Towards Circular Bicycle Development

Introducing a tool for progression towards a circular bicycle development process

Master thesis
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Enjoy reading

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2020

Executive summary

This thesis report is an overview of the work performed in research and development of the first step towards the integration of a sustainability strategy for the product development process of Accell Group. Delft University of Technology was contacted to extend the knowledge, and lay the foundation of a future sustainability strategy for the company. This graduation project proposes a circular tool for Accell Group, that offers guidelines, assessments and a roadmap for project teams to work towards a more sustainable bicycle development. All of these can be integrated in the product development process.

In the **analysis** phase of the project, the context, sustainable progression and product development process were analyzed. Insights from sustainable progression were that currently no strategy for sustainable progression exists, and biggest opportunities for lowering impact on the environment were in the use of recovered materials, and better end-of-use processing. Next, the product development process and its users were analyzed. Although designers are motivated to make design choices of influence to the sustainability of the bicycle and / or production process, the culture in Accell currently not actively encourages such choices in design as costs and speed of execution have a higher priority. To validate such choices in design, it should be quantified enabling it's integration in bicycle requirement documents. These insights resulted in the choice of the circular economy as main approach in the project. It provides a clear vision (zero impact on the environment) and includes strategies that combine financial and sustainable demands. Furthermore, circular methodologies are being developed that enable to assess progression.

In the **circular exploration** phase, the perspective of the circular economy is used to analyse the current bicycle lifecycle (from production to end-of-use) to spot opportunities for improvement. Various circular economy assessment methodologies are tested through application on Accell Group. Insights gathered from this phase were translated into requirements for the development of the circular tool. The methodologies, strategies and guidelines were discussed, validated and tested during the exploring phase on several project teams, and feasability also discussed with new business development and supply chain. Insights gained from these interactions were implemented in the development of the circular tool.

In the **development** phase a circular tool was designed, using insights from the circular exploration. The tool functions a circular conversation facilitator, and simultaneously as a indicator for circular progression of a bicycle development project. Therefore, it can communicate the circular value of a project between project teams, I&T department and managements, enabling to set goals and work towards them. The score achieved in a project is linked to assessments created on a system, design and component level, using indicators such as (dis)assembly time, percentage of recovered materials, use of toxic materials and established recovery players in a project. Furthermore, it includes guidelines on these same levels to help thinking in circular loops, create circular business models, choose green materials and circular plastics, design for disassembly and finally select sustainable suppliers. Circular indicators were created to include in the documents used in the product development process, with the goal of gathering information about materials and components from suppliers. Finally, moments of using the tool were established for integration in the product development process.

In the **validation** phase, the final Accell circular tool is tested on the a public transport tender.

Finally, **communication** of the tool during the project is summarized, and recommendations for further activition within accell are given

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Project introduction

Project context

Accell Group is the European market leader in e-bikes and the European number two player in bicycle parts and accessories. Well-known bicycle brands in their portfolio include Babboe, Batavus, Ghost, Haibike, Koga, Lapierre, Raleigh, Sparta and Winora.

Accell Group focuses on the mid-range and higher segments of the market for bicycles and bicycle parts and accessories. Their brand Sparta is the inventor of the modern e-bike and Haibike was the first brand introducing an e-mountainbike (e-MTB)

Spread over 18 countries, they employ approximately 3,000 people who are active in areas such as development and design, logistics and assembly and marketing and sales.

Part of Accell Group, is Accell Nederland. They are in charge of the development of Batavus, Koga & Sparta bikes [Apendix A]. Their headquarters are located in Heerenveen (originally Batavus). This is also where the paintwork and assembly of the bicycles takes place. The other Accell Nederlands location related to this project is in Apeldoorn. Originally ‘Sparta’, now the Apeldoorn location also hosts a number of Accell employees that are involved in R&D, prototyping and service & communication.

The R&D department is spread over both locations; Heerenveen & Apeldoorn. Employees from Accell are also flexible in their working places and switch between these two cities.

* A more indepth analysis of these and the brands of the full Accell Group can be found in appendix A.

Problem definition

When it comes to sustainability, a bicycle is considered a green product [Hyde, 2013]. During use, cycling is amongs the most sustainable modes of urban transport, feasible not only for short trips but also for medium-distance trips too long to cover by walking (Pucher & Buehler, 2008*). According to the LCA performed in 2018 on 4 different Accell bikes, even the electric bicycles have a significant lower impact on our environment than trains, cars or busses.

However, the production of these bicycles still has a negative impact on the environment, due to the use of finite materials, energy-intensive fabrication processes, shipment, and end-of-life treatment (LCA 2018).

Accell as a company is already working on sustainable entrepreneurship. For example, Accell tries to lower the emissions the production place releases and is actively separating waste, such as packaging. But when it comes to the development of new bikes, the development process doesn't include any documented sustainability concerns.

In first conversations with designers and engineers, they mentioned design choices related to sustainability are not taken in consideration in the product development process.

Since Accell has decided to give sustainability a higher priority, there is a need / opportunity to integrate sustainability in the product design process (also referred to as PDP).

The goal of the assignment is to design a tool that guides and quantifies the use of circular design in the Accell product development process.

Project deliverables

1. Circular Design Tool

What? Tool that guides employees from different departments (of Accell Nederland) towards (more) circulair design of bikes.
How? By providing circular design methods and enabling them to create bike-specific statement of requirements that connect to the (circular) business plan.
[subgoal; lock moments of use in PDP]

2. Circular Design Label

What? Label that can be used to evaluate and motivate design choices

How? Combine relevant EU criteria, TU Delft criteria & workshop-generated Accell criteria (all related to circular design.)

[subgoal; integrate moments of use in the product development process]

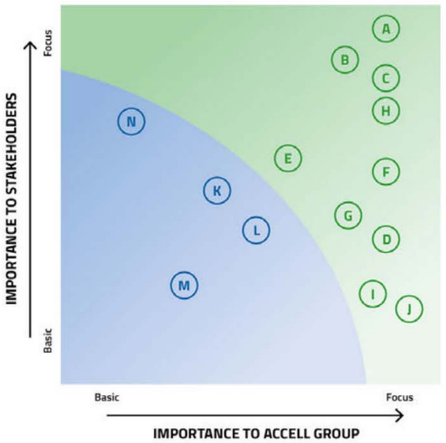
3. Validation Case

Test of the Sustainable Design Tool on an Accell project, to validate the tools feasibility and desirability.

Analysis

1.1 Current progress towards sustainable development

To develop a strategy for progressing in sustainable product development, information was analysed about the current status of sustainable development. An internal document with current status, sustainability goals and steps towards these goals did not exist at the moment of writing this thesis. However two sources of information are available with regard of sustainable progression of the past years. The first are the yearly reports published by Accell, the second is a quick LCA performed in 2018 on 4 Accell bicycles.



Topics from A to J are the most material topics. In our annual report we cover these topics in detail. Topics from K to N are covered briefly. Boundaries for each material issue are noted in our GRI Content Index.

MATERIAL TOPICS

BRANDS & PRODUCT
- A Customer satisfaction
- B Healthy, safe & green mobility
- C Innovation & design

PROCESSES & PRODUCTION
- D Carbon footprint reduction
- E Sustainable production
- F Supply chain

ORGANIZATION & PEOPLE
- G Job satisfaction and wellbeing
- H Health & safety
- I Diversity

ECONOMY
- J Profitability

OTHER MATERIAL TOPICS
- K Bicycle infrastructure
- L Distribution
- M Community involvement
- N Recycling / upcycling

Figure 1.1.1

Annual report

The annual report in 2019 is the first to mention sustainability in relation to the product development process, the focus of this thesis. It states; ‘In the years ahead, our design team and the Innovation Board will be devoting more attention to sustainability. This will cover a wide range of topics, from design and materials used, to reducing our carbon footprint, to more circular business models. Our ambition is to have sustainable elements in every newly launched innovation by 2025.’ How this will be achieved, is not mentioned.

Sustainability is interpreted in all recent year reports through ‘material topics’ [figure 1.1.1]. Some of these topics are discussed in the materiality matrix, which ‘takes into account what we believe is important but also what our stakeholders feel is important’. Healthy and green mobility is one of the highest scoring topic on both axes. Accell states it wants to ‘Play a leadership role when it comes to increasing sustainability in mobility’.

Lower rated (a scale is not defined) is sustainable production. Mentioned in the report about this is; production of bicycles with the lowest impact on the environment, reduction of waste and energy consumption, and attention paid to the use of packaging and materials.

Further discussed in the annual reports, are the sustainable development goals (introduced by the united nations). In terms of products, bicycles, Accell focuses primarily on SDG 3 (Good health and well-being) and SDG 11 (Sustainable cities and communities), in the way that their products help to create a better environment, better living conditions in cities and a more healthy way of living.

A target set for 2025 with the relation to the PDP is the reduction of single-use (SU) plastics, with special attention devoted to eliminating fossil-based plastics:
100% SU plastic-free packaging of Accell bicycles, parts & accessories;
50% reduction of SU plastics in transport packaging from our suppliers;
Banning the use of SU plastics in our offices and organisation;

Accell has set some goals regarding energy use (within own production facility) and packaging of bicycles (material and design). Small steps are achieved, for example reduction of total energy of 6% in 2018 compared to 2017, (while losing 2% in the relation green-gray energy, going from 10% green back to 8%)

It is later mentioned that as a goods manufacturer, they feel it is their responsibility to contribute to SDG 8 (Decent work and economic growth), not just with a focus on Accell Group employees, but on everyone who works for Accell, including the supply chain. To contribute to SDG 12 (Responsible consumption and production), it is stated ‘we constantly work on reducing our environmental footprint and promoting the safe and responsible use of our products.’ However, how this is achieved, how far they are in achieving this or future steps are not mentioned.

Annual report - Insights

The ‘leadership role when it comes to increasing sustainability in mobility’ is cleverly phrased; it aims at the fact that the products Accell produces offer a green mode of transport compared to other mobility products.

However, the thesis focussus on Accells own product development process, not bicycles versus cars. Exept for the reduction of single use plastics, lowerering energy use and using green energy, initiatives in sustainable production are not mentioned in the Annual report.

Sustainability in the design process - Interviews

Interviews were conducted with 2 project leaders, 1 product manager, 4 engineers, 1 stylist (more on these functions in the 'users' chapter). The interviews were performed in the form of 'semi-conducted interviews, following the approach from Adams; conducting semi-constructed interviews (2015) [1]. Appendix B shows the preparation of interview style and points of attention, and interview questions. When participants were asked about if they think sustainability receives enough attention within Accell, and if they think about sustainability in your working method of this process; the answers were all similar. 'Sustainable requirements or design choices are not currently integrated in the product development process. Quotes from these interviews are displayed on this page.

One conversation from a product designer was about a personal effort to use a recycled shelf in the luggage rack of a bicycle, created from recycled bottles. Through support of the project leader, it was further developed up to a functioning prototype. However, when the costs of this shelf were compared to the costs of a regular, non-recycled one, the idea was cancelled and not taken into production.

'If it's sustainable, it's a nice extra. But not something we keep in account while designing'.

'It has not been consciously promoted so far.'

'You try to take it into account, but it does not have the full focus. Focus on good, fast, no bullshit.'

'Sustainability is not a concern.'

Sustainability in the design process - Interview insights

Sustainability not integrated in development process
There are currently no top-down requirements or motivations for making choices that lessen the impact on the environment.

Intrinsic motivation
Through the interviews conducted with all members of a project team, there was great energy and motivation in the topic of sustainability. Many suggestions and ideas were provided during the interviews.

Different aspects of sustainability
During the interviews, different suggestions and ideas for improving the sustainability of a bicycle were opted. These ideas included various, and sometimes contradiciting, approaches; using less material (as Accell doesn't have time for reducing material after the first safety test has passed) versus increasing thickness for longer use of the bicycle. Some focussed on the selection of green materials, others looked into the processability of end-of-use components.

Costs & Time effectiveness are prioritized
Financial targets and time effectiveness are the main drivers of design choices within Accell. As discussed above, suggestions for sustainable components were provided by designers, but not taken into account due to costs & time priorities.

Life Cycle Analysis

A life cycle analysis (LCA) from 2018 provides insights in the impact 4 bicycles have throughout their entire lifetime. This means it not only contains environmental impact from production and use, but also reduction of impact through 'end-of-life' processing. The LCA shows the environmental impact of the bicycles over their total life cycles, on the basis of 24.000 cycling kilometres. The LCA mentions for all bicycles, the recycling of the metals, batteries and other waste processing reduces the environmental impact between 38% and 48%. Although the LCA states the residual waste contributes to reduction in two ways; energy recovery and recycling material, it does not say in which ratio. However, it means there is a 52% to 62% to gain if the product end-of-life recovery could be optimized.

It is not mentioned in the LCA where these numbers are based on. The data is expressed in 'eco indicator', a variable where 1000 Pt corresponds to the annual environmental footprint of an average European citizen. This indicator is outdated and replaced by three categories; Human Health, Ecosystems and Resources. But the company that performed the LCA thought the increased amount of graphs to express the impact (over these 3 categories) would create confusion by the reader, and therefore applied the subdued weighting procedure to come to one end point: the former eco-indicator. This means that the environmental impact of the categories Human Health and Ecosystems weigh 40% and Resources weighs 20% in the total impact score.

The figure shows that the bicycles with electric pedal assistance clearly have the highest environmental impact and the lightweight road bike has the lowest impact. The high impact of the E-Bike and E-MTB is partly caused by the batteries, though it is also related to the total weight of the bicycles and their extensive equipment. When analysing the materials of the bikes, the main environmental impact comes from the extraction of raw materials and the production of semi-finished products, which is an environmentally intensive process: particularly for metals. The impact that the transport of materials and parts to the assembly site plays a limited role in the environmental impact of the bike when compared to the impact of raw material extraction.
The frame, the battery and the tires have an important share in the environmental impact of each bicycle, though the ratio varies per bicycle.

For example, the frame of the city bike is only responsible for 9% of the environmental impact of all components together, while the frame of the E-bike only contributes for 15%. For the racing bike, the drive is one of the most important parts (28%) influencing the environmental impact, where this percentage for the drive is between 5% and 10% for the other bicycles. For both the E-bikes and the E-MBT the battery clearly has a major environmental impact.

Insights

Material use main influence of impact
The environmental impact of each bike is strongly related to its total weight, especially when the focus is on production and end-of-life (scenario 1). A heavier bike means a higher environmental impact, partly as a result of the use of energy-intensive metals such as aluminium. Negative impact on the environment is for 84% to 90% the result of the materials and energy used during material extraction and fabrication into components.

Most to win in electric bicycles
The electric bicycles benefit the most from good and environmental processing, where the recycling of the batteries is the most important factor.

Significant impact of batteries
The production, charging and replacement of the batteries have a significant impact on the environment, and particularly on the emission of greenhouse gases. The use of green electricity can, especially for charging, be an important factor to reduce the impact (up to 21% reduction in the total environmental impact).

Assembly, transportation and packaging highest impact internal processes
The highest environmental impact for internal processes are to be found in the energy use of the assembly, transportation and the packaging of the bikes.

Current sustainable progression

Key Insights

Big opportunity in using recovered materials
As material use has by far the biggest negative impact on the environment (84% to 90%) it should be the main focus in the selection sustainability strategy.

Big opportunity in end-of-use
The impact a bicycle has on the environment can be lowered by 52% to 62% (theoretically resulting in 0%), if the product would have a perfect end-of-life recovery.

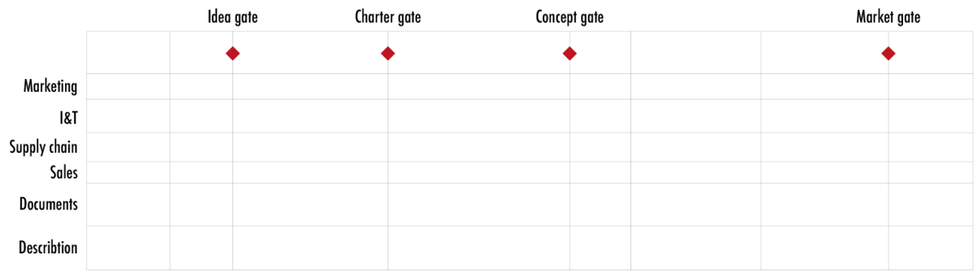
Low awareness / data about lifecycle bicycle
Except for the LCA discussed in this chapter, there is little known about what kind of materials (virgin / recovered) components are created from, where the bicycles Accell produces end up, and what this means in terms of environmental impact.

Need for a sustainable strategy
A sustainable strategy is needed, as currently there are no clear targets set to progress (insights from the yearly reports and from interviews conducted). Preferably such a strategy answers the insights stated above (using recovered materials and providing end-of-use, profitable solutions)

Need for financially attractive sustainability solutions
As it became clear that financial targets are the biggest priority at Accel, the most effective way to progress is a solution that is simultaneously profitable and sustainable.

These insights are used in the selection of a sustainability approach, showed in the chapter ‘methodologies in approaching sustainability’.

1.2 Product development process



Framework of the PDP - Figure 1.2.1

The project goal of this thesis is focussed on the product development process (hereafter referred to as PDP) within Accell. The PDP is a phase-gate process (also referred to as a stage-gate process or waterfall process), a project management technique in which an initiative or project is divided into distinct stages or phases, separated by decision points (known as gates). Since this PDP is the process in which all mandatory steps towards a new product are included, its content, and users are analysed in this chapter.

The 5 stages

The main component of the product development process are its stages. The process each stage is build on and its relevance to the project goal is analysed in ‘stage process’. Individual stages are shortly described and interpreted in the other 5 subchapters.

Stage Process.

During all 5 stages of the PDP, the same stage process is used. Input is used from the last stage, to improve the project (learn). This improvement takes place through defining, developing and validating new project goals. When objectives for the specific stage are achieved, the project arrives at one of the 4 stage gates. The innovation board decides whether to continue the project at this point, or kill it (Go / No go).

Relevance to project goal

This consistent process in every stage offers room for integration of sustainable progression in two manners. The first is during the ‘learn’ and ‘develop’ moment. If sustainable guidelines and methodologies could be offered during the development team during these moments, they could help in the creation of more sustainable projects. The second are the ‘define’ and ‘validate & verify’ moments. If sustainable progression can be quantified into clear, achievable goals, this could be used during these moments of the stage process.

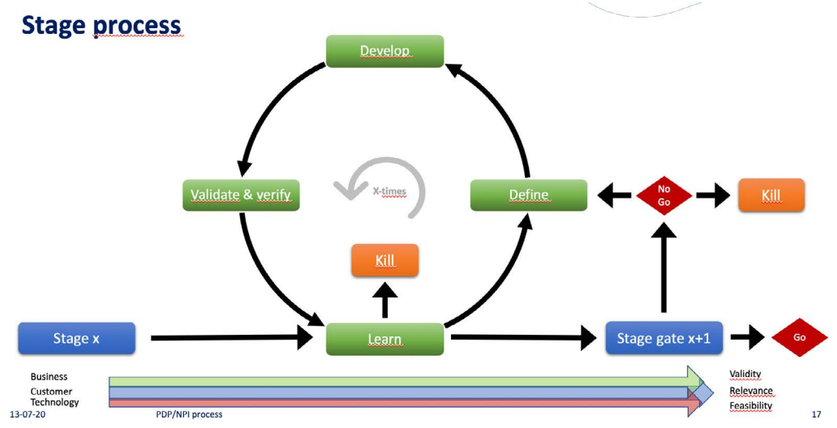
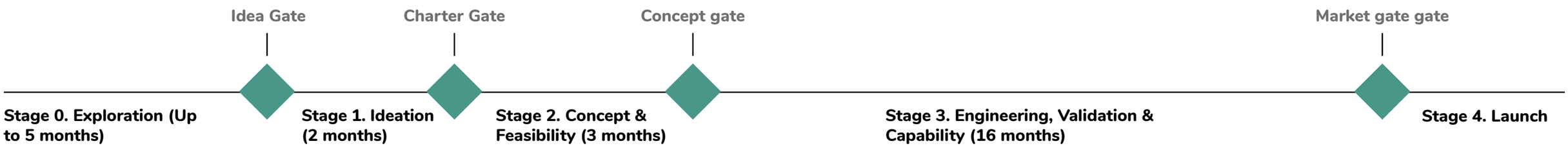


Figure 1.2.2



Exploration - Relevance to project goal

The new product needs are currently based on consumer, competition, supplier/technology and channel research analysis. Alignment with sustainable development goals are possible for both marketing and I&T.

For marketing, this would be answering a core element of Accell's brand positioning; playing a leadership role when it comes to sustainability in mobility (Year report 2019). Other motivations are falling behind on competitors sustainable progression and responding to a more sustainably aware consumer. For example, one study found that the most concerned Spanish consumers were willing to pay a price premium of 22–37% for green food products (Sanjuán et al.,2003). Japanese consumers were reported to be willing to pay a premium of 8–22% for green food products (Sakagami et al., 2006).

I&T could actively search for sustainable technologies and production facilities to use during the PDP. Also, the think tank could initiate new projects driven on sustainable innovation.

Another possibility is to include sustainability opportunities and trends as a starting point for innovation. New business development has the opportunity to start thinking circular. Concepts like the circular economy offer business models based on circular loops, extending product lifetime while generating revenue.

Ideation - Relevance to project goal

As the ideation phase offers a lot of design freedom, it opens up room for sustainable choices. Different functional proposals such as geometry, kinematics and mechanism are explored. As these choices have a high influence on production processes and material use, they also influence the impact on the environment. A second thing to consider, is ease of repair and ease of disassembly, which lowers the impact of a bicycle on the environment by extending its lifetime. It's during this stage that there is a lot of freedom in design choices regarding sustainable production, sustainable use and preparation for end-of-life

Concept & Feasibility - Relevance to project goal

As we progress in the development of the bicycle, the freedom in major design choices, and therefore choices with regard to the sustainability of the project are narrowed down and include less possibilities for integration of sustainable elements. However, sustainable guidelines for designers and engineers could still help in making low-impact production choices. Supply chain assesses assembly possibilities and decides where to produce, which has an influence on where products are shipped from, and the degree of design freedom (make or buy). These choices are documented the BOM, and therefore the creation of the BOM could be guided by design rules / guidelines, and the document itself could be used for defining and validating choices with regard to the sustainability of the project.

Engineering, Validation & Capability - Relevance to project goal

As in this stage the PSD is not adjusted, all possible requirements with regard to sustainability need to be integrated during the stages before (meaning 1 & 2). There is limited design freedom during this stage. Only small changes in design take place, like types of connections. Mainly the form of the bicycle is tested for safety and made ready for launch.

Launch - Relevance to project goal

As this is the final stage, the only thing that can be achieved by the I&T department in the light of sustainable progression is evaluating and learning from the project. In case any insights are developed with regard to sustainability of the project or sustainable opportunities, these can be used in the think tank of future projects to improve the sustainability of the PDP. For the marketing department, it would help in this phase if there's value / sustainable achievement(s) that can be communicated to consumers. Documentation of such values or achievements can help in communication these between I&T.

Stakeholders

The phases discussed represent the different timeslots in the PDP. Now we will discuss the the different stakeholders that play a role in the PDP. Although most steps in the process are designed for the innovation and technology department, other players included are global marketing, regional marketing, supply chain and sales. Their roles are discussed below.

MSU / Regional marketing
Regional marketing starts in phase 0 with the target group, competitor and marketing scan. This is later on passed on to the I&T department for further development. They focus on the value proposition of the project and are responsible for communicating this to the market. Sustainable aspects of products could be used as a unique selling point in marketing communication.

Supply chain
Supply chain is responsible for selecting suppliers and procurement. Here is an opportunity for sustainable progression by selecting local suppliers, or supplier that comply to higher sustainability standards. They are very much involved in creation of the BOM.

Sales
In charge of creating the sales forecast creation and sales forecast update.

Innovation & Technology
This department is responsible for development of Accell bicycles and innovations. They are involved in the PDP from the very first stage (exploration) to come up with ideas for new product development. This potentially includes projects with a focus on sustainable production / design. The hierarchy within I&T is desplayed below. Team members playing a role in the PDP and their responsibilities of this department are described in this chapter.

Hierarchy I&T
The lifestyle department situated in Heerenveen is led by the innovation center manager - lifestyle, and directly answers to the I&T director. The I&T director is supported by the I&T Deputy manager. This is important, because they have the final word in accepting changes in the PDP.

Important of documents mentioned in the PDP

The PDP not only contains responsibilities for different departments, but also includes the documents that need to be developed for each stage. It is worth discussing the most important ones, since they serve as potential carriers of tools and therefore serving the project goal; the integration of a sustainability strategy in the PDP

Stage gate review document
The head of sustainability had two ideas for using the stage gate review documents.
In phase one, it should be reviewed if corporate social responsibility has an active role in the project.
At the end of stage two is that if sustainability played a role in the project, this should be highlighted as a unique selling point.

Other documents that relate, or potentially relate to sustainability are;

Business case
The first version is created in stage 0, in the initiation phase. Later it is updated during phase one and two. The business case could potentially have include sustainability targets. If sustainable progress goes together with profitability, chances of implementation and aligning all departments to achieve these goals are very high.

Initial product specification document
Interviews with several designers and engineers from Accell said this document is the basis for their design decisions. Multiple times it was mentioned that to achieve sustainable goals, targets need to be locked in in the product specification document.

Bill of materials
This list includes all parts and all components used in the production of bicycles. They include details like costs, quantity and the name of the supplier. From an absolute perspective, Accell produces a very low percentage of the components used in the production of their bicycles. Almost all parts are ordered from third companies. Including details about sustainability aspects of components in this list can help to gain insight in sustainability of these materials, and set sustainability goals.

Teams playing relevant roles in the PDP

Stage 0 and 1 from the PDP are the ‘fuzzy front end’ where exploration and ideation takes place, and are therefore the best place to start thinking about circularity. Because the earlier circularity plays a role in the design of a bicycle, the better it gets implemented. Therefore the teams that are involved in this ‘exploration to ideation’ process and their hierarchy, are analyzed.

Brand team
The brand team comes up with concrete innovation proposals and a roadmap for a specific brand, which is then submitted to the Brand innovation group for approval

Brand innovation group
This is a group per brand that indicates the direction in which the brand wants to innovate for that brand. They are the ones who take suggestion from the brand team into consideration, and work these out. The BIG then proposes the idea to the innovation board to start the product development progress

Innovation Board
The innovation board views the proposals from the total project portfolio of all brands. They are the once to decide if there is enough money / time to implement the project and if the idea is profitable enough

They come together during all 5 stages of the development process.

Project Team
This is the team that actually executes the project. It consists out of a project manager, industrial designer, engineer and stylist. Responsible for the project is the project manager, who answers to the head of project management [Figure 1.2.3]. Responsibilities, functions and needs are discussed on the following page.

As sustainability is a very broad topic and many approaches can be taken, a starting point and a sustainability strategy is needed. Within a project, it's not only the design that can progress in sustainability, but also the lifecycle it flows through and the business model behind it. Are we going to minimize material use? Optimize lifetime? Sometimes goals are contradicting; therefore a strategy would help in making these choices.

As the project leader, you are the connection between your project team and marketing team, and top-down project initiators; the innovation board and the brand innovation group. At the moment of writing this thesis, there is no ability to communicate efforts related to sustainable design within these stakeholders. A need exists for a sustainability value for projects that can be communicated internally.

In two stages of the design process the contact of the project leader with marketing has a focus; during the briefing (stage 0) and during the communication of design results (stage 3 and 4). For the second stage, there is a need for marketing to communicate sustainable project choices to the customer. This can be the value (named above), but also communication sustainable aspects of the project / bicycle.

As the bicycle is created for roughly 60%-90% out of components bought from external suppliers, sustainability in the development process doesn't stop at the innovation & technology department. Suppliers and the selection of them are of high impact in the sustainability of the bicycle. Which one to choose? How to help them delivering sustainable components?

During the development of bicycles, there's multiple suppliers offering different versions of components. To take sustainability in account in these choices, there is a demand for a value for the sustainability of these bicycle components, making it possible to compare different options.

Needs

- **Sustainability strategy**
- **A value rating the sustainability of projects.**
- **Improving communicating with marketing department**
- **Attention to supplier components**
- **A value for sustainability of bicycle components**

User needs

Interviews were conducted with 2 project leaders, 1 product manager, 4 engineers, 1 stylist. The interviews were performed in the form of 'semi-conducted interviews, following the approach from Adams; conducting semi-constructed interviews (2015) [1]. Appendix B shows the preparation of interview style and points of attention, and interview questions. User needs were extracted, coloured in **orange boxes,** and later referred too in the circular exploration and tool development requirements. The following insights were gathered;

Responsibilities;

Project planning and timelines
Project documentation
Setting deadlines (action list)
Projectbudget
Scope monitoring
Project progress

Project leader

The project leader is responsible for facilitating and guarding the project, making sure it passess through the product development process within 2 years time. After the brand team has created the project brief, the project leader takes over and is from then on responsible for the project. (meaning phase 1-4). Basically, the collection manager (brand team) becomes the client of the project leader. The project leader keeps the team on track, and is the main communicator between the team and other stakeholders; mainly the brand team and product expert committee, and the innovation board.

Responsibilities;

Determine purchasing parts
Testing purchasing parts
Compliance entire bike
Technical product specifications
Material costs
BOM

Product manager

The main goal of the product manager is to make sure the bicycle is produced within the assigned costs, and that it's aesthetics fits the concept described in the project brief.

Needs

- **Including sustainable goals in program of requirements**
- **More time for sustainable development**
- **Checklist**
- **Guidelines**
- **Coating Guidelines**

Responsibilities;

Makeability of self-developed parts
Strength and stiffness of self-developed parts
ATP tests self-developed parts
Technical contact with supplier
Price-dependent choices for technical solutions

Engineer

The engineer is the technical expert of the project team. After the files from the designer are passed on to the engineer, he manages the detailing, force calculations and relationship with the testing centre.

Responsibilities;

3D design within requirements program and brand key
Fitting of purchase parts within design
Delivery of good 3D for Engineer
Design for Assembly

Designer

The designer is in charge of ideating and modelling all 3d parts from the bicycle that are produced by Accell. Normally, this is the frame. Other frequently designed components are the front fork and luggage rack. Less often follows lightning of the bicycle and steering wheel. The designer is also responsible for design for assembly, meaning that he influences the timespan needed to assemble a bicycle and easiness of assembling.

Responsibilities;

Holistic styling interior options PVE and budget
Artwork on relevant parts within the Brand Key

Stylist

The stylist is in charge of the overal styling of the bicycle. The bicycle receives it character by choosing colors, coatings and further artwork

In the current situation, there is no focus on sustainable design choices. If a bicycle component is sustainable it's a nice extra, but not a focus point like costs. Therefore, including such goals in the specification document would ensure such sustainable choices play a role in the decision making proces.

To be profitable as a company, the development process is continuously streamlined, optimised, and time has been reduced for different phases. Especially phase 1, the design phase, has been shortened, limiting room for ideating the (sustainable) design of the bicycle. This phase is of high importance to the bicycle sustainability, because as the process progresses, design freedom becomes smaller.

There's many design aspects that relate to sustainable bicycle development. It is mentioned that a checklist would be helpful, to help the designer & engineer keeping track of the sustainable choices covered during the process.

The design process in the innovation & technology department is optimised for lowering costs, while creating safe and aesthetically pleasing bicycles. Although designers have many ideas for improving sustainability, they mention this is an uncharted area and guidelines would be helpful.

Although various ideas were given about possible sustainable improvements, it was also mentioned that there was a lack of understanding of how different coating processes affect impact to the environment

Product Development Process

Key Insights

Focus on early stages
As the stages progress, the design narrows from ‘fuzzy’ innovation idea to a bicycle ready for production. During stage 3, small changes can be made with a possible sustainable impact (like material reduction).

Importance of product specification document
the requirement specification document is mentioned as highest influence in design-decision making.

Use of PDP
During the interviews with several members from the project teams it was mentioned that the PDP was not something of high importance to them, or of high use during the process. One described the PDP as ‘a document lying safely in the desk drawer’. Therefore the initial project goal was questioned; how important is integration in the PDP? What needs to happen to integrate ‘sustainability elements’ in the PDP? What approach fits this? These questions are answered at the end of this chapter; assignment reframing.

Company culture
During the interviews, it became clear that sustainability is not ingrained in the current company culture. There are no initiatives for progress making in sustainable development. Accell is a more conservative and financial company, making small margins with a high production. Drivers are targets based on financial goals and amount of bicycles sold.

1.3 Methodologies in approaching sustainability

After understanding the current sustainable progression and needs and opportunities from the product development process, several concepts for defining and approaching sustainability were analysed. This is done because the concept 'sustainability' is broad; For many in the field, sustainability is defined through the following interconnected domains or pillars: environmental, economic and social concerns.

Brundtland defines sustainable development in 1987 as "development that meets the needs of the present without compromising the ability of the future generations to meet their own needs".

To achieve such a development, many systems of appoaching sustainability have been developed in the last decades. Selected for analysis were life cycle assessment, the circular economy (with a focus on circular product design), cradle to cradle (developed by William McDonough and Michael Braungart) and sustainable development goals (developed by the united nations).

In the analysis attention was paid to;

1. **How well does the sustainability approach relate to the product development process?**
2. **How well translates the concept into executable goals within Accell Group?**
3. **What is the 'momentum' of the sustainability methodologie?**

Although the questions are answered in a qualitative way, also a quantative conclusion is added to be able compare the different sustainability approaches.

--	Very low
-	Mediocre
0	Reasonable
+	Good
++	Excellent

Question number 3 is in a later stadium of this chapter answered (page 32).

LCA

Life-cycle assessment is a methodology for assessing environmental impacts associated with all the stages of the life-cycle of a commercial product, process, or service.

For instance, in the case of a manufactured product, environmental impacts are assessed from raw material extraction and processing (cradle), through the product's manufacture, distribution and use, to the recycling or final disposal of the materials composing it (grave). [x]

The methodology therefore focuses on the environmental concerns. Sociological and economical concerns are not taken into account.

The biggest advantage of an LCA is the fact that the methodology translates the impact of all life stages of a product into quantifiable results; the impact of each stage on the environment. Therefore, actions can be taken according to these results. It becomes clear which actions possibly taken by Accell will have bigger or smaller effects on the environment.

The results of the LCA can be used for communication with clients and as input for certification.

1 +

The fact that an LCA is able to quantify the impact of a product by assessing all the stages of the life-cycle, means it can be used to analyse what aspects of the PDP have most negative impact on the product from a material and production perspective (embodied product energy). However, it serves purely as an assessment and does not provide a 'vision' for sustainable product development

2 +

As it quantifies impact, it shows what aspects of the PDP have biggest influence in lowering negative impact.

Circular economy

In the way the LCA is developed to assess a linear life cycle; from cradle to grave, the circular economy is not necessaraly a methodology for assessment, but a guideline; a circular economy aims to redefine growth, focusing on positive society-wide benefits.

A circular economy is one that is restorative and regenerative by design. Better product design is key to facilitating recycling and helping to make products that are easier to repair or more durable, thus saving precious resources. Therefore, the vision of a circular economy relates directly with the product development proces.

The circular economy drives on three principles; designing out waste and pollution, keeping products and materials in use, and regenerating natural systems.

These 3 pilars can be translated into a design guidelines for the innovation and technique department, and on a system level into executable goals for Accell Group.

The concept of the circular ecoonomy is visually easy to understand. Everybody can imagine a circle, in the same way that everyone can imagine a line. Because simplicity helps in understanding the core principle, it gives an advantage in the communication towards the different stakeholders within Accell. Mutual understanding helps in aligning the different users in the movement towards a new goal. [source?]

1 ++

As product readiness for a circular economy is heavily dependent on product design, the concept relates directly to the PDP

2 ++

The design principles, together with the fact that there are currently indicators developed to assess circular progression, make a great foundation for executable goals within Accel Group.

Cradle to cradle

The ‘circular economy’ and ‘cradle to cradle’ have been developed alongside each other since the early 1990’s and are based on the very same principles; designing out waste and pollution, keeping products and materials in use, and regenerating natural systems.

The term “Cradle to Cradle” is a registered trademark of McDonough Braungart Design Chemistry (MBDC) consultants. It can be used by companies to certify their products using cradle to cradle standards

Figure 1.3.1

A distinguishing feature introduced through cradle to cradle is the term ’nutrient metabolisms’; a distinction between biological and technical nutrients. They can also be referred to as ‘consumption products’ (products that are consumed, like soap or food) and ‘service products’ (products that are used, like bicycles;). However, this distinction has been integrated in the circular economy now as well. Within Accell, the focus lies on the technical cycle, since Accell offers products that are used, not consumed.
Where the circular economy has a focus on creating loops for products and their materials in an economically profitable way, cradle to cradle has a focus on material health. They’ve established lists on toxiticy and recyclability of materials and chemicals. The cradle to cradle certificate has a strong focus on optimilizing the materials used in products to prepare those for a circular economy.

Two other principles of cradle to cradle are;

Power with renewable energy. “Use current solar income.” Maximize the use of renewable energy.
Respect human & natural systems. “Celebrate diversity.” Manage water use to maximize quality, promote healthy ecosystems and respect local impacts. Guide operations and stakeholder relationships using social responsibility.

① ++

Similarely to the circular economy, in cradle to cradle the design of a product is of high influence to it’s vision to keep products and materials in use. On top of that, cradle to cradle has extensive guidance on healthy material use, which is also of relevance to the PDP.

② ++

The cradle to cradle movement includes ‘cradle to cradle certification’ devided over 5 levels. These can be used a targets for circular product development, and therefore translates into executable goals for Accell.

Sustainable development goals

The Sustainable Development Goals (SDGs) is the set of 17 global goals provided by the UN to unite global stakeholders in the work towards a better and more sustainable future for everyone. The SDGs provide a historic opportunity for international partnership in order to address the global challenges the world faces, such as extreme poverty, environment degradation, injustice, and discrimination.

The SDG’s are used by Accell in their Annual reports. This is an advantage for further using this . Out of the 17 goals, Accell as a company contributes to 5 of them.

Figure 1.3.2

① -

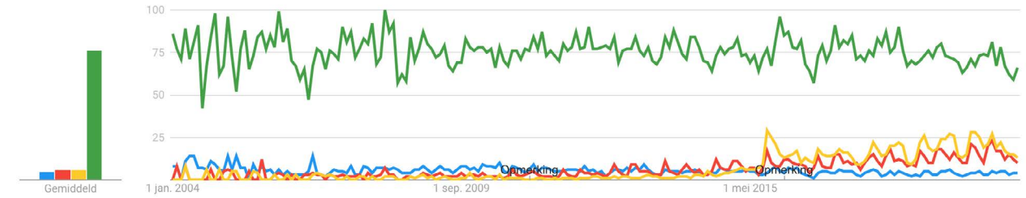
The SDG’s aim to unite countries by addressing the global challenges we face, including those related to poverty, inequality, climate change, environmental degradation, peace and justice. Although it offers a very broad vision on sustainable development, its guidance and relation to sustainable product development is rather low.

② +

The inclusive vision of SDG’s on global sustainable development can be used to create goals within Accell tackling. A tool like the SDG compass (developed by UN) can help in translating the SDG into goals for Accell.

Momentum in sustainability assesment systems

Finally, research was performed on the ‘momentum’ of the different assesments. The reasoning behind this, is that a momentum in a sustainability assessment could be benifcial for alignment of the different stakeholders within Accell, which could help with a a faster progression towards implementing the strategy in the product development process.



Life cycle assessment

Circular economy

Sustainable development goals

Cradle to Cradle

Figure 1.3.3

Because of the limited time and lower priority of this analysis goal, all 5 methodologies we’re analyzed using ‘google trends’, which gives insight in the amount of active searches for certain terms.

Life cycle Asssment shows a slow decline over the time period starting in 2004 up to 2020. It is the assesment that has been around for the longest time, which does help with a general understanding / familiarity.

3 +

Sustainable development goals shows a big increase in 2015, which is also the year they the SDG’s became public. It’s world wide concerns make it a popular search term and a steady increase is shown since 2015.

3 ++

Cradle to cradle has by far on average most searches. However, it shows a decline in searches since the introduction of the concept.

3 0

The circular economy shows a steady growth over the years, gaining momentum start 2013. This could be the result of a paper published by the Ellen MacArthur Foundation, published in 2013. It outlined the economic opportunity of a circular economy, bringing together complementary schools of thought in an attempt to create a coherent framework, thus giving the concept a wide exposure and appeal.[18]

3 +

Conclusion

Based on the analysis of the 4 sustainability assessment systems, circular economy was chosen the best fit for sustainable progression in the product development department.

How well translates the assessment into executable goals within Accell Group?

2 ++

The circular economy provides the ultimate environmental vision; no negative impact on the environment, by providing circular strategies that keep materials endlessly in loops. To achieve its vision, a circular economy also offers strategies in the form of circular, profitable loops. This gives a great starting point for a strategy and executable goals within Accell.

How does the methodology relate to the product development process?

1 ++

Furthermore, using recovered materials and preventing material from turning into waste are also responses to the two factors that currently have the biggest impact on the environment in the product development process (use of virgin materials & end-of-life processing). The main strategy of the circular economy to reach its vision (extending lifetime of products and keeping them in loops) is achieved through rethinking the design of products. Several strategies are developed that help in preparing products for these loops. This makes a great fit with the product development process.

On top of that, the circular economy has a balanced ecological and economical rationale; providing not only sustainable but also profitable ways of driving business. This resonates with the needs in Accells company culture where sustainable progression is often seen as a trade-off for financial progression; and where financial progression has won so far. The profitable opportunities in the world of recovery could katalyse their progression towards sustainable product development. The system level approach on which the circular economy is based contributes to a company wide implementation: not only in the PDP but also other company departments like marketing and supply chain.

What is the ‘momentum’ of the assesment?

3 +

Lastly, the term ‘circular economy’ is visually self-explanatory, and has developed momentum over the recent years. The easiness of understanding the main goal and growing familiarity with the concept, could be a possible benefit for a faster progression towards implementing the strategy in the PDP.

1.4 Getting ready to explore

To achieve the project goal, initial research on the circular economy and its application within Accell showed that in order to establish circular design guidelines, you need to involve the circular system in which it operates. With circular system I mean the circular loops the product will move through, and the circular business model which make these loops economically feasible or even profitable for Accell.

Although my preference was in designing these business models (as this is a very attractive motivator for Accell to move towards a circular PDP, because of the financial opportunities), it was repeated to give priority to integration in the development process, by establishing design guidelines for the project team. There was a ‘conflict’ between the insights gathered during the analysis phase, and the direction of this priority. Eric asked for focussing on the PDP and guidelines for designers and engineers, as they are the ones who develop the bicycle. Although agreed that this would be part of the research (insights from interviews also showed the demand for such guidelines and need for a checklist), there was also the clear insight that although designers are motivated to progress in sustainability, the culture in Accell doesn’t allow this design freedom as costs and speed of execution have a higher priority. Furthermore there was the insight circular product design only has value, when the system in which the product lives uses it’s circular advantages.

As the business model was no option, the main goal was establishing a circular progression tool that initiates the people from I&T and Accell as a company to make steps towards the circular economy, that could be integrated in the PDP.

To achieve this, it was concluded the tool would include guidelines and assessments on a **system** level and on a product development level (**design**). This bridges bottom-up efforts (progressing in circular product development and being able to quantify this) and top-down decision making (setting goals and evaluating progress).

The last circle, **components**, was identified because of the large amount of components included in bicycles that were not designed by Accell, and therefore guidelines could not be applied directly. This wasn’t a topic for research, but is mentioned already to show the correlation between system, design and (supplier) components.

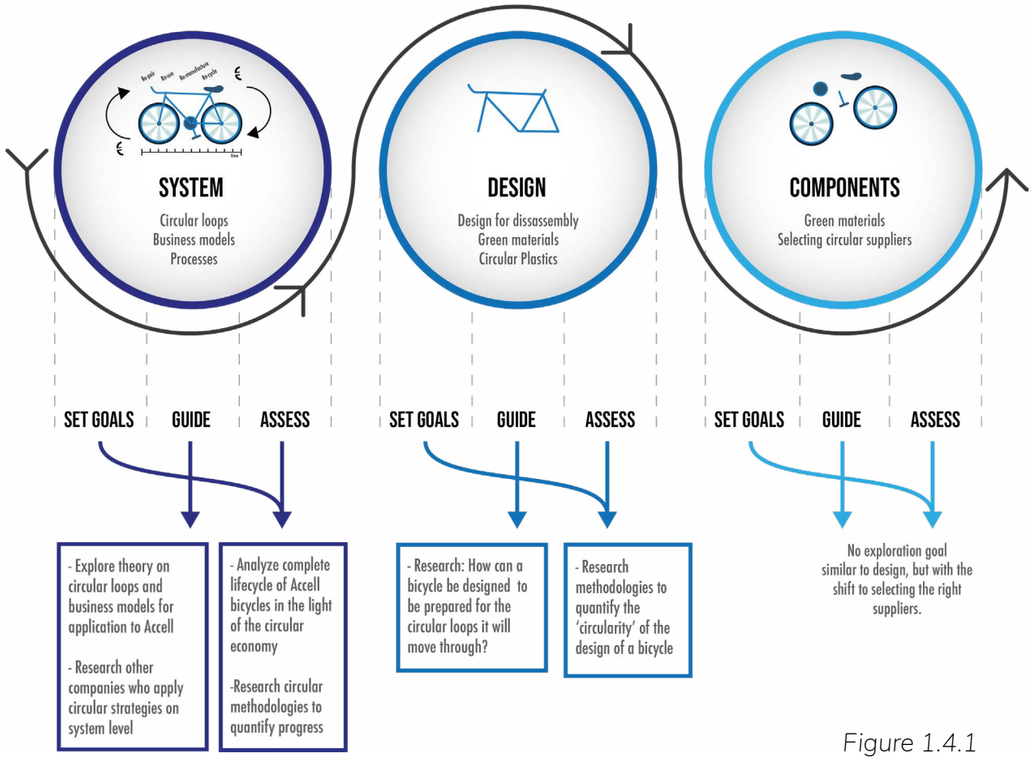


Figure 1.4.1

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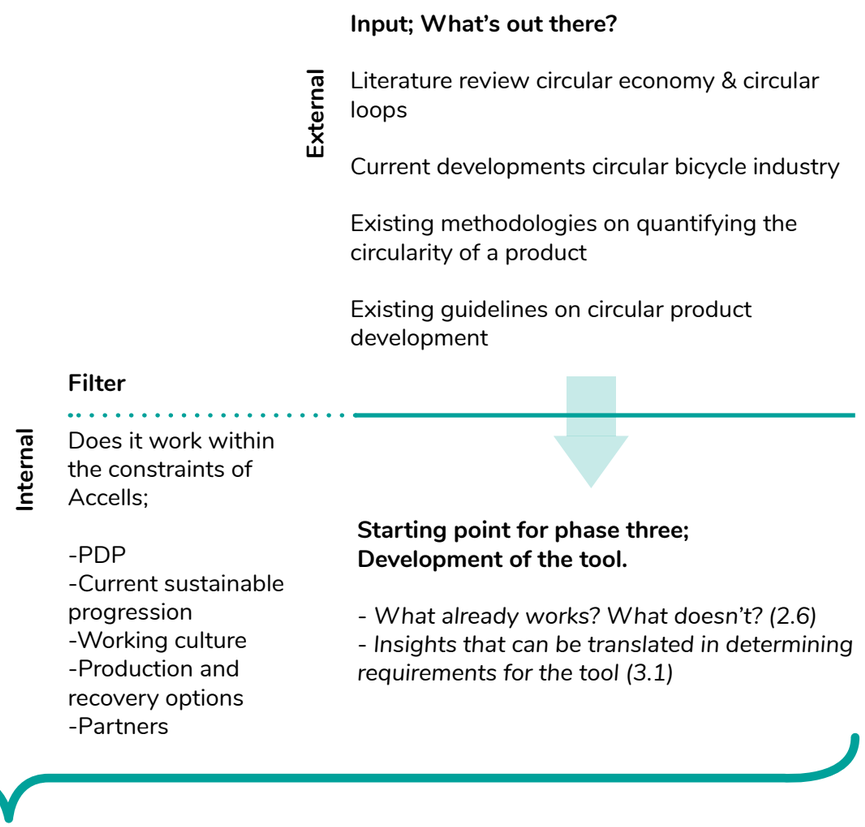
Circular exploration

2.1 Chapter introduction

Now the circular has been chosen as the main strategy, this chapter aims to explore what strategies, processes, methodologies and guidelines can be of use to the creation of a circular tool for Accells PDP.

First external information with regard to the circular economy is analyzed; circular strategies used by other companies, current development in the bicycle industry, existing methodologies on quantifying product circularity and circular guidelines.

Then, research into Accells own possibilities and limits (some already established in chapter 1) are used as a filter to create a starting point for phase three, development of the tool



Research questions for exploration

1. Which circular loops and circular business models can be applied to Accel (in the short & long term)?

2. What circular strategies used by other companies are applicable to Accell? What can we learn from their business models / circular loops? What can we learn from their design of bicycles?

3. What can we learn from the lifecycle of a bicycle from a circular perspective. What should designers focus on?

4. How can a bicycle be prepared for the circular loops it will go through, in its design?

5. What methodologies are there to assess progression in circularity, and to which extent can they be used in the current PDP?

2.2 Introduction to circular loops

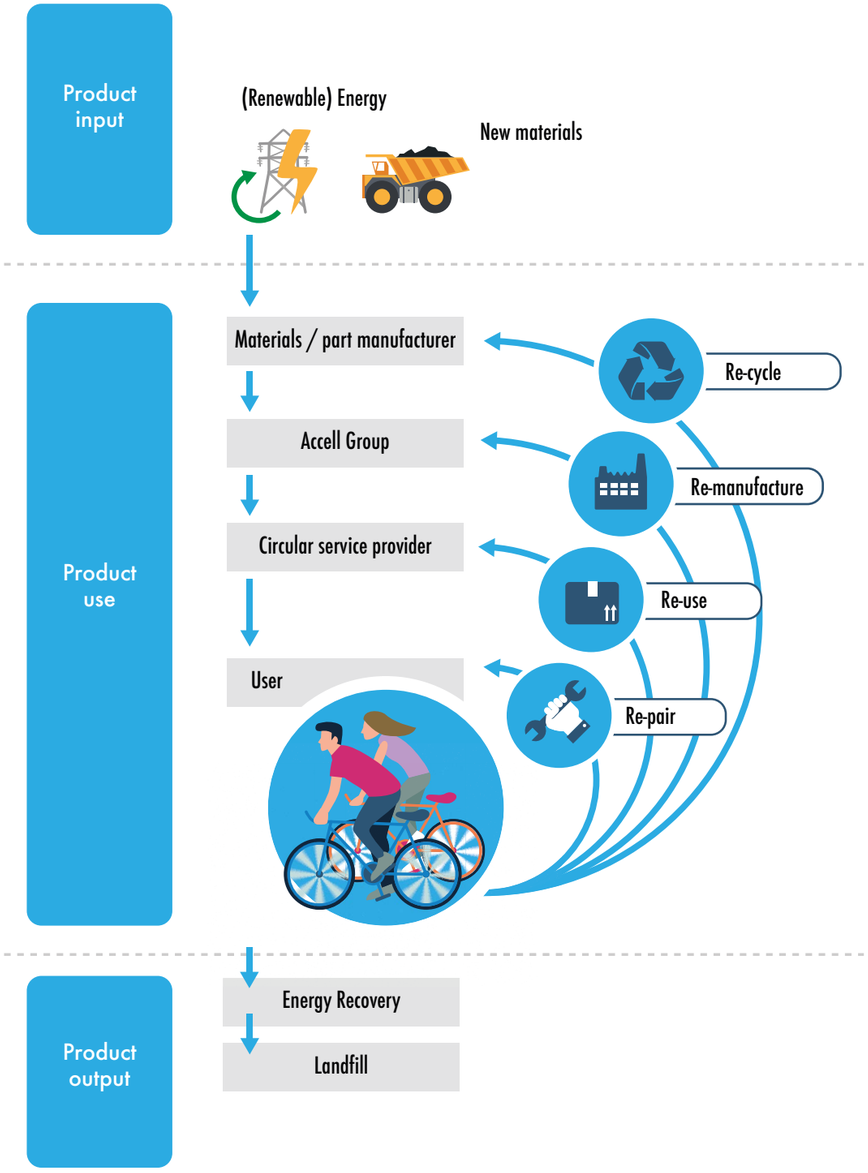


Figure 2.2.1

To better understand the concept of the circular economy and it's circular loops, in this chapter the vision, principles and loops of a circular economy are reviewed. This chapter is meant for those who are yet unfamiliar with the concept of a circular economy, and purely interpretates existing literature from a product perspective; the bicycle. Further investigation in to what extend the current lifecycle of Accell bicycles fit within the model of a circular economy, and potentially can in the future, is investigated in chapter 2.5.

The circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models." (Kirchherr, Reike & Hekkert, 2017)

Restorative and regenerative are responses to the idea of 'technical' and 'biological' loops, a distinguishing feature introduced by cradle to cradle. They can also be referred to as 'consumption products' (products that are consumed, like soap or food) and 'service products' (products that are used, like bicycles)

With relation to the Accell product development team, this results in three points of focus to comply to during the development of new products in sync with the vision of the circular economy;

Make Using as many recycled and/or reused materials as possible

Use Extending the useful life of products as much as possible

Recover Collecting as many materials and products for recycling and reuse as possible
(By designing products that are easy to reuse and recycle)

To extend the useful life of a product as much as possible, 4 circular loops are introduced. Although in all steps materials are being preserved, this gets harder and more energy intensive on the outer loops (recycling) as it breaks down all components including their embedded production energy into seperate materials.

Re-use

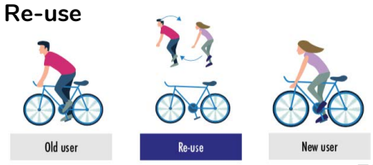


Figure 2.2.2

By re-using a bicycle, value of the bicycle is kept most high by simply providing it to a new user. This can for example be a consumer buying the bicyle second-hand, or through leasing the bicycle to customers.

Re-pair

Figure 2.2.3

Another way to prevent a bicycle from being discarded, is to repair it. By adjusting the bicycle design to more easily repair it, it can extend it's lifetime.

Re-manufacture

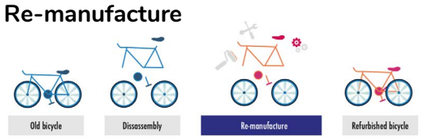


Figure 2.2.4

Instead of repairing what is broken, it is also possible to take the well-working parts of a broken device and use them for something new, or sandblast and repaint a component into a second life. This process is called remanufacturing.

Re-cycle

Figure 2.2.5

With recycling you take something apart until you get back the original resources you used to make it, these can then be used to make new products and parts from scratch. This can be something entirely different, like a new bicycle model.

2.3 Accel Circular business models

This subchapter researches the question; Which circular business models can be applied to Accel (in the short & long term)? The book 'Products that last' was used to identify circular business models that Accell currently uses or potentially fit in the short term future. Three out of 5 business models were selected; The classic long life model, the hybrid model and the access model.

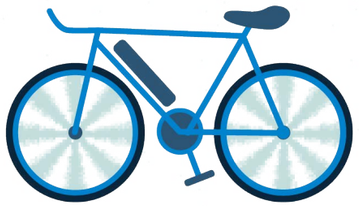


Figure 2.3.1

Classic Long Life Model

The classic long life model proposes a high quality product with a long lifespan, with sales as the classic income. This is the business model Accell traditionally has always applied by having a portfolio of high-quality durable bicycles. Their bikes are designed to have an expected useful lifetime of either 6 or 10 years, depending on the type of bicycle.

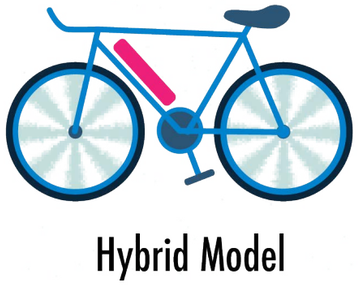


Figure 2.3.2

Hybrid Model

In this model, profits are made from the repeat sales of relatively cheap products with a short lifespan that only function together with a dedicated high-quality durable product. Currently, Accell is partly doing this with their brand XLC, that globally sells bike parts. But a lot of circular options are still unexplored. Think about selling the bicycle but leasing the battery, which is according to the LCA the component with the biggest impact on the environment. Subscription models for shortest lifespan bicycle components, like brake pads, the chain, sprockets, cables and tires, could increase revenue while easing maintenance and expending lifetime.

Access Model

The third and final one is the access model. The fundamental difference is that with the access model, the ownership of the product created by a company remains with the access provider. There is a time limit and products are used in turns. This change has big influence on the design requirements a company develops for it's products, since for example a longer product lifetime can save costs or create extra value.

Access models can help to facilitate the collection of the products while creating new sources of revenues (e.g. by combining the model with a service offering) and capturing larger market share (e.g. by making a product available at a low initial investment). [source; ellen macarthur foundation]. In the case of Accell, Access models can be obtained by either leasing contracts for their individual brands, or third parties could serve as the access provider.

The first case was introduced in the beginning of 2020; leasing options for Sparta, Batavus and Koga bicycles. Sten van der Ham, regional director Accell Benelux mentioned '"The bicycle market is shifting from ownership to use with complete unburdening for the consumer. Without purchase costs for an (electric) bicycle with a uniquely low deductible.' But all possibilities concerning

Figure 2.3.3

circularity and the related marketing value if these benefits are communicated well with the consumer, are not yet explored.

The second possibility is third parties serving as the access provider. This would mean Accell could still sell the bikes to these third parties (therefore not keeping ownership). However, design goals could still be in line with the ones prefered for an access model, since this is beneficial for the third party. Also, at the moment of graduation, is involved in such a project. One of their main theme of criteria is sustainability. Currently we're developing a response to the tender where circular thinking is applied on both a system level (collaboration with a circular service provider to re-manufacture and disassemble for recycling) and product level (optimization for disassembly, reduction of toxic materials, optimization for repairability and optimization for recycling).

Conclusion

Short term and long term focus in circular business models

For the majority of bicycles, Accell applies the classic long life model, by creating high quality bicycles. If remanufacturing and recycling are not considered by Accell management, their focus should be on using as many recycled materials as possible, and producing high quality - long lasting bicycles.

As Accell has already partnered up with a leasing service company to lease their bike, it is recommended to consider adjusting to leasing model to the vision of a circular economy.

For the long term, Accell should consider shifting from a product-company to a product-service company, to fully profit from the opportunities of the hybrid and Access model and stay relevant and profitable in a more sustainably demanding society.

Inclusion of the three models guidelines to create understanding of their potential

As awareness of the relation of circularity to these business models is very low, these 3 business models will be included in the system guidelines to include sustainable benefits in the development of new business models.

2.4 Circular strategies

For Accell, circular bicycle development is a new movement. But also in existing literature; Although in research the role of bicycles in a circular economy has been explored in the area of shared mobility,

To it helps to know what existing bicycle companies play a role in the circular economy, and in what manner.

Relevant research question:
What circular strategies used by other companies are applicable to Accell? What can we learn from their business models / circular loops? What can we learn from their design of bicycles?

Figure 2.4.1

Dutchfiets

Dutchfiets is a circular bike made out of recyclable plastic. In their own definition, it is not a bike, but a circular mobility concept. This is an excellent example of a product that is the result of design for the circular economy. The company takes responsibility for their waste, by offering up to 100 euros to their customers if bikes are returned. This shows how Dutchfiets integrates circular thinking not only in the development of their bikes, but in the way they operate as a company. The 100 euro pay-back, part of their business model, enables them to have a bigger grip on the impact of the environment.

Following the business model, the design of the bicycle is completely focussed on circular principles. They aim for low maintenance through robust design, lowering the chances of components breaking. All materials used in the frame, wheels and sadle are 100% recycable. In addition to their effort to close all material loops, their production runs on solar energy.

Insight

Possibility to retreive bicycles also works in classic long life business models, by Incorporating a pay-back.

Figure 2.4.2

Roetz

Roetz, an Amsterdam based company, has circularity at the core of it's purpose. They provide new, unique, customizable bicycles through re-manufacturing discarded bicycles. While doing so they train people with a distance to the labor market into experienced bicycle makers. But even without the lower costs of this working group they are able to be profitable, became clear in an interview with Tiemen ter Hoeven, one of the founders.

With their current collection, they are 30% circular. In a project performed for NS, they were able to achieve a significantly higher score of 70%. Their mission is to become 100% circular. They have a strong focus on the German market because of their interest in sustainability and willingness to pay extra for this. This is a positive insight for Accell, since Germany is one of the biggest buyers from Accell bicycles.

Although they are known for their circular production, their main unique selling point is creation of unique bicycles that contain a story. One of the ways they communicate this, is by attaching a card with the name of the builder to the bicycle.

Insight

It is proven by Roetz that remanufacturing bicycles can be profitable.

Figure 2.4.3

Mokumono

Another dutch brand, Mokumono, produce lightweight urban bikes; both electric and non-electric. While the bicycle industry is looking to the Far East for its production, Mokumono is looking locally. To be able to produce a bicycle frame in the Netherlands, they developed a radically new production process. One requirement was that to compete with the Far East low cost production, they had to make the production process as automated as possible. Due to this high degree of automation, they looked to the automotive industry for inspiration.

The production process of a Mokumono frame starts with two flat plates of aluminum. To make two mirrored frame halves, the plates are pressed into shape. In the final production step, the halves, together with the bottom bracket, seatpost tube and steering head, are connected by means of robotic 3D laser welding.

This significantly reduces the ecological footprint for the environment by not using outsourcing, but keeping the production process entirely in the Netherlands. As an added benefit, this also has a positive impact on employment.

Insights

Mokumono proves rethinking the production process can make local production feasible. However, such radical changes in design could have trouble fitting in Accell's current brand portfolio with regard to aesthatics

Figure 2.4.4

Figure 2.4.5

The Imagine Project

The imagine project is an initiative from Isla Bikes. Isla Bikes is a company that mainly focusses on the design of bikes for childeren, based in England. Their imagine project is rethinking the way bicycles will be made and supplied in the future.

The guidelines for design the Imagine Project used:

- Materials and components will originate close to the place of manufacture, minimising the environmental impact and energy used in their transport.
- Material composition (including any applied finish such as paint) must facilitate easy separation and reprocessing at end of life and ensure material value is maintained, not downgraded.
- 100% reused materials, therefore removing demand on finite natural resources.
- Manufacturing to be done in the UK.
- A 50 year lifespan for each Imagine Project bicycle.
- Zero maintenance for the user during the typical rental period.

Insight

The guidelines show a very complete approach; not only design is taken into consideration, but also the complete lifecycle of the bicycle and the role of Islabikes in this. With regard to the circular principles, they focus on all of them (make - use - and recover); from a recovered material origin, to extendid lifetime (50 years, ambitious), to end-of-use strategy's.

This is their first imagine project prototype. For the frame, stainless steel is used. It has very understood properties since it has been used in the development of bikes for 130 years. [source] Stainless steel is more expensive than regular steel, but this would require a coating to prevent the frame from corroding. The choice was made to use non-coated stainless steel to avoid the need of removing paint and other finishes at the end of life.

The Sadle is designed in collaboration with Brooks, established in 1866 in Bermingham. Their 'Cambium' saddle is constructed with stainless steel rails and natural vulcanised rubber with an organic cotton top. Designed for long life, they are also fully re-buildable with spare parts readily available.

The pedals are manufactured from rice husks, a product of rice processing. This Taiwanese produced pedal has sustainable credentials and is a novel way of taking a waste product from a mass production process and turning it into something usable.

Figure 2.4.6

Ziltbikes

Ziltbikes sells and leases both new and second-hand bicycles to customers and B2B. Similarly to Roetz, they involve people with a distance to the laber market in the service they offer. They don't manufacture the bicycles themselves, but have a partnership with Accell. Their main value is in offering maintenance to company bicycle fleets.

Insights

The main value in the partnership Ziltbikes currently has with Accell is the service (maintenance of bicycles) they are able to offer in leasing bicycle fleets (business to business).

Although through this partneship Accell can align projects with one of the circular loops (repair), this partnership potentially opens up the possibility to remanufacture bicycles produced by Accell. Ziltbikes is able to collect and disassemble bicycles. Dissassembled components can be remanufactured using Accell's facilities in Heerenveen (sandblasting, paintjobs, stickers, assembly). Re-Distribution could be performed by Ziltbikes.

A plan for such a collaboration is formed during the tender response the tool was validated by. More information on this can be found in chapter 5, validation.

Conclusion

First of all, we can validate that various examples of existing bicycles and companies prove the fact that a bicycle can be desiged and adjusted for a circular economy, through a wide variatons of design solutions and business model adjustments.

Although this validation its examples can be used to motivate Accell management and activate employees, it gives insights in project-specific solutions. Our tool is created for a general process and therefore should leave interpretation of business model and bike adjustments open.

For that goal, we can conclude that partnering up provides multiple purposes that benefit the circularity of a project; the partner being a circular service provider (re-use) and the partner helping in the remanufacturing process.

2.5 Circular lifecycle

Three main principles of the circular economy are; Using as many recycled and/or reused materials as possible, extending the useful life of products as much as possible and collecting as many materials and products for recycling and reuse as possible (By designing products that are easy to recover). To integrate these principles in the Accell product development process, it helps to know to what extend this is happening at this moment, and where opportunities for improvement are. Therefore, the bicycle life cycle is analysed from the perspective of the circular economy.

Relevant research question

What can we learn from the lifecycle of a bicycle from a circular perspective. What should designers focus on?

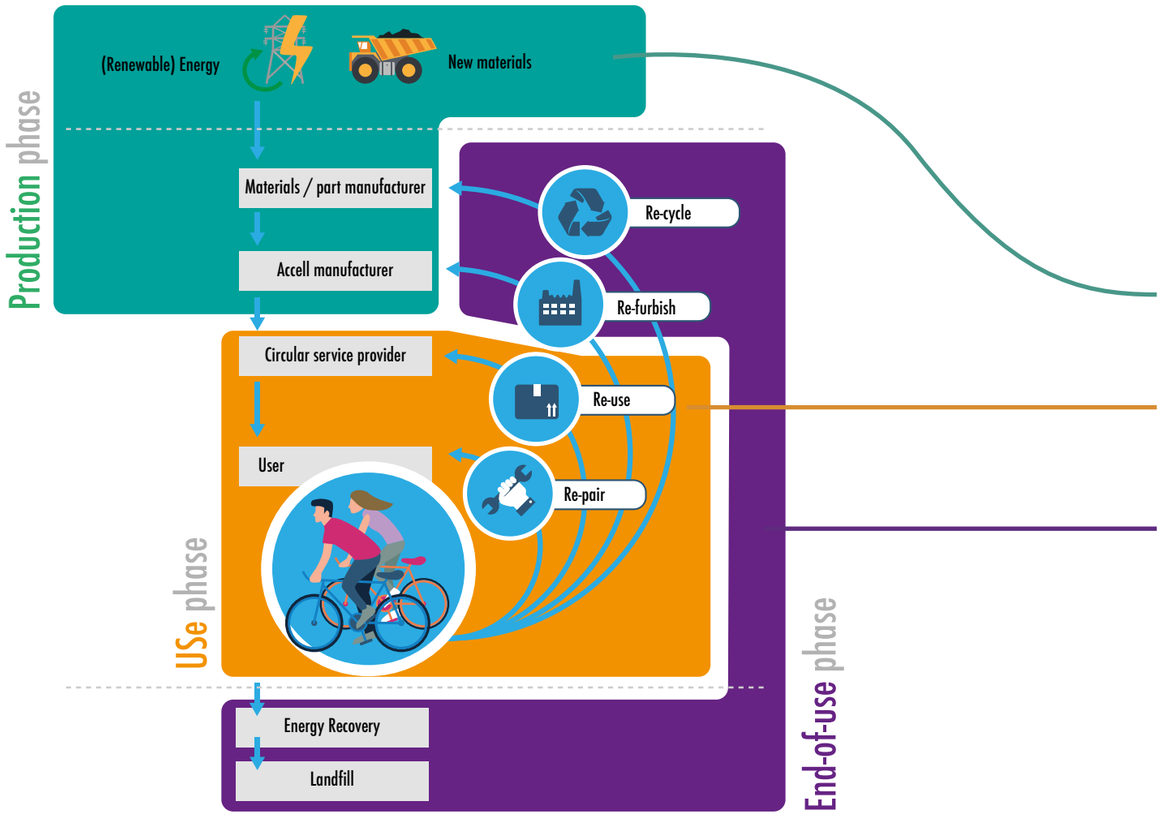


Figure 2.5.1

Where do Accell components and materials come from?
To what extend from recovered sources?
Any processes in the production process that are currently or potentially enable remanufacturing or recycling?

How durable are bicycles produced by Accell compared to the industry standard?
Are they easy to repair and maintain, to extend the lifetime of the bicycle?

Where do the bicycles end up?
Do any initiatives for bicycle recovery exist?
Do all go to waste processors?
And if so, how does the waste processor process an end-of-life bicycle?
Which materials are recovered, which not, and why?
With the analysis of current end-of-use, what opportunities for future end-of-use within Accell?

Production Phase

Insights;

The design freedom of the designer can be categorized in two options.

- form (always the frame, most of the times; front fork & bicycle carrier. Depending on the bicycle; lightning, steering wheel)

- choice; All of the other components used in the bicycle, not designed by Accell, ordered from suppliers

Where do Accell components and materials come from? To both of them applies that almost none are locally produced, majority of the components in the far east. Of Both Accell designed components and supplier designed components the materials used in components are known.

To what extend from recovered sources?
No internal knowledge currently provides designers with information on energy usage in production of these materials, the origin of materials used in production of components and their recycling properties. Also, the weight of components from suppliers is not documented.

Although the information is not known, it is assumed all frames are created from 100% virgin materials as this is considered a to provide a higher quality.

'The higher the percentage of recycled material you would use, the more unstable and lower the quality'

When HKS metals was contacted about this, they mentioned in the recycling process materials get downgraded but metals are preserved. Alluminium 6061 (almost used for every metal frame produced by accell) has the potential to be 100% fully recycled, and properly recycled 6061 does not have a lower quality than virgin 6061. When Accell was asked for feedback / different experiences with this matter, no response was given. HKS further mentioned that it would make recycling more easy if purely aluminium 6061 was used in the recycling process (by providing selective recovery).

Any processes in the production process that are currently or potentially enable remanufacturing or recycling?
It has been proven the current assembly lines can be used for dissassembly.

Opportunities lie in selecting suppliers based on their material use, as this would directly target one of the main negative impacts on the environment (chapter 1.1), and directly aligns with the recycling circular economy strategy (chapter 2.2) To achieve this, transparancy has to be created in the supply chain.

Recovering used components could potentially be more profitable, since a selection of only aluminium 6061 would simplify the recycling process (confirmed by HKS metals).

Points of improvement in the production phase of the lifetime of a bicycle;

Start using recovered materials in stead of virgin materials;

Accell should create the ability to select suppliers based on their use of recovered materials. Therefore, supply chain needs to create transparancy in material origin using their audits. Also, the Technology & Innovation department needs to integrate this data in their PDP documentation. Most logic choice is the Bill of Materials.

Accell could research what the costs of dissassembly of a bicycle would be using the assembly lines in a reversed proces. The fact that it has been done before proves it's feasible. In combination with the creation of new circular business models, it could start a movement of re-manufactured bicycles created from recovered components in stead of using virgin materials.

How can these point of improvement be achieved?

The documents used in the PDP should include placeholders regarding material origin to create both transparancy and data about recovered material use

The tool should differentiate components designed by Accell, and components bought from suppliers

Designers should be informed on sustainability aspects of common materials used in the Accell PDP, and more sustainable alternatives

Use Phase

How durable are bicycles produced by Accell compared to the industry standard.
In the research of this thesis, no relation has been found between the lifetime of an Accell bicycle versus those of the industry in general, due to a lack of data. Accell does have information available about expected lifetime of a bicycle, but there was no industry data to compare this to.

Designers from Accell did mention Accell safety regulations for testing often take an extra 20% on saftey requirements than what the industry considers safe. Furthermore, Accell builds mid to high-range bicycles, of which the quality can be considered in alignment with the goal of extending the lifetime of a bicycle.

Are they easy to repair and maintain, to extend the lifetime of the bicycle?
Repairability of their bicycles in general is considered relatively easy, since wear parts are easy to reach and replace. A methodology to test this is further analaysed in chapter 2.5.

End-Of-Use Phase

It is of importance to analyze this recycling process, because understanding the recycling process can give insights in how the design of the bicycle can be adopted to be better prepared for this process.

Where do the bicycles end up?
Although some directly in incenators, most at scrap dealers and container parks.

Do any initiatives for bicycle recovery exist?
Some Companies like Roetz (chapter 2.4) recover bicycles. However this concerns relatively small businesses. there is no industry solution currently for bicycle recovery.

How does the waste processor process an end-of-life bicycle?
Figure 2.5.2 displays a summary of the recycling of a bicycle. Extensive research on this question can be found in appendix D.

Which materials are recovered, which not, and why?
Most metals are recoverd, the majority in downgraded form. To recycle these, virgin metals need to be added to upgrade the quality

Can design prepare the bicycle for this type of processing?
Many details about material properties on both metals and carbon were found during research. The information was won through online research and contact with waste processors and provides relevant knowledge for Accell designers and engineers. Therefore it will be included in the circular guidelines.

With the analysis of current end-of-use, what opportunities for future end-of-use within Accell?
Conversation with the head of sustainability showed little interest in creating a remanufacturing loop for their end-of-use products, but wants to prepare bicycles for disassembly in case the industry comes up with a solution. Since this is not something that the industry is planning to do on the short term,

With respect to remanufacturing; because with manufacturing the shape of the component remains the same and a complete loop of recycling is prevented, lots of value is retained. Erwin from HKS metals confirmed this and believes in a possible profitability in case Accell implements such a loop in their business model.

With respect to recycling; because of the complexity and use of many materials in current bicycle design, manual disassembly for recycling is economically not attractive. Only If assembly time can be broken down drastically, and the results are a few main components created out of the exactly the same material, it could be an opportunity for profitable recycling.

From an environmental perspective, it is valuable, since the materials used in the bicycle wouldn't be downgraded and burned, would be recycled (depending on the material health). Keep in mind though, that although lots of material is downgraded, almost all metal is preserved and kept in loops for lower purposes.

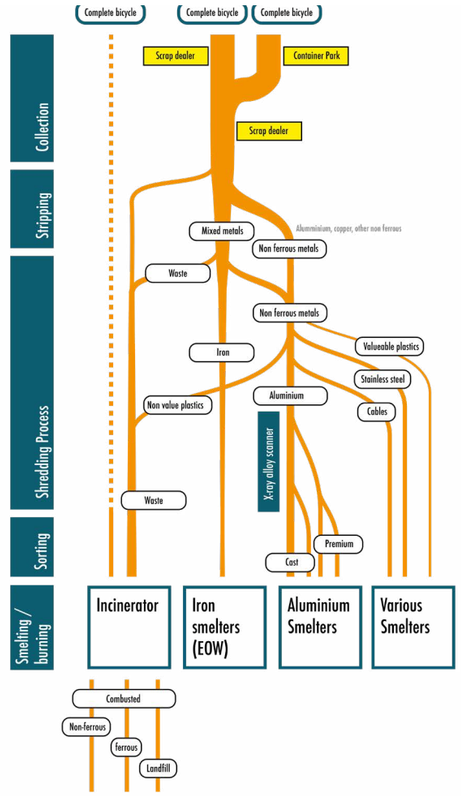


Figure 2.5.2

What can we learn from the lifecycle of a bicycle from a circular perspective. What should designers focus on?

Knowledge / Guidance for designers

Analyzing the lifecycle of a bicycle provided insights in what is important in the design of a bicycle to function in a circular economy. One takeaway is to prepare the way it is designed for the circular loop the business model provides. How to do this is discussed in chapter 2.6 'exploring guidelines'. This chapter mainly gave insights in the material aspects of bicycle design in a circular economy. As 'Designers should be informed on sustainability aspects of common materials used in the Accell PDP, and more sustainable alternatives', information won during the analysis was included in the guidelines.

For the three circular principles, what is important about materials?

Make

How much % of the material from the supplier is recycled?

How much energy does it take to supply this material (embodied energy)

Is the material toxic?

Use

How durable is the material?

Is the material toxic?

Recover

Can the material be recycled, or biodegraded?

Will it be recycled? (Circular Systems)

How much energy to recycle the material?

Is the material toxic?

Figure 2.5.3

	Recycle?	Downcycle?	Combust for energy recovery?	Biodegradeble?	Toxicity rating	Embodied energy primary production (^7 J/kg)	Embodied energy recycling (^7 J/kg)	Ratio	Casting (^7 J/kg) (for metals)	Extrusion (^7 J/kg) (for metals)	Polymer extrusion energy (^7 J/kg)	Polymer molding energy (^7 J/kg)	Recycle fraction in current supply (worldwide)
Aluminium 6061	1	1	0	0	Non-toxic?	20	3,4	5,9	x	0,67	x	x	42%
Staal	1	1	0	0	Non-toxic	3,1	0,81	3,8	1,17	0,55	x	x	42%
verchroomd staal	1	1	0	0	Non-toxic	3,2	0,85	3,8	1,25	x	x	x	53%
messing	1	1	0	0	Non-toxic	7,25	1,6	4,5	1,01	0,98	x	x	38%
koper	1	1	0		Non-toxic	5,9	1,31	4,5	0,91	0,16	x	x	43%
rvs	1	1	0	0	Non-toxic	7,3	1,6	4,6	1,14	1,02	x	x	37,5%
zamac	1	1	0	0	Non-toxic	5,25	1,23	4,3	0,67	x			22%
PE	1	1	1	0	Non-toxic	8	2,65	3,0	x	x	0,62	2,2	8,4%
PP	1	1	1	0	Non-toxic	6,9	2,35	2,9	x	x	0,62	2,15	5,6%
pu schuim	0	1	1	0	Non-toxic	8,2	x						0,1%
PET	1	1	1	0	Non-toxic	8,3	2,65	3,1	x	x	0,625	2,2	8,4%
EPS	0	1	1	0	Non-toxic	12,8			x	x	x	2,2	0,7%
PC	1	1	0	0	Non-toxic	10,5	3,67	2,9	x	x	0,62	1,85	0,7%
rubber	1	1	1	0	Non-toxic	11,28	x			x	x	1,61	0,01%
PA	1	1	1	0	Non-toxic	14,5	4,3	3,4	x	x	0,625	2,15	0,71%
ABS	1	1	1	0	Non-toxic	9,2	3,25	2,8	x	x	0,62	1,85	4%
li-ion	0	1	0	0	Toxic								
karton	1	1	1	1	Non-toxic	5,2	2,2	2,4	x	x	x	x	72%

Figure 2.5.4 - Sustainability aspects of most used Accell materials (source; CES)

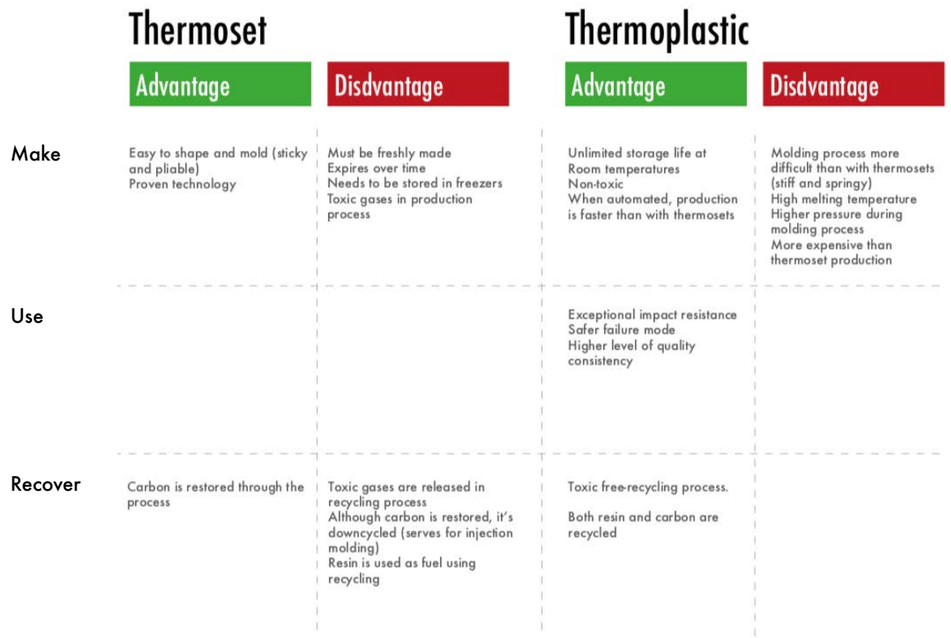


Figure 2.5.4 - Comparison thhermosets and thermoplastics

Figure 2.5.5 -Comparing recycling of thermosets & thermoplastics

2.6 Exploring Guidelines

The redefined project goal stated in chapter 1.5 states the necessity to guide different users towards circular product development.

In chapter one we've chosen the circular economy as sustainable strategy for the PDP. Insights and knowledge from analyzing a bicycle in a circular perspective (2.4) was used a starting point for guiding designers. Now, research is performed towards existing guidelines for circular product development.

Relevant research question

4. How can a bicycle be prepared for the circular loops it will go through, in its design?

The following guidelines were selected by initial impression (relevance to bicycle design, connection to the circular economy , and reliability of the source (known organization or grounded by research) and further analyzed to see what aspects of these guidelines were applicable for Accell. Although summarized and compared at the end of this chapter, finding and applying guidelines took place through a 2 month timespan with the internship at Accell.

A product design framework for a circular economy - van den Berg M.R. and Bakker C.A.
Autodesk design guidelines - Autodesk
The circular design guide by - IDEO
10 golden rules by ecodesign - KTH Machine Design
Designing circular plastics - PolyCE consortium

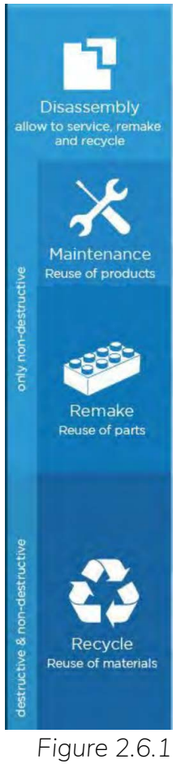


Figure 2.6.1

A product design framework for a circular economy

A paper published by van den Berg M.R. and Bakker C.A. provides a circular economy framework from a product design perspective with tools to aid product designers in applying circular product design in practice. Insights were gained in master graduation project for Philips that led to an adapted circular economy model. Next, several tools were developed to aid a designer with the application of circular product design.

The three tools that were developed are; A vision, a guideline and a spider web. One main takeaway from the guideline is that disassembly is part of every circle and thus represented by a line on the left side extended downwards, divided in non-destructive and destructive disassembly.

Analysis

Extensive, grounded guidelines
From the guidelines analysed, this one is the most extensive. Guidelines are categorized and sub-categorized on the goal they want to achieve. Each goal is connected to 1 or more means, which are backed up by literature (Balkenende, Aerst, Occhionorelli, & van Meensel, 2011) (Desai & Mital, 2003) (Hata, Kato, & Kimura, 2001) (Hultgren, 2012) (Ijomah, McMahon, Hammond, & Newman, 2010) (Mital, Desai, Subramanian, & Mital, 2008) (Peeters, Vanegas, Dewulf, & Duflou, 2012) (Peeters & Dewulf, 2012) (Sundin, 2004) (Mulder, Basten, Jauregui Becker, Blok, Hoekstra, & Kokkeler, 2014).

Alignment in tools
What really sets this tool apart, is the fact that the vision directly translates to the guidelines, and the guidelines directly to the spider map. There is a very clear alignment through the 5 core principles that are stated; future proof, disassembly, maintenance, remake, and recycle. The circular design vision can be used for a quick-scan approach, the guidelines for detailed design and the spider map for comparing products and as a discussion tool with experts from other areas.

Scope
Product-focussed, with some relevant system guidelines (for example; local production, product can be easily returned).

Theoretical vs practical
Practical; the guidelines are divided over goals & means, supported by different sources of literature / research that acknowledge the methodology.

Autodesk design guidelines

Autodesk offers in the form of video a very complete list of guidelines. The guidelines are not explicitly linked to the circular economy, but do perfectly align with the principles it is based on. Their instructions range from system thinking (improving product lifetime) to product thinking (design for disassembly and recycling, design for repair and maintenance).

Analysis

Especially their product thinking guidelines form a great start for Accell; specified for different aspects of a circular economy, practical, understandable. The individual guidelines are very logically connected and follow each other up. They have clearly distinguished guidelines. On a product design level; one focuses on ease of disassembly and recycling, one on repair and maintenance, and one on choosing green materials.

Scope
System-focussed and product focussed.

Theoretical vs practical
System-focussed is theoretical; understanding the lifetime of a product. Product focussed guidelines are practical; straightforward .

The circular design guide

A collaboration between the Ellen Macarthur Foundation and the IDEO company resulted in ‘the circular design guide’. An online platform that offers workshops, methodologies and stories about getting started with designing circular products, services, business models and systems. They lined up a number of methodologies to help to understand, define, make, and release circular innovations. These activities are split into 4 different categories; Understand, Define, Make & Release.

Analysis

Lack of relation
Although the segmentation of 4 categories makes a lot of sense, each methodology is stand-alone and there is no clear order or connection between the methodologies, except for their category.

Scope
System level - The ideo guidelines are created for complete company transformation. There are some product-related workshops (material selection, product redesign workshop) but the majority is related to system-transformation; understanding circular flows, service flip, create brand promise.

Lack of clear design principles
They provide workshops / methodologies using a combination of ‘design thinking methodologies’ and the main theoretical principles of a circular economy. There is a clear overlap with general design methodologies, but no detailed product design suggestions like ‘A product design framework for a circular economy’ provides.

Checklist
Included in the circular design guide, is a checklist; covering design for dissassembly, design for repair and upgrades, designing for closing material loops, and designing for optimal business model.

10 golden rules for ecodesign

The 10 golden rules for ecodesign is a pedagogic summary of many of the guidelines that can be found in company guidelines and in handbooks of different origins. Although a bit outdated, not that known and the ‘different origins’ are not stated in the paper, it is a very decent set of guidelines that cover the whole lifetime of a product; considered is pre-use, use and after-use (and therefore could have guidelines in line with the circular economy). Topics covered in the 10 golden rules for ecodesign; toxicity, housekeeping, weight, energy, upgradability, long life, protect, inform, simple (decrease mixed materials) and structure.

Analysis

General
The 10 golden rules are strong in the fact that they provide guidance in product design through a simple set of 10 rules. However, these are the most general rules of the guidelines analysed.

Scope
Product level

Theoretical / Practical
Although theoretical explanation supports these guidelines, they are very practical.

Designing circular plastics

These guidelines are from PolyCE; Post consumer high tech recycled polymers for a circular economy. They were discussed during a webinar from Pezy Group. Pezy Group is an industrial design company with a lot of expertise in plastics. They became the first accredited Dutch cradle to cradle consultants in 2009, and have since enlarged their knowledge about bioplastics and recycled plastics. The guidelines provided by PolyCE are a results of insights from many stakeholders (industry, designers, compounders, manufacturers, ngo’s, weee collectors, researchers).

Figure 2.6.2

Analysis

‘World of recovery’
In the tool Pezy Group make a clear distinction between ‘the world of development’ and the ‘world of waste recovery’, which I found very clear for labeling the upper half and bottom half of the tool I had designed so far myself. The terms were integrated.

Detailed plastics design guidelines
The guidelines were shown to two Accell engineers who had experience with creating lightning components made out of plastics. Conversation gave the insight that when it comes to lightning (and therefore plastics design), the designer at Accell have no in-depth knowledge and are only responsible for aesthetics and form. The design is then send to a third company, who checks the design for strength and producibility.

Therefore, the engineers mentioned they would appreciate the plastic guidelines being integrated in the tool, as they provide very clear instructions for thicknesses and material choices, and this knowledge currently isn’t available

Outcomes

Design for Dissassembly

In both ‘a product design framework for a circular economy’ as the autodesk design guidelines, the main strategy for recovering components of products is by design for disassembly. The repair and maintenance guidelines by Autodesk were less relevant to bicycles because of Accells high-segment quality and good accessability of rapidly wearing parts (chapter 5.7).

Therefore 6 out of the 11 Autodesk guidelines were chosen as a start for guiding project in design for dissassembly teams filtered by their relevance to bicycles, and by the fact they had overlap in three out of the 5 guidelines (Autodesk, a product design framework for a circular economy, the circular design guide). As my personal expertise of bicycles of course does not compare with the level of the Accell designers, a designer was consulted to validate the choice of guidelines (and the rejection of the others). It provided a starting point, was easy to understand, and formed the basis for a first try out in a project (more on this in development of the tool).

Relation between circular business models and product design.

Shortly later in the thesis project, the insight that the design of a product is dependent on the circular system it lives in, was reason for creating an ‘understanding’ sheet to inform the project teams about this relation. The three different business models stated in 2.3 were set against the 4 circular strategies (repair, reuse, remanufacture and recycle. By using the 4 sets of guidelines analyzed, related guidelines were extracted that fitted both design strategy as circular business model. In chapter 3.5 it is further explained how this sheet was used in the first workshop on an Accell project.

Starting guidelines design for dissassembly

Fewer tools - The fewer fasteners you use, the better. Use common and similar fasteners that require only a few standard tools for dis-assembly

Faster is better
Screws are faster to disassemble than nuts & bolds
Minimize fasteners
You can minimize fasteners by using a single set to hold down several layers of parts

Use of snap - fits
Snapfits are prefered above nuts & bolds, but make them intuitive and ensure they can be done & undone

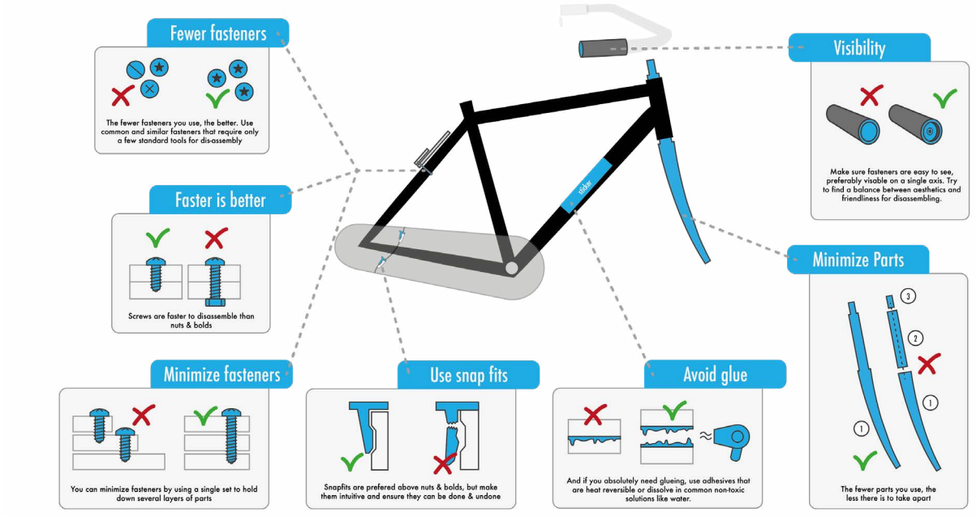
Avoid glue
And if you absolutely need glueing, use adhesives that are heat reversible or dissolve in common non-toxic solutions like water

Minimize parts
The fewer parts you use, the less there is to take apart

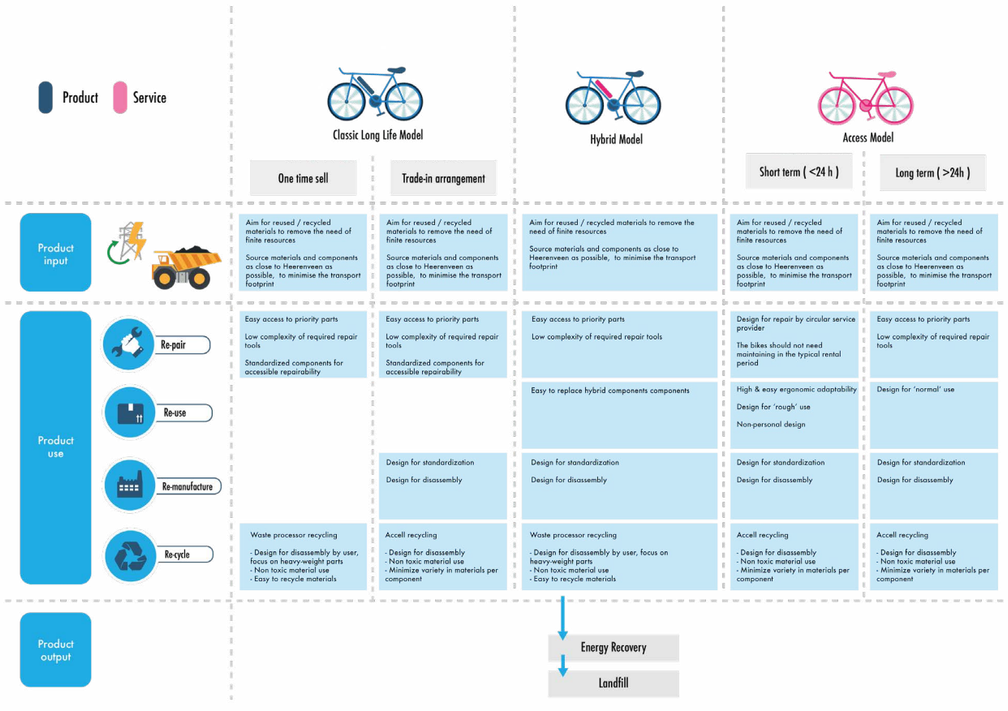
Visibility
Make sure fasteners are easy to see, preferably visable on a single axis. Try to find a balance between aesthetics and friendliness for disassembling.

Conclusion

This chapter was used to create a start in guiding project teams in circular bicycle design. Design for dissassembly was concluded the most usefull strategy within Accell and 6 guidelines to achieve this, covered by the guidelines analyzed and relevant for bicycle design, were used as a start. Furthermore, a guiding sheet was develop that linked circular business models to circular product design, using the relevant guidelines analyzed.



Visualization of the 6 guidelines - design for disassembly - Figure 2.5.4



Relation between circular business models and circular product design

2.7 Exploring assessments

In order to assess an Accell project, why not start with looking at existing indicators? This chapter researches the use of existing indicators by applying them on Accell bicycles and the data available about them. Insights are used for the quantification of circularity in Accell projects. Two main indicators were selected because of their reliable sources; Ellen Macarther Foundation & Granta Design (Material Circ ularity Indicator) and TU Delft (Hotspot Mapping Tool).

Relevant research question

5. What methodologies are there to assess progression in circularity, and to which extent can they be used in the current PDP?

Material Circularity Indicator

The Material Circularity Indicator (MCI) tool, allows companies to identify additional, circular value from their products and materials, and mitigate risks from material price volatility and material supply. MCI measures how restorative the material flows of a product, which can be aggregated up to product portfolio, and even further up to company level.

Users

The indicator can be used as a decision-making tool for designers but might also be used for several other purposes including internal reporting, procurement decisions and the evaluation or rating of companies

The indicator can be used internally to compare the circularity of different product ranges and departments. They can also allow tracking of progress on a product range, department or at whole company level.

Lastly, the indicators can be used externally by third-party stakeholders to compare the circularity of different companies that make their scores available to them.

Indicator methodology

The methodology calculates the percentage of circularity by classifying the data into 3 phases;

Construction phase
Use phase
End-Of-Life phase

For the construction phase, material circularity increases as virgin feedstock decreases. Simultaneously, if recycled feedstock or reused component increase, material circularity increases as well.

To calculate the use phase, two variables play a role. One accounting for the length of the product's use phase (lifetime) and another for the intensity of use (functional units).

For the End-Of-Life phase, material circularity increases as the percentage of material collected for recycling, and components collected for reuse increases. Also higher effectiveness in recycling increases the material circularity. This depends on various factors

How the product is collected; ranging from completely separated parts of which the exact material type is known, to a non-disassembled bike that is shredded by the recycling facilitator.

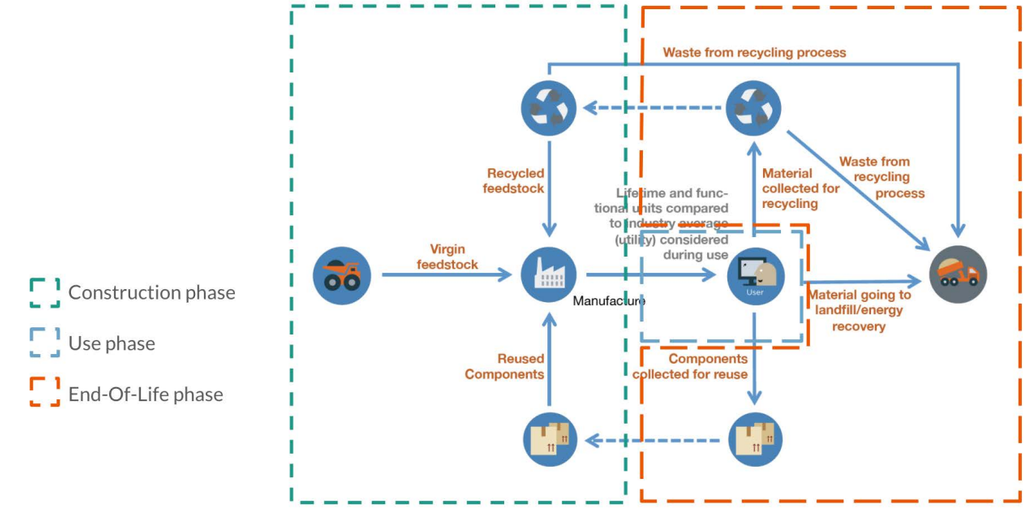


Figure 2.7.1

Application

Data was used from the LCA developed in 2018. This LCA analysed 4 bicycles on their impact on the environment. In order to do so, the bikes were completely disassembled; first component level, afterwards part level. In collaboration with Accell the type of material of parts was determined. Note; this is a 'quickscan' LCA, meaning a good picture is obtained of 80-90% of the environmental impacts of the product's life cycle. It's used as an initial inventory for process optimisation and the exploration of the environmental impacts of different product or processes. This cannot guarantee that all the data used was complete; possibly more types of materials were involved. The used bicycles in the LCA;

City bike
E-Bike
Racing bike
E-Mountainbike

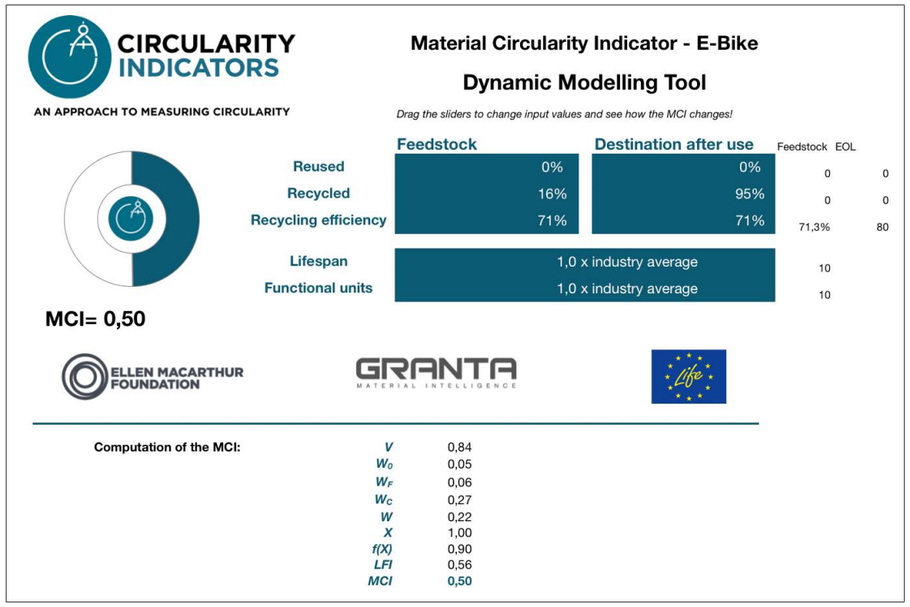


Figure 2.7.2

Outcomes

As no data was available on material origin except for supply chain mentioning using virgin materials for frames. The carbon frame used in the racing bikes was also considered not recycled and non-recyclable. The sum of all percentage of materials multiplied by their end-of-life recycling input rates (EOL-RIR) from CES was used to determine the recycling efficiency of a bicycle.

MCI City bikes = 0,26
Recycling efficiency 32,7

MCI Racing bike = 0,24
Recycling efficiency = 27,9%

MCI E-bike = 0,26
Recycling efficiency = 31,2%

Basically, the MCI represents the % of materials in Accell bicycles that through recycling gets a second life. The rest is burned and used for energy winning.

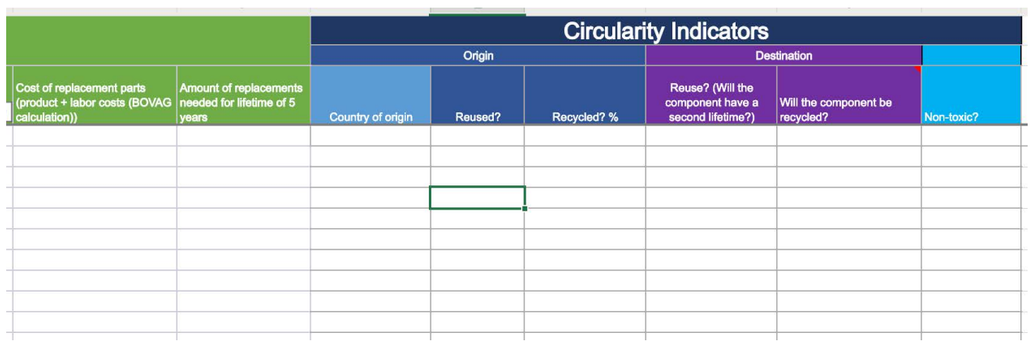


Figure 2.7.3

Insights from application of the tool

To calculate the percentage of circularity for a bike, a huge amount of data is needed. First, we need to know information about every part of every subassembly; what is the origin of the material, was it recycled or not? Taking the E-Bike as our example, exists out of 260 different parts (generally different, individually speaking even more because parts are used multiple times in the design of the bike). Of all these parts information is needed about the type of material they are designed out of, but also the source of the material and level of recycling.

A disadvantage of the circularity indicator is how consciously taken design choices with regard to circularity are left out in the result.

As an example; deciding to use less parts by combining multiple parts into can help with disassembling the bicycle; there's less parts to disassemble. Also it can help with recycling, if through combining different parts a smaller variety of material is used. Another example is the reduction of weight of parts to lower the total amount of materials used in a product. This wouldn't reflect in the material circularity index.

Furthermore, energy used in the fabrication of parts or components is not taken into account in the model. Therefore, designer choices that involve fabrication processes that require less energy, won't reflect in a more positive outcome of the material circularity index.

Take-aways using the Material circularity indicator tool for assessing circular product design.

Use component data in stead of material data

The circularity indicator uses material data from the LCA 2018 combined with CES data on worldwide recycling efficiency to compute the MCI. However, in Accell's PDP the material data is not available. What sometimes is available by requesting information from suppliers, is the overal recovered material use in components (therefore spread over multiple types of materials).

Therefore, the MCI can not easily be integrated in the PDP. However, the BOM circularity indicators developped during application of the MCI tool are based on % recovered material of a component.

Include circularity indicators in the BOM

The BOM was tested within an Accell project and worked well;

- It helps in the demand for creating transparancy.

- It can be used for component data in stead of material data.

- It serves a central place for data regarding material origin and destination, and therefore as input for evaluating assessment targets.

HotSpot Mapping

A design tool for product architecture mapping called HotSpot mapping (originally Disassembly Map) was developed by Francesco De Fazio in 2019 [5]. It offers a method to represent the architecture of a product, showing disassembly depth of all the product components and the intricate logic connections which link them to each other. The most important components for product repairability and retirement are spotted using special indicators, guiding the attention of designers towards these products' "hot-spot".

Why is this methodology explored?

The ease of disassembly is important for most value recovery strategies. A product that's easy to disassemble helps to create feasible solutions for recycling, remanufacturing, as well as making it easier to repair or maintain. As this tool is used to analyse disassembly, it serves as a good starting point for finding a way to assess the circularity of bicycle design.

Function

Analyzes the bicycle on the ease of disassembly.
Insights can be used to re-design bicycles for faster disassembly.

Defining Hotspot parts;

1. Critical Activities Hotspots
a. Activities which take up a long time to disconnect;
b. Activities which involve difficult or critical steps;

2. Critical Parts Hotspots
a. Parts which have a high priority due to a high maintenance or failure rate or are important for the primary functionality of the product;
b. Parts which have a high embodied economic value;
c. Parts which have a high embodied environmental impact;

Selecting the bicycle

For the evaluation of the indicator, the Sparta E-Bike was chosen. This because of the following reasons;

The bicycle was also used for assessment in the LCA in 2018. Since information from this LCA formed the basis for the assessment of the circulatory indicator, it possibly enables to create a circular quantification for this specific bicycle.

The bicycle is electric; it includes a motor and battery. The LCA of 2018 shows the high impact of the battery in energy use during lifetime and production. After discussion with an Accell employee (pre-production) we decided the assessment is of higher interest when choosing an electric bicycle.

The Sparta E-Bike was the winner of the bicycle innovation award in 2016, organised by RAI. This award made the bike more known among employees of Accell, which is an advantage in understanding and creation of support for the methodology.

Set Up

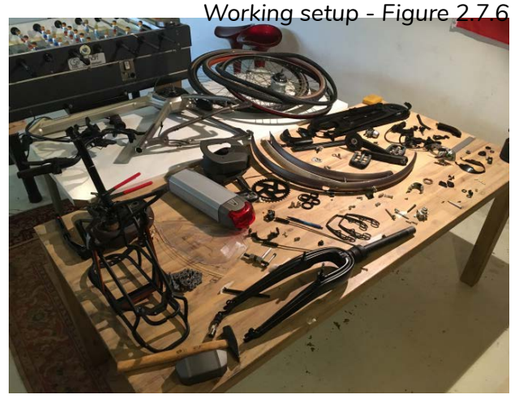
Initially, the goal was to disassemble the bike either at the prototyping workplace from Accell, or the Applied Lab repair table at the TU Delft. Due to the coronavirus, both ended up being not an option. Therefore the disassembly has been performed at home, in the basement. The set up included;

- Camera. Mounted to the ceiling, which was the best recording point to capture the steps taken to disassemble the E-Bike
- 2 Light spots, on aimed at the front of the bike and one at the back. Both were mounted to the ceiling.
- Support objects; chairs & beer crates. These purely served to position the bike either standing up or upside down, depending on the parts that were disassembled.
- Tool table; Table that included 148 standard tools.
- Part table; Table to lay down and label all the disassembled parts from the E-Bike.

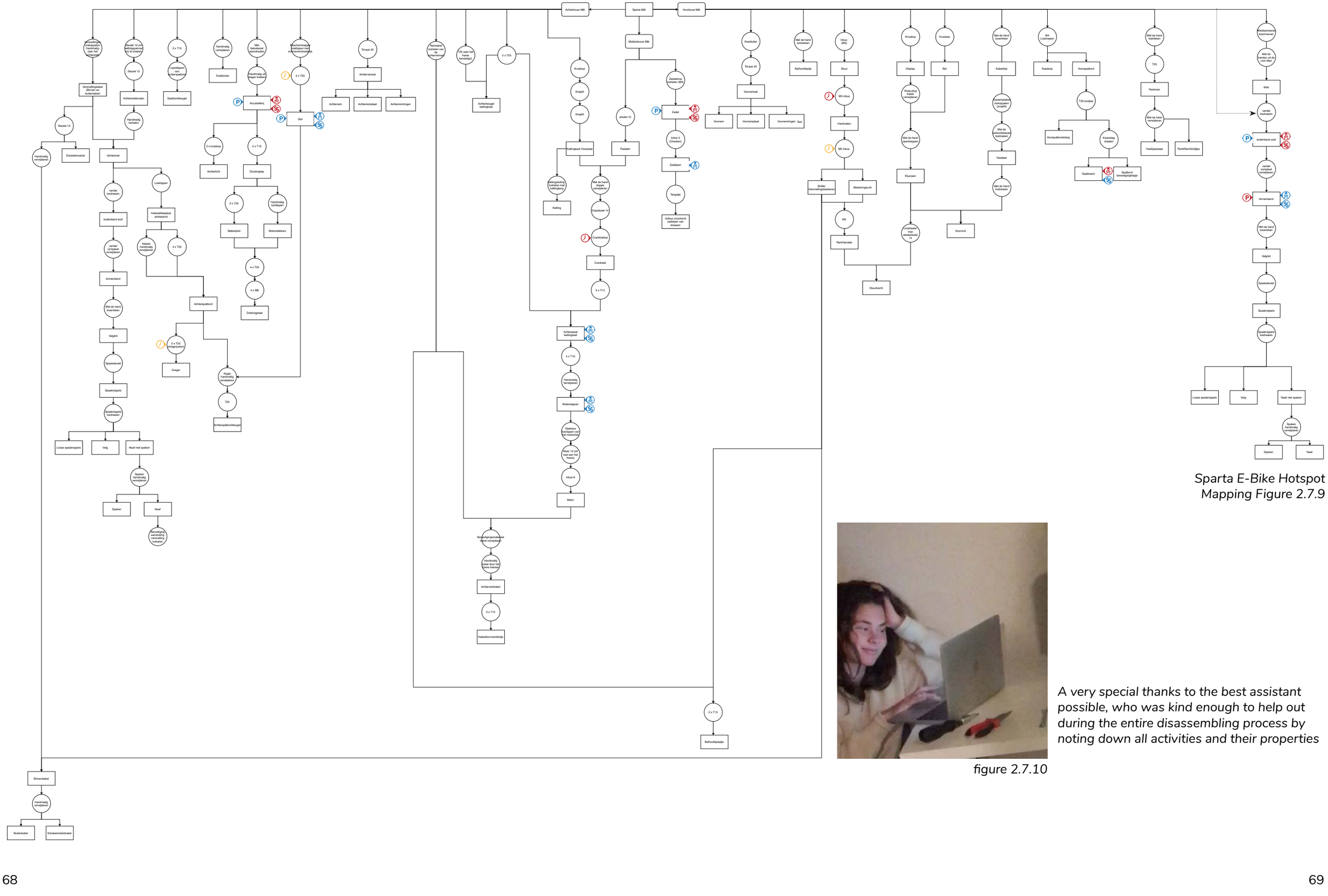
Me dissassembling the E-Bike with shaved head due to absence of barbers during corona. Figure 2.7.5

Working setup - Figure 2.7.6

Sparta E-Bike - Figure 2.7.8



Fully disassembled E-Bike - Figure x2.7.7



Sparta E-Bike Hotspot
Mapping Figure 2.7.9

figure 2.7.10

A very special thanks to the best assistant possible, who was kind enough to help out during the entire disassembling process by noting down all activities and their properties

M8i Dissassembly Analysis

As the findings in dissambling the e-Bike is model specific and not considered representable for Accell bikes in general, all conclusions apply to the e-Bike model only.

The dissassembly map of the Sparta e-Bike displays a rather broad figure. To fully dissamble the bicycle, it offers 21 starting points. And even within the vertical sequences, sometimes parts can be reached through shortcuts. For example, an inner tube can be replaced without taking off the complete bicycle wheel. Although no comparison is possible with other bicycle models (since these are not analyzed), it shows the bicycle has many parts that are easy to access, which mainly benefits the re-pair strategy.

A long sequential disassembly sequence is visible in the process of reaching the motor, and its connecting cables to the shifter and breakes. To be able to do so, the pedals have to be disassembled and the axle removed, which takes a lot of time and force to do so.

To disassemble the pedals, a tool had to be bought from a bicycle store (crank puller). It can be assumed most people don't have this tool lying at home, as in normal situations people don't disassemble this component of a bicycle.

Another tool that is considered less common, is the chain wrench, needed to open the chain clasp in other to free the chain. However, also this tool is available at the regular bicycles shop.

The component with the highest impact on the environment (battery) is very easy to dissassemble from the bicycle. However; it should be noted that the battery itself cannot be dissassembled (as this is highly dangerous).

The fact that cables are integrated in the frames makes it hard to reach them. Furthermore, the cable connection from the hand grips to the brakes is a hydraulic brake drive, which I experienced by getting a splash of brake oil on my sweater.

Some screws are made invissible by plastic parts that are pressed into a cavity. As instructions lack, its hard to understand how to disassemble the components connected to these hidden screwes. Also, removing these parts involves using a screwdriver to 'pop' it out, which is not an easy activity.

One final remark is that the dissassembly has taken place with low expertise in bike disassembly and a set of standard tools. In case of recovery and dissassembly by a circular service provider with the right and optimalized tools for bicycle dissassembly, results could highly differ, as this could influence activity time and activity difficulties.

In overall, the bicycle is designed for offering comfort to the consumer, but leaves enough starting points for improvement of dissassembly.

Using the analysis, points of improving the e-Bike easyness of dissassembly were established. As only one bicycle is analyzed using the Hotspot Mapping methodology, it can be used to improve current design, not to establish general guidelines.

Points of improvement Sparta E-Bike

1. Replace different sizes of torque tools by a singular one (T15, T20, T25), to lower the amount of tools needed.

2. Either place the cables on the outside of the frame (which is not preferable for aesthatics), or enble easier disconnectiong points directly attached to the shifter and brakes instead of in the frame.

3. Place instructions on the hidden the plastic parts that hide screws .

4. Instead of using glue to fix the position of the handlebars, use a different extrusion for the steering wheel bar that automatically fixes the position.

5. The shifters and bell are mounted into bigger components. If attached seperately, it would become easier to disconnect them as individual components.

Relation with general guidelines for dissassembly

Although general guidelines cannot be establed from analyzing only the e-Bike, reversed wise some improvements do connect to the guidelines extracted in the last chapter. Improvement 1 links to **'fewer tools'**, 3 to '**visibility**', and 4 to '**avoid glue**'. 2 and 5 are considered bicycle specific, but fit within the overall design goal; design for dissassembly.

Conclusions using the Hotspot Mapping tool for assessing circular product design

The Hotspot Mapping tool is an effective tool to use for bicycle-specific improvements in design for dissassembly. For the e-Bike, the tool shows that although the bicycle is designed to easily reach wear parts (like the inner tube), components that are less frequently replaced can improve in easyness of dissassembly.

Time consuming
The process of applying the full methodology to a bicycle (to part-level, by creating both a hotspot analysis and a disassembly tree) takes a long time. The full disassembly including reportation took me 5 days. Interviews with an Accell pre-production employee who is specialized in disassembling bicycles, says it would take him half a day to fully disassemble the bike himself, and normal distributors a day. This excludes the reportation, which would take additional time.

Moments of use
Furthermore, it is a methodology to assess an existing product. Performing this methodology on a range of bicycles within a segment, can help Accell in establishing specific guidelines for future bicycle development.

Changing design goals vs analyzing current designs
Although the hotspot mapping tool is very good in highlighting points of improvement, these improvements are still based on a design that is not build for dissassembly. One could argue, that including the guidelines for dissassembly from moment 1 (project goal) is a more effective method to decrease time of dissassembly.

The HotSpot mapping tool could still be used to optimize these easy-to-dissassemble bicycles, by offering a very extensive insights into what can be further improved in these designs. But for the short term, Accell would benefit more from integrating the goal; 'design for dissassembly' in the project requirements.

Concluded is the tool functions more as a guideline creater than an assessment. And for guidelines, it is recommended to use in the long term, and start with applying general 'design for dissassembly' rules on bicycles. Another way of measuring needs to be established to quantify the easiness of dissassembly.

2.8 Circular exploration conclusions

In the beginning of this chapter, several research questions for exploration were developed. As different research questions led to coherent conclusions, some questions are clustered. Through the 'outside'-'inside' approach, we can now conclude what existing knowledge, experience and methodologies can used for the development of the Accell Circular Tool, by answering the research questions of the circular exploration chapter.

Insights from the following three research questions were combined into one answer;

-Which circular loops and circular business models can be applied to Accel (in the short & long term)?
-What circular strategies used by other companies are applicable to Accell?
-What can we learn from their business models / circular loops?

Three out of five circular business models are concluded applicable to Accell; the classic long life, hybrid and access.

For the short term, two main strategies are recommended to help Accell move towards a circular PDP

The first is adjusting their current 'classic long life' model to better fit the principles of a circular economy. A take back model can be considered, but since these bicycles are designed for a long life, their return dates could spread over various amounts of time. It could become rather difficult with respect to re-manufacturing or re-using parts from outdated models. More realistic adjustments and impact in classic long life business models can be achieved in designing from recovered materials. More on this is explained in 'how can a bicycle be prepared for the circular loops it will go through?'

The second circular strategy focusses on hybrid and access models. For the short term development of these models, a collaboration with circular partners is recommended, as these are service-oriented business models, which Accell currently is not familiar with and lacks resources in.
A good starting point is their current leasing model. When using the strengths of circular partners to establish an access model, this model could potientially become more profitable and simultaniously circular.

For the long term, Accell is recommended to transition from a product company to a product-service company. By providing mobility as a service and taking ownership of the bicycles, they have the opportunity to control the bicycles complete lifecycle while simultaniously creating new models for profit.

Potentially, Accell itself can enable the remanufacturing process by using it's assembly lines for dissassembly. Based on the insight that disassembly time corresponds to assembly time, which ranges between 30 and 60 minutes, it can be estimated that total disassembly costs would range around 100 euros per bicycle. Although differences in dis-assembly would influence these costs, the variation would be fairly small compared to differences in component prices of bicycles. This would mean that disassembling gets more interesting as the complexity of tooling and production of bicycle components goes up, as the value of these components are higher. It is recommended Accell further investigates costs and feasibility of disassembling, but from initial research it would be recommended to start with high segment electric bicycles.

What can we learn from the lifecycle of a bicycle from a circular perspective. What should designers focus on?

The main thing learned is how little information is available about the lifecycle of a bicycle. There is little data on material origin and circular aspects of materials (such as embodied production energy, or can it be recycled). No specific design strategies could be extracted from the recycling process, except for design for dissassembly.

How can a bicycle be prepared for the circular loops it will go through, in its design?

What can we learn from the bicycle design of bicycle companies?

It is concluded, the design of the bicycle is dependent on the system it lives in. To maximize results achieved through circular bicycle design, understanding, defining and planning the system should be integrated in the Accell circular tool.

If the world of recovery is included in a project (by for example enabling remanufacturing), the main strategy to prepare the design for these loops is design for disassembly. Design for disassembly supports 3 of the circular strategies (re-pair, re-manufacture, re-cycle). Different design guidelines for design for dissassembly were analysed and the relevant ones for bicycles were extracted. Furthermore, standardization of components is a key design strategy to re-use components both within models, as between different bicycle models.

For every type of circular system, a bicycle should be designed from recovered components; either fully recovered components or recycled materials. The main material used by Accell; alluminium 6061 can be fully recycled en using the recycled 6061 is therefore adviced. Specific findings on use of other materials (carbon composites, plastics) can be found in the appendix, and are used in the guidelines to inform designers.

What methodologies are there to assess progression in circularity, and to which extent can they be used in the current PDP?

The methodologies evaluated were the HotSpot Mapping (HSM) which and the material circularity indicator.

The HSM provided insights in the product architecture mapping and was applied to the Sparta E-Bike (chapter X, assessment methodologies). It successfully determines what hotspot parts are difficult to reach using the variables activity time and activity difficulty. Once multiple bicycles would be analyzed, their insights could be used as a basis for improvement in design for dissassembly guidelines for bicycle specific segments, something not included in the scope of this thesis. It is advised Accell sets this up as a seperate project to create in-depth insights in different segments of bicycles.

However, the assessment does not function as indicator during the product development proces, as it takes too much time and is meant to provide insights assesing existing bicycles, not projects in development. Therefore, a new indicator for easyness of dissassembly needs to need to be established.

The material circularity indicator requires a complete package of product and recycling data, which for the short term is an obstacle. However, during its application, the circularity indicators (colomns on material origin and destination) were developed and integrated in the BOM. Including these colomns in the BOM is a start in gathering the necesarry information about material origin from suppliers, and opens up the possibility to only use limited data available about a model as input for a circularity score.

Design of a circular tool for Accell

3.1 Tool requirements

Out of all the insights described in the chapter one and two, a list of requirements was made for the design of the circular tool. These requirement formed the basis of development of the tool, combined with various iterations through validations with Accell employees. These processes are described in the subchapters.

Integrate sustainability topics in the Product Development Process (PDP) of the Accell Group

The goal of the assignment is to design a tool that guides and quantifies the use of circular design in the Accell product development process

Guidance	Requirements
Insight; Although most employees are familiar with the concept of the C.E., in-depth knowledge is often missing. Lack of Terminology was often causing confusion during workshops.	**Requirement 1. The project team needs to be informed about the chosen strategy (circular economy), it's core principles, strategies for keeping materials in loops and associated terminology.**
Insight; there is unawareness / no access to sustainable properties of materials used in the PDP, and support needed on how to achieve the main strategy for circular bicycle design; design for dissassembly.	**Requirement 2. The guidelines need to inform projects teams about circular aspects of most used materials in the design of a bicycle, and on design for disassembly.**
Insight; Currently there is no information available regarding the origin of materials, which is needed to make design decisions with regard to circularity.	**Requirement 3. When selecting components from suppliers or designing components, the guidelines should inform the project team what circular aspects to focus on.**
Insight; Thinking about the end-of-use of a bicycle is new to Accell employees. They are in need of guidance in planning what components will be designed for recovery, and establishing partners / processes to enable this recovery.	**Requirement 4. The guidelines should include questions meant for suppliers with regard to material origin and production sustainability of materials, which can be used by the supply chain.** **Requirement 5. Data collected regarding material origin should be stored in (an extension of) the tool, as there currently isn't a platform to do so.**

Quantify	Requirements
Insight; high demand for being able to express the level of circularity in **one score.**	**Requirement 6. The label needs to define in one score what level of circularity is linked to a project; either as goal, or as evaluation.**
Insight; The circularity achieved in a project is not only dependent on the design of components produced by Accell, but also the components bought from suppliers and the system that ensures a circular lifecycle. Existing indicators that were analyzid did not function / fully cover the segments described above.	**Requirement 7. Although one score, this score should cover what to what extend the design of the bicycle is developed for the circular economy, to what extand the components are selected on circular principles, and to what extend a circular system is established in which the bicycle will move.**
Relation to the PDP	
Insight; Accell specifically asks to 'integrate' the 'sustainability strategy' in the PDP.	**Requirement 8. The tool needs to be developped in a format that potentially can be integrated in the PDP.**

3.2 Designing the tool

As the requirements (3.1) and first content (chapter 2) are created for guiding and assessing circular product development, we will now discuss how the tool is developed. Specifically, this subchapter defines the relation between guidelines, assessments and the accell circular label.

Although the Accell Circular tool sounds singular, it covers;

- a label that communicates the level of circularity established within a product development project (tool 1)
- a tool in which project teams are guided circular product development (tool 2)
- assessments that quantify the circularity of a project and can be translated into the value represented by the label (tool 3)
- circularity indicators that can be integrated in the BOM, to document component origins and recovery plans, and use this as an input for the assessments. (tool 4)

Connecting the tools

During the exploration phase, the ‘product design framework for a circular economy’ was analyzed. In this framework several tools were developed to aid a designer with the application of circular product design.

The first serves as a quick introduction, a discussion tool, a tool used in a workshop for a short design exercise or as a memory aid during the design process.

These 5 topics related to circular product design are directly connected to a vision for circular product design

And lastly, the same ‘framework’; a circle surrounded by the 5 circular topics, translate into a spider map.

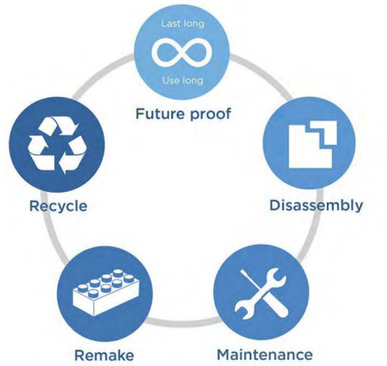


Figure 3.2.1

Figure 3.2.2

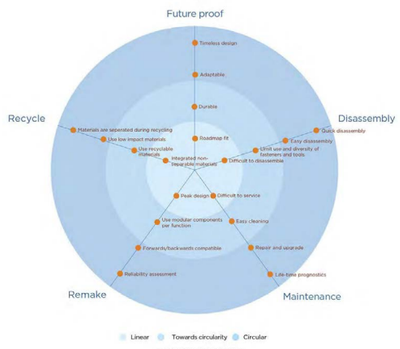


Figure 3.2.3

This translation between vision, to guidelines, to assessment was in my opinion very clever and easy to understand. It created clarity in the relation between the information gathered in chapter 2.

It became a design goal to create a tool that functions both circular conversation facilitator, and simultaneously as a indicator for circular progression of a bicycle development project.

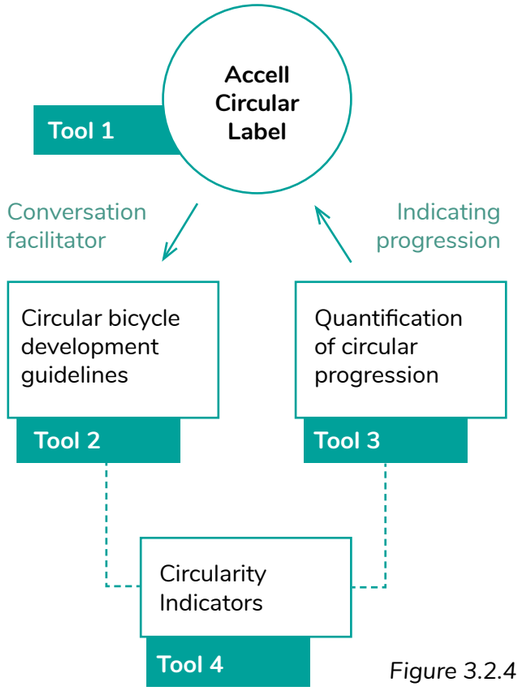


Figure 3.2.4

The circularity indicators (tool 4) is will be used to document circular properties about components in materials.

In the guidelines it can be referred to when either material origin is discussed, or future plans made for bicycle components.

Also, it serves as an input for quantification of circular progression, as this is dependent on mateiral origin and the lifecycle of a product.

3.3 Designing the label

Tool 1

Accelll Circular Label

Input

Requirement 6. The label needs to define in one score what level of circularity is linked to a project; either as goal, or as evaluation.

Requirement 7. Although one score, this score should cover what to what extend the design of the bicycle is developed for the circular economy, to what extand the components are selected on circular principles, and to what extend a circular system is established in which the bicycle will move.

Other design goals

Functions both circular conversation facilitator, and simultaneously as a indicator for circular progression of a bicycle development project.

Integrate make - use - and recover in the label. The reason is an insight during workshops; in majority of conversations the three circular economy principles were used to define objectives / evaluate current designs;

Make	Using as many recycled and/or reused materials as possible
Use	Extending the useful life of products as much as possible
Recover	Collecting as many materials and products for recycling and reuse as possible (By designing products that are easy to reuse and recycle)

Development

For the design of the tool, the form of a circle is chosen. This because of the visual resonation with the circular economy.

Along the circle are the three principles of the circular economy; [make] Using recycled materials and / or reused components, [use] extending the useful life of products, [recover] recover components for re-use and recycling. This choice in design was made as result of an insight retrieved from several circular economy discussions with Accell employees; these three principles resonate and were important in distinguishing the different starting points for improvement.

The 3 stages; making, use and recovery, are of relevance to **the system** they operate in, **the design** of our bicycles and **the components** bought from suppliers. These three layers are visualized in three blue gradient layers; starting from the outside - circular systems - towards - circular design - and finally - circular components.

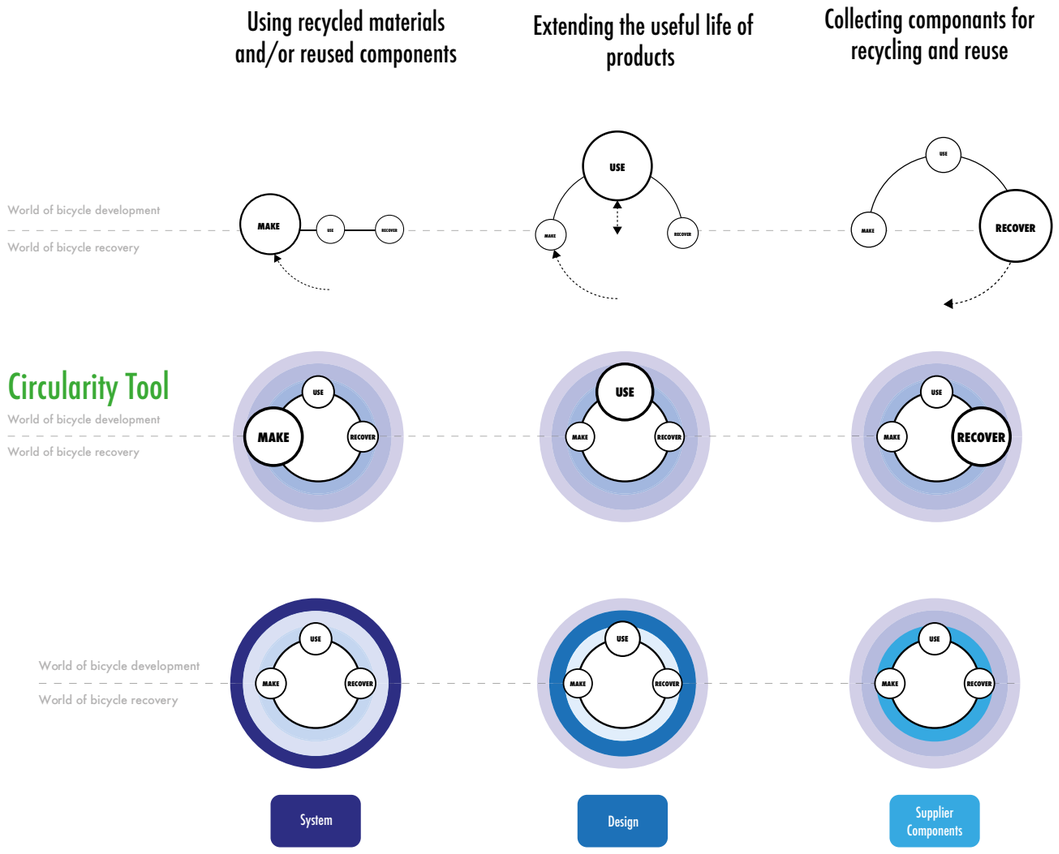


figure 3.3.1

Operating as a company within the circulary economy starts by thinking in systems. In what ways can we recover bicycles? What loops exist in which components and materials can flow? How is it profitable?

After envisioning what processes, partners and business models are crucial for a circular bicycle lifecycle (circular systems), we can start to adapt our design for it. Our design freedom is divided over the components design by Accell (frame, front fork) and the components we select. This layer ‘circular product design’ focusses on the components designed by Accell.

Although the biggest components are designed by Accell, most components in Accell bicycles are bought from suppliers all over the world. We cannot decide how to design them, but we do have the freedom to select them. The layer ‘supplier components’ help with this selection, by offering information about sustainability aspects of materials, questions to ask your supplier regarding material use, energy use and circular loops.

Requirement 6. The label needs to define in one score what level of circularity is linked to a project; either as goal, or as evaluation.

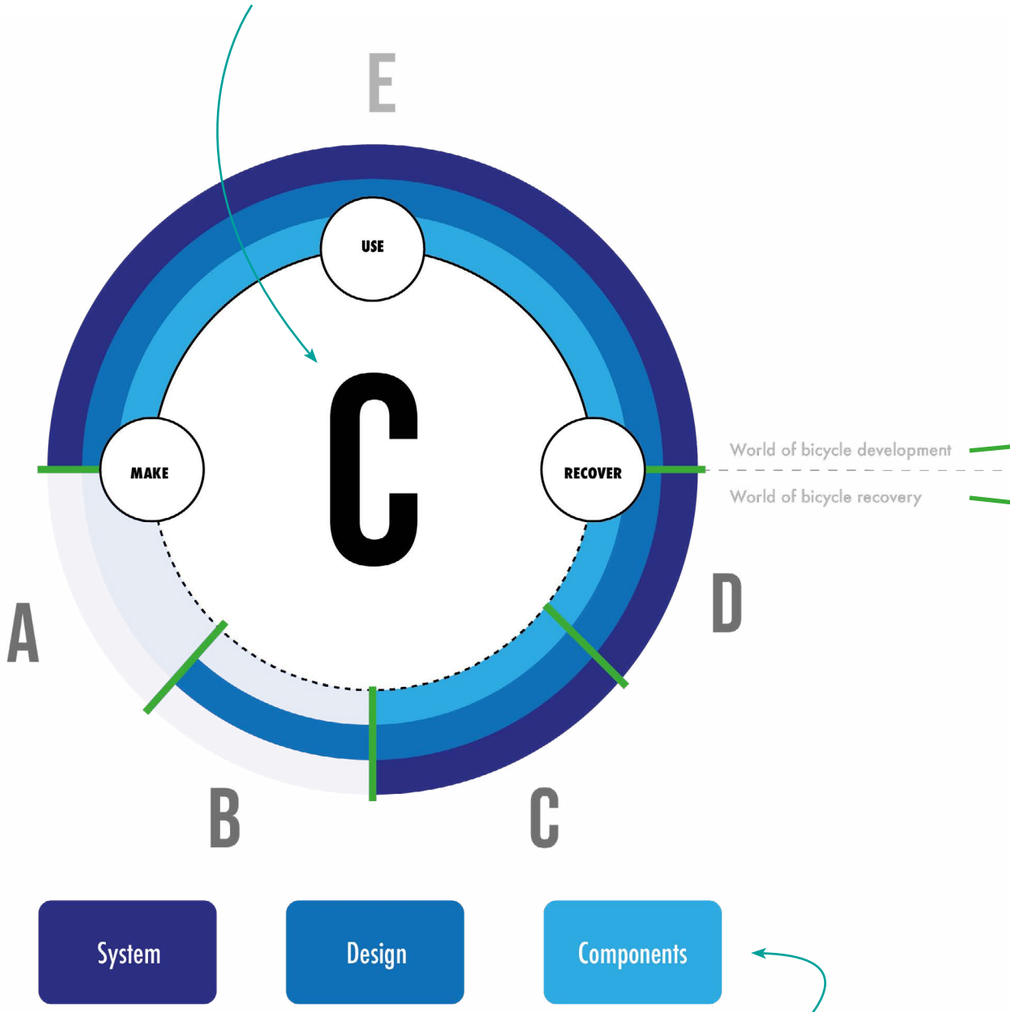


figure 3.3.2

Requirement 7. Although one score, this score should cover what to what extend the design of the bicycle is developed for the circular economy, to what extand the components are selected on circular principles, and to what extend a circular system is established in which the bicycle will move.

World of bicycle development & World of bicycle recovery

In one of the principles Accell has achieved significantly more progress than the other two; extend the useful life of products, by designing high quality bicycles that offer next to functional value a high emotional value to its customers. Designing from recovered components / materials, and recovering components / materials are the two principles that offer room for improvement. Because of this, the tool can be segmented into two worlds; the 'world of development' and the 'world of recovery'.

The upper half of the tool represents 'the world of the development', including the use phase of the bicycle.

The bottom half is the 'world of recovery'. This half is less known to Accell.

The world of recovery half is divided in the 4 segments [A, B, C, D, E] that rate the degree of circular progress achieved within projects.

E represents a high quality bicycle that is designed to last, but none of the circular assessments are achieved in the project.

D to A represent relatively lower to higher progression in achieving circular goals within a project. Requirements are found in the 'circular assessment' subchapter.

It is deliberatly chosen to always have the upper half of the circle coloured (as this represents E, no circular assessments are achieved). This has been done to 'motivate' project teams, and represents the fact that Accell creates high-quality durable bicycles, designed for long-use, therefore contributing to a circular economy. But where the room of improvement is, the world of recovery, D to A are represented.

One value for quantifying circular progression

During development of the label and it quantification, it was a real challenge to 'summarize' what level of circularity is set or achieved during a project in one value, as it depends on many factors.

The solution was through inspiration from the assessment methodology of cradle to cradle certification.

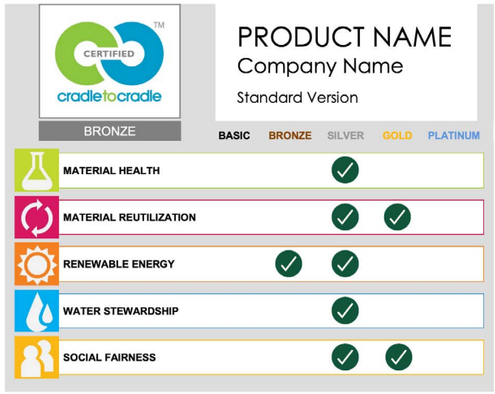


figure 3.3.3

Their certification system is based on 5 segments; material health, material reutilization, renewable energy, water stewardship and social fairness. Only if all 5 surpass one of their levels (basic, bronze, silver, gold and platinum) that certification is achieved for a product.

The same assessment system was integrated in the Accell circular label; Only if each of the three segments (system, design and components) surpass one of the 5 levels (E,D,C,B,A), that level is achieved for the overal project. What the scores depend on, is further explained in 'quantifying project circularity'.

3.4 Quantifying project circularity

Quantification of circular progression

Tool 3

So what are the circulartiy scores of system- design and components based on? This chapter discusses how insights from material circularity indicator (Ellen Macarthur Foundation), the HotSpot Mapping tool (HSM), insights from analysis of PDP, the assembly process and workshops, are translated into a list of variables that defines the circular score achieved in each segment.

Input

Requirement 7. Although one score, this score should cover what to what extend the design of the bicycle is developed for the circular economy, to what extend the components are selected on circular principles, and to what extend a circular system is established in which the bicycle will move.

Requirement 8. The tool needs to be developped in a format that potentially can be integrated in the PDP.

Further input;

The idea from the head of sustainability to assess the use of guidelines and circular indicators, which was the foundation of 'circular thinking'

The segmentation between applying circular strategies, and actual results being achieved, represented through 'circular thinking' and 'circular readiness'

The insights that assembly time correlates directly with dissassembly time, and data is available about all bicycle categories

The lessons learned from assessment of methodologies (2.5);

Using C2C material health lists to evaluate circular potential of materials used in a design.

Results

Variables to measure project circularity of the system, design and components were established;

The **system** circularity focusses on enabling that the bicycle can enter the world of recovery through creating a lifecycle plan. It is dependent on establishment of recovery players, and the planned percentage of recovered components.

The other two segments; **design** and **components**, focus on the origin and health of materials.

Both their scores depend on material health of components (using C2C material health lists), and the percentage of recovered materials used in components, although targets set for supplier components are lower.

Other variables defining circularity of **design** are achieved (dis)assembly time and use of circular guidelines on plastics and disassembly.

Circularity of **components** is further dependent on the use of the circularity indicators and transparancy created in the supply chain.

In the following pages; details about the variables themselves and the proces in finding these variables are further explained.

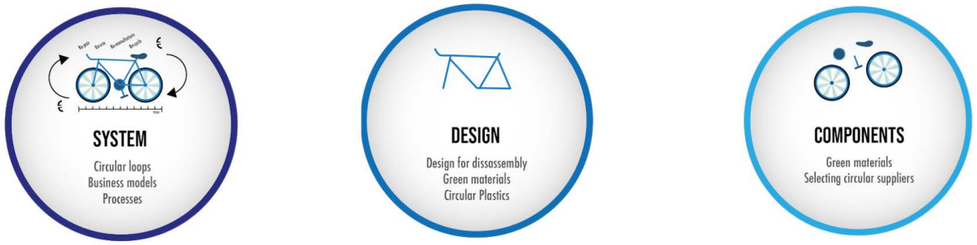


figure 3.4.1

Circular thinking

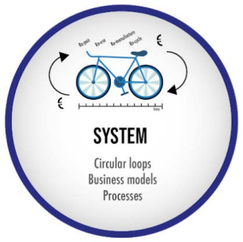
The circular thinking variables were created as an attempt to stimulate the project team in the use of guidelines and the circularity indicators. By using the workshops (circular plastics & design for dissassembly), designers can check if they used all the circular design strategies (which was mentioned as a need in the interviews, and main goal of the head of sustainability). By using the circularity indicators, they prepare a plan for the lifecycle of the bicycle, and are motivated in sellecting supplyers using recovered materials. Simultaniously, through usage of the circularity indicators, data is gathered on material origin and destination. These variables provide Accell insight to what extend circular design is used in the PDP.

- Design for circular plastics use
- Design for disassembly use
- Use of BOM list material circularity indicators

Circular readiness

However, showing the use of circular thinking in the PDP doesn't make a project circular. To provide Accell with information about if the bicycle and validate if it's planned lifecycle is indeed ready for the circular economy, variables are created to truely value the project circular readiness;

- Recovery players established
- (Planned) % components recovered
- (Dis)assembly Time (% improvement)
- % Recovered materials
- C2C Materials
- Transparency in supply chain
- % Recovered materials
- C2C Materials



Circular system assesment

Proces

Need to think in bicycle lifetime instead of only sales

Using circular loops to brainstorm on recovery solutions through internal processes and partners

First workshop created inspired on IDEO design guidelines, tested at NS project, worked

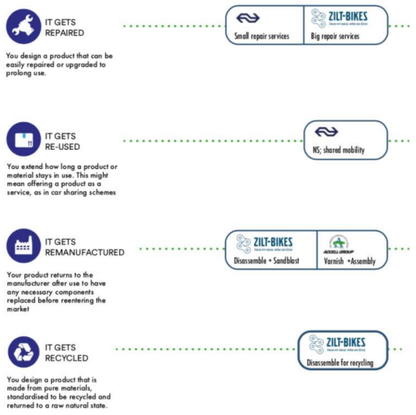


figure 3.4.2

Recovery players

Proven to work in NS project

Circularity indicator (Ellen Macarthur)

Created for measuring product & working system circularity

Too many variables missing (material origin, recycling efficiency, recovered components)

Using BOM to think about component future

Instead of measuring recovered components, define what components are planned to re-use in a project

Document these decisions in BOM to ensure data is available to measure progression

% (Planned) Recovered materials

Proven to work in NS project

Applicable during project

figure 3.4.3

Circular thinking

Establishment of recovery players

In the assessment sheet, the ‘circular loop providers’ sheet is mandatory to be filled in. This means that in the project responsibility is taken by either Accell, a circular service provider, a client, a user or third party to ensure circular loops are provided for the bicycles.

In case of the validation project for example, 3 different stakeholders were established.

The client with the responsibility responsible for smaller repairs, and re-use in the form of the client being the service provider.

The circular service provider got responsibility for bigger repairs and disassembling the bicycles and sandblasting the painted components to prepare for remanufacturing. In the BOM list the planned which components to re-use, and based on the mass of this list, the % ‘recovery of components’ sector can be filled in.

Business model

Although in the guidelines include ‘circular business models’, in assessment of a project this was left out. During the client project it became clear this was tough to set goals for.

Circular Readiness

Recovery of components

The main variable chosen to measure the level of circularity achieved on a system level, is the percentage of components that are recovered.

This is a clear indicator, measured at this stage by the data included in the BOM circularity indicator columns. Therefore it can be executed during a development of a project.

By being able to recover a certain % of used components, either in component form or in material form, it must be so that the circular loops and business models in order to do so are established. Therefore, these indicators represent the circular progress made on a system level.

The indicator doesn’t restrict weather Accell themselves and partners are responsible, or the bicycle industry in general. This to leave recovery plan open; either Accell takes responsibility themselves, or unite forces with other bicycle development companie to recover bicycles on an industry level.

Defening the targets for variables as a thresshold for the 5 scores (E-D) was done in collaboration with the head of sustainability There were a number of bounderies used for setting these target.

Circular business plan
As described in chapter 2.6, for the short term it is not likely Accell is going to change in the short term from a product to a product-service company.

Established recovery players
For D, recovery players don't have to be established. From B on they do, simple as that. It shows Accell takes a pro-active approach in making sure materials are recovered.

% Recovered components
To set goals for % of recovered components, it was suggested to align them with the c2c goals of Accell for 2035, that were introduced in the very last phase of the project. The main goal; 'by 2035 all bikes have a gold c2c certification with respect to re-usage of materials'.

Although it's a great thing sustainable goals are being set and discussed within management, these goals are very low. To score gold on 're-usage of materials' within a cradle to cradle certification, a material reutilization score that is higher than 65 percent is the thresshold (figure 3.3.x). The following formula is used to compute this number;

$$\frac{\left[\begin{matrix}\%\ recycled\ or\ rapidly\ renewable \\ product\ content\end{matrix}\right] + 2\left[\begin{matrix}\%\ of\ product\ recyclable \\ or\ biodegradable/compostable\end{matrix}\right]}{3} \times 100$$

figure 3.3.x

This means the use of recyclable materials weighs twice as high as recycled product content. The majority of materials used in Accell bicycles already is recyclable. No actual re-usage of materials is obligated in the cradle to cradle 're-usage of materials'.

The data in the excel sheet created to calcute the MCI was used to calcute the % of product recyclable materials.

E-bike	90,3%
Racing bike	79,6%
City bike	96,5%

Then, with the assumption that no recycled materials were used, the following re-usage scores were established;

E-bike	60,2%
Racing bike	53,1%
City bike	64,3%

This means we've almost achieved the score for 2035, without even taking into account that probably some of the materials used are recycled. Therefore more challenging goals were established based on the current data and insights.

The sum of all percentage of materials multiplied by their end-of-life recycling input rates (EOL-RIR) from CES, which if Accell would take no initiative themselves in recovering bicycle components would represent the % of recovered components (through general recycling systems)

E-bike	31,2%
Racing bike	27,9%
City bike	32,7%

It was chosen to take 30% as a baseline, rewarding some of Accell's bicycles with a B. It might seem easy to score this already, but the fact that Accell uses a lot of recycleble materials in their product may be rewarded, and motivates looking into alternatives for their carbon composite frames (racing bike, scoring A). Goals go up to recovery 80% of materials to be rewarded an A.

LEVEL	ACHIEVEMENT
BASIC	Each generic material in the product is clearly defined as an intended part of a biological or technical cycle (this is covered by the Material Health requirement at Basic level; see Material Health guidance in Section 3.2).
BRONZE	The product has a Material Reutilization Score that is ≥ 35.
SILVER	The product has a Material Reutilization Score that is ≥ 50.
GOLD	The product has a Material Reutilization Score that is ≥ 65. The manufacturer has completed a "nutrient management" strategy for the product including scope, timeline, and budget.
PLATINUM	The product has a Material Reutilization Score of 100. The product is actively being recovered and cycled in a technical or biological metabolism.

figure 3.4.3

To assess if Accell thought about the circularity of their project, responsibility for circular loops is mandatory to be planned within the project.

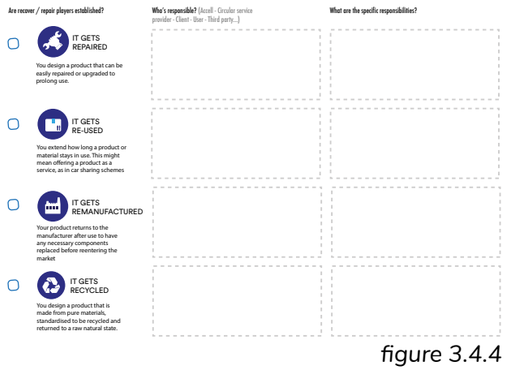


figure 3.4.4

	System	D	C	B	A
Circular thinking	Circular business plan	'Circular Business Models' developed or identified during project	Circular strategy integrated in circular business plan	Take-back / Lease / or industry recovery of full bicycle at core of business plan	Take-back / Lease / or industry recovery of full bicycle at core of business plan
Circular readiness	Recovery players established within project			■	■
	Recovery of 30% of components		■	■	■
	Recovery of 50% of components			■	■
	Recovery of 80% of components				■

figure 3.4.5

Circular design assesment

Proces

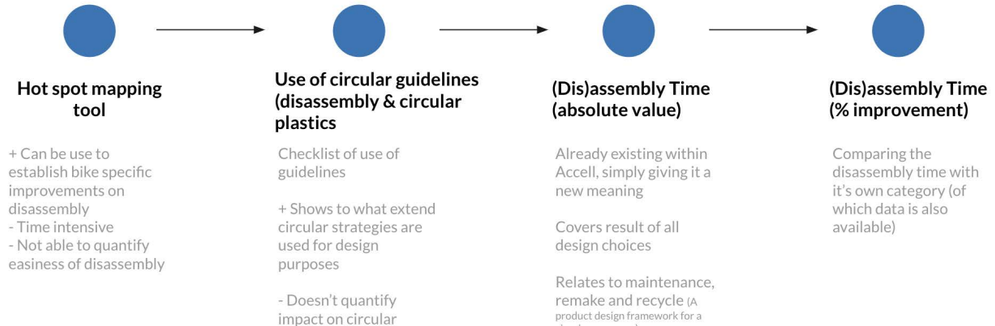


figure 3.4.6

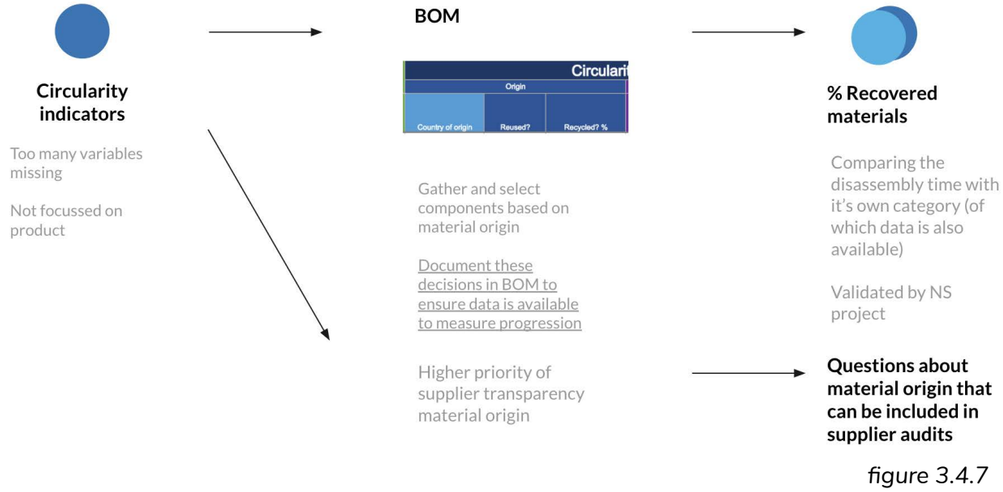


figure 3.4.7

Circular thinking

Use of circular guidelines
To ensure the project teams thinks about design for disassembly, evaluating its checklists became a variable. The higher the amount of guidelines used in the design, the higher the score rewarded for this indicator.

Design for circular plastics
Similarly, the use of the 'design for circular plastics' guidelines has become part of the assessment as well. Score is calculated by the amount of do's that can be checked from the checklist in the design of Accell bicycle components, expressed in a percentage.

Use of BOM list Material Circularity Indicators
To motivate the of use the circularity BOM indicators, this indicator is expressed in three levels of use that can be integrated in the product development process.

Circular Readiness

Reduction of disassembling time
To assess actual progress achieved in simplifying the disassembly of bicycles, the time to assemble is taken as a main variable. An Interview with both the assembly department from Koga, Sparta and Batavus gave the insight of how assembly times relate to disassembly times for different segments of bicycles, including different goals in disassembling (material level takes 10%-15% less time than component level). This is translated into goals for assembly time for specific segments of bicycles.

Recovered material use
To measure the amount of materials used in the design of new bicycle components produced by Accell, this indicator was established. Because Accell has a higher freedom in selecting suppliers that can oblige to these goals, the % of recovered material use in Accell designed components is higher than those from supplier bought bicycle components.

Cradle to Cradle material health
Two indicators were taken from the cradle to cradle methodology, since Accell mentioned it's goal to work according to cradle to cradle material health assessments. The first identifying chemicals used in the development of bicycles from the C2C banned list chemicals, followed by banning these. The second is the development of a strategy to optimize all remaining X-assessed chemicals, which is mandatory from level C.

Circular design assessment

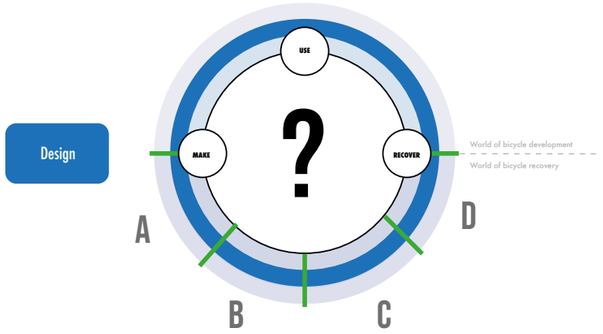


figure 3.4.8

	Design	D	C	B	A
Circular thinking	Design for Disassembly Use	Workshop used in the project	50% of checkbox 'design for disassembly' integrated in design	75% of checkbox 'design for disassembly' integrated in design	100% of checkbox 'design for disassembly' integrated in design
	Design for 'Circular Plastics'	Workshop used in the project	50% of checkbox 'Circular Plastics' integrated in design	75% of checkbox 'Circular Plastic' integrated in design	100% of checkbox 'Circular Plastic' integrated in design
	Use of BOM list Material Circularity Indicators	Circularity indicators are included in every new BOM	Circularity indicators are included in every new BOM +	All coloms are filled in by requesting the necessarry data from suppliers and creation of a plan for reuse of components and recycling of materials	
Circular readiness	C2C Banned List chemicals	Identified	0	0	0
	Strategy developed to optimize all remaining X-assessed chemicals.		■	■	■
	Disassembly time reduced by 10% from baseline		■	■	■
	Disassembly time reduced by 15% from baseline			■	■
	Disassembly time reduced by 25% from baseline				■
	Recovered material use > 30%		■	■	■
	Recovered material use > 50%			■	■
	Recovered material use > 80%				■

figure 3.4.9

Model routing assembly (time to assemble)

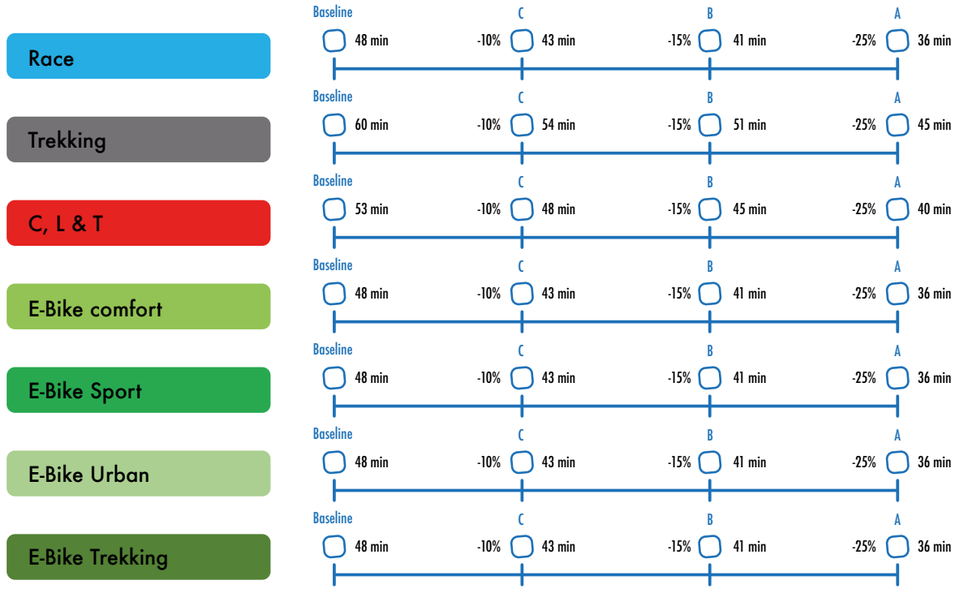


figure 3.4.10

Recovered material use
One of the lowest hanging fruits in decreasing the negative impact the bicycle has on the environment, is using recovered materials. which can be achieved by selecting suppliers that use recycled materials. As this concerns components developped by Accell, such requirements could be communicated to suppliers and goals are therfore set high. Entry was decided at 30% at B. If in the further future Accell (or the industry) also starts recovering components, there is even more opportunities for increasing the % of recovered materials. It was set at 80%

Model Routing Assembly
Management from the assembly line provided data on assembly times of different bicycle models, and the estimated ratio between assembly and disassembly time. A baseline could be computed for different segments of bicycles. Using the ratio assembly time-disassembly time given by the assembly management, the disassembly time per segment was calculated. Goals for reducing this time were set at a decrease by 10%, 15% and 25% respectively for B,C and D.

Circular Readiness

Cradle to Cradle material health
Similarly to the circular design assessment, an indicator from the C2C methodology is included in the circular component assessment.

Transparency in supply chain
To start improving the amount of recycled material in components bought in supply chain, the first step is to build transparency. This indicator starts with including the questions from the 'questioning supplier' workshop in the Audits. Followed by goals for transparency. These goals were validated through two interviews with an employee from procurement audits.

Use of BOM list Material Circularity Indicators
To motivate the of use the circularity BOM indicators, this indicator is expressed in three levels of use that can be integrated in the product development process.

Recovered material use
Similarly to the circular design assessment, goals for recovered material use are set for the components bought from suppliers. These targets set are lower than with Accell designed components, because it depends on suppliers offer. This choice is limited due to other reasons that come into play when choosing suppliers like price, quantity and reliability.

Circular supplier component assessment

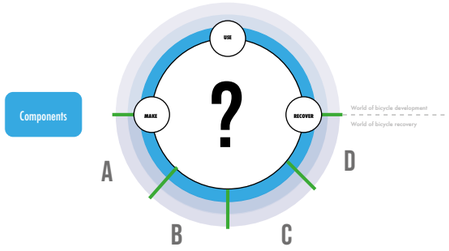


figure 3.4.11

Circular readiness

Components	D	C	B	A
C2C Banned List chemicals	Identified	0	0	0
Transparancy in supply chain	Audits include questions from 'questioning supplier' workshop	At least 50% transparancy of recycled material in components	100% transparancy of recycled material in components	100% transparancy of recycled material in components
Use of BOM list Material Circularity Indicators	Circularity indicators are included in every new BOM	Circularity indicators are included in every new BOM +	All coloms are filled in by requesting the necessarry data from suppliers and creation of a plan for reuse of components and recycling of materials	
Recovered material use > 10%		■	■	■
Recovered material use > 30%			■	■
Recovered material use > 50%				■

figure 3.4.12

3.5 Guiding circular product development

Circular bicycle development guidelines

Tool 2

The main goal of the thesis includes the develoment of a tool that guides the use of circular design in the Accell product development proces. This chapter includes the final guidance tool and the process of arriving there.

Input

Input by requirements

Requirement 1. The project team needs to be informed about the chosen strategy (circular economy), it's core principles, strategies for keeping materials in loops and associated terminology.

Requirement 2. The guidelines need to inform projects teams in circular aspects of most used materials in the design of a bicycle, and on design for disassembly.

Requirement 3. When selecting materials from suppliers or designing components the guidelines should inform the project team what circular aspects to focus on.

Requirement 4. The guidelines should include questions meant for suppliers with regard to material origin and production sustainability of materials, which can be used by the supply chain.

Requirement 5. Data collected regarding material origin should be stored in (an extension of) the tool, as there currently isn't a platform to do so.

Other forms of input

Format
Inspiration by the IDEO circular design sheets; although their content was only for a small part relevant to the Accell PDP, their format was very functional; they provided users with guidance, and connected this to workshop sheets.

Guiding sheets created until now;

Understanding circularity

figure 3.5.1 - Understanding C.E.

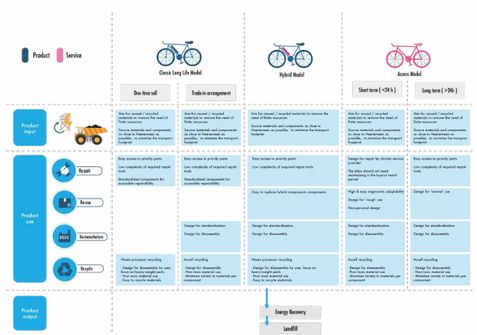


figure 3.5.2 - Business model & Product design

Brainstorming circular loops

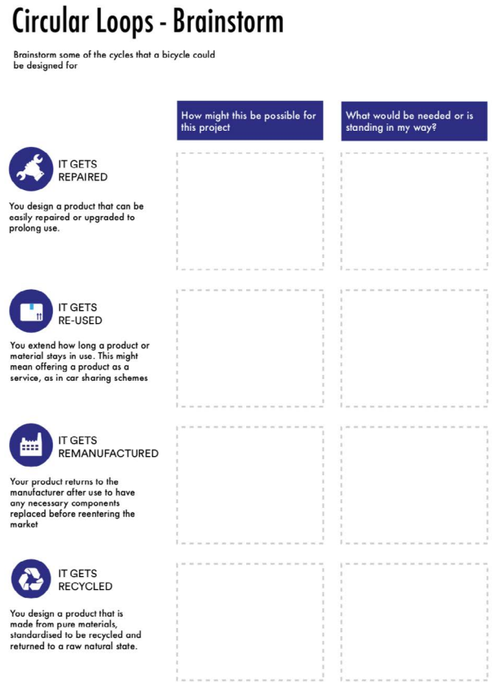


figure 3.5.3 - Developping circular loops

Design for dissassembly guidelines

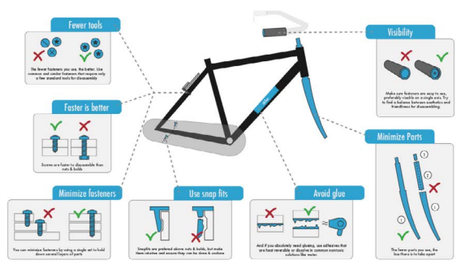


figure 3.5.4 - Design for disassembly

Material properties guidelines

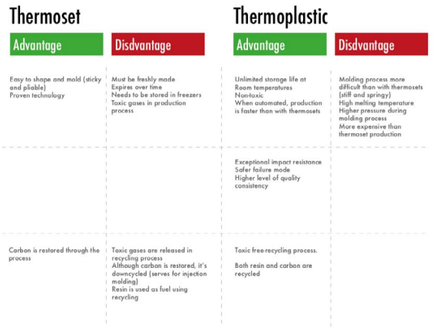


figure 3.5.5

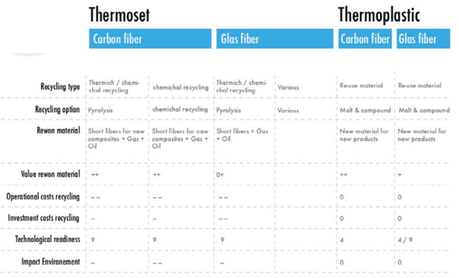


figure 3.5.6

Do	Don't	Why?
Keep mold parts as big as possible (>>10mm)	Never mold too smal (<<10mm)	Products are shredded and grinded. Small parts produce fines = losses
Use plastics as thick as possible (>>10mm)	Never mold too smal (<<10mm)	All recyclers use density seperation technoologies, that also seperate by weight / mass
Use plastics uniformly (1 polymer per molded piece)	Try not to mold plastics around metals	Plastics are burned in the melters as they go with the recycled material
Use plastics uniformly (1 polymer per molded piece)	Avoid 2K molding of different polymers	2K molded polymers cannot be seperated
Use a limited number of polymers (ideally 1-3)	Avoid >5 polymers in a product	Too many grades in a product make recycling inefficient
Use halogen free polymers	Do not use PVC and BrFR polymers	Softeners in PVC and bromine flameretardants are becoming frequently SVHC
Use POM unblended	Never use POM alloys (POM-ABS etc.)	POM traces produce cancerogenic formaldehyd (0,5 ppm limit at extrusion)
Use thermoplastics for foams	Avoid elastomers and thermosets for foams	Thermosets are causing surface issues
Use rubber in a solid, bulky form	Do not use silicon rubber and foamed rubber	Rubber particles and silicone rubber contaminate surfaces
Paint your parts with thin layers	Avoid heavy coatings	Coatings are causing surface issues
For high modules use carbon fibre or talcum filled plastics	Avoid the use of glass fibre filled coatings	Traces of glass fibre reduce mechanical properties and cause wepar
Connect parts with moderate forces	Avoid to connect parts permanently	Shredders must be able to seperate the individual parts of a product.
Choose virgin for very demanding parts (transparent, ...)	Do not use too strict specifications	20% of the polymer can be virgin
Choose geometries that allow easy flow paths	Avoid tight and narrow geometries	High shear rates stress and degrade the polymers
Consider more structured surfaces	Consider more structured surfaces	Traces of rubber and glass fibre reduce the quality of big surfaces

figure 3.5.7

	Recycle?	Downcycle?	Combust for energy recovery?	Biodegra dable?	Toxicity rating	Embodied energy primary production (*7 J/kg)	Embodied energy recycling (*7 J/kg)	Ra tio	Casting (*7 J/kg) (for metals)	Extrusion (*7 J/kg) (for metals)	Polymer extrusion energy (*7 J/kg)	Polymer molding energy (*7 J/kg)	Recycle fraction in current supply (worldwide)
Aluminium 6061	1	1	0	0	Non-toxic?	20	3,4	5,9	x		0,67	x	x	42%
Staal	1	1	0	0	Non-toxic	3,1	0,81	3,8	1,17	0,55	x	x		42%
verchroomd staal	1	1	0	0	Non-toxic	3,2	0,85	3,8	1,25	x		x	x	50%
messing	1	1	0	0	Non-toxic	7,25	1,6	4,5	1,01		0,98	x	x	28%
koper	1	1	0		Non-toxic	5,9	1,31	4,5	0,91	0,16	x	x		43%
rvs	1	1	0	0	Non-toxic	7,3	1,6	4,6	1,14	1,02	x	x		37,5%
zamac	1	1	0	0	Non-toxic	5,25	1,23	4,3	0,67	x				22%
PE	1	1	1	0	Non-toxic	8	2,66	3,0	x	x		0,82	2,2	8,4%
PP	1	1	1	0	Non-toxic	8,9	2,35	2,9	x	x		0,82	2,15	5,6%
pu schuim	0	1	1	0	Non-toxic	8,2	x							0,1%
PET	1	1	1	0	Non-toxic	8,2	2,65	3,1	x	x		0,825	2,2	8,4%
EPS	0	1	1	0	Non-toxic	12,8			x	x	x		2,2	0,7%
PC	1	1	0	0	Non-toxic	10,5	3,67	2,9	x	x		0,82	1,85	0,7%
rubber	1	1	1	0	Non-toxic	11,28	x			x	x		1,61	0,01%
PA	1	1	1	0	Non-toxic	14,5	4,3	3,4	x	x		0,825	2,15	0,71%
ABS	1	1	1	0	Non-toxic	9,2	3,25	2,8	x	x		0,82	1,85	4%
linten	0	1	0	0	Toxic									
karton	1	1	1	?	Non-toxic	9,2	2,2	2,4	x		x	x		72%

figure 3.5.8

This visual represents the proces that led to the establishment of the design guidelines.

Process

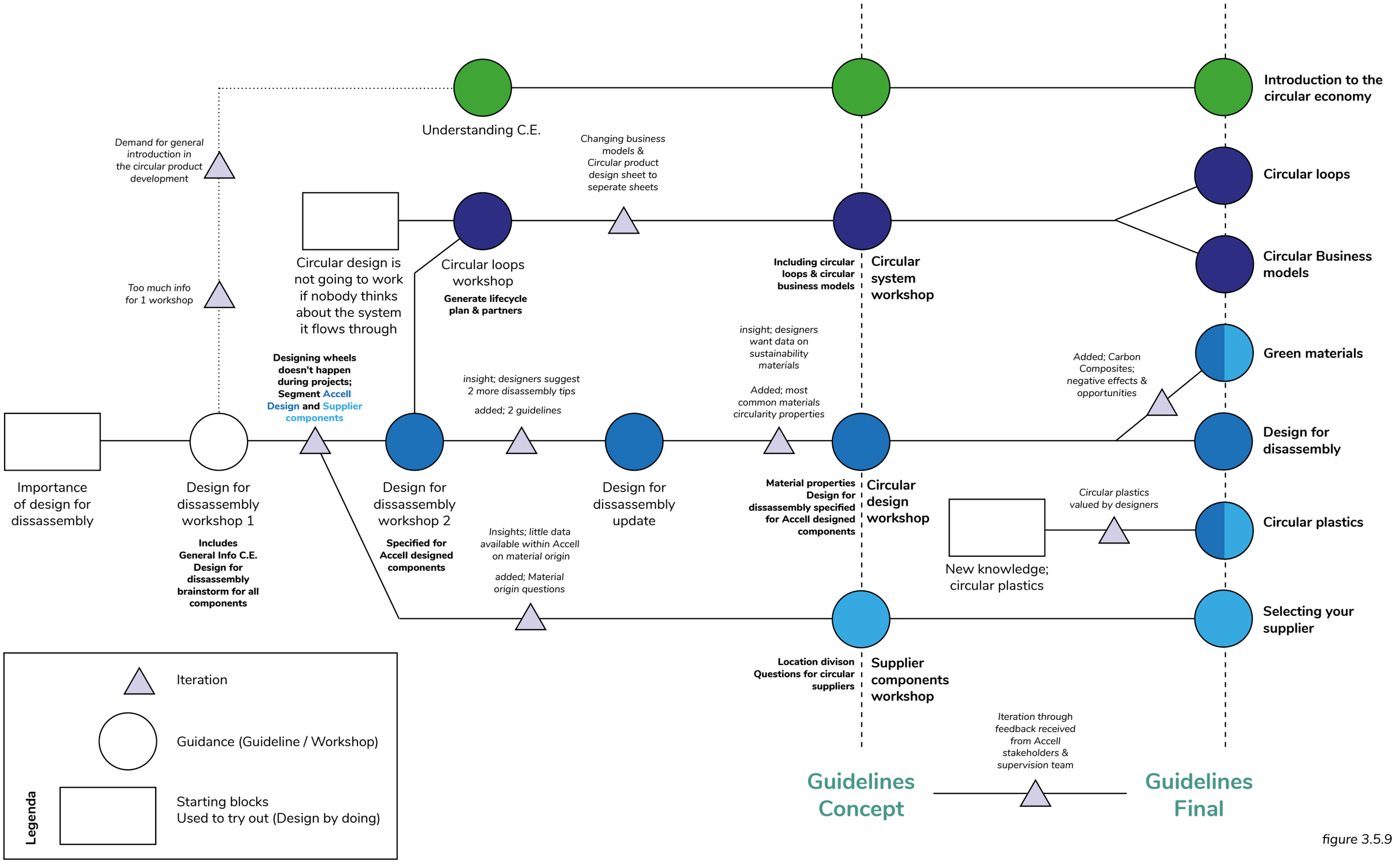


figure 3.5.9

Workshops

The guiding sheets were merged into workshops. During the workshops, created guidelines and workshops sheets were tested on their desirability, understanding and effectiveness in generating outcome. A 'design by doing' approach was taken; if the workshop functioned well, it was integrated in the guidance tool. If not, adjustments were made. This chapter discusses the workshops.

General Set up

Due to corona, the workshops took place in digital form. The workshop sheets designed were sent to all participants in advance, with the request of printing them.

During the zoom everyone could brainstorm / generate ideas with those sheets, after which they were uploaded in a google folder that was shared with everyone. This was followed by a feedback round with all participants, while my screen was split so that everyone looked at the same photos.

Results were then discussed. In the first workshop, we also arranged the ideas on their easyness of difficultness of achieving

Digital workshop insights

Positive;

All documents created during the workshop are easily stored in the right folders, online. This is opposed to when a normal workshop takes place, where it can take a while to document all the results.

Negative;

Retrieving feedback is a lot harder during workshops. Asking frequently if everybody is following up and understands the workshop helps.

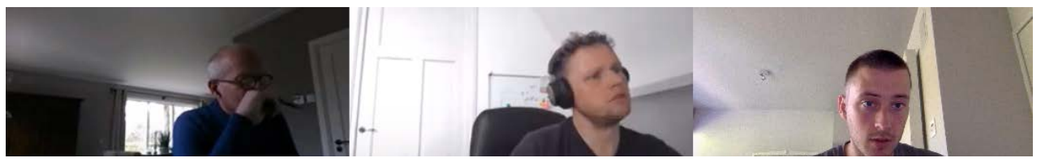


figure 3.5.10

Circular component brainstorm

Workshop creation

Using the format of IDEO worksheets, first 'understanding pages' were designed, using insights from chapter 2. An introduction sheet about understanding circularity, including the three basic principles of C.E. and the technical circular cycle applied to bicycles.

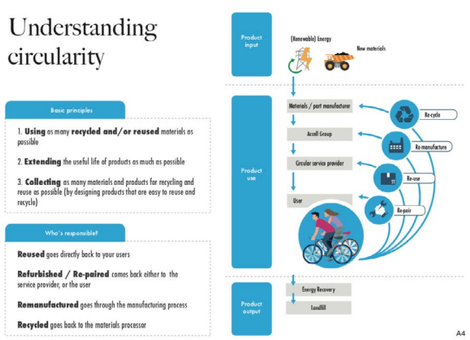


figure 3.5.11

The second sheet was used create understanding within the project between the relation of circular business model and product design.

Then a sheet using the bicycle of the project (not shown) was created to choose a specific bicycle component to brainstorm on

A fourth sheet was used for brainstorming on how the design of the component could be adjusted, to circulate in the loop defined in the relation sheet (figure 3.5.12).

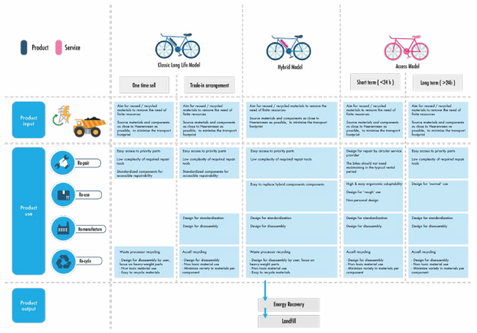


figure 3.5.12

The ideas were captured through 'ideas capture' sheets, based on the designs of IDEO.

Then, when all ideas created by the project group were collected within the project group, the 'winning' idea was selected using the 'concept selection' sheet, providing 2 axes; difficultnies of developing the component, and the impact it makes

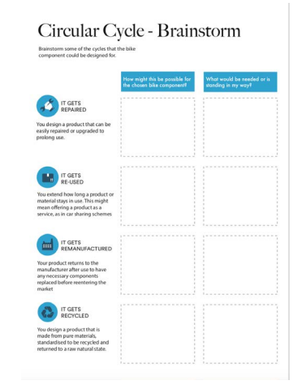


figure 3.5.13

Goal

Test if the guidelines and workshop

- make the project team understand the concept and strategies of the circular economy
- are succesfull in letten the project team generate and evaluate ideas

figure 3.5.14

Conclusions

- The relation between business model and guidelines was too much information and not referred to. It was decided to make a seperate sheet for circular business models.

- Adjust the workshop to the Accell frame specific in stead of trying to cover the full bicycles

- Combination between the different sheet (understanding & workshop) worked very well. It was used for further development of guideliness.

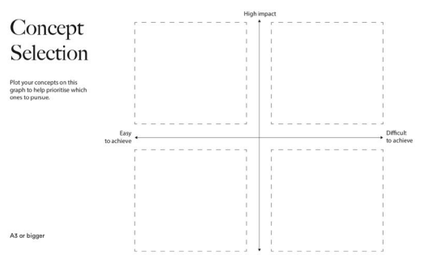


figure 3.5.15

Design for dissassembly Brainstorm

Using feedback from the previous workshop, a second workshop was designed. Instead of involving loops, the goal was to design for disassembly (which directly contributes to repair, remanufacture and recycling). The selection of components was limited within the components that were designed by Accell.

This workshop was led by project product manager, to validate if the workshop was ready for use within a I&T project team.

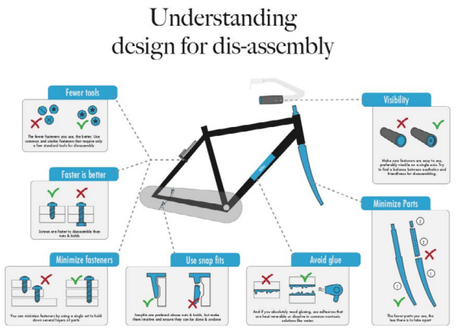


figure 3.5.16

Goal

- See if the design for disassembly guidelines properly functioned on the frame

- Validate if the workshop also is well executed and understood if presented by the product manager

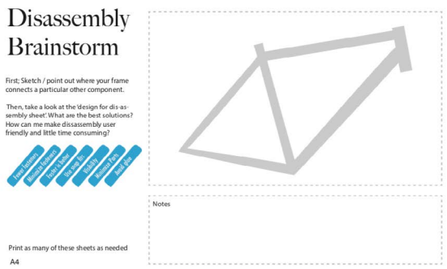


figure 3.5.17

Conclusions

The product manager successfully used the guidance and workshop sheets to execute the workshop. Using the checklist - design for disassembly, changes were implemented in the design of the frame.

- Two additions to the design for dissassembly strategies;

Standardize
Standardization is the process of establishing uniformity across manufacturing materials and processes. Potential benefits of standardization include lower production and procurement costs through economies of scale, easier and less expensive repair and replacement, and faster and more efficient processes

Inform
Inform on parts what type of material the part is created from, and how to take it apart.

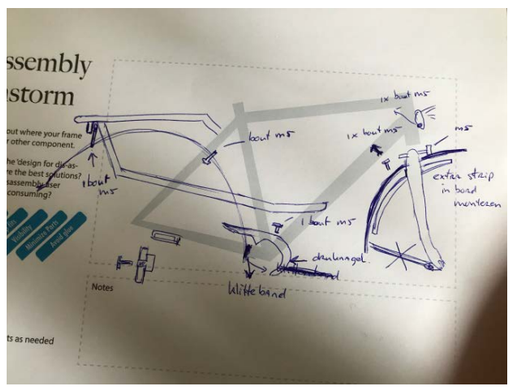


figure 3.5.18

Guidelines Concept

After the differentiation of system - design and components, the different guidelines (understanding the general theory, circular business models, material knowledge, design strategies, supplier aspects) could be grouped.

First, a general understanding of the circular economy served as a basic C.E. understanding for everyone in the project group.

This knowledge could then be used in the three workshops; system, design and component. Depending on the stage the project is in, a different workshop is used. In earlier stages (0-1), system is used, to establish or define the circular life of the bicycle. In later stages (1-3), design and components are used, to establish the product itself.

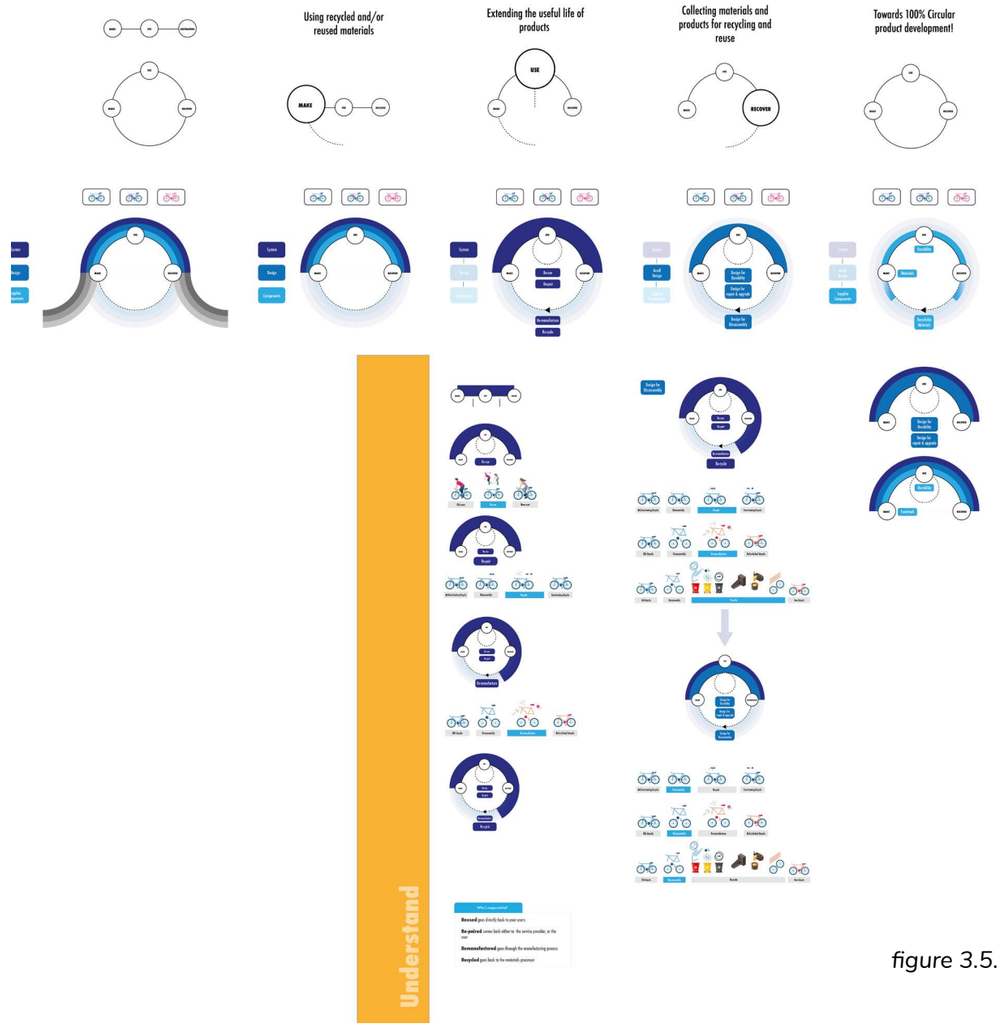


figure 3.5.19

System

If you design a wonderful product with a great material, but there is no way for that material to circulate effectively, the product itself has a limited life and is hard to disassemble, and there is no economic situation in which the company can get it back.. Is that a great product? No. It failed in functioning in a system effectively. That is system thinking; to stop designing a bottle or a chair without thinking how it fits. [Ken Webster]

Classic Long Life
The classic long life model proposes a high quality product with a long lifespan, with sales as the classic income.

Hybrid
In this model, profits are made from the repeat sales of relatively cheap products with a short lifespan that only function together with a dedicated high-quality durable product.

Access
In this model, profits are made from the repeat sales of relatively cheap products with a short lifespan that only function together with a dedicated high-quality durable product.

Circular Cycle - Brainstorm

Brainstorm some of the cycles that a bicycle could be designed for

	How might this be possible for a this project	What would be needed or is standing in my way?
IT GETS REPAIRED You design a product that can be easily repaired or upgraded to prolong use.		
IT GETS RE-USED You extend how long a product or material stays in use. This might mean offering a product as a service, as in car sharing schemes		
IT GETS REMANUFACTURED Your product returns to the manufacturer after use to have any necessary components replaced before reentering the market		
IT GETS RECYCLED You design a product that is made from pure materials, standardised to be recycled and returned to a raw natural state.		

figure 3.5.20

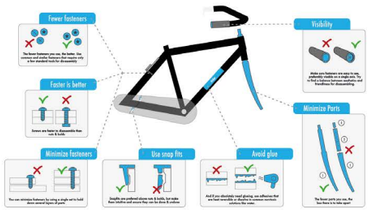
Accell desgin

Now we've envisioned what processes, partners and business models are crucial for a circular bicycle lifecycle, we can start to design for it. Start by watching the circular product design video, to understand the relation between circular systems and circular product design.

80% Of environmental polution and 90% of manufacturing costs are the result of decisions made in the product design stage. Our design freedom is divided over the components design by Accell (frame, front fork) and the components we select. This chapter 'circular product design' focusses on the components designed by Accell.

Design for Dissassembly

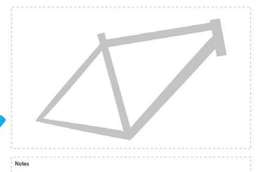
Workshop



Disassembly Brainstorm

First: Sketch / point out where your frame connects a particular other component.

Then, take a look at the 'design for dis-assembly sheet'. What are the best solutions? How can me make dissassembly user friendly and little time consuming?



Notes

Print as many of these sheets as needed

A4

Materials

	Recycle?	Downcycle?	Combust for energy recovery?	Biodegra dable?	Toxicity rating	Embodied energy, primary production ("1" eMJ)	Embodied energy, recycling ("1" eMJ)	Re use	Coating ("1" eMJ) (per meter)	Extrusion ("1" eMJ) (per meter)	Polymer extrusion energy ("1" eMJ)	Polymer molding energy ("1" eMJ)	Recycle fraction in current supply (worldwide)
Aluminium 6061	1	1	0	0	Non-toxic?	20	0,4	0,9	x	0,67	x	x	42%
Staal	1	1	0	0	Non-toxic	3,1	0,81	0,8	1,17	0,55	x	x	42%
vezelversterkt staal	1	1	0	0	Non-toxic	3,2	0,85	0,8	1,25	x	x	x	55%
messing	1	1	0	0	Non-toxic	7,25	1,8	4,5	1,01	0,56	x	x	38%
koper	1	1	0	0	Non-toxic	5,9	1,31	4,5	0,91	0,16	x	x	45%
rvs	1	1	0	0	Non-toxic	7,3	1,8	4,8	1,14	1,22	x	x	37,5%
zamac	1	1	0	0	Non-toxic	5,25	1,35	4,5	0,87	x			35%
PE	1	1	1	0	Non-toxic	8	2,05	3,0	x		0,82	2,2	8,4%
PP	1	1	1	0	Non-toxic	6,9	2,26	2,9	x		0,82	2,15	5,6%
pu-schuim	0	1	1	0	Non-toxic	8,2	x						0,1%
PET	1	1	1	0	Non-toxic	8,3	2,85	3,1	x		0,825	2,2	8,4%
EPS	0	1	1	0	Non-toxic	17,9		x	x	x		2,2	0,7%
PC	1	1	1	0	Non-toxic	10,5	3,87	2,9	x	x	0,82	1,85	0,7%
rubber	1	1	1	0	Non-toxic	11,25	x		x	x		1,81	0,01%
PA	1	1	1	0	Non-toxic	14,5	4,3	3,4	x	x	0,825	2,15	0,7%
ABS	1	1	1	0	Non-toxic	9,2	3,25	2,8	x	x	0,82	1,85	4%
li-ion	0	1	0	0	Toxic								
karton	1	1	1	1	Non-toxic	0,2	2,2	2,4	x	x	x	x	77%

figure 3.5.21

Supplier components

Although the biggest components are designed by Accell, most components in Accell bicycles are bought from suppliers all over the world. We cannot decide how to design them, but we do have the freedom to select them. The workshops of 'supplier components' help with this selection, by offering information about sustainability aspects of materials, questions to ask your supplier regarding material use, energy use and circular loops.

Questions to ask your supplier

1. What raw materials do you use? What percentage of the materials used in the component is recycled?
2. Do you have an environmental management system in place? Is it consistent with an internationally accepted standard, e.g. ISO 14001? Can you provide a copy?
3. Do you use renewable energy in your facilities?
4. Do you recycle any of your key inputs, such as water or chemicals?
5. Do you use any hazardous chemicals or materials in your production? How do you manage them to ensure they don't enter waste streams or water?
6. How do you package your final products? Do you use any recycled or recyclable materials?
7. Can we send back used components (in batches) to your company for recycling? In case yes, do you have information regarding recycling efficiency?

Local = Better!

Materials

	Recycle?	Downcycle?	Combust for energy recovery?	Biodegra dable?	Toxicity rating	Embodied energy, primary production ("1" eMJ)	Embodied energy, recycling ("1" eMJ)	Re use	Coating ("1" eMJ) (per meter)	Extrusion ("1" eMJ) (per meter)	Polymer extrusion energy ("1" eMJ)	Polymer molding energy ("1" eMJ)	Recycle fraction in current supply (worldwide)
Aluminium 6061	1	1	0	0	Non-toxic?	20	0,4	0,9	x	0,67	x	x	42%
Staal	1	1	0	0	Non-toxic	3,1	0,81	0,8	1,17	0,55	x	x	42%
vezelversterkt staal	1	1	0	0	Non-toxic	3,2	0,85	0,8	1,25	x	x	x	55%
messing	1	1	0	0	Non-toxic	7,25	1,8	4,5	1,01	0,56	x	x	38%
koper	1	1	0	0	Non-toxic	5,9	1,31	4,5	0,91	0,16	x	x	45%
rvs	1	1	0	0	Non-toxic	7,3	1,8	4,8	1,14	1,22	x	x	37,5%
zamac	1	1	0	0	Non-toxic	5,25	1,35	4,5	0,87	x			35%
PE	1	1	1	0	Non-toxic	8	2,05	3,0	x		0,82	2,2	8,4%
PP	1	1	1	0	Non-toxic	6,9	2,26	2,9	x		0,82	2,15	5,6%
pu-schuim	0	1	1	0	Non-toxic	8,2	x						0,1%
PET	1	1	1	0	Non-toxic	8,3	2,85	3,1	x		0,825	2,2	8,4%
EPS	0	1	1	0	Non-toxic	17,9		x	x	x		2,2	0,7%
PC	1	1	1	0	Non-toxic	10,5	3,87	2,9	x	x	0,82	1,85	0,7%
rubber	1	1	1	0	Non-toxic	11,25	x		x	x		1,81	0,01%
PA	1	1	1	0	Non-toxic	14,5	4,3	3,4	x	x	0,825	2,15	0,7%
ABS	1	1	1	0	Non-toxic	9,2	3,25	2,8	x	x	0,82	1,85	4%
li-ion	0	1	0	0	Toxic								
karton	1	1	1	1	Non-toxic	0,2	2,2	2,4	x	x	x	x	77%

figure 3.5.22

Feedback retreived on first version of the tool

Language
The word 'feedstock' refers to the biosphere. Therefore another term should be used, like 'raw material'

The word 'destination' which was meant to cover both the linear and circular economy, does not resonate with the change between the two economies. To amplify the difference, the word 'dispose' is chosen in lineair, and 'recover' used in the circular economy.
Design vs component
As the difference between the two is mainly in-house design versus outsourced components being bought, this should be made clear in the tool

Understanding the use of the BOM circularity indicator
In the tool the use of the BOM is not introduced.

Impact circular business model.
The tool should explain more explicitely what impact the circular business model has on the main focus of circular design for the project team

Guidelines Final

All insights in workshops and reflections on the tool led to the final version of the Accell Circular Guidlines.
It's content is shown on the following pages.

Introduction to the circular economy

Hello and welcome to the 'towards circular product development' platform! This platform is created to provide guidelines and assesment for the use of circular design in the I&T product development process.

Our global society is not sustainable. We all know about the challenges we're facing: waste, climate change, resource scarcity, loss of biodiversity.

At the same time, we want to sustain our economies and offer opportunities for a growing world population. The Circular Economy offers a model that not only reduces impact on the environement, but possibly benefits it.

So lets get started.

Goal

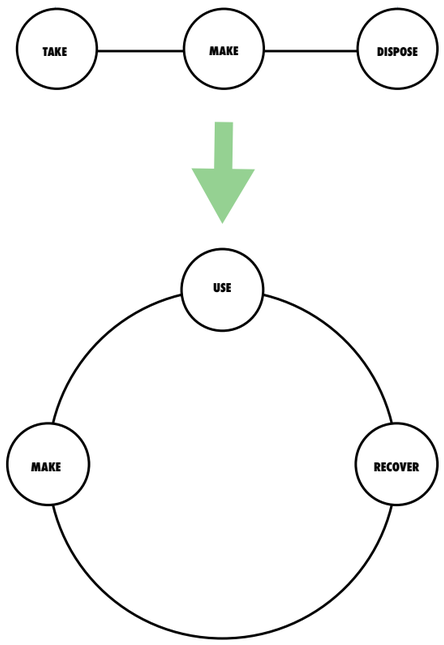
- Understand the difference between a linear and a circular economy

- Understand the three basic principles Accell can apply in her way of operating and design of bicycles, to contribute to a circular economy

- Understand the use of the tool

From Linear

In a linear economy, finite raw materials are taken from the earth, turned into products and eventually wasted. Each time this happens, we're using earth's finite sources and producing (toxic) waste. It simply can't work long term. So what can?



To circular

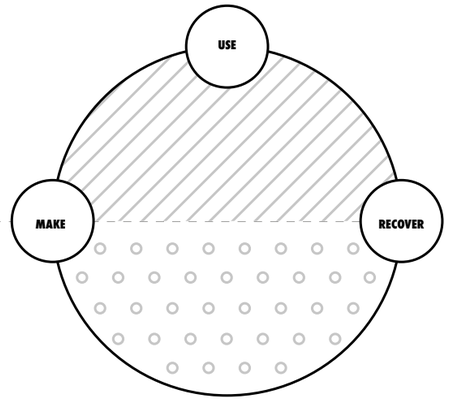
A circular economy is an economic system in which value is maintained or created by reusing products and raw materials and minimizing destruction of raw materials. There's a world of opportunity to rethink and redesign the way we make stuff.

For Accell, this shift from linear to circular means to include a new world in the way we design bicycles; the world of bicycle recovery.

Traditional recovery (the recycling performed by waste processors) loses a lot of value of materials (downcycling). So how can we optimize our system and bicycle design for the world of bicycle recovery?

World of bicycle development

World of bicycle recovery



Below are three basic principles that Accell can achieve, to contribute to a circular economy.

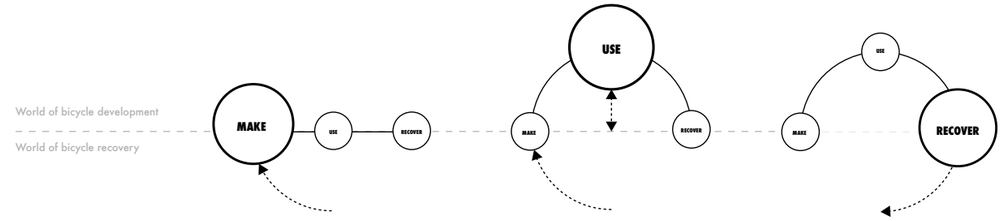
Using recycled materials and/or reused components

Extending the useful life of products

Recover componants for recycling and reuse

World of bicycle development

World of bicycle recovery



Introduction to the Circularity Tool

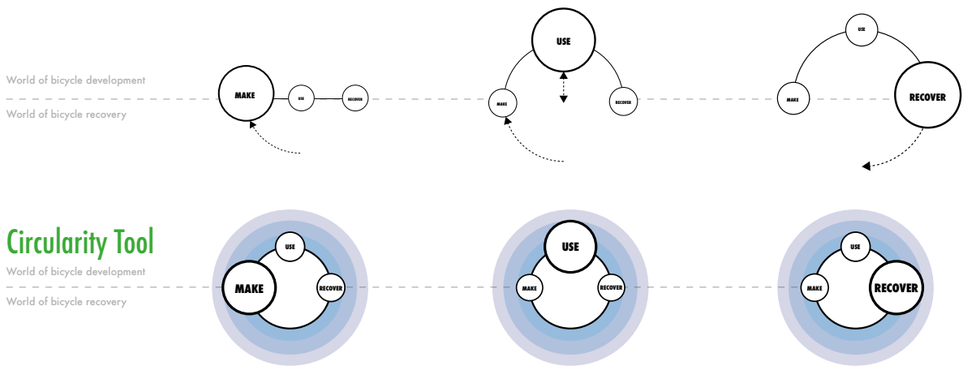
MAKE - USE - RECOVER

These same principles are implemented in the circularity tool.

Using recycled materials and/or reused components

Extending the useful life of products

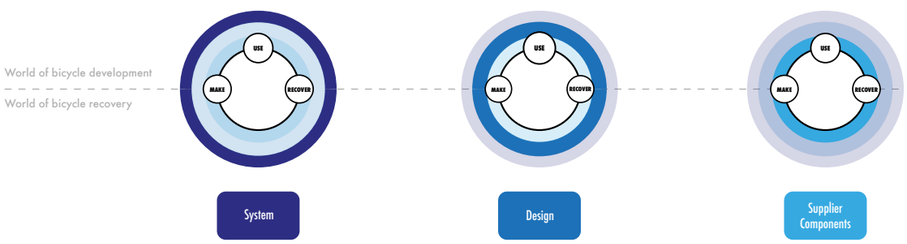
Collecting componants for recycling and reuse



Introduction to the Circularity Tool

SYSTEM - DESIGN - COMPONENTS

These 3 stages; making, use and recovery, are of relevance to the **system** they operate in, the **design** of our bicycles and the **components** we buy from suppliers.



Operating as a company within the circulary economy starts by thinking in systems. In what ways can we recover bicycles? What loops exist in which components and materials can flow? How is it profitable?

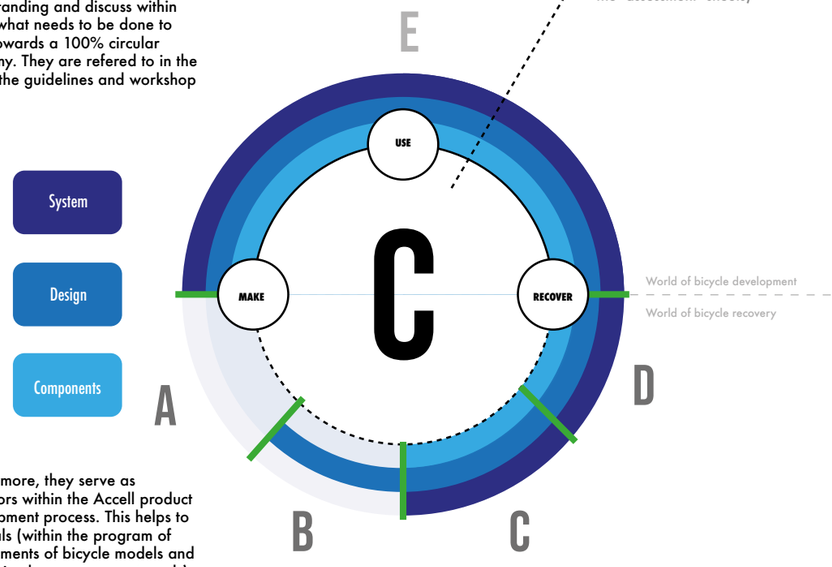
After envisioning what processes, partners and business models are crucial for a circular bicycle lifecycle (circular systems), we can start to adapt our design for it. Our design freedom is divided over the components design by Accell (frame, front fork) and the components we select. This layer 'circular product design' focusses on the components designed by Accell.

Although the biggest components are designed by Accell, most components in Accell bicycles are bought from suppliers all over the world. We cannot decide how to design them, but we do have the freedom to select them. The layer 'supplier components' help with this selection, by offering information about sustainability aspects of materials, questions to ask your supplier regarding material use, energy use and circular loops.

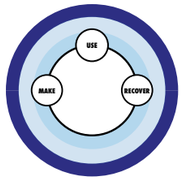
Introduction to the Circularity Tool

The tool including it's 2 divisions; make - use - recover, and system - design - components, helps in understanding and discuss within teams what needs to be done to work towards a 100% circular economy. They are refered to in the rest of the guidelines and workshop sheets.

Total circularity score of produced product
(More explanation about this in the 'assessment' sheets)



Furthermore, they serve as indicators within the Accell product development process. This helps to set goals (within the program of requirements of bicycle models and within circular management goals), and assess our progress towards being circular. Criteria can be accessed by everyone and found in the 'assessment' folder.



System

Circular Loops

Design

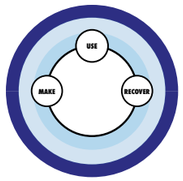
At its core, a circular economy means that products no longer have a life cycle with a beginning, middle, and end, and therefore contributes less waste and can actually add value to their ecosystem. When materials stop getting used, they go back into a useful cycle, hence the circular economy. Imagine what would happen if everything was designed to be restorative and regenerative?

Goal

- Understand the 4 strategies of circular loops.

- Brainstorm how these loops can be profitable within the project you're working on

Understanding Circular Loops



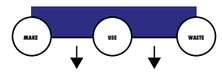
System

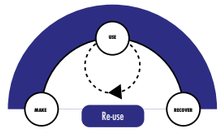
When we look from a system level to a circular lifecycle of a bicycle, 4 strategies enable the bicycle and it's components to keep in the circular loop.

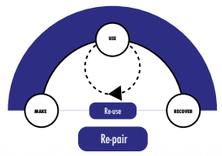
The first two take place in the world of development.

1. Re-use
By re-using a bicycle, value of the bicycle is kept most high by simply providing it to a new user. This can for example be a consumer buying the bicyle second-hand, or through leasing the bicycle to customers. Brainstorm on this using the 'circular business models' workshop.

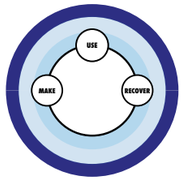
2. Re-pair
If things do break, and we can't use them anymore, we should consider if we can fix it. Too often do we throw away things of which only a really small part is defunct. Unfortunately, the more complex products get, the harder they get to repair. But this doesn't have to be!
If products are designed more in a way that people can easily repair key components, the amount of time we can use a product (the so-called life cycle) can be extended a lot







Understanding Circular Loops

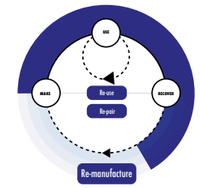


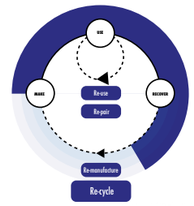
System

When a bicyle is not able to circulate in the world of development anymore, recovery can be achieved using 2 other strategies.

3. Re-manufacture
Instead of repairing what is broken, it is also possible to take the well-working parts of a broken device and use them for something new, or sandblast and repaint a component into a second life. This process is called remanufacturing. Because the components keep their embodied production energy, the circular value of this strategy is higher than with recycling

4. Re-cycle
With recycling you take something apart until you get back the original resources you used to make it, these can then be used to make new products and parts from scratch. This can be something entirely different, like a new bicycle model.

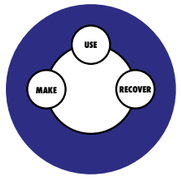




Circular Loops - Brainstorm

Brainstorm some of the cycles that a bicycle could be designed for

	How might this be possible for this project	What would be needed or is standing in my way?
IT GETS REPAIRED You design a product that can be easily repaired or upgraded to prolong use.		
IT GETS RE-USED You extend how long a product or material stays in use. This might mean offering a product as a service, as in car sharing schemes		
IT GETS REMANUFACTURED Your product returns to the manufacturer after use to have any necessary components replaced before reentering the market		
IT GETS RECYCLED You design a product that is made from pure materials, standardised to be recycled and returned to a raw natural state.		



Circular Business Models

System

Making bicycles for a circular economy requires a mind shift in the way of being profitable.

The take-make-dispose model is an economic model where value is created by producing and selling as many products as possible. This way of generating revenue has the risk of resulting in low-quality production to cause premature product failure, purely to increase the need for consumers to buy more products. Furthermore, it doesn't encourage recovering and recycling end-of-use products, since these are seen as costs.

In a circular perspective, this changes. Throughout its life a product can be modified, updated, re-used, repaired, sold, rented, borrowed, taken apart, divided up, re-manufactured, re-cycled and so on. Every change represents an opportunity to contribute to the closure of its economic circle, to create and maintain value over time, and to keep revenue coming in (Bakker, 2014).

So where to start? Instead of thinking in one-time-sales revenue, we need to think about how to generate income through the circular lifecycle of a bicycle. Generate profit through the world of bicycle development, ánd the world of bicycle recovery. Let's start by understanding what circular business models* apply to Accell, and what their relation is with the circular economy

** Products that last; product design for circular business models (2014)*

Goal

- Develop (stage 0, initial business case) or identify (stage 1, business case) the circular business model that your project will be build on.

- Understand relation between this circular business model and the world of waste recovery

Understanding Circular Business Models

From the three basic principles of a circular economy, Accell is advanced in number 2; Extending the usefull lifetime of products. Accell produces bikes for the mid-high segment, by guaranteeing qualitative, durable design. The circular business model that fits this, is the classic clong life model.

Two other circular business models are 'hybrid' and access'.

Product component of value proposition

Service component of value proposition

Classic Long Life

The classic long life model proposes a high quality product with a long lifespan, with sales as the classic income.

Hybrid

In this model, profits are made from the repeat sales of relatively cheap products (bicycle components) with a short lifespan that only function together with a dedicated high-quality durable product (the bicycle itself)

Access

Is about making money through providing access to a products, while its ownership remains with the access provider.

Examples

-Leasing the battery while selling the bicycle

-Offering subscriptions on brakes and tires while selling the bicycle.

-Leasing the battery while selling the bicycle

-Offering subscriptions on brakes and tires while selling the bicycle.

-Designing a bicycle for a mobile service provider (NS public transport bikes for example)

-Leasing bicycles to clients, either B2B or B2C

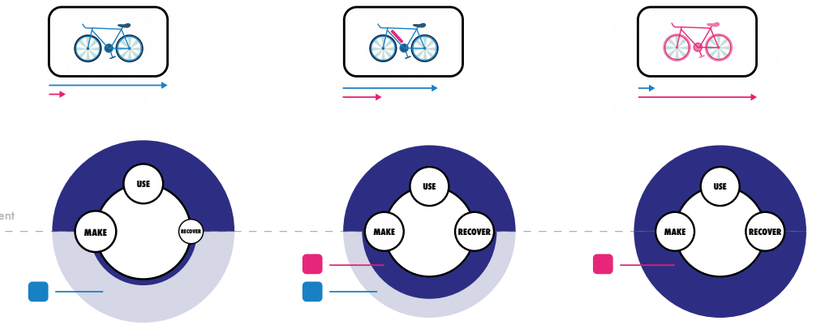
Understanding Circular Business Models

Product component of value proposition

Service component of value proposition

World of bicycle development

World of bicycle recovery



Your business model is focussed on the world of long life bicycle development meaning

MAKE + You are able to select green raw materials and or recycled materials

USE + By qualitative and easy to repair design you can provide a long use phase

RECOVER - You are little in control of the end-of-use of the bicycle

A combination of a high quality bicycle and selling / leasing bike components makes sure

MAKE + You are able to select green raw materials, re-manufactured components and or recycled materials

USE + By qualitative and easy to repair design you can provide a long use phase.

RECOVER + It opens the possibility of recovering components (for example, the battery)

When Accell (or a partner) provides the bicycle as a service and remain ownership of the bicycle

MAKE + You are able to select green raw materials, re-manufactured components and or recycled materials

USE + Through re-using the bicycle you are able provide a long use phase

RECOVER + You can be in control of re-manufacturing and -ecycling the bicycle.

Developing Circular Business Models

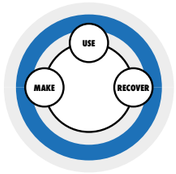
Use the 'understanding circular business Models' sheets to start the conversation within the project team; What circular business model is identified? How will value be created?

What will generate income?

☐ Classic Long Life

☐ Hybrid

☐ Access



Design for Dissassembly

Design

When it comes to the end-of-use of a product, the easiness of disassembly and recovery is greatly determined by the way the product is designed.

Thinking about the end-of-use during the design phase, benefits how the product, components and materials can be deconstructed. The main goal that design for disassembly aims for, is decreasing disassembly time. The shorter time to disassemble, the easier and more profitable a bicycle will be repaired, remanufactured or eventually re-cycled. This workshop offers guidelines for designing bicycle components for disassembly.

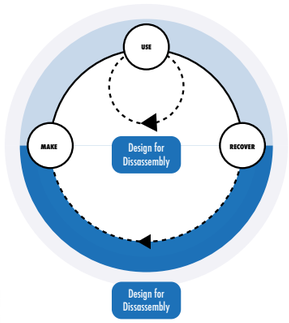
Goal

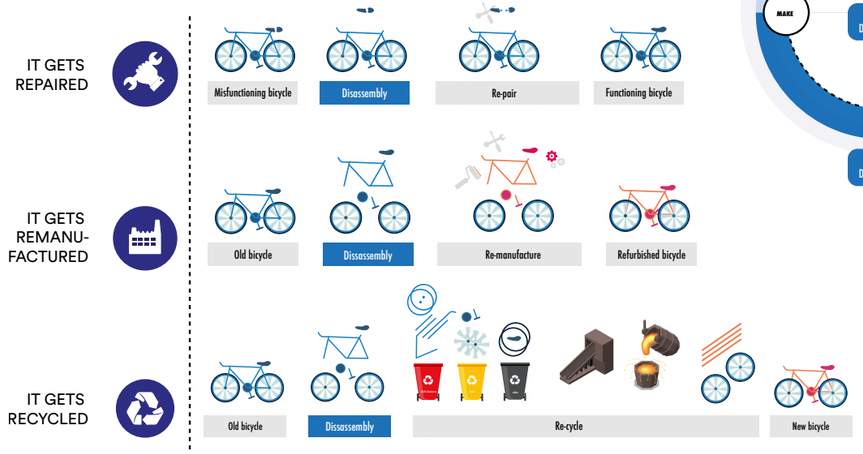
- Understand how to design bicycles for easy dissassembly

- Brainstorm with a component of your choice

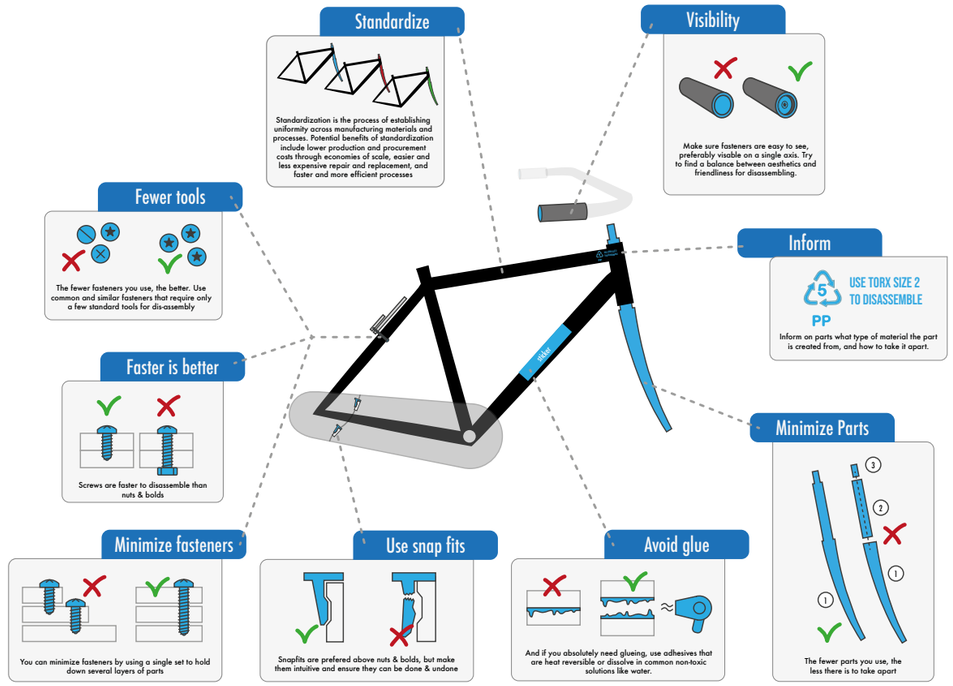
Understanding Design for dissassembly

Design for dissassemlby is crucial for enabling a economically profitable recovery proces. The more we think and prepare the bicycle for his end-of-use during the design process, the less time and effort it takes to dissassemble a bike. And if dissassembly time is low and easy enough, going circular becomes profitable. In the graphic below it is shown why dissassembly is important to 3 of the 4 r's; re-pair, re-manufacture and recycle.





Understanding Design for dissassembly



Brainstorm Design for dissassembly

First; Sketch / point out where your bicycle component connects

Then, take a look at the 'design for dis-assembly sheet'. What are the best solutions? How can me make dissassembly user friendly and little time consuming?

Print as many of these sheets as needed

A4

Notes

Green Materials

Design

Supplier components

Environmental properties of materials are important for making smart choices in the selection of the materials you use in the design of your bicycle. But also when ordering components from a supplier, knowing the impact of the materials that are used in these components can help in making the most sustainable choices.

This document can be used to better understand the environmental properties and make choices between the use of different materials

Goal

- Understand the environmental properties of materials

- Compare different materials based on their environmental properties

Understanding Green Materials

What to pay attention to?

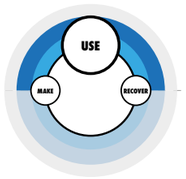
World of bicycle development

World of bicycle recovery

How much % of the material from the supplier is recycled?

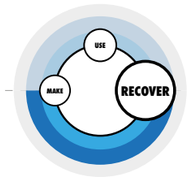
How much energy does it take to supply this material (embodied energy)

Is the material toxic?



How durable is the material?

Is the material toxic?



Can the material be recycled, or biodegraded?

Will it be recycled? (Circular Systems)

How much energy to recycle the material?

Is the material toxic?

Understanding Green Materials

Did you know..

It takes nearly **6 times** more energy to mine and manufacture 1 kg of vrigin aluminum than it takes for 1 kg of virgin steel

Using recycled aluminium, cuts the embodied energy by **90%**

ABS, PC, PC/ABS, PP, HIPS, PA are excellent for recycling and are recommended for use in a circular economy by the PolyCE consortium

Selecting Green Materials

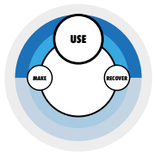
	Recycle?	Downcycle?	Combust for energy recovery?	Biodegradeble?	Toxicity rating	Embodied energy primary production (^7 J/kg)	Embodied energy recycling (^7 J/kg)	Ratio	Casting (^7 J/kg) (for metals)	Extrusion (^7 J/kg) (for metals)	Polymer extrusion energy (^7 J/kg)	Polymer molding energy (^7 J/kg)	Recycle fraction in current supply (worldwide)
Aluminium 6061	1	1	0	0	Non-toxic?	20	3,4	5,9	x	0,67	x	x	42%
Staal	1	1	0	0	Non-toxic	3,1	0,81	3,8	1,17	0,55	x	x	42%
verchroomd staal	1	1	0	0	Non-toxic	3,2	0,85	3,8	1,25	x	x	x	53%
messing	1	1	0	0	Non-toxic	7,25	1,6	4,5	1,01	0,98	x	x	38%
koper	1	1	0		Non-toxic	5,9	1,31	4,5	0,91	0,16	x	x	43%
rvs	1	1	0	0	Non-toxic	7,3	1,6	4,6	1,14	1,02	x	x	37,5%
zamac	1	1	0	0	Non-toxic	5,25	1,23	4,3	0,67	x			22%
PE	1	1	1	0	Non-toxic	8	2,65	3,0	x	x	0,62	2,2	8,4%
PP	1	1	1	0	Non-toxic	6,9	2,35	2,9	x	x	0,62	2,15	5,6%
pu schuim	0	1	1	0	Non-toxic	8,2	x						0,1%
PET	1	1	1	0	Non-toxic	8,3	2,65	3,1	x	x	0,625	2,2	8,4%
EPS	0	1	1	0	Non-toxic	12,8			x	x	x	2,2	0,7%
PC	1	1	0	0	Non-toxic	10,5	3,67	2,9	x	x	0,62	1,85	0,7%
rubber	1	1	1	0	Non-toxic	11,28	x			x	x	1,61	0,01%
PA	1	1	1	0	Non-toxic	14,5	4,3	3,4	x	x	0,625	2,15	0,71%
ABS	1	1	1	0	Non-toxic	9,2	3,25	2,8	x	x	0,62	1,85	4%
li-ion	0	1	0	0	Toxic								
karton	1	1	1	1	Non-toxic	5,2	2,2	2,4	x	x	x	x	72%

Source; CES by granta design.This program can be used to compare all kinds of material characteristics; such as weight, costs and sustainability qualities

Carbon Composites Comparison - Green Materials

Thermoset

Advantage	Disdvantage
Easy to shape and mold (sticky and pliable) Proven technology	Must be freshly made Expires over time Needs to be stored in freezers Toxic gases in production process



Advantage	Disdvantage
Exceptional impact resistance Safer failure mode Higher level of quality consistency	

Advantage	Disdvantage
Carbon is restored through the process	Toxic gases are released in recycling process Although carbon is restored, it's downcycled (serves for injection molding) Resin is used as fuel using recycling

Thermoplastic

Advantage	Disdvantage
Unlimited storage life at Room temperatures Non-toxic When automated, production is faster than with thermosets	Molding process more difficult than with thermosets (stiff and springy) High melting temperature Higher pressure during molding process More expensive than thermoset production

Advantage	Disdvantage
Toxic free-recycling process. Both resin and carbon are recycled	

Circular plastics

Supplier components

To create plastic components that are ready to circulate in recovery loops, several guidelines are listed in the sheet below.

They can be used as design guidelines within the I&T department of Accell. For example in the production of lightning components.

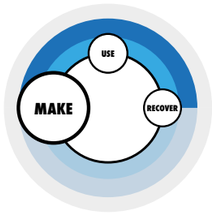
Also, this list could be send to suppliers to help them getting started in creating components suitable for the circular economy

Goal

- Understand how to design plastics for a circular economy

Carbon Composites Recycling - Green Materials

	Thermoset			Thermoplastic		
	Carbon fiber		Glas fiber	Carbon fiber	Glas fiber	
Recycling type	Thermich / chemi-chal recycling	chemichal recycling	Thermich / chemi-chal recycling	Various	Re-use material	Re-use material
Recycling option	Pyrolysis	chemichal recycling	Pyrolysis	Various	Melt & compound	Melt & compound
Rewon material	Short fibers for new composites + Gas + Oil	Short fibers for new composites + Gas + Oil	Short fibers + Gas + Oil		New material for new products	New material for new products
Value rewon material	++	++	0+		++	+
Operational costs recycling	– –	– –	– –		0	0
Investment costs recycling	–	–	– –		0	0
Technological readiness	9	9	9		4	4 / 9
Impact Environement	–	– –	–		0	0



Do's and don'ts Circular Plastics

Source; PolyCE Consortium

Do	Don't	Why?
Keep mold parts as big as possible (>>10mm)	Never mold too smal (<<10mm)	Products are shredded and grinded. Small parts produce fines = losses
Use plastics as thick as possible (>>10mm)	Never mold too smal (<<10mm)	All recyclers use density seperation technoologies, that also seperate by weight / mass
Use plastics uniformly (1 polymer per molded piece)	Try not to mold plastics around metals	Plastics are burned in the melters as they go with the recycled material
Use plastics uniformly (1 polymer per molded piece)	Avoid 2K molding of different polymers	2K molded polymers cannot be seperated
Use a limited number of polymers (ideally 1-3)	Avoid >5 polymers in a product	Too many grades in a product make recycling inefficient
Use halogen free polymers	Do not use PVC and Br-FR polymers	Softeners in PVC and bromine flameretardants are becoming frequently SVHC
Use POM unblended	Never use POM alloys (POM-ABS etc.)	POM traces produce cancerorgenic formaldehyd (0,5 ppm limit at extrusion)
Use thermoplastics for foams	Avoid elastomers and thermosets for foams	Thermosets are causing surface issues
Use rubber in a solid, bulky form	Do not use silicon rubber and foamed rubber	Rubber particles and silicone rubber contaminate surfaces
Paint your parts with thin layers	Avoid heavy coatings	Coatings are causing surface issues
For high modules use carbon fibre or talcum filled plastics	Avoid the use of glass fibre filled coatings	Traces of glass fibre reduce mechanical properties and cause wear
Connect parts with moderate forces	Avoid to connect parts permanently	Shredders must be able to seperate the individual parts of a product.
Choose virgin for very demanding parts (transparent, ...)	Do not use too strict specifications	20% of the polymer can be virgin
Choose geometries that allow easy flow paths	Avoid tight and narrow geometries	High shear rates stress and degrade the polymers
Consider more structured surfaces	Consider more structured surfaces	Traces of rubber and glass fibre reduce the quality of big surfaces

Selecting your supplier

Supplier components

Although the biggest components are designed by Accell, most components in Accell bicycles are bought from suppliers all over the world. We cannot decide how to design them, but we do have the freedom to select them.

These sheets help with this selection, by offering information about sustainability aspects of materials, questions to ask your supplier regarding material use, energy use and circular loops.

Goal

- Understand how to design plastics for a circular economy

Selecting based on circular progression

Source; PolyCE Consortium

Questions to ask your supplier

1. What raw materials do you use? What percentage of the materials used in the component is recycled?
2. Do you have an environmental management system in place? Is it consistent with an internationally accepted standard, e.g. ISO 14001? Can you provide a copy?
3. Do you use renewable energy in your facilities?
4. Do you recycle any of your key inputs, such as water or chemicals?
5. Do you use any hazardous chemicals or materials in your production? How do you manage them to ensure they don't enter waste streams or water?
6. How do you package your final products? Do you use any recycled or recyclable materials?
7. Can we send back used components (in batches) to your company for recycling? In case yes, do you have information regarding recycling efficiency?

Selecting based on circular progression

Source; PolyCE Consortium

The questions to ask your supplier function to get transparancy in the impact of your suppliers components on the environment.

Some of the questions provide information that is used in the 'circularity indicators' coloms used in the BOM list.

		Circularity Indicators					
		Origin			Destination		
Cost of replacement parts (product + labor costs (BOVAG calculation))	Amount of replacements needed for lifetime of 5 years	Country of origin	Reused?	Recycled? %	Reuse? (Will the component have a second lifetime?)	Will the component be recycled?	Non-toxic?
			1	1	7	7	5

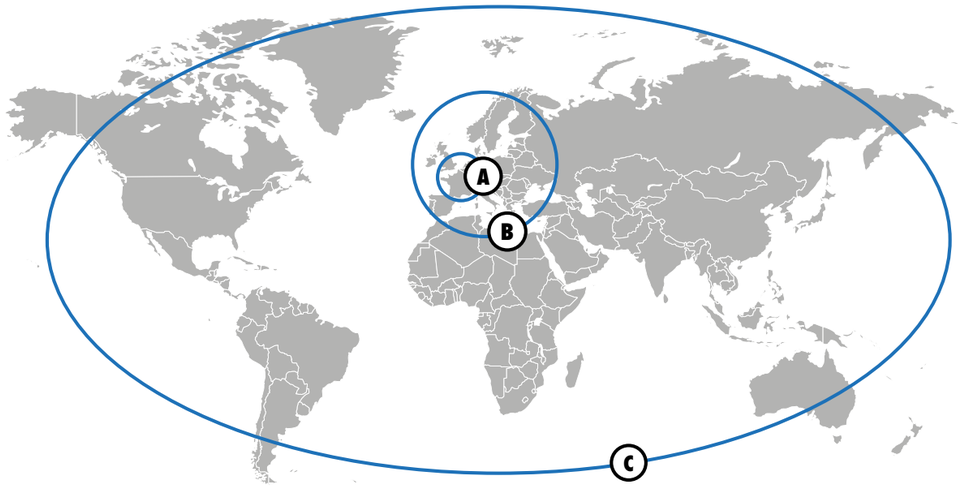
Selecting based location

Source; PolyCE Consortium

Another variable for selecting your supplier, is the location your supplier is based. The further away, the longer distance the components have to be shipped, the higher the impact on the environment. Although the % of re-used and re-cycled material are of higher impact to creating a circular economy, supplier location is also included in the BOM list.

Supplier location is classified in 3 categories;

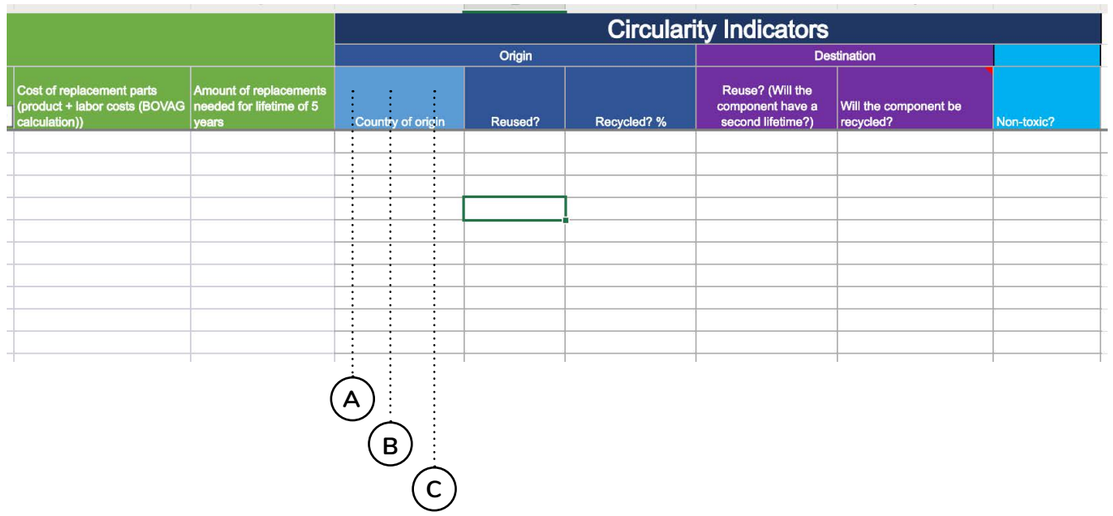
A. France, Belgium, Netherlands, Germany, England, Swiss, Italy, Austria.
B. Europe
C. Worldwide



Selecting based location

Source; PolyCE Consortium

The first colom of the circularity indicators is the country of origin, devided over the categories A, B and C. A is prefered of B, B is prefered over C. If the percentage of sub-components ordered by your supplier is above 50% procent from a different category, fill in this one.



3.6 Circularity indicators

Circularity Indicators

Tool 4

To define the circularity score, two key variables are the percentage of recovered materials in components and the planned destination of the components. Although already established in an earlier phase of the project, the BOM circularity indicators are is one of the 4 tools and therefore formally introduced in this chapter.

Input

Requirement 5. Data collected regarding material origin should be stored in (an extension of) the tool, as there currently isn't a platform to do so.

		Circularity Indicators					
		Origin			Destination		
Cost of replacement parts (product + labor costs (BOVAG calculation))	Amount of replacements needed for lifetime of 5 years	Country of origin	Reused?	Recycled? %	Reuse? (Will the component have a second lifetime?)	Will the component be recycled?	Non-toxic?

figure 3.6.1

Basically, the circularity indicators is what remained after trying to apply the material circularity indicator from the Ellen Macarthur Foundation.

- It helps in the demand for creating transparancy in material origin

- It helps to establish a plan for component recovery (validated during the test project)

- It can be used for component data in stead of material data.

- It serves a central place for data regarding material origin and destination, and therefore as input for evaluating assessment targets.

3.7 Roadmap - Towards Circular Product Development

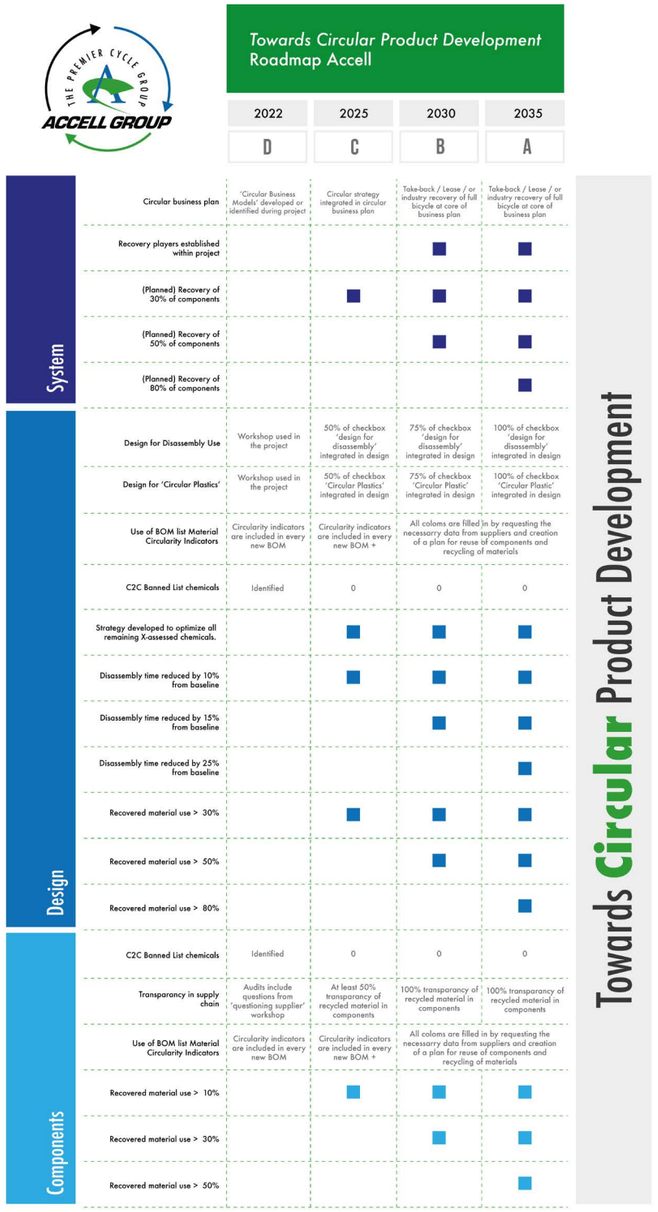


figure 3.7.1

As a final and extra tool, a roadmap towards circular product development was created. By combining all 3 assessment, a 4 stage circularity roadmap was established.

The years 2022 to 2035 were determined in collaboration with the head of sustainability as targets for future progression in sutainability, and aligned with Accell's C2C goal for 2035 (although the targets in the roadmap are higher). By linking them to the circularity score's (D, C, B & A) targets are suggested for the future product development projects.

Validation, Communication & Implementation

4.1 Validation - Project tender

Accell was responding a (confidential) tender with a big focus on sustainability. As this was a requirement normally not included in Accell PSD, it created a great opportunity for developping and validating the circular tool.

All Accell tools were tested and further developed during participation in this project. Details about the outcomes cannot be shown due to confidentially restrictions. In this chapter, we will therefore only evaluate weither the tools were desirable and feasible, without displaying outcomes.

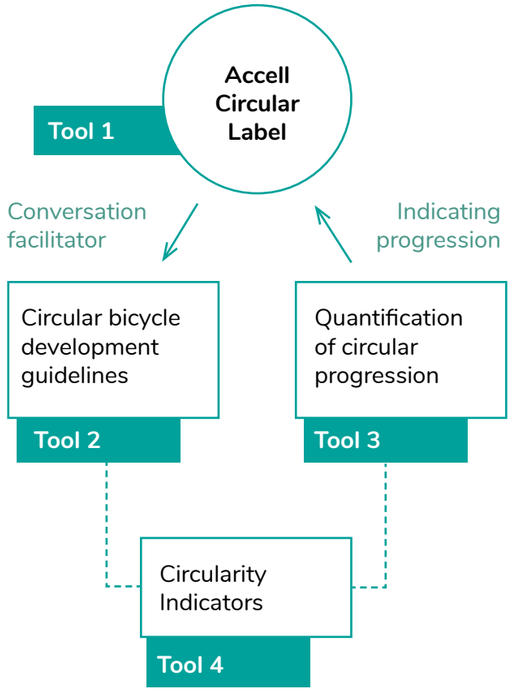
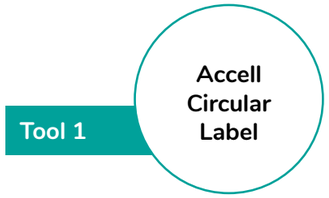


figure 4.1.1

Validating the AccelII Circular Label



As the label functions as a conversation facilitator and indicator of progression, both functions are evaluated.

During the project, the label (in combination with it's guidelines) functioned well as a conversation facilitator. As for both the Accell project team as for the circular partner circular thinking was a new strategy, the label helped in getting everyone on the same page, and focus on the full spectrum of the C.E. principles, and project approach (using system, design and components)

As a progression indicator, the tool was validated at the very end of the thesis. Unfortunatly, due to corona, the tender was paused and the project put on hold. Therefore, we could not evaluate all variables (more on this in assessment validation). However, as the tool function without the need for complete input (although resulting in a lower score), the team was still able to determine a score. It's low score on 'product design' compared to the other 2 segments, even motivated to take action (more on this in assessment validation).

Validating the AccelII Circular Guideliness

Circular bicycle development guidelines

Tool 2

Introduction to the circular economy

The introduction to the circular economy in combination with use of the Accell Circular Label as a conversation tool, was usefull to get everyone on the same page, understand the principles behind the circular economy, and relate these to the clients project.

Circular loops

The introduction to circular loops and its miniworkshop helped to establish a circular project partnership between Accell and Ziltbikes, and succesfully established processes for remanufacturing.

Circular Business models

Instead of responding to the tender with a price per bicycle, a price per total lifecycle, including part replacement costs, was proposed by the project team using the circular business model guidelines.

Green materials

Green materials guidelines were used for a various number of supplier components; the saddle, dress guards, fenders, handles, call and belt drive. The guidelines were used to pick the supplier based on their circular characteristics

Design for disassembly

The two design for dissassembly workshops performed during the project led to several design changes (which unfortunately cannot be shown in this report), related to the following dissassembly strategies; Use snap fits, minimize parts, fewer tools and standardize.

Circular plastics

The use of the circular plastics guidelines has not been validated during the clients project

Selecting your supplier

In the selection of suppliers, attention was paid to the materiality aspects of the components and even return options from suppliers. Suppliers responded very warmly to questions regarding the circularity of components, and were open to certain collaborations

Validating the Accell Circular Assessments

Quantification of circular progression

Tool 3

After final development of the assessments, the individual score achieved in the assessment sheets (which are not displayed here due to protect confidential information) helped to communicate the circular and sustainable aspects of the project towards the client.

Able to determine score

Potentially works

Not validated

Recovery players established

Recovery players were established (A)

Planned % components recoverd

Using the ‘destination’ colomn in the circular indicators, Ziltbikes established a detailled plan showing which components would be recovered. Except for 2 components which were uncertain, all data was available and the ‘planned % components recovered was calculated by Excel (confidential)

Design for disassembly use

Where possible, the frame was designed for dissassembly, covering the checklist

Design for Circular plastics use

(Was developed after ending involvement in the running project)

(Dis)assembly time improvement

The project did not yet arrive at the stage where assembly time was calculated. However, if it does so, the score can be calculated

% Recovered materials

The % recovered materials could be calculated using the the circularity indicators data.

C2C Materials

Use of BOM list material circularity indicators

Circularity indicators completed as much as possible.

Transparancy in supply chain

Althoug audits did not include questions from ‘questioning supplier’ workshop, the assessment score of % recovered materials motivated the project manager to ask supply chain if this was posssible

% Recovered materials

The % recovered materials could be calculated using the the circularity indicators data. However, of the majority of components material origin was unknown, resulting in a lower score (exact score confidential)

C2C Materials

Validating the Circularity indicators

Circularity Indicators

Tool 4

		Circularity Indicators					
		Origin			Destination		
Cost of replacement parts (product + labor costs (BOVAG calculation))	Amount of replacements needed for lifetime of 5 years	Country of origin	Reused?	Recycled? %	Reuse? (Will the component have a second lifetime?)	Will the component be recycled?	Non-toxic?

The circular indicators were implemented in the BOM list of the circular bicycle project. as can be read in the ‘circular loops’ segment of this chapter, the collaboration between Zilt Bikes and Accell was not only aimed at offering NS a bicycle itself, but also to provide a life-cycle service of the bicycle, including its remanufacturing.

The circular partner determined, based on their experience with bicycle recovery, which elements of the bicycle they were planning to re-use. Specifics about these choices can not be mentioned in the report.

In the selection of suppliers, attention was paid to components that were created out of (partly) recycled material.

To validate choices with regard to low maintenance and durability, an additional column reflects the average estimated number of replacements in a lifetime of 5 years. To integrate this in the business model, the costs of replacement parts were expressed in the costs of the product + labour costs, based on data provided by BOVAG.

Seeing these bikes would be developed without a currently running recovery program, no components came from reused sources.

Conclusion

When the assessments and Accell Circular Label were used by the group to calculate the final score of the product, they functioned as a motivator. In the situation of the client project the; ‘circular assessment’ was kept to a D because of the low use of recovered materials in the design of the bicycle. This activated the project leader to ask supply chain about the possibilities of getting information on material origin, or pick a different supplier for production.

The understanding of the C.E. , the planned lifetime of the bicycle and the circular advantages in the partnership between Accell and the circular service provider, were used to promote the sustainability of thr poject in the response to the tender.

4.2 Communication

Involvement in the design process

By involving not just employees from the innovation & technology department, but also including employees from ouside the I & T department in the development of the tool, its existence and value was immediately widely communicated.

However, Corona did drastically reduce this form of communication. In the first month I had a lot more contact with Accell, compared to the 5 months that followed, due to the necessary precautions of to the Covid-19 pandemic. Using programs like Zoom and Microsoft teams, i was able to communicate new findings / progress, but to a lower extend than before corona.

Microsoft teams

The guidelines and assessment sheets were placed on microsoft teams to enable company wide access. Ownership of the page was transfered to Accell.

After form and content of the tool were created, forms of communication and displaying its content had to be established. Starting with the choice of physical communication (paperwork, booklet, game) versus digital. The choice for digital was made because of the ability to update content through insights, ability spread information rapidly through digital channels and share insights and articles with relation to the circular economy (figure 4.2.2).

As a starting point I thought of developing an app within the ‘OKTA’ platform used by Accell. Interviewing a member from the I&T staff gave the insight this wasn’t a possibility, but he highly recommended using Teams & Sharepoint, two platforms used by a high number of Accell employees and are directly linked to each other. Basically sharepoint functions as it’s on website and has the possibility of adding news related to circular economy developments (figure 4.2.1) and have discussions. The teams version is the software program used for internal communication and sharing files. In both platforms there is the possibility to add documents and uploading in one of them automatically syncs to the other. This choice was validated by the head of sustainability and the head of project management.

Presentations

Multiple presentations were given to show progress and results of developping the tool, and spreading the word amongst Accell. These included;

March 17; Presentation innovation board

May 13; Presentation innovation board

June 29; Innovation Steering Committee

July 14; Presentation HR

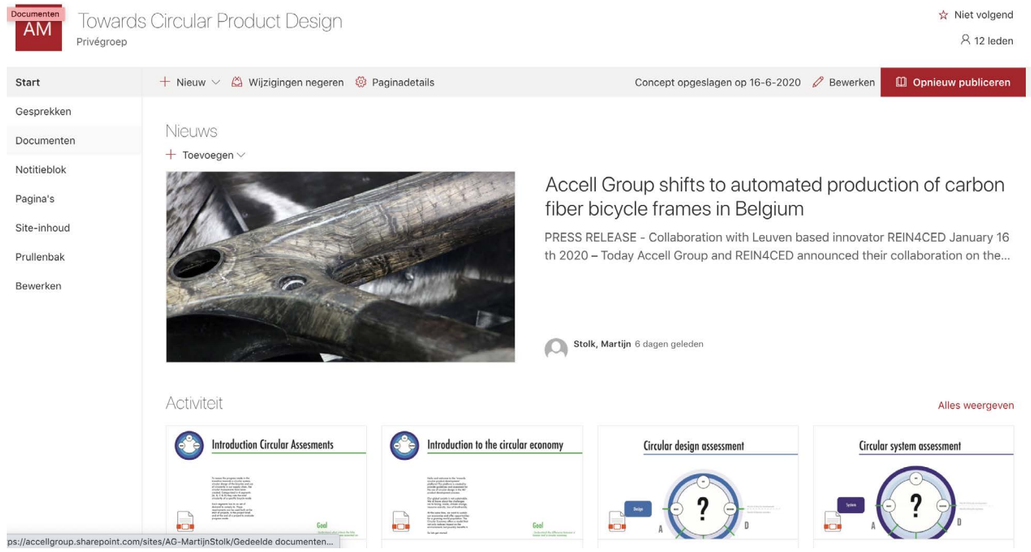


figure 4.2.1

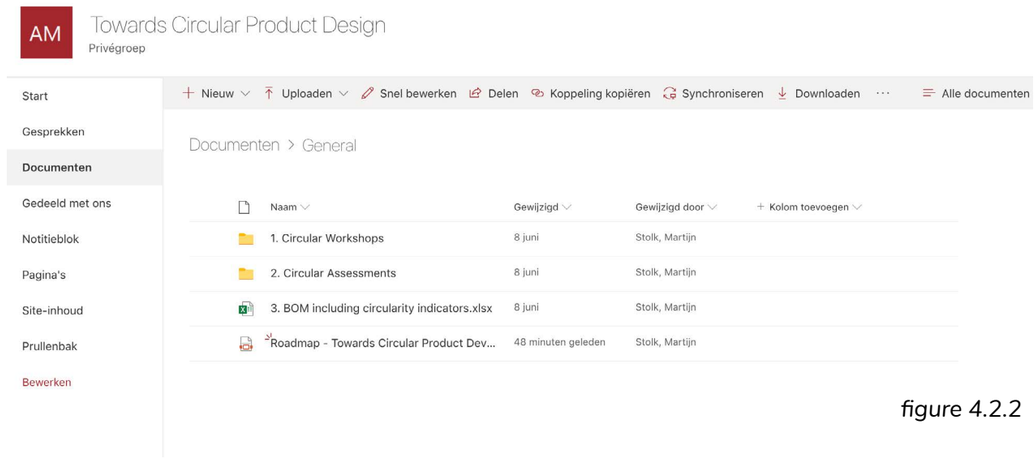


figure 4.2.2

Animation

To communicate and stimulate the use of the guidelines and assessment an animation was created.

For who?
Mainly; Project teams within I&T
Marketing and New Business Development
Wider; Accell as a company

Animation goals
To inform
- Problem with current situation - opportunities for the future
- Concept and operation of the circular economy, applied to Accell
- Value and operation of the Accell circular tool

Activate
- Create enthusiasm
- Activation; how can i get started? What can I do now?

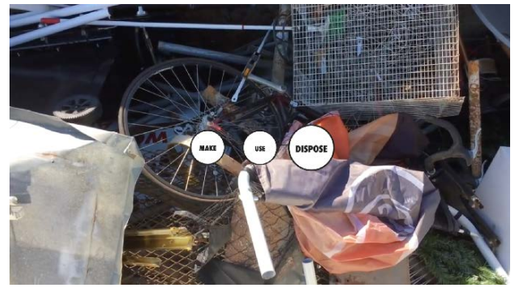
Feedback
Thanks! Clear movie. It clearly explains the purpose for our company and the methods and resources you have devised to help achieve the goal.

Looking awesome. What a professional animation you have made of it. Super.

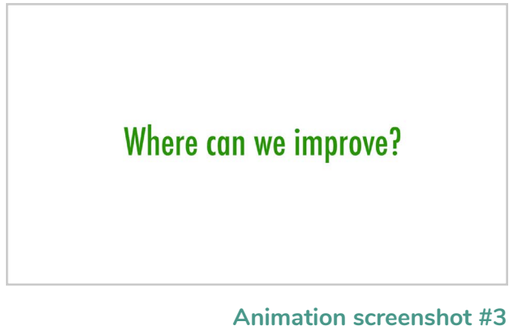
This is great! Thank you Martijn !!

Showed the video this morning during the HR department update; everyone thought it was super cool !!
It was proposed to use part of it during the Accell management meeting in September as a trigger towards circular thinking and our C2C objective.

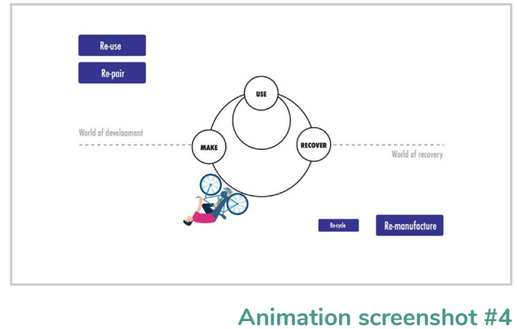
Animation screenshot #1
Introduction, using a part of Accell's purpose video where climate change is featured, followed by Accell delivering the solution; bicycles



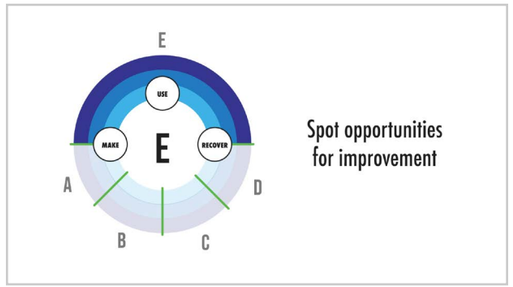
Animation screenshot #2
Response - 'if we want to be part of the solution we cannot neglect the responsibility of sustainably developing our bicycles.'



Animation screenshot #3
Problem definition; defining what aspects of the current PDP have the biggest negative impact / offer biggest chances for improvement



Animation screenshot #4
Solution; Circular Economy. General introduction to C.E., introduction to circular loops. What can Accell do in their PDP to progress in circularity? Introducing System, Design and component



Animation screenshot #5
Transition from System, Design and Component to the Accell Circularity Tool. Followed by introducing the assessments and guidelines

Animation screenshot #6
Activation. 'Access our guidelines and assessments at our microsoft teams page, and start applying these circular principles in the project you're involved in.'

4.3 Implementation

My focus in design was creating a tool that, with permission of management, could be integrated in the PDP. The reason was to ensure that projects could be linked to a sustainability score, and therefore future goals could be set by Accell for I&T. I've suggested these goals in the form of a roadmap.

The moments of using the different tools have been based on the conent of the PDP. A simplefied version is shown in figure 4.3.1 and figure 4.3.2)

I've hosted 2 presentations to demonstrate my research and use of the tool, to show it's value and plead for it's implementation. Also, the head of sustainability has sent the animation and report throughout the Innovation & Technology department to stimulate circular product development. It was proposed to use part of it during the Accell management meeting in September as a trigger towards circular thinking and their C2C objective.

Supply chain has mentioned to consider including the material origin questions in their contact with suppliers.

The tool was validated by application on the a running project. Tool 4 (circularity indicators) was implemented in the BOM of this project.

Implementation by other projects can happen through volentary use of the microsoft teams page. Motives herfore can be intrinsic motivation, and use of the label for external communication.

However, during the production of this thesis no mandatory inclusion (top-down) of the Accell Circular tool in the PDP has been established. With the enthousiastic feedback and plans to choose a project manager for implementation, hopefully this will happen in the short future.

The Microsoft teams page includes the roadmap, assessment sheets and guidelines and ownership is transfered to Accell, to host the page for future purposes and be able to update new insights.

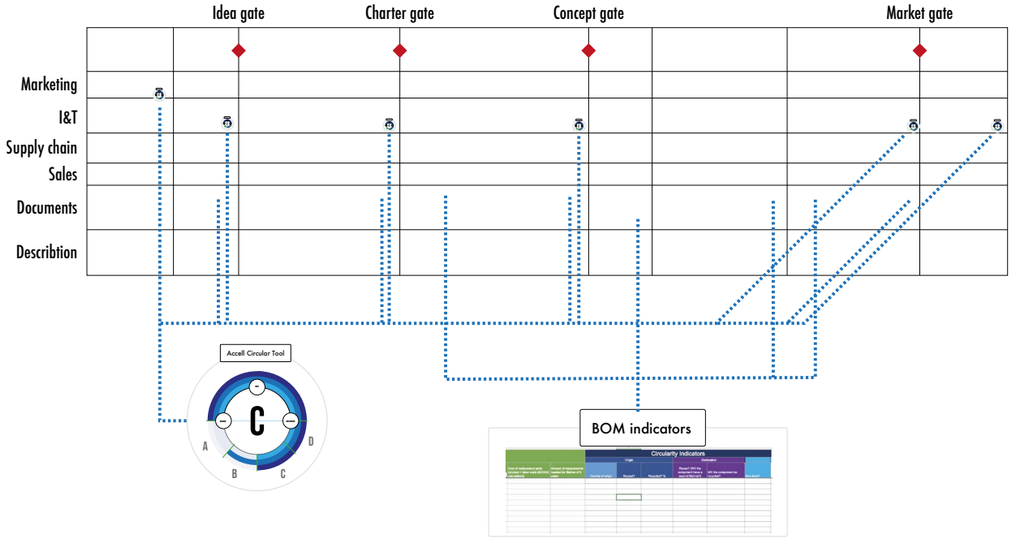


figure 4.3.1

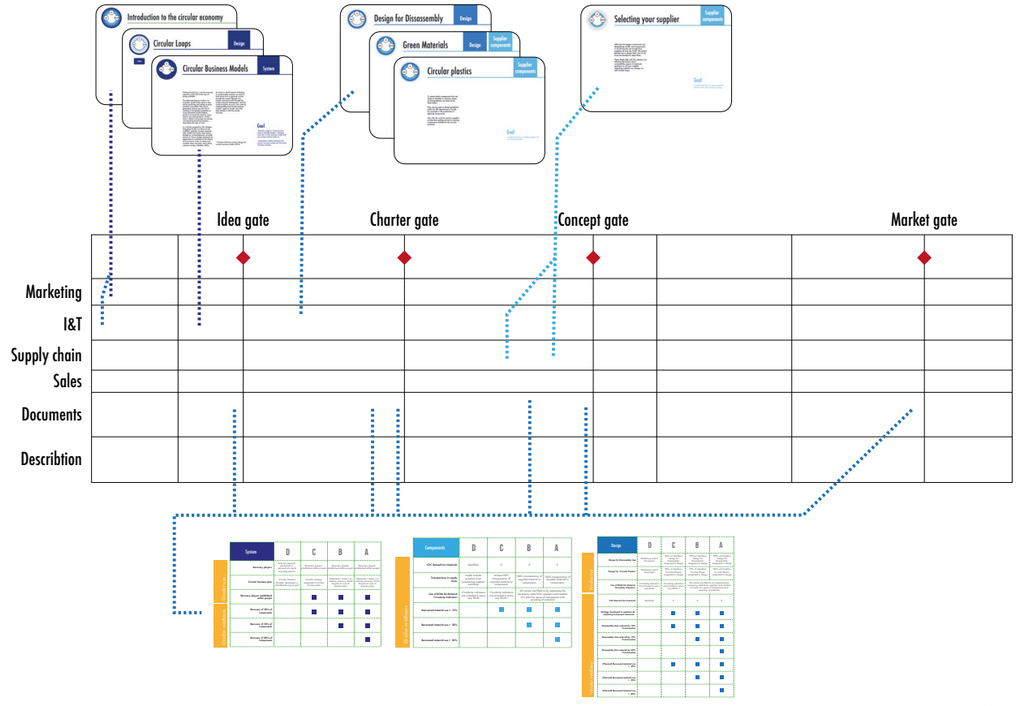


figure 4.3.2

Conclusion

The intial goal of the assignment was to set the first step towards the integration of a sustainability strategy in the product development process of Accell Group,

To select the right approach to sustainability, the current sustainable progression and product developent process were analyzed. Main findings were the need for a sustainability strategy that has a strong economic rationale and that responds to the main negative impacts current bicycles have on the environment. This resulted in the use of the circular economy as a vision for future product development, offering strategies that respond to the main negative impacts current bicycles have on the environment.

To be able to implement a circular strategy in the product development process, an Accell Circular label was created to set and evaluate goals in the design process. In the creation of the label, the segmentation between system, design and component has been developed as an Accell specific assessment format to quantify the circularity of I&T projects.
The score of is label is dependend on assessments that cover a total of 9 different variables to measure circular progression.

They are chosen to fit Accell's current measuring capabilities. It's division of 5 categories (E meaning no circular progression, A meaning the highest standards) can be used to set targets for future bicycle development projects, evaluate current projects and communicate results both internally and eternally.

Furthermore, guideliness were created to help project teams. Use of these guidelines was validated through application during the test project, in which the design was adjusted for disassembly, recovery partners were established and the remanufacturing of bicycles became integrated part of the response towards the project tender.

Two aspects were not completely integrated in the Accell circular tool. The first is the integration of the supplier location as a variable in the assessments. It is however integrated in the BOM circularity indicators for future purposes. The second is the development of guidelines for paintwork, which is also not concluded in the tool.

Both the circular design tool and the circular design label (project deliverables, stated in project introduction) have been delivered. Feedback on the tool verified its desirability and feasibility.
Moments of use of both guidelines and calculating the circularity score have been suggested for implementation in the PDP.

The I&T deputy manager has decided to select a project manager to manage the implementation. However, no mandatory use of the label for projects or inclusion of circularity indicators in BOM's has been established at the moment of writing this conclusion.

Recommendations

For Accell

Higher goals
During the end of this thesis, Accell gave a higher priority to the cradle to cradle certification. The target now being discussed within Accell, is certifying all bicycles with re-use certified as gold in 2035. Cradle to cradle re-use certification doesn't take actual end-of-use recovery processes into account. Its re-use score is for 2/3ths defined by the % of recyclable materials a product contains, and 1/3 the % of actual recycled materials used in a product. Therefore, the long term goal is already almost achieved, and little progress has to be made towards 2035. Suggested is using the goals set in the roadmap in this thesis, to aim for a higher progression in sustainable product development.

From isolation to collaboration
The working culture in Accell can be considered conservative, (financial) goal-oriented, and very hierarchical. The industry works with small profits and high volumes. The result of this is that the responsibility of researching and motivating Accell to a more sustainable future (like the circular economy) falls on one person; the head of sustainability. For only one person in a company counting over 3000 employees is quite a task, espacially if not able to share this responsibility with others or having more authority in implementing the visions you have. During the graduation it became clear this function is somewhat isolated from the rest of the management positions and working teams within Accell. Thoughts and visions of the head of sustainability should be more connected to the I&T department. Suggestions are either having an employee who shares the responsibility for sustainability within the I&T department, or by the innovation board giving a higher priority to the head of sustainability in implementing suggested targets and strategy's in the PDP.

From vision to implementation
Flyers in the I&T department show 'sustainability is our every day business' and in the latest phase of the thesis, Accell decided to set it's mind on cradle to cradle. It is a very good thing that these kind of activations and visions are out there. However, it will help if the discussion is opened about how to progress towards these visions and targets, what steps can be set.
This tool can provide a first step, and can be used to implement circular design goals in the PDP.

From product to service
To be able to control the full lifetime of a bicycle and therefore it's impact on the environment, Accell either needs to take ownership of its product, collaborate industry wide or partner up with circular service providers, to provide mobility as a service. Although this is a long term goal, smaller steps can be

Researching possibility and costs of dis-assembly
To create business models that include the recovery strategies mentioned in this report, research about the feasibility of dis-assembly is necessary. Initial research was performed during the thesis, showing the potential of re-manufacturing bicycles of higher price segments, especially battery included. A more detailed analysis (which could be performed relatively quick by Accell employees) could show management-positions quickly the possible financial opportunities of disassembling. As financial goals are of high importance to Accell, this could katalyse the progression towards a circular PDP

(Internal) Sustainable progression document
At this moment, the Annual reports published by Accell are the only source to find information about sustainable progression. As mentioned before, topics differ per year report, and it's not easy to gain insight in the current status. Documenting this would help.

Modularity of the tool
As the tool is designed in Illustrator, its not easy to adjust it's content. Its recommended to translate the microsoft teams page into an Accell Circular Economy website. Ideally, the website would have a administrator (specialized in sustainability / circular economy) who allows content created by Accell employees according to its relevance and usefulness. This way, employees can continuously update guidelines using insights from previous projects (insight PDP).

Include circular indicators in documents
It is recommended to include the circularity indicators of this project in the bill of materials, to motivate the I&T department to gain insight in material origin.

For circular economy projects

Consider project approach above process approach
In my thesis, my project focussed on a process. However, my experience learned that a company like Accell innovates on a project level. Hereby I mean that if a seperate bicycle or component project would have been launched of which the goal is to make a bicycle perfectly prepared for the circular economy, the company would then learn from this project and possibly implement aspect of it in other bicycle projects. Things get really tangible when working on a project / product level.

For other students

Own your thesis
Doing your thesis in together with a company is a very valuable collaboration. It lifts the theoretical approach being practised at university, to a practical, real-world level. Feedback that professionals from the industry provide your offers direct insight in the feasibility of your project; is this really going to work?
However, do remember the number 1 priority of the collaboration with your company is your research. If you gather insights showing you want to move into a direction at the start of your project that contradict with the initial project instructions, be confident enough to do so. It is in the end, your thesis. Also remember this while getting involved in company project (which is a really motivating). Try to define the line between doing an internship, and doing a research project.

Report tips
Really push yourself to write down what you did that day, even if the picture is not complete yet.

The second; make a division in your report that includes the outcome in the end, and the research that influence the outcome. During the research part, keep track of your insights using time periods (for example, monthly). Freeze your outcome at that moment, document it. So in the final report, you can show for example 3 iterations of your outcome, including the insights that caused this, sorted by 3 time periods.

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