaboration within companies
- Knowledge about how to go about the involvement of external stakeholders (when, how, to what extent) in the operationally complex process of developing a circular product and service
- Knowledge about what factors, processes, and activities companies should consider in the realization of collaborative circular value chains
- Prescriptive frameworks and methods for the co-design of circular value chains that go beyond a generic process description and can be applied in a practical and operational company context
- Studies that assess the experiences and effectiveness of proposed frameworks that facilitate stakeholder collaboration in the development of circular value chains and ecosystems

The review of 36 existing frameworks that address the development of circular products, business models, and value chains led to the following insights (see figure 3 for an overview):

- Tools mostly focus on individual ecosystem elements (product, business model, or value chain).
- Few tools address the integration of value chain collaboration with digitalization and data management.
- Tools for mapping necessary data and information flows for circular value chains are limited.

Figure 3. An overview of results from reviewing 36 existing tools that address the development of circular products, business models, and value chains.

Factors for the development of collaborative circular value chains

1) Sustainability leadership
Develop holistic and intra-organizational leadership

- Sustainability champions to promote cultural and structural transformation
- Establish collaboration between environmental managers and R&D (to avoid sustainability decisions as stand alone activities)

3) Build trust
Provide certainty and mitigate risks

- Trust crucial with absence formal agreements and standards
- Ask partners for support and expertise
- Provide certainty for partners role and responsibility
- Foresighting and strategy building
- Develop skills and mindset throughout value chain
- Establish and maintain trust

2) Stakeholder & value mapping
Identifying external stakeholders and shared value

- Identify shared value, ownership, and risks
- Link stakeholder interests to shared values
- Identify positive economic interlinks between actors
- Assign competent facilitator
- Shift focus from individual profits of circularity to shared benefits
- Iterative approach towards CBM mapping and implementation
- Assess differences in concerns, BMs, and sustainability interpretations
- Map (unintended) consequences for external stakeholders and find solutions together

4) Collaborative governance
Create structures for collaboration

- Avoid fragmented collaboration (holistic focus downstream and upstream)
- Rules for collaboration and collective decisions
- Penalties and incentives promoting sustainable behaviour
- Sharing risks, responsibility, and data
- Involve policy organisations and financing mechanisms
- Involve competitors for system level innovation

5) Collaborative processes
Create processes for collaboration

- Design thinking to align stakeholders
- Stakeholder workshops to clarify perspectives and stage discussions and negotiation
- Co-design processes to identify and include stakeholders in design stage
- Visual language to inspire, motivate, and align stakeholders
- Adapt based on supply chain position, power balance, shared vision, mutual trust
- Facilitate common vision building and actor learning

6) Ecosystem orchestration
Establish and operate a circular ecosystem

- Technology providers key for initial ecosystem
- Shift orchestrator responsibilities (PO/market creator)
- Transparently measure and distribute value for stakeholders
- Continuously adapt individual and collective goals
- Adopt a system perspective towards value creation
- Foster support from the supply chain network

7) Monitoring and evaluation
Measuring progress in the circular value chain

- Indicators measuring progress towards value chain collaboration
- Define metrics to measure circularity
- Use circularity metrics for stakeholder communication

Figure 4. Summary of clustered themes identified in the literature review.

6.3 Findings from the interviews

The conducted interviews produced several insights regarding current procedures related to value chain collaboration, co-creation and collaboration, and information and data management. Listed below is a summary of key insights that were extracted from the interviews:

Automotive specific insights:
- Intensified collaboration with suppliers around sustainability and circularity, development and use of new protocols and documentation to facilitate interactions between procurement and suppliers (e.g., guidelines, checklists)
- Use of self-assessment protocols and audits to ensure suppliers meet OEM's sustainability goals and criteria
- Still a perceived lack of proactive involvement of suppliers in the design process of more sustainable solutions
- An enabler for moving towards more collaboration alongside the value chain is intensifying efforts on pilots, joint development, and sending partnership initiatives
- No formalized methods and processes established for collaborating with suppliers and other value chain actors in the development of circular and sustainable business models. Networks and collaboration need more structure and established industry standards.
- Challenges with value chain traceability (relying on second-hand information from suppliers) and gathering accurate material information and data which hinders sustainability performance measurements as well as structuring and improving collaborations

Aerospace specific Insights:
- Greater experience in early value chain collaboration in design due to industry characteristics (high safety requirements, focus on technology research and innovation)
- Emphasis on closer collaboration and co-creation with the value chain.
- Challenges in articulating collaboration methods and processes.

General insights:
- Suppliers & waste management have desire for input on final product design but are limited by vendor-client dynamics and current routines and processes
- Apparent trade-offs between information sharing for the sake of sustainable development and protecting intellectual property and competitive interests
- Many participants emphasize importance of closer collaboration and co-creation with value chain (e.g., between suppliers, manufacturer, waste handling) but find it difficult to articulate how and in what form such collaboration take place and should be improved
- Overall issues with accuracy and trustworthiness of sustainability-related data that is exchanged throughout the value chain, need to define accurately what data and environmental information is needed

- Need for industry standards and new technologies for value chain data management and exchange to build trust, improve collaboration, and increase transparency and traceability
- Interest amongst participants in developing processes for mapping data flows and exploring technologies to manage and exchange data with partners, and how that can benefit sustainability performance and value chain collaboration
- Expressed need for pilots and demonstrators to develop the governance models, procedures, and data-related capabilities to accelerate the shift towards circular ecosystems and assess their feasibility on a smaller scale

6.4 Results from the CADCOD framework development

As a starting point for the development of the CADCOD framework, an initial list of requirements was formulated describing the various tasks and processes that the framework should support in as well as expected outcomes of applying the tools and methods included in the framework. This initial list is based upon learnings and insights extracted from two earlier projects focusing on product development using digital product passport (DIPP, 2022-2023) and digital sustainability implementation package (DSIP, 2021-2023). Next, the initial requirement list was complemented with relevant factors extracted from the literature review to ensure that the framework covers all the relevant processes and activities for the development of collaborative circular value chains. The updated list was then used as a basis for a workshop with project stakeholders of Volvo Group, where participants shared deeper insights and reflections regarding the various factors in the framework and ranked the different principles by importance on a scale from 1-5 (see table 2).

Table 2. List with CADCOD framework themes, actions, and guiding questions. Actions and questions were assessed on priority (1 being lowest priority, 5 being highest priority) by 5 project stakeholders of Volvo Group.

Theme	Action	Guiding questions	Priority (1-5)
		How important is it that..	
Stakeholder governance & collaboration	Mapping stakeholders	the framework supports in identifying relevant actors in the circular ecosystem?	3.8
	Mapping values	the framework supports in understanding in what way your circular strategy has value for actors in the circular ecosystem?	4.2
	Mapping opportunities	the framework supports in identifying opportunities from collaborating with relevant actors in the circular ecosystem?	4.2

	Mapping risks	the framework supports in identifying the risks and barriers related to collaboration with relevant actors towards a sustainable and circular ecosystem?	4
	Roles & responsibilities	the framework supports in clarifying what roles and responsibilities are needed to govern and sustain the circular ecosystem?	4.8
	Facilitate collaboration & co-creation	the framework supports in facilitating collaboration & co-creation amongst the actors in the circular ecosystem?	4.4
Data governance	Data transparency and availability	the framework supports in defining and concretizing what data and information flows are needed to realize the circular ecosystem?	4.6
	Data capabilities	the framework supports in understanding what capabilities are needed for data and information management to enable the circular ecosystem?	4
Legislations	Legislations	the framework supports in understanding how upcoming legislations will affect projects, products, and the collaborations within the ecosystem?	3.8
Sustainability & circularity	Sustainability criteria	the framework supports in understanding how the sustainability performance can be improved?	4.4
	Demystifying circularity and sustainability	the framework supports in understanding and clarifying the relationship between circularity and sustainability performance?	3.8
Roadmap	Define steps	the framework supports in defining what steps are needed to go from the current situation to the future vision? (towards the ideal circular ecosystem)	3.6
	Visualize & communicate	the framework supports in visualizing and communicating a roadmap towards a circular ecosystem?	3.6
	Experiment & pilot	the framework supports in understanding what experiments and pilots can be done to understand the value and feasibility of the circular ecosystem?	3.2

The results of this workshop indicated that there were no factors of low importance (below 3) but also that participants particularly prioritized activities such as: (1) how to identify shared opportunities in the value chain and assign roles and responsibilities, (2) how to facilitate collaborative and co-creative processes, (3) how to go about data sharing and management issues, and (4) how to define and measure sustainability performance. The framework was then further developed in several iterations by the researchers in the project with regular meetings with project stakeholders in which they provided feedback. The conceptual CADCOD framework is shown in figure 4 and consists of three main themes

(collaboration, data & information, and sustainable circular ecosystem) and a set of strategic actions to engage with these themes.

Collaboration
The theme collaboration refers to a set of collaborative processes, structures, and governance mechanisms that can promote collaboration towards circular value chains. More concretely, it refers to the establishment of processes (how do we build trust and co-create value), structures (how do we organize and manage collaboration over time through establishing agreements and partnerships), and mechanisms (how do we set up rules and procedures that ensure accountability and decision-making).

Data & information
The exchange of sustainability-related information throughout the value chain is crucial for the development, measurement, and improvement of circular value chains. Targets and claims regarding the sustainability performance on a product- and organizational-level cannot be substantiated without accurate and reliable material, product, and production data exchanged throughout the value chain. Here, it is crucial for individual companies to map current and necessary data flows, promote sharing and transparency, and establish capabilities and platforms for shared data & information management.

Sustainable circular ecosystem
To ensure that a circular value chain is also sustainable, it is vital to account for a broader range of environmental, social, and economic considerations that are not implicit to circularity or a circular value chain. Therefore, the CADCOD framework provides guidance in the development of capabilities and criteria to evaluate the sustainability performance of the circular value chain. The term circular ecosystem is used as it better reflects the complexity, interconnectedness, and holistic nature of circular economy systems where flows of resources and information are always multi-directional and shared for the benefit of the ecosystem as a whole.
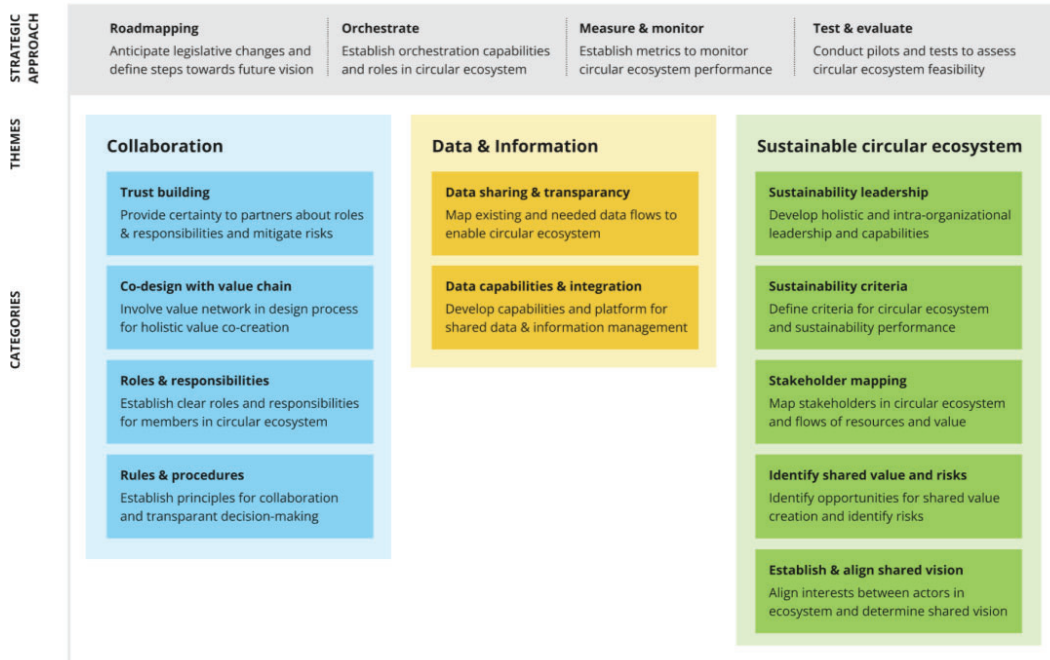
Strategic approaches
To strategically move towards a circular value chain, it is crucial to develop a roadmap that takes into account a future vision as well as iterative and short-term steps and implications that may influence the vision (e.g., legislative changes). To secure the long-term success and operation of the circular ecosystem, it needs to be clarified 'who' orchestrates the ecosystem and 'how', and the overall performance of ecosystem needs to be monitored through dedicated metrics. As there is no 'one size fits all' solution for the development of a circular ecosystem, it is crucial that companies adopt an agile and iterative approach towards setting up pilots and tests to assess the feasibility of the circular ecosystem (which incorporate the product, business model, and value chain considerations).

CADCOD

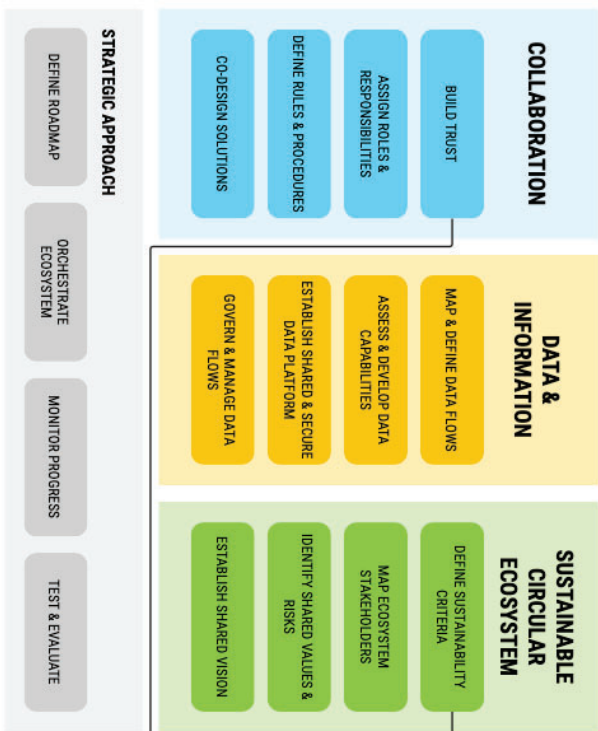A framework for the development of collaborative circular value chains

STRATEGIC APPROACH

Roadmapping
Anticipate legislative changes and define steps towards future vision

Orchestrate
Establish orchestration capabilities and roles in circular ecosystem

Measure & monitor
Establish metrics to monitor circular ecosystem performance

Test & evaluate
Conduct pilots and tests to assess circular ecosystem feasibility

THEMES

Collaboration

Data & Information

Sustainable circular ecosystem

CATEGORIES

Trust building
Provide certainty to partners about roles & responsibilities and mitigate risks

Co-design with value chain
Involve value network in design process for holistic value co-creation

Roles & responsibilities
Establish clear roles and responsibilities for members in circular ecosystem

Rules & procedures
Establish principles for collaboration and transparant decision-making

Data sharing & transparancy
Map existing and needed data flows to enable circular ecosystem

Data capabilities & integration
Develop capabilities and platform for shared data & information management

Sustainability leadership
Develop holistic and intra-organizational leadership and capabilities

Sustainability criteria
Define criteria for circular ecosystem and sustainability performance

Stakeholder mapping
Map stakeholders in circular ecosystem and flows of resources and value

Identify shared value and risks
Identify opportunities for shared value creation and identify risks

Establish & align shared vision
Align interests between actors in ecosystem and determine shared vision

Figure 4. Conceptual CADCOD framework describing three main themes for the development of a collaborative circular value chain (collaboration, data & information, and sustainable circular ecosystem) and corresponding categories. The strategic approach outlines a set of activities vital for circular value chains that are relevant for all three themes.

After presenting and evaluating the framework in a workshop with project stakeholders, it became apparent that it was necessary to apply the framework in the context of a specific case or product to reduce abstractness and make it easier to judge the potential and integration of the framework in an operational context. Therefore, the framework was further developed into a prototype (see figure 5). The figure shows the potential of framework as a functional toolkit that could be further developed into a digital application or website. While the first page shows the overall framework with themes and specific actions, the actions are buttons that lead into pages with dedicated principles, guidelines, and tools to further engage with the relevant topics. The outlines tools and methods on the individual pages are partly already existent and based on consolidated research, while ideas for new tools were also initiated which will be explored and further developed in future projects.

Figure 5. First prototype for a functional version of the framework that can be further realized in the form of a digital application or website.

7. Dissemination and publications

7.1 Dissemination

How are the project results planned to be used and disseminated?	Mark with X	Comment
Increase knowledge in the field	X	The results gave insights and understandings of the knowledge gap in current frameworks. Key results are presently prepared for scientific publications. Invited as a keynote speaker to ICORD 2025 in India.
Be passed on to other advanced technological development projects	X	The results provide a foundation of a novel framework to develop further and to be adopted, applied and demonstrated in further projects with additional stakeholders. Presentations at e.g. FFI conference 2025, and Wingqvist Laboratory annual seminar 2025.
Be passed on to product development projects	X	Industrial partners bring results into their organisation. Research participant (PhD student) plan for on-site actions research in product development.
Introduced on the market		Not applicable at this stage, but long term aim.
Used in investigations / regulatory / licensing / political decisions		Not applicable

7.2 Publications

Manuscripts are being prepared with tentative titles:
- Collaborative framework for Circular Design in Automotive Valuechains. In ICED conference in USA 2025.
- Data Informed Design of Circular and Sustainable Transport Solutions. Journal publication in 2025.

8. Conclusions and future research

This small project of a total budget of 1 084 000 kr for 10 months have developed a novel **Circular and Data Driven Collaborative Design Framework**- including guidelines and systematic methodology enabling sustainable and circular innovations.
Future research will focus on:
  i)   further development and testing of the framework with concrete and applicable methods and tools in industrial demonstrators and cases.

ii) Develop knowledge, methods and tools for data driven design that use the increased availability of data.

iii) Contribute to international standardization of key concepts, necessary to scale solutions in the automotive industry.

The aim is consequently to increase capabilities in manufacturing companies to identify the common readiness level of the value chain to achieve a realistic circular and sustainable solution. Furthermore, the aim is to be able to co-create alternative sustainable and circular concept solutions that follow the ISO standard (ISO 59010:2024, IDT), and be able to anticipate different stakeholders' perspectives and to find optimal alternative solutions for the value chain. The goal is therefore to develop and customise the CADCOD framework, including relevant and customised support tools and methods for the automobile industry. In addition, a next step of CADCOD will have the goal to develop a proposed process of CADCOD activities - based on identified order of dependencies.

9. Participating parties and contact persons

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