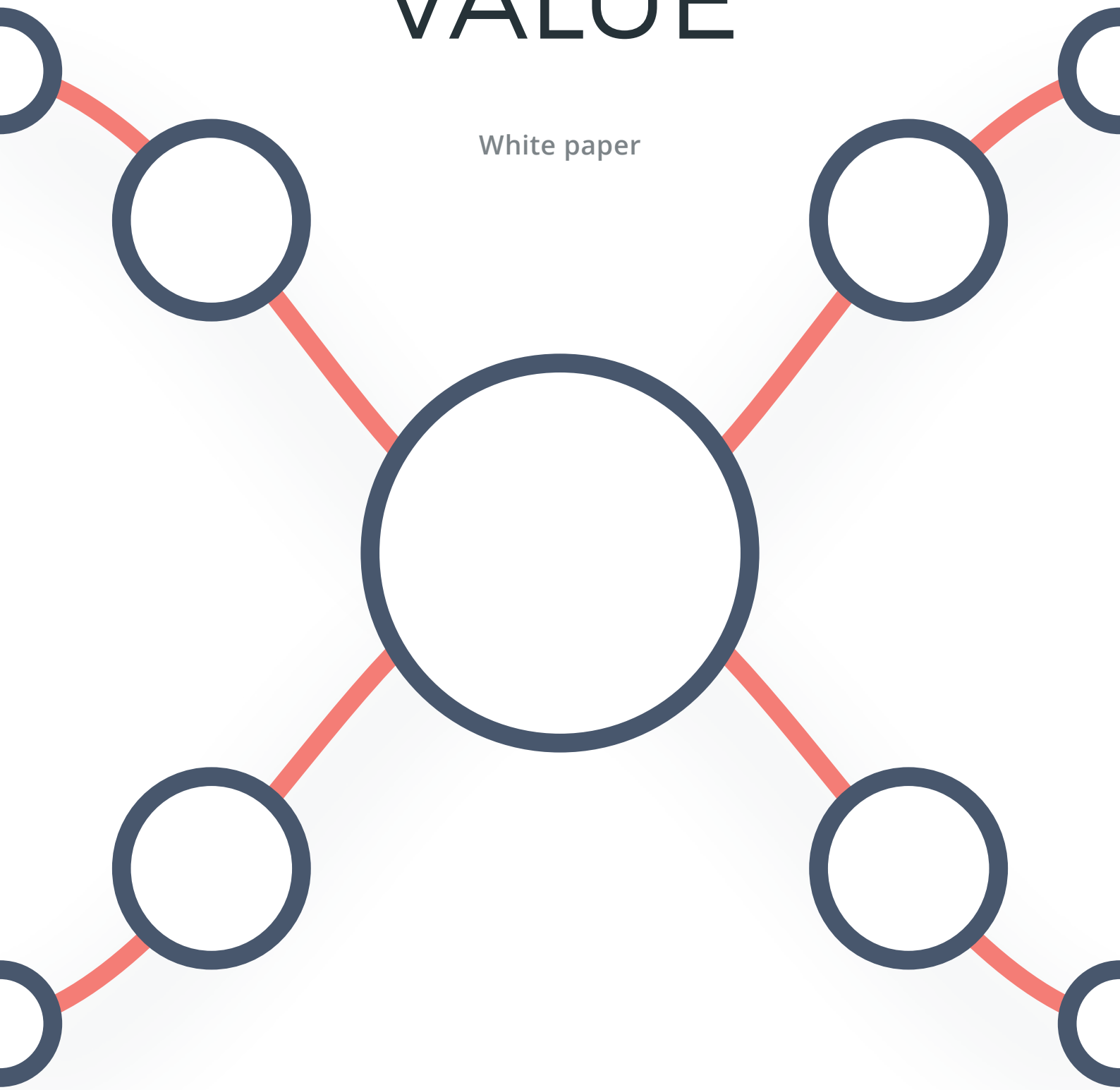
TRACKING VALUE

White paper



NEDERLAND CIRCULAIR!

SUSTAINABLE FINANCE LAB

FAIRPHONE

CIRCLE ECONOMY

COLOPHON

We are very thankful for the valuable contribution of all members of the Community of Practice and their organisations. Their expertise, motivation and collaborative spirit resulted in a tangible and transferable outcome.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

ABOUT THIS COMMUNITY OF PRACTICE

A Community of Practice (CoP) is an open innovation, pre-competitive environment where tangible and replicable solutions are co-created to facilitate viable circular business models. Product-as-a-Service (PaaS) entrepreneurs retain ownership of their assets, which requires having more control over the product and hence the need for tracking and monitoring. The mission of this CoP was to tackle the complexities around tracking assets, with a focus on identity, location and condition of the assets. The relevant existing technologies have been explored and the financial and legal implications of tracking assets have been investigated.

THE CASE STUDY: FAIRPHONE

Modularity makes the recently launched Fairphone 3 easy to repair for customers and service partners, reducing associated time and material costs. Although Fairphone currently has a for-sales business model in which they lose control and ownership of the devices after the sale, the social enterprise intends to offer Fairphone-as-a-Service (FaaS) to businesses. This requires tackling a few key challenges:

1. Tracking location, condition and corresponding (residual) value of circulating Fairphones and/or modules over their lifecycle.
2. Managing the increased organizational complexity associated with providing a service.
3. Overcoming financial challenges with respect to, for example, defining value propositions for the different qualities of assets.
4. Addressing legal challenges with respect to data privacy.

WHY TRACKING ASSETS?

Tracking the value of modular assets in a PaaS proposition is of utmost importance. Decision-making is improved with regards to the cascading of components (e.g. refurbishing, re-using or recycling) and predictive maintenance, aiding to the circular goals of the entrepreneur to improve future design aimed at increased longevity of the assets and recovery of as much material as possible. Tracking assets creates ways to optimize the business model by creating intelligence that is needed to provision for future costs and to accurately price the service contract.

Using the FaaS business model as a case study, this white paper focuses on providing answers to:

- What are the possibilities of tracking for intelligent management and monitoring of circulating assets?
- How can asset tracking contribute to an improved business case in circular business propositions?

DESIGNING A PROOF OF CONCEPT

As part of this CoP, a proof of concept was designed to illustrate the potential of automated tracking of different metrics focused on the condition of the battery. First, a feasibility study was done to understand which tracking techniques worked best on the different modules, including the battery. Secondly, an app was built from which the most important battery-metrics could be read: the charging temperature and the total charge. Lastly, a mock-up software instruction was written that models the condition of the battery from the metrics. This way, batteries can easily be categorized and sorted according to their condition.

KEY LEARNINGS

1. Based upon research of multiple tracking technologies, it was found that QR codes, memory chips and RFID tags are the most suitable tracking technologies.
2. Tracking assets provides insight into the location and condition of assets giving the entrepreneur a better grip on the assets. Therefore tracking can help to lower the risk profile of the proposition, making it an interesting business case for financiers.
3. Gathering data on the condition of and required maintenance for assets leads to improved estimates of future contractual obligations (provisions) and inventory required, which strengthens the business case.
4. Collecting insights about usage and performance of assets enables the entrepreneur to improve the product and further increasing the product lifespan
5. The data generated when tracking assets is subject to data protection laws and regulations. The main questions an entrepreneur should ask himself are: How is the data retrieved? What type of (personal) data is collected and processed? Why is this data needed?
6. Obtaining consent from a user for gathering (personal) data is the preferred and safest route to choose, however, customers should be able to withdraw their consent. The main question to be addressed is whether the withdrawal of consent is technically feasible.
7. For enterprises in need of an infrastructure that provides better grip over their assets, tracking technologies generate insights that are indispensable for a transition to the circular economy. Circular business models can be improved and track records can be built, which ultimately could provide the comfort for financiers to take the plunge. This pilot with Fairphone paves the way.

INTRODUCTION

TSUNAMI OF E-WASTE

Electronic waste, or e-waste, is the fastest-growing waste stream in the world, estimated at 48.5 million tonnes in 2018.[1] If nothing changes, e-waste is predicted to more than double to 120 million tonnes by 2050.[2] The United Nations is calling it a "tsunami of e-waste".[3] E-waste includes all electrical and electronic items or equipment that have been discarded as waste without intended reuse. Only 20% of global e-waste is formally recycled, the remaining 80% will likely be incinerated or dumped in landfills leaving a trail of toxic materials and valuable precious metals to waste.[4] In addition to being environmentally relevant, e-waste is also important economically. The total value of all raw materials found in e-waste is estimated at 55 billion euros in 2016.[5] Next to reducing the consumption of electronics, a circular electronics system needs to be adopted to encourage closing the loop of these materials through better design, reusing and recycling valuable materials and diminishing the need to extract and waste raw materials.

RESOURCE EFFICIENCY SIGNIFICANTLY REDUCES CARBON FOOTPRINT

2018 research by McMaster University in Canada calculated that the IT industry, including devices and servers, is responsible for around three percent of global greenhouse gas emissions.[6] This is two percent more than 10 years ago, with smartphones being the fastest growing IT category in terms of emissions. Notably, more than 80% of the carbon footprint of a mobile phone comes from the production phase. Modularity is an effective design strategy to facilitate repair and upgrades.[7] Next, with proper software support, the lifetime of smartphones can be extended to five years and beyond. An extension to five years reduces 30% of the footprint related to global-warming-related emissions.[8] Therefore, in order to maximize resource efficiency and minimize emissions, it is important for a company to track their assets and have the ability to estimate their condition at key moments in their lifecycle.

Our planet is reaching its limit of available resources. We urgently need to re-evaluate our future and change our attitudes towards product lifecycles and their obsolescence. By collectively building expertise, we can get the most out of the material resources we use by working towards extending the lifetime of the products we make. We are therefore very grateful to work with partners who share our passion to make this transition, so that we can take the first steps together.

– **Eva Gouwens,** CEO Fairphone.

1 - COMMUNITY OF PRACTICE

TACKLING THE COMPLEXITIES OF TRACKING ASSETS

Circular business models, like Product-as-a-Service (PaaS), provide opportunities to shift traditional patterns that keep the industry stuck in the linear economy. The mission of this project as presented in this whitepaper was to tackle the complexities around tracking assets and exploring the technologies that can provide the relevant data. For enterprises in need of an operational infrastructure that provides grip and control over their assets, to improve their business model and to win over financiers, such insights are indispensable and can be groundbreaking for the transition to the circular economy.

THE COMMUNITY OF PRACTICE: A COLLABORATIVE APPROACH

A Community of Practice (CoP) is an open innovation, pre-competitive environment where tangible and replicable solutions are developed to facilitate viable circular business models. It is a one-of-a-kind network of relevant stakeholders who together dive into a particular case. The partners of this Community of Practice are Circle Economy, Sustainable Finance Lab, Fairphone, Nederland Circulair!, Rabobank, Allen & Overy, Schiphol Group, Avery Dennison on behalf of the NBA (the Royal Netherlands Institute of Chartered Accountants), Everledger and Circularise.

DEEPDIVE INTO FAIRPHONE-AS-A-SERVICE

Fairphone is a social enterprise that inspires sustainable change in the electronics industry. The company uses the development and marketing of its phones to drive awareness, provide the example and enable industry action in four key pillars: long-lasting design, fair materials, good working conditions, and reuse & recycling. A modular phone was adopted to ensure long-lasting and circular design. Modularity makes the phone easy to repair for customers and partners, reducing time and material costs. The CoP partners cooperated to find a technical solution for tracking the modular assets and to tackle the financial and legal complexities related to such a tracking solution. Using the business model Fairphone-as-a-Service (FaaS) as a case study, this CoP focussed on the following research questions:

- What are the possibilities of tracking for intelligent management and monitoring of circulating assets?
- How can asset tracking contribute to an improved business case in circular business propositions?

OUTCOME: A PROOF OF CONCEPT

Tracking assets enables higher resource efficiency through monitoring asset performance, improvement of predictive maintenance, and the use of gathered data to improve future design of products and components. In our quest to find solutions the focus has been on one component of the Fairphone 3 device, the battery. The technologies that came out as most suitable and interesting for our purposes are RFID tags, memory chips incorporated in the modules' electrical circuits, and QR codes.

ABOUT THE REPORT

This report is structured as follows:

- Chapter 2 explains the context of the research questions. Why is there a wish to track circulating assets?
- Chapter 3 describes the scope of this CoP, introduces what can be tracked, why this would be interesting and concludes with a Circular Tracking Wishlist to guide the pilot.
- Chapter 4 is about how to track. Technologies available for asset tracking are researched and the most appropriate technologies for this CoP are highlighted.
- Chapter 5, 6 and 7 elaborate on the technical proof of concept and the financial and legal implications of using such tracking technologies.
- Chapter 8 concludes by means of reviewing the Circular Tracking Wishlist and summarizing which wishes have been fulfilled and which elements need further research.

2 - CONTEXT TRACKING VALUE

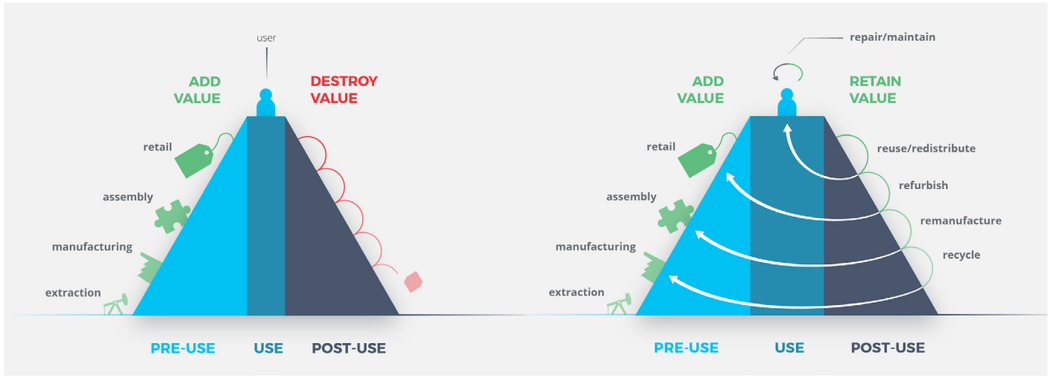
TAKING A TOUR ON THE VALUE HILL

The 'tsunami of e-waste' is a consequence of society's 'take, make, use, waste' economy. In the linear economy, raw materials are extracted to create products often consisting of many different materials, which makes it hard to recycle these complex products. Next, many consumer goods are used only until a newer, cooler, faster version becomes available. These consumer goods have a limited economic lifespan, while their technical lifespan can be much longer (figure 4). Producers are incentivised to boost sales figures, to seduce customers to buy new products repeatedly, resulting in many products that are wasted, ending incinerated or as landfill. Only 8.6% of materials are reused and recycled, meaning over 91.4% of the materials currently used are being wasted.[9] This is not a sustainable situation and the need for a more circular economy is becoming increasingly apparent.

The Value Hill, please see figure 1, is a circular business strategy tool to help businesses position themselves in a circular context and can be divided into three phases:

- The **pre-use** phase (mining, production, distribution) where value is added in every step as the product moves uphill.
- The **in-use** phase depicted on top of the hill, where the value of a product is at its highest.
- The **post-use** phase, where the product loses value as it moves downhill.

Figure 1. The Value Hill. Adapted from Achterberg et al. (2016).



In a linear economy (left Value Hill) resources are extracted as if there are no limits. This is followed by a short use phase after which products enter post-use where value destruction is fast. In a circular economy (right Value Hill) the value of products is retained at their highest level for as long as possible through four main business strategies[10]:

1. Circular design: facilitating lifetime extension and re-use of products. Products are designed and manufactured to be long-lasting, easy to maintain and repair.
2. Optimal use: extending the lifetime of products by optimising the use of the products through circular business models such as PaaS.
3. Value recovery: closing the loop and retaining a product's value for as long as possible. These businesses generate revenue by capturing the value from used products, e.g. refurbishment, remanufacturing.
4. Network organisation: Doing business in one of the three aforementioned categories does not automatically create a circular business. There is a need for coordination of information, material, and money flows.

PRODUCT-AS-A-SERVICE: MOVING FROM PRODUCT SALES TO PROVIDING A SERVICE

In circular business models, such as Paas, assets are no longer sold. This enables a shift from a linear supply chain where control is lost over products, to a circular one where value is controlled and recaptured (figure 2). These business models could be the solution to dematerialising the electronics industry and untangling profits from the use of resources. In a PaaS business model, customers no longer pay for ownership of a product, but for the use of a product through a *use fee* giving them access to the product and the additional services provided. PaaS providers retain ownership of their products, and therewith the responsibility of their maintenance. This incentivizes them to create high quality and durable products that retain value over time through easy upgrades, repairs, refurbishing or take back at the end of life.

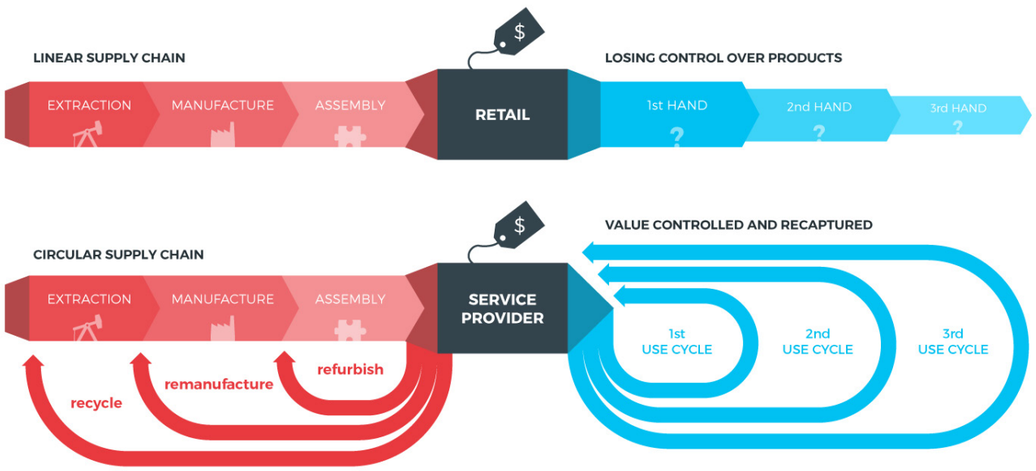
The transition to a PaaS proposition, however, entails organizational and financial complexities, such as a need for initial investments in the fleet of assets against a backdrop of longer payback periods, which puts pressure on the cash-flows.

Furthermore, robust contracts are required to stipulate the terms and conditions between customers, end-users and the PaaS provider. These challenges were tackled in the previous COP, The Circular Phone, by the development of a financeable business model and a corresponding contract.

Moreover, circular supply chains require cooperation and coordination between all actors, leading to high administrative costs and need for trust, transparency and long-term agreements between chain partners. In The Circular Service Platform an infrastructure was tested that provides the asked-for transparency and trust between stakeholders (e.g. repair shop, end-user) and automates administrative tasks against low cost.

These solutions assume the existence of data regarding material composition, condition, location, maintenance, supply chain actors, asset use and corresponding revenues and costs. Yet, this data needs to be structurally generated, gathered and stored. How this can be achieved is the central challenge of this CoP.

Figure 2. Controlling & recapturing value in multiple use cycles vs losing control over products (Fischer and Achterberg 2016)



FAIRPHONE-AS-A-SERVICE: A CIRCULAR MOBILE SOLUTION FOR BUSINESSES

Although Fairphone currently has a for-sales business model in which Fairphone loses ownership and control of the devices after the sale, the social enterprise intends to offer Fairphone-as-a-Service (FaaS) to businesses. This innovative proposition requires businesses to pay a fixed monthly fee, which guarantees access to a functioning Fairphone device, maintenance services, device updates and take-back of devices when use is ended.

FaaS in a business-to-business (B2B) environment means:

- Fairphone **retains ownership** of the Fairphone devices;
- Fairphone is **incentivized to offer high-quality, durable products** that can be easily upgraded, repaired and taken back at the end of its useful life;
- Product modularity allows Fairphone to **optimize value creation** based on the technical life of the individual modules instead of the entire device;
- The transactional relationship with the customer becomes an **ongoing engagement**.

The four main benefits of FaaS in a B2B environment are:

1. **Flexibility:** customers are not limited to the devices in their contract, businesses can up- or downscale their phone ‘fleet’ every month;
2. **Always-on service:** Fairphone will always provide a solution when a device breaks;
3. **End-of-life ease:** Fairphone collects the phones and/or phone modules before end-of-life to either reuse or recycle;
4. **Corporate Social Responsibility/Environment** e.g. give companies metrics on how much CO2 emissions they have saved compared to their old procurement model.

FAAS CHALLENGES TO BE TACKLED

Being able to track and trace the modular assets is of utmost importance, but with its current operational set-up Fairphone faces the following challenges when transitioning towards a FaaS business model:

- The **inability of tracking the condition** and corresponding (residual) value of assets over the lifecycle accurately;
- **Increased organizational complexity** as assets, while owned by Fairphone, keep on circulating between users and other stakeholders (e.g. repair, logistics, refurbisher). This involves an ongoing (return) flow of materials, information and money between these actors that needs to be managed;
- **Financial challenges** with respect to defining value propositions for the different quality of assets, and setting the right price for each value proposition as intelligence on residual value is still in development;
- **Legal challenges** with respect to data privacy and contractual agreements in the circular value chain in order to align incentives of all stakeholders.

RESEARCH QUESTIONS

Using the FaaS business model as a case study, this report provides valuable answers to:

1. What are the possibilities of tracking for intelligent management and monitoring of circulating assets?

2. How can asset value tracking contribute to an improved business case in circular business propositions?

TECHNICAL SPECIFICATIONS FAIRPHONE 3

The Fairphone 3, launched in August 2019, is the subject of study for this CoP. The Fairphone 3 contains eight modules: top module, bottom module, speaker module, display module, camera module, battery, core module, and the back cover, please see figure 3.

Figure 3. Fairphone 3 Modules and their main obsolescence drivers

ACTIVE

PASSIVE

5 - BATTERY

Main obsolescence drivers:

- Loses capacity with every charging cycle
- Loses capacity when charged at extreme temperatures

7 - BACK COVER

Main obsolescence drivers:

- External parts of the device suffer most of wear & tear

6 - CORE MODULE

Main obsolescence drivers:

- New chipset technologies drive obsolescence of the whole device.
- Sensitive to humidity and drops.

Relevant component: chipset

1 - TOP MODULE

Main obsolescence drivers:

- Clogging of the audio connector due to lack of maintenance by the user.
- Camera market technology developments

Relevant components: selfie camera, audio port

4 - CAMERA MODULE

Main obsolescence drivers:

- Camera market technology developments

Relevant component: main camera and image sensor

3 - DISPLAY MODULE

Main obsolescence drivers:

- Sensitive to drops

Relevant component: display, glass

8 - SPEAKER MODULE

Main obsolescence drivers:

- Wears off faster in humid environments.

Relevant component: loudspeaker

2 - BOTTOM MODULE

Main obsolescence drivers:

- Clogging of the USB port due to lack of maintenance by the user.

Relevant component: usb port

The definitions used in the figure are:

- **'Active' modules:** Contain a component with an electronic chip that can 'communicate' with the operating system to be used, for example, to automatically track the ID number.
- **'Passive' modules**: Unable to respond and store information.
- Whether a module is active or passive is important when choosing the most suitable tracking technology.
- **Obsolescence drivers:** all the factors that affect the lifetime of the modules. Technological and market trend developments influence the economic lifetime of modules. Drivers that affect the technical lifetime of the modules are:
- **Wear & Tear:** Factors that damage the modules progressively over time being the natural result of using the phone.
- **Accidents:** Due to the human factor in using the phone, some modules are prone to accidental damages. For example, it is estimated that the average user drops his or her phone seven times a year[11].

UNDERSTANDING THE VALUE GAP OF ASSETS

In order to create a truly long-lasting device, the value gap between the technical lifetime and the economic lifetime of the device needs to be closed (figure 4). Technical lifetime refers to the actual durability of the assets and is affected by wear & tear and improper use, while economic lifetime is the expected time a user considers the asset to be valuable and is affected by technological developments and user behaviour.

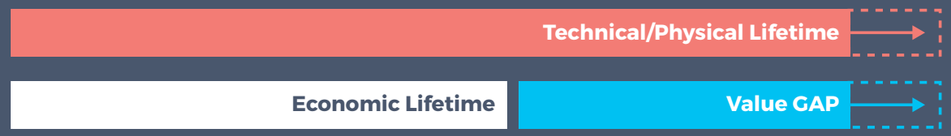


Figure 4. Economic versus technical lifetime

Closing this value gap would lead to a longer use-phase of the device. Modularity is part of the solution to diminishing the gap.

Think for yourself! How do your assets age during the life cycle? What are the events that can provoke damages? How do market developments affect your users wishes?

ADDRESSING THE CIRCULAR THOUGHT IN THE FAAS BUSINESS MODEL

In order to extend the use phase of an asset, one could set different value propositions for different types of customers and different conditions of the device. Customers do not always demand a product to be 'new', but also accept a product that is 'as good as new'. Those who are on a tighter budget can opt for a value proposition where refurbished assets play the main role against a lower service fee. Based upon the different conditions of the modules, Fairphone drafted new value propositions allowing optimal use of the Fairphone devices, please see Table 1.

TYPE	VALUE PROPOSITION (DRAFT)	IMPLICATIONS
Premium	Assurance that users will have a working phone within four company hours, no matter what breaks or happens to the phone and no matter how often this occurs. The user is always guaranteed to have the most powerful device and modules.	The device always looks as good as new. The battery holds > 90% of charge. The phone and its modules are tracked.
DIY	Users always have access to spare parts. After the user requests a spare part, this will be delivered within 24 hours. The contract covers one new screen for free.	The phone looks good. The battery holds between 60-90% charge. A back-up battery is included (this holds charge less than 50% and is only used for emergencies). The phone and its modules are tracked.
Refurbished	Not as a value proposition but a second hand market to sell refurbished phones	

Table 1. Overview of the different value propositions for FaaS

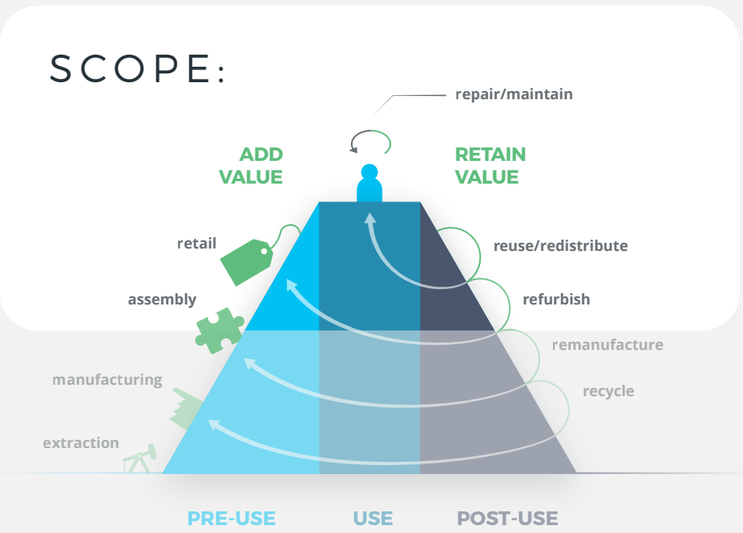
3 - CIRCULAR TRACKING WISHLIST

With a solid idea of the composition of the Fairphone in mind, the required data points to be tracked to solve (some of) the challenges as mentioned previously need to be determined. An overview is provided here of all the tracking ideas with regard to the scope of this project, from which a selection was made to be tested small scale in a pilot.

GOAL & SCOPE

The ultimate goal of this tracking exercise is to keep the Fairphone circulating even longer on top of the Value Hill. Tracking technologies could aid this goal by optimizing preventive and targeted maintenance and enabling efficient re-use of components. The focus is on the use and re-use phase, i.e. the phones are either in-use or being repaired, upgraded to be directly re-used. Tracking the provenance of materials uphill through the supply chain is out of scope of this project, see figure 5.

Figure 5. Scope of this tracking value pilot: Use and re-use. Adapted from Achterberg et al. (2016)



TYPES OF DATA THAT CAN BE COLLECTED

Data regarding product use and performance is a critical part of value creation in PaaS business models. Four types of data are distinguished[12]:

- **External factors:** e.g. humidity or temperature that impact the functioning of the product;
- **Location:** in real time or based on connected checkpoints;
- **Condition:** either related to the technical performance and/or the cosmetic/visual condition of an asset. This could, e.g. be data collected from the repair centre or data about use patterns, which can inform maintenance actions by predicting and preventing failure;
- **Availability:** information on the availability of an asset communicates whether an asset is idle but also could provide market (supply/demand) dynamics. Availability also includes information about asset ownership.

USE OF THE DATA

Data can be used in various ways. Firstly, *monitoring* data provides insights and feedback to the user or other relevant stakeholders. For example, changes in the environment, location, condition or availability can alert users, or maintenance providers, to act.

Secondly, *controlling* data allows stakeholders to control their own systems remotely, or let the service provider exercise control without user involvement. This could entail, for example, switching a device off, when bills are not paid. But it could also take the form of controlling product functions or personalizing the user experience.

Thirdly, *optimizing* data, is about goal-based improvements using algorithms which learn from historical data. Real-time monitoring of module conditions would allow for replacing modules when failure is imminent. This can enhance product performance and predictive diagnostics for service and repair.

Lastly, *autonomous* products combine monitoring, control and optimization capabilities to achieve a level of autonomy. Such products could 'self-diagnose' and act accordingly. Think of sending a drone to do repairs[13].

All these possibilities seem very promising. By keeping all of the above in mind, the Circular Tracking Wishlist was established. This list serves as a guide when exploring the solution space of tracking technologies in the following chapter.

USING PRODUCT DESIGN INTERVENTIONS TO NUDGE USERS TOWARDS SUSTAINABLE BEHAVIOR

Collected data can potentially also steer users towards more sustainable behavior and engage them in the company's mission. This can be done in various ways[14]:

Guiding: providing usage information and feedback

- Users are informed about usage, which encourages reflection and enables them to make more responsible decisions.
- Rather than only providing the information, users can also be friendly invited to change their behavior through information about consumption. For example, by providing personal or social comparison.

Steering: steer behavior through design

- Users are guided to do what the designer intended through constraints or affordances, e.g. defaults, limits, targets or physical constraints.
- Sustainable use can also be made so easy that the user does not think about it, e.g. by making the functionality more prominent than others.
- Other ways to steer behavior are by providing economic incentives by giving rewards to prompt desired behavior or penalties to 'punish' unsustainable usage.

Embedding: more 'forceful' strategies

- Decisions are taken by the (intelligent) product itself to mitigate unsustainable user behavior. For example, the battery will not charge itself when temperatures are below a certain threshold.

LOCATION AND IDENTITY OF MODULES	
	Localization and identification of modules and devices
	Identifying changes to the composition of modules in a Fairphone
	Optimizing (reverse) logistics for service of replacing broken modules
ASSESSING AND INFLUENCING THE CONDITION OF MODULES	
	Assessing the condition of the modules and estimating actual remaining lifetimes
	Minimizing or preventing downtime thanks to predictive maintenance
	Accurate asset valuation by considering the condition of the modules, their expected remaining lifetime and costs
	Improving decision-making of future loops: i.e. re-use, reparability, remanufacturing or recycling
	Interact with (human) users to change use patterns to minimize wear and tear and stimulate sustainable use and repairs
	Develop specific value propositions and individualized interactions & experiences that contribute to circular goals
ASSESSING THE AVAILABILITY OF A PHONE OR MODULES	
	Transparency of availability of phones and modules to optimize re-use of modules
FACILITATING DESIGN & OPERATIONAL IMPROVEMENTS, CHAIN COLLABORATION & PRIVACY	
	Improving the design of the Fairphone and its modules and processes in the future
	Optimizing operational efficiency (i.e. balancing resource utilization with rapid redeployment of modules, and keeping assets in service)
	Provide information to involved stakeholders (e.g. repair, logistics) to improve chain collaboration
	Adhere to privacy and GDPR regulation
MEASURE CORRESPONDING IMPACT	
	Measure utilization rate for modules and devices and its corresponding material, footprint and cost
	Measure increase in customer trust[15]

Table 2. The Circular Tracking Wishlist.

4 - TRACKING TECHNOLOGIES

Smart tracking solutions are continuously developing to become more integrated and ubiquitous, proving beneficial in the logistics and warehousing industry. To reach the goals of this Community of Practice, as summarized in the *Circular Tracking Wishlist* (see Table 2), different tracking technologies were explored. Please see Table 3 for an overview of the technologies highlighted in this whitepaper.

Three factors were considered crucial for application to the Fairphone case:

1. The amount of information that can be stored or collected;
2. The size of the physical tracking technology as some of the modules are small;
3. The readability, the context needed for reading the information (e.g. manual scanning, detection)

HIGHLIGHTED TRACKING TECHNOLOGIES

The modules of the Fairphone 3, except for the back cover and the core module, have a QR code label identifying their serial number. The design also contains an NFC reader. Some modules contain memory chips, like the screen, and could be programmed to store their own serial number. Passive modules, such as the bottom module, would require the addition of a chip in their hardware. Most mobile phones, including Fairphones, already contain bluetooth, wifi and other over the air communication capabilities as well as a long list of sensors like thermistors, accelerometers, light sensors, etc.

SUCCESSFUL TRACKING EXAMPLES

End-to-end traceability for the wine industry

How to ensure that the fine wine you drink is not a counterfeit? Everledger and Avery Dennison partnered up to combat counterfeit and fraud in the wine industry. Secure, non-copy and tamper-resistant inlays with Near Field Communication (NFC) technology were injected in the labeling of wine bottles, giving each bottle a unique digital identity. By means of supporting blockchain technology, supply chain data can be captured allowing customers to follow the journey of their wine from grape to bottle.[20]

Elimination of disposable cups

Cup Club is launched with a mission to eliminate disposable cups without removing the convenience of disposable cups. Each cup can be used 132 times before it is recycled. Cup Club combines a set of technological solutions to track individual cups and reward their users, namely Radio Frequency Identification (RFID tagging), mobile interface and Internet of Things (IoT). The RFID chips provides a single cup with a unique identity which enables Cup Club to follow the cup throughout its lifetime. Their reusable cups can be picked up at coffee shops by consumers who are using the app and dropped off at collection points to re□enter circulation after cleaning. If you do not return the cup to a collection point, Cup Club assumes you want to keep the cup and you are charged a fee. The latter should incentivize the user to always return the cup to a collection point.[21]

APPLICATION	STORAGE SIZE	READABILITY	SIZE
Printable codes on surfaces like labels or product housings are used extensively in logistics and retail industry. Their cost is very low.	**Barcodes** are one dimensional and limited to a character string.	~10 - 60cm Depending on resolution and reader type. The tags require a **line of sight** to the scanner. **Tampering** is very easy.	Several centimeters long
	QR Codes are two dimensional, have different storage sizes with much more capacity than barcodes.		Can be very small; under 1 cm^2
Radio-frequency (RF) methods are an antenna-based technology that allows the wireless transfer of data to and from electronic tagged-chips attached to items (eg. labels). Examples of use are animal microchipping, access control cards for buildings or car doors or baggage tracking.	**NFC[16] chips** typically store **~2 KB** (kilobytes) of data; which is sufficient for a long serial number.	~0 - 10 cm **No line of sight** needed for reader but range is short. **Consumer-friendly** reading (e.g. present in smartphones). Reasonably tamper-proof.	> 13 mm
	UHF[17] tags can store up to **64 KB.**	~0 - 10 meters Tags are active or passive. The reading range varies widely, making it suitable for use in warehousing. Tags do **not require line of sight**, they can be read through other materials. Metals (ie. in electronics) can distort or impede reading[18]. Reasonably **tamper-proof.**	~5-7 cm
Integrated RF Chips, technologies like bluetooth/wifi are also used for transferring large amounts of data but obviously require to work with a software operating system and are typically embedded in the design of the product and require this one to be 'on'. **Integrated Memory Chips** are widely available and can be integrated in the design of electronic products to store large amounts of information for the operating system to use, or send to databases. **Integrated sensors** can be used in the design to collect information about the environment in which the device is used.	**Flash Memory** chips can store around **32 Mb - ~1 Tb.**	They can be useful to store large quantities of data, like usage data to define the condition of parts of the device.	~1 mm - 10 mm[19]
	Sensor's collected Information is stored in memory chips.	Sensors fulfill many different functions, for example, thermistors can sense temperature and accelerometer can be used to track when a device is dropped.	n/a

Table 3. Highlighted Tracking Technologies

5 - PROOF OF CONCEPT

EXPLORING THE CIRCULAR VALUE CHAIN OF THE BATTERY

In our quest to find solutions, the focus has been on one of the most important components of the device, the battery. Batteries have an estimated life cycle of 2.5 years, and decrease charge capacity per charging cycle. A poor performing battery is often a reason for the purchase of a new device, as consumers highly value having a battery that lasts long enough with one single charge. In Fairphone's current business model, batteries are not reused. When a battery has been used and recovered it goes straight to recycling. In order to close the value gap, batteries that still have a certain charging capacity could be used in a second value proposition or used as back-up batteries.

Similar opportunities arise when considering other modules that can be 'rescued' from used devices to be put again in service. In the CoP The Circular Phone the different stakeholders that are part of FaaS were discussed. These core partners are essential to the service proposition and key for maintaining the longevity of the phone. The core partners are Fairphone, logistics/warehousing and repair centres, and customers.

Additionally, there are key component producers that provide parts that are crucial for the functioning of the device (e.g. chipset manufacturers or battery manufacturer). In the case of a battery, a battery is produced according to certain specifications. The battery then moves to a manufacturing factory where it gets assembled onto a phone and then it enters the logistics warehouse. As FaaS is a proposition for business customers the devices go through logistics, to a business and finally to the end-user.

SUITABLE TRACKING TECHNOLOGIES

The technologies that came out as most suitable are **RFID tags (NFC), memory chips** incorporated in the design, and **QR codes**. It was decided that these would be the most easy and interesting technologies to try during the pilot. Furthermore the Fairphone 3 already has an NFC reader, some modules have a memory storage chip and all electronic modules contain a QR code. An overview of the main tracking technologies has been provided in the previous chapter.

PROOF OF CONCEPT

To illustrate the potential of automated value tracking, a proof of concept was designed as part of the CoP. The condition of the battery depends on different metrics, e.g. the temperature at which the battery is charged, the amount of charging cycles it goes through and how much it is charged per cycle. Models that explain the condition of the battery are studied by various scientific communities. For the purpose at hand, we restrict our focus to the collection of some of these metrics and not to the underlying models that explain how these actually degrade the life of the battery.

STEP 1: UNDERSTAND THE BATTERY JOURNEY

The journey of the battery through the supply chain was investigated and graphically mapped (see figure 6) to understand who the different actors are that interact with the battery along its journey. All the different steps were codified to identify tracking opportunities. Identified was, for example, that a radio frequency tag could be applied at the manufacturing stage as this would enable the battery to be 'scannable' without opening the device.

STEP 2: WHAT TAGGING TECHNOLOGIES WORK ON A BATTERY?

A battery is packed with metals (e.g cobalt, lithium, aluminium), which can distort the radio frequency signals of RFID technologies. Avery Dennison, partner in this CoP, made a feasibility study to understand which tags worked best to identify and track the different modules (more information to be found in appendix B). In conclusion, all of the modules were readable when using different RFID tags, but some had a very limited readability range.

STEP 3: WHAT BATTERY LIFECYCLE INFORMATION CAN BE TRACKED ALREADY?

The software team at Fairphone extracted all the metrics that the operating system of the phone can read from the battery (a list of more than 20 different metrics) and built an app that can read and display all these values. A selection from these metrics was made to be used in the proof of concept: the charging temperature and the total charge.

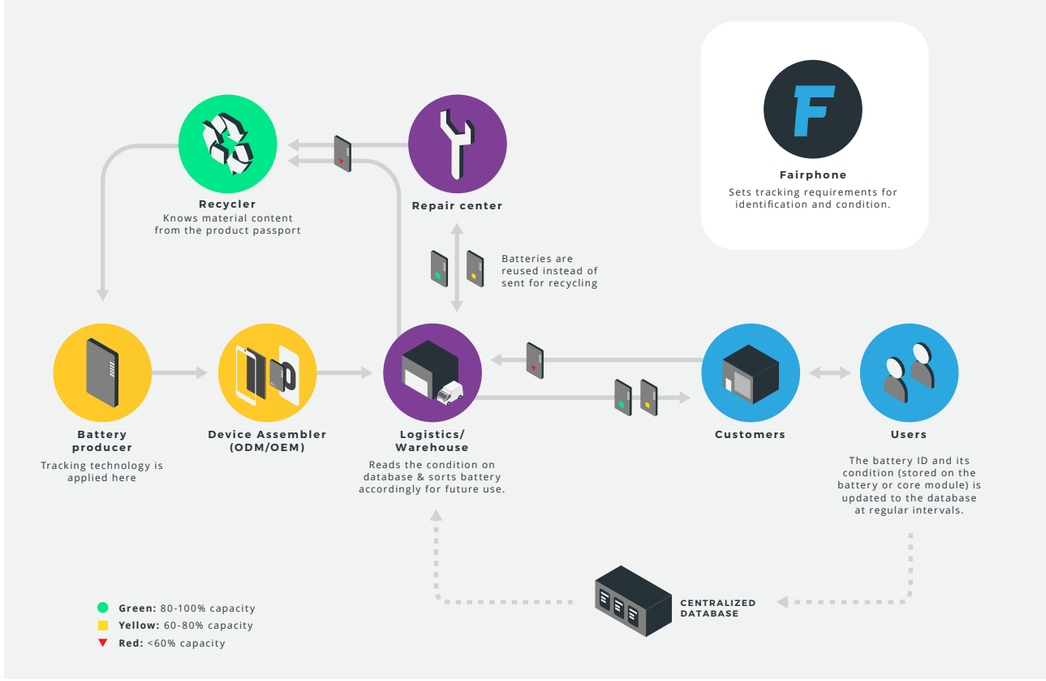
STEP 4: BUILDING A SIMULATED 'CONDITION TRACKER' FOR THE BATTERY

A software instruction was created to read and record the aforementioned metrics when the user carries out actions that influence the condition of the battery (e.g. charging the battery at high temperatures). This action serves as a proxy for a deterioration of the condition of the battery (i.e. its state of health) and assigns a specific condition value to that specific battery in a database (e.g. 'Battery xyz has a condition of 60%").

STEP 5: CONDITION TRACKER EASES SORTING

Thanks to the condition data, batteries can easily be categorized according to their condition, for example, when they are scanned at a warehouse and subsequently assigned to the applicable value proposition.

Figure 6. The journey of the battery through the supply chain.



6 - FINANCIAL IMPLICATIONS

DATA PROVIDES COMFORT FOR FINANCIERS

In general, the backbone of financial decision making at the level of banks is based on historical financial data (i.e. track record), available collateral and revenue generation. Early stage financiers, i.e. financiers who are willing to take a higher degree of risk, focus most often on young companies with no track record. As historical data is lacking, these financiers focus primarily on forecasts of future financial results and qualitative aspects, such as the background and experience of the entrepreneur. As the PaaS entrepreneur stays the owner of the assets, the financial risk for the asset throughout its lifetime will be carried by the entrepreneur. Transparency on the location and condition of assets gives the entrepreneur a better grip on its assets and hence might improve the value of the asset as collateral to underwrite a loan. As tracking improves accuracy of forecasted cash flows and control over assets (i.e. collateral), it lowers the risk profile of the entrepreneur and increases his/her chances to obtain funding.

The generated data also provides information with respect to the valuation of the modular assets and can influence depreciation schedules and the asset value on the balance sheet. However, as these are non-cash effects, the focus of this whitepaper has been on the influence of data tracking to improve the FaaS business case and setting the right price for each value proposition.

DEVELOPING FINANCIAL INFORMATION

As a PaaS entrepreneur there are quite a few financial challenges to conquer, see box Financial Challenges. Tracking assets generates information on the location and the condition of assets. This information is essential for a sound PaaS business model, through accurately pricing the business case. Tracking the condition of assets enables the entrepreneur to define different asset categories that can be offered in different value propositions to the customer, as presented in chapter 2. Different value propositions extend the lifetime of the assets as they can be offered in multiple use cycles, which also increases the revenue generation of these assets.

FINANCIAL CHALLENGES

With respect to setting up a viable PaaS business case there are some financial challenges to overcome:

- predicting cash-flows in a service business model;
- defining different value propositions for the different conditions of assets;
- estimating the costs of future service obligations;
- estimate the residual value of the assets when to be refurbished.

Taking all these points into consideration, the last challenge is setting the right price for each value proposition.

Finally, data tracking supports the buildup of product history data, which can lead to improvements in operational efficiency and can have a positive impact on cash flows, for example to make better estimations with respect to future costs, e.g. repair and replacement costs and inventory (see next sections). Having access to this type of information enables the entrepreneur to set the right level of margin for a specific value proposition.

SMART TRACKING IMPROVES THE QUALITY OF THE ESTIMATIONS OF FUTURE SERVICE OBLIGATIONS

In a PaaS business model the PaaS provider is responsible for the condition of the assets. Repair and replacement costs thus need to be included in the service proposition. With respect to estimating the expected future obligations, it is important to focus on your expected costs to cover future service obligations under the PaaS proposition: *provisions*.

Provisions are a balance sheet item representing funds set aside to cover anticipated future costs with uncertain timing and/or amount. An entity recognises a provision if it is probable, i.e. have a 50% probability of occurring, that an outflow of cash or other economic resources will be required to settle the provision. If an outflow is not probable, the item is treated as a contingent liability.

An accurate estimation of provisions for repair and replacement throughout the lifetime of the assets is key for setting the right service fee for each value proposition.

SMART TRACKING IMPROVES ACCURACY IN REQUIRED LEVEL OF STOCK

The data captured by means of tracking assets can also provide valuable input for inventory management. Part of the service proposition is a fast replacement of Fairphone modules when the asset does not function in accordance with the agreed service contract. Being able to swiftly replace parts requires Fairphone to keep a sizeable inventory position. Inventory which sits idle does not generate any revenue. It is therefore of utmost importance to be able to estimate the condition of your assets accurately in order to avoid keeping too many assets in stock.

LIFETIME EXTENSION

The expected financial obligations under a service contract should be lower in comparison to the additional cash flow generated from longer use cycles. The question should be asked: How much additional lifetime (i.e. cash-flow generation time) is created by repairing/ upgrading a modular asset of the phone? Figure 7 graphically shows that the ratio between the additional cash flow created from the lifetime extension (purple arrow) and costs to be made to realize the additional lifetime (green arrow) should be smaller than 1 (i.e benefits are larger than costs) and is relevant to distinguish feasibility of cascading products or components (e.g. refurbishing, re-using or recycling).

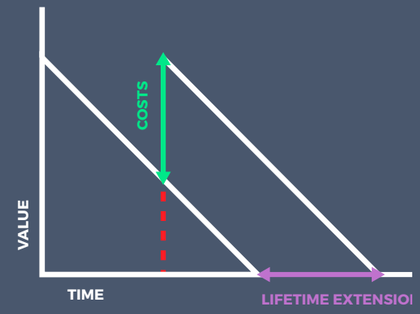


Figure 7. Ratio investment costs versus lifetime extension.

7 - LEGAL IMPLICATIONS

DATA PROTECTION REGULATION

The data generated when tracking assets is subject to data protection laws and regulations. The main questions entrepreneurs should ask themselves are:

- **How** is the data retrieved?
- **What** type of (personal) data is gathered?
- **Why** is this data needed?

Some information about the usage of a device, in this case a smartphone, could be labelled as personal data. The amount of times a device is dropped, been in humid environments or charged at high temperatures, could give important information to be used to estimate the technical condition of the device to, for example, assess repairability or refurbishing opportunities, or simply to exercise preventive maintenance for users. The other side of the coin is that this data can easily say something about the places where the user has been or the type of daily activities the user has undertaken.

Entrepreneurs servicing the European market and gathering data from their users should take into account the below EU regulations:

1. ePrivacy Directive (ePD) - applicable for general and personal data
2. General Data Protection Regulation (GDPR) - only applicable for personal data

ePRIVACY DIRECTIVE (ePD)

The ePD is the existing directive that sets out strict rules for the electronic communications industry. In the Netherlands, these rules are set out in Article 11.7a of the Dutch Telecommunication Act. When using tracking technologies whereby data is sent to or retrieved from a personal device, two requirements need to be adhered to:

a. Before the sending or retrieval of data the user must have given his/her consent;

b. The user needs to be informed, in line with GDPR (please see below), why the data tracking technology is used.

In other words, the use of the tracking technology requires the *informed consent* of the user. This can be obtained by means of e.g. expression of consent via marking a tickbox.

PERSONAL DATA

Any information relating to an identified or identifiable natural person; an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person[22].

The point to take into account when obtaining consent is that customers should always be able to withdraw their consent. Therefore, the withdrawal of consent should be technically feasible, i.e. it should be possible to technically stop tracking the (personal) data.

Some exemptions exist to the consent requirement. For example, if the placement of information or access to it has as sole purpose to enable the communication over an electronic communication network or is strictly necessary to deliver an information society service (e.g. a website) at the request of the user. A third reason for an exemption is when instead of 'pulling' data from a personal device, one could also develop a solution that 'pushes' the required data from the device, such as an IP address is pushed from a device. In this case, it could be argued that no consent from the customer is required. However, this could be a long shot. The supervisory authorities will most probably argue that all tracking technologies used fall under the scope of the rules of the ePD and Dutch Telecommunication Act.

In any event, it is always required to clarify how (personal) data is gathered and processed and for which purposes.

Since 2017, there has been an e-Privacy Regulation in the make as a follow up of the current directive. Similar rules to the ones known under the ePrivacy Directive are introduced in this regulation.[23]

GENERAL DATA PROTECTION REGULATION (GDPR)

GDPR became applicable as of May 2018. Whereas the ePD is applicable to all data, GDPR is only linked to personal data. If personal data is collected from the device or otherwise processed, companies, among other legal obligations, need to ascertain a ground for processing this data gathered from the device. These grounds can be either:

1. User consent;
2. Execution of an agreement; or,
3. Legitimate interest (upholding company's commercial interest and provided that this interest outweighs the privacy interest of the users).

If consent is required under the ePD, then consent is also needed under GDPR. Therefore, obtaining consent from a customer might be the preferred and safest route to choose. The disadvantage, however, as stated in the previous paragraph, is that customers should always be able to withdraw their consent Therefore the question should be asked if the withdrawal of consent is feasible.

If it is possible to base the retrieval of data from the device, on one of the exemptions set out in the ePD, then one could opt for executing an agreement with the customer or for processing the data in line with its legitimate interest (please see box).

It is fair to argue that there is a legitimate interest for companies in the Circular Economy to gather (personal) data to increase the efficiency of circular business models. The interesting question is how to balance that interest with user rights. 'Privacy by Design' principles (please see next page) enable individuals and society to stay in control of what personal data is shared and how.

Basing the processing of (personal) data on the execution of an agreement with the customer and/or under legitimate interest brings some advantages, for example, not needing a technical solution to enable withdrawal of consent, but may bring risks should the information about data gathering not be very clear to users. On the other hand, communicating effectively and very transparent about the (personal) data tracked and the purposes, could ensure high consent percentages and a positive attitude towards the matter by the users.

In the next section the ethical aspects are discussed and some solutions are proposed to practice Privacy by Design.

A THREE-STEP TEST CAN BE UNDERTAKEN WHEN CHOOSING FOR LEGITIMATE INTEREST[24]:

1. **Purpose test:** Identify a legitimate interest (personal interest / interest of third parties / societal interests)
2. **Necessity test:** Show that the processing of personal data is necessary to achieve this interest. If you can obtain the same result without obtaining this data then legitimate interest will not apply; and
3. **Balancing test:** Balance your interests against the individual's interest. If the retrieval of data would cause unjustified harm, then the individual's interest most probably will override your legitimate interest.

ETHICS OF GATHERING DATA

As mentioned already, data gathering can help to establish an efficient and cost-effective PaaS proposition. With the rise of digital data storage and communication in the last decennia, a business uses a multitude of online services which hold consumer data. It is easy to lose overview of the information traffic in and out of the company. There are multiple ways in which data can leak out of the system or targetted by externals to be hacked.

The former Information & Privacy Commissioner of Canada, Ann Cavoukian, created the 7 principles of Privacy by Design. A helpful tool to set up a responsible and secured value tracking system for modular assets and user data in general. Please see below a summary of her practical tips:

- **Proactive and Preventive:** When designing a value tracking system, keep data privacy central in the process from the start. Do not wait with solving privacy issues after implementation or when they arise.
- **Privacy as the Default:** "No action is required on the part of the individual to protect their privacy – it is built into the system, by default." This means that the amount and type of data is kept to the minimum necessary for a well defined purpose. It is retained for the duration needed for that purpose, before being securely destroyed.
- **Privacy Embedded into Design:** Think of privacy as an integral part of the architecture of the IT system and of business practices related to the value tracking system.
- **Full Functionality** - no zero- sum: It is always possible to find a way to satisfy all legitimate objectives of value tracking IT systems, be it functionality, security or privacy. Center the discussions around finding these ways, without losing time on trade-off discussions.
- **End-to-end security:** Secure the user data throughout its entire lifecycle. Technical measures needed to attain this include up-to-standard encryption, methods of secure data destruction, strong access control and logging methods.
- **Visibility and Transparency:** Collection of user data should be accountable, open, transparent and compliant. Always communicate clearly to your users what data you are tracking, how it is used, and for how long you will keep it.
- **Respect for user privacy:** Keep it user-central. Provide good information and make the options user-friendly. "The individual's free and specific consent is required for the collection, use or disclosure of personal information, except where otherwise permitted by law. The greater the sensitivity of the data, the clearer and more specific the quality of the consent required. Consent may be withdrawn at a later date"

To sum up, any entrepreneur in this circular journey, needs to be well aware of the risk of data gathering and surely should avoid collecting data just because it is possible. Think about what needs to be gathered to make the value proposition successful and less risky and make sure you get a good feel of how your users will think about it.

8 - CONCLUSION

TRACKING IS INVALUABLE

Tracking the value of modular assets in a circular PaaS proposition is invaluable. It improves decision-making regarding the cascading of components (e.g. refurbishing, re-using or recycling) and predictive maintenance, aiding to the goals to make smart design decisions to increase longevity of devices and recover as much material as possible. It also allows for providing a timely and high quality, customer type-specific service, ensuring customer satisfaction and retention. Finally, it creates ways to optimize the business model by creating intelligence on necessary provisions to cover future costs, accurately price the contract, optimize operational efficiency and cross-selling opportunities that makes the value proposition richer.

QR CODES, MEMORY CHIPS AND RFID TAGS ARE MOST SUITABLE TO FAIRPHONE

For Fairphone's as-a-service proposition, this CoP found that QR codes, memory chips and RFID tags (NFC and UHF) were found to be most suitable. QR codes have the advantage that they are easily readable by any device. NFC technology has the advantage that the reading equipment does not need line of sight, but the disadvantage that the signal can be distorted if the modular assets have metallic parts. UHF has the advantage that multiple modules can be read at once and from a distance, but requires more specialised reading equipment. QR codes and RFID tags are widely used by manufacturers and logistic companies, and are suitable for many other products and (circular) business cases. These technologies can be possibly extended with other types of identifying technologies. Next, integrating memory chips in the design of new modules can open up possibilities for tracking the condition of modules or other actions done by the user. Being part of the design, software can specifically respond to a certain context and can serve as a valuable tool to deliver rich insights to service providers in a service proposition.

FINANCIAL AND LEGAL IMPLICATIONS

Tracking assets provides transparency on the location and condition of assets and therefore gives the entrepreneur a better grip on its assets and the assets can serve as collateral to attract financing. In addition, tracking can help to lower the risk profile of the entrepreneur by providing lifecycle information of the assets, improving pricing and quality of estimating future service obligations (i.e. provisions). An accurate estimation of provisions for repair and replacement throughout the lifetime of the assets is key for creating a viable PaaS business case and setting the right service fee for each value proposition. The data captured by means of tracking assets also provides valuable input for inventory management, aiming to optimize inventory costs. With respect to legal implications, the data generated when tracking assets can be subject to data protection laws and regulations. Obtaining consent from a customer for gathering (personal) data is the preferred and safest route to choose. The disadvantage, however, is that customers should always be able to withdraw their consent as well. Therefore the main question that should be asked is: would the withdrawal of consent technically be feasible?

WHAT IS ACCOMPLISHED?

The following table provides a summary of the wishes that have been (partially) fulfilled and how this has been achieved.

LOCATION AND IDENTITY OF MODULES		
●	*Localization and identification of modules and devices*	**Either by QR-codes or by RFID tags.**
●	*Identifying changes to the composition of modules in a Fairphone*	**Ideally by programmed memory chips that are implemented in every module.**
●	*Optimizing (reverse) logistics for service of replacing broken modules*	**Reverse logistics solution still need to be developed.**
ASSESSING AND INFLUENCING THE CONDITION OF MODULES		
●	*Assessing the condition of the modules and estimating actual remaining lifetimes*	**Batteries are categorized according to their condition. Solutions for other modules still need to be developed.**
●	*Minimizing or preventing downtime thanks to predictive maintenance*	**Key condition factors of the battery are tracked and stored in a centralized database, which enables predictive maintenance. Solutions for other modules still need to be developed.**
●	*Accurate asset valuation by considering the condition of the modules, their expected remaining lifetime and costs*	**Data on condition, lifetimes and costs are ready to be gathered. Intelligence on corresponding valuation still needs to be built and will continuously be updated.**
●	*Improving decision-making of future loops: i.e. re-use, reparability, remanufacturing or recycling*	**Elicit re-use scenarios of the battery are distinguished. Similar information on the other modules would improve cascading decisions.**
●	*Interact with (human) users to change use patterns to minimize wear and tear and stimulate sustainable use and repairs*	**A user facing tool is currently being developed that could communicate lifetime extending use (e.g. charging behaviour) to the end user.**
●	*Develop specific value propositions and individualized interactions & experiences that contribute to circular goals*	**Value propositions were designed to include newly developed intelligence. This will be continuously improved and built upon.**
ASSESSING THE AVAILABILITY OF A PHONE OR MODULES		
●	*Transparency of availability of phones and modules to optimize re-use of modules*	**Tracking modules' location (based on connected checkpoints), condition and availability (in-use or idle) enables optimal allocation of devices and modules.**
FACILITATING DESIGN & OPERATIONAL IMPROVEMENTS, CHAIN COLLABORATION & PRIVACY		
●	*Improving the design of the Fairphone and its modules and processes in the future*	**There are effective feedback loops between operations and engineering teams. However, building more historical data about use, lifetimes and cascading decisions, will provide additional insights.**
●	*Optimizing operational efficiency (i.e. balancing resource utilization with rapid redeployment of modules, and keeping assets in service)*	Combining above, feedback loops for product design, knowledge on availability and condition provides a solid ground for improving operational efficiency.
●	*Provide information to involved stakeholders (e.g. repair, logistics) to improve chain collaboration*	Data sharing opportunities still need to be addressed as well as aligning stakeholders further with the FAAS value proposition.
●	*Adhere to privacy and GDPR regulation*	There are a couple of ways to both adhere to privacy by design principles as well as comply with privacy regulation.
MEASURE CORRESPONDING IMPACT		
●	*Measure utilization rate for modules and devices and its corresponding material, footprint and cost*	This point was out of scope for this paper. However, at the time of writing, the Life Cycle Assessment of Fairphone 3 has started which will deliver interesting insight on the reuse and repair of modules.
●	*Measure increase in customer trust*	**This point was out of scope for this paper. The role of the user is very important. Some of the considerations in this paper will require an active participation of the user and it is expected that this will increase the trust in the proposition.**

● Wish fulfilled
● Wish partially fulfilled
● Wish to be included in future research

Table 4. Evaluation Circular Tracking Wishlist.

9 - CHALLENGES & FUTURE DEVELOPMENTS

NEED FOR PILOTING AND AN OPEN MINDSET

In the previous CoP, featuring The Circular Phone, a sound business proposition was prepared. One of the challenges that remains, however, is the need for an open mindset from all stakeholders involved. Although tracking technologies can reduce some of the risks, it still requires room for piloting and testing, as track record still needs to be built and validated. Many companies, especially the larger ones, have difficulties finding room for experiment if that means stepping outside their existing processes and procedures.

UNCLEAR RETURN ON INVESTMENT

A challenge that needs to be addressed, is that upfront capital investment is required to invest in the tracking technologies, while at the same time a clearly defined return on investment is lacking. Although the opportunities seem evident, how big the efficiencies will be in the long-run can only be estimates.

COLLECTING DATA DOES NOT ENSURE THAT THE INFORMATION IS PUT TO GOOD USE

Communication between business and technical experts is a challenge. To ensure that the right data is collected, subsequently processed in the right way and eventually put to proper use, good communication between the IT/software team, the business and operations is essential.

PRIVACY EASIER TO INCLUDE IN DESIGN THAN TO PATCH UP ISSUES LATER

When devising an architecture for a data tracking system, it is crucial to address concerns about how innovators, companies and government agencies use, share and protect personal data. It was found to be simpler and safer to integrate from the start than to patch up issues later. An important starting point is to make the link between the individual user and the corresponding data as difficult as possible to match. Additionally, in light of privacy, only necessary data - and only for the required period - needs to be collected, rather than collecting whatever might be useful. Mechanisms need to be developed that prevent potential criminal activity from harming private individuals and businesses. This, in turn, requires a legal infrastructure that ensures trust and security over personal data, which is currently a major hurdle for *Internet of Things* (IoT) related market development. Blockchain technology, for example, could provide useful in cases where trust is an issue, to protect data from being altered by involved partners.

STORING INFORMATION SECURELY IS A CHALLENGE

Securely and reliably storing information about assets' provenance, identity, condition, availability, use and ownership (i.e. digital rights) is difficult. It needs to be verified that a given device is genuine, and that its software and settings have not been tampered with or breached. The area of data security is being increasingly developed, but also requires deep expertise and large investments. Companies can benefit from identifying their partners within the intelligent circular asset economy, to determine whether they can join a partner's platform or need to develop their own. By joining existing platforms, interoperability (i.e. seamless data sharing between assets and networks of different industry players) will improve.

INTEGRATE TRACKING RESULTS INTO EXISTING BUSINESS UNITS

At the time of writing, a troubleshooting tool is being developed that allows more efficient repair service and easier in-house repairs. The insights that are gathered through the value tracking pilot (e.g. for the battery) could be well incorporated into the app, updating the condition of the modules. It might also be used to provide more accurate information on how much material, emissions and energy is saved compared to a benchmark.

PROVIDING CHAIN PARTNERS WITH THE RIGHT INCENTIVES

A big future challenge is how to align all stakeholders in the circular value chain to work towards the same objective: extending the longevity of the Fairphone device and re-using as many components as possible. In The Circular Phone, the Circular Service Contract can be found which stipulates the rules and responsibilities between Fairphone and its customers. However, key stakeholders providing services around the asset, such as the repair center, but also component providers, manufacturers or even consumables (e.g. telecom services) also need to be involved. Incentive alignment can be achieved by integrating partners in a circular contract in which responsibilities around the asset, components, or service lie at the best situated company and is rewarded accordingly (e.g. from the service fee).

BRAINSTORM WITH US!

How to optimize the Fairphone-as-a-Service proposition? You are being challenged to share any smart, crazy, bold ideas with us! For example:

Extend the Product-as-a-Service Proposition to other related products! Include headphones, covers, screen protectors as a service! Liaise with a green energy supplier to offer the possibility to charge your phone with green energy or liaise with students specialised in design & innovation to invent offering 3d personalized printed covers as an additional service.

APPENDIX A: FAIRPHONE 3 - MODULES & OBSOLESCENCE DRIVERS

MODULES	MAIN SUBPARTS	ACTIVE OR PASSIVE		OBSOLESCENCE DRIVERS		
				WEAR & TEAR	ACCIDENTS	MARKET
1) Top Module	Earpiece speaker, proximity and light sensors, notification LED, selfie camera, audio port, secondary microphone, and connector to core module.	Active; The selfie camera contains a camera sensor activated by a chip which can store predefined information and communicates with the operating system.		The audio connector is subject to mechanical forces when used. The audio connector can be clogged due to lack of maintenance by the user.	The audio connector can have a mechanical accident.	Camera technology advances at a fast pace but depends on whether the users want a better camera.
2) Bottom Module	USB port (power and data), primary microphone, the vibration mechanism, and connector to core module	Passive		The charging connector is subject to mechanical forces when used. The USB port can be clogged due to lack of maintenance.	The USB port can suffer from mechanical forces when the product is dropped while charging.	USB type C is becoming the norm and looks like no new advancements will be introduced anytime soon in the shape of the port; though compatibility remains an issue.
3) Display Module	Display, closing mechanism, connector to core module	Active; Contains a chip that processes orders from the operating system and manages the functioning of the screen. The chip communicates to the core module.		Scratches may appear over time. The LCD display might turn yellowish over time.	Glass on display is likely to break due to impact when dropped enough times.	A plateau has been reached on actual improvement of image quality, but further improvements can be done in energy efficiency with AMOLED displays or in functionality like with foldable displays.
4) Camera Module	Main camera sensor, LED flash, and connection to the core module	Active; The camera contains a sensor that is activated by a chip. See Top Module.		The camera module is not heavily affected by wear and tear.	Drops can affect operation	Camera technology advances at a fast pace. Fairphone 2 was the first device to offer a camera hardware upgrade :
5) Battery	Li-ion battery and connection to the core module	Passive		The battery loses capacity with every charging cycle.	The battery can be damaged when the phone is dropped or exposed to high or low temperature among others.	Low relevance; research and development is being done on new battery technologies, but so far none seem to be close to being industrially available .
6) Core Module	Chipset, antennas, battery connector, multiple other electronic components, connectors to all the modules	Active; The core module contains a chipset that operates the entire phone and can process and store information		Wear and tear is not significant for the core module.	The core module contains the most critical electronic parts and is therefore sensitive to humidity and drops but cases can be designed to be drop resistant.	Main driver is the development of new chipset technologies which defines the speed and compatibility of the device to the latest software developments. Drives the obsolescence of the whole device.
7) Back Cover	Translucid plastic plate that protects the electronics of the phone. Easily removable.	Passive		External parts of the device suffer most of wear & tear	Accidents are unlikely to affect the back cover.	Not relevant, only if Fairphone releases new covers
8) Speaker Module	Loudspeaker	Passive		The moving parts of the speaker wear faster in a humid environment.	Accidents are unlikely to affect the speaker module.	Low relevance, big improvements in speaker technology are not expected a new, more powerful speaker can be implemented with an upgrade.

APPENDIX B: FAIRPHONE 3 - ASSET TRACKING TEST BY AVERY DENNISON

AVERY DENNISON | RFID

Fairphone Reading Tests

RAIN-UHF Readability on parts

OBJECTIVES

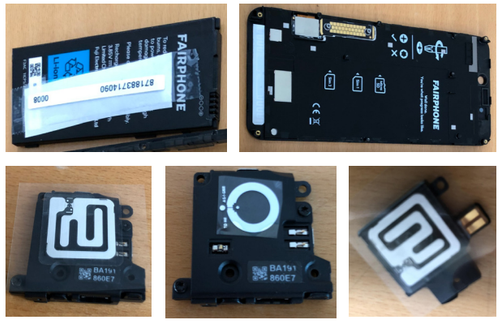
Fairphone wants to assess the feasibility of an RFID tagging solution for the main parts of their modular smartphone. Parts are classified according to the priority level in terms of interest. Three different use cases have been identified:

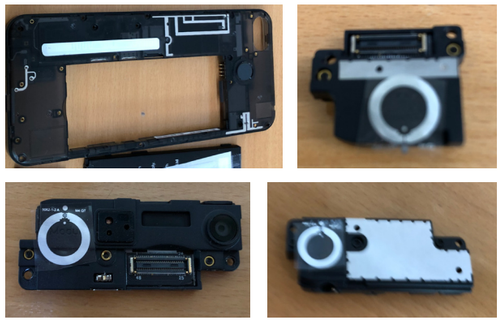
- Single part identification (track & trace)
- Parts in a smartphone configuration (assembled)
- Logistics and inventory management of the single parts

This is a preliminary assessment to understand the level of readability of the different parts in the different scenarios. When use cases are defined more detailed reading tests could be performed. The assessed parts can be found in the image above: Battery, display, bottom module, core module, top module, speaker module and camera module.

INLAY SELECTION

Best performing inlay and positioning have been selected per each part avoiding metallic surfaces.





- ***Battery:*** because the all-metal construction of the battery, only on-metal tag AD-456u8 (sized: 64 x 6mm and 0,5mm thickness) is possible to be used. Note this inlay is 0.5 mm thick.
- ***Display:*** It has a metal play behind the display area. The bottom area is free of metal and AD-160u7 trimmed (sized: 52 x 6 mm) fits.
- ***Bottom module:*** Both AD-806u7 (sized: 19 x 19 mm) and AD-850 (sized: 14,5mm diameter) have been tested, even AD-806 is covering the connector area.
- ***Core module:*** Space available for a large tag AD-160 (sized: 64 x 6 mm) but metal plane inside.
- ***Top module:*** Only AD-850 fits. Choosing an area free of metal. Grade in the plastic piece has to be considered when integrating the tag to the part.
- ***Speaker module:*** Both AD-850 and AD-806 inlays fit. Internal metal piece. Right side of the module is chosen.
- ***Camera module:*** Only AD-850 inlay fits.

READING CONDITIONS

The Zebra RFD8500 handheld reader ETSI 1 watt was used in this test. The inlays tested are types AD-850m4QT, AD-806u7, AD-160u7, AD-160u7 Trimmed and AD-456u8 in 3 reading conditions: free space, inlay attached to the part disassembled and inlay attached to the part assembled.

READING RESULTS

READING CONDITIONS (READ RANGES IN CM)

	Inlay	*Free Space*	*Disassembled*	*Assembled front reading*	*Assembled back reading*
Battery	AD-456u8	60	150[a]	**25[d]**	**30[d]**
Display	AD-160u7 trim	-	140[b]	**140**	**40**
Bottom	AD-806u7	50	10[c]	**60**	**95**
Module	AD-850m4QT	30	2[c]	-	-
Core module	AD-160u7	100	40[c]	**15[d]**	**30[d]**
Top module	AD-850m4QT	30	2	**2**	**contact**
Speaker module	AD-806u7	50	10[c]	**contact[c]**	**contact**
	AD-850m4QT	30	2[c]	-	-
Camera	AD-850m4QT	30	2	**2**	**2**

Comments:

- All metal. No readability with regular tags. A thicker tag (0,5mm) is needed (AD-456)
- Out of metal plane area
- Metal plane on the back of the module
- Display is shielding

CONCLUSIONS

Most of the parts are readable both assembled and disassembled. In general though, the read range is quite limited and suitable for identification purposes but not for logistics/inventory cases (except for larger parts (batter, display, core)).

Some small parts are difficult to tag for the small dimensions and the lack of flat surfaces. Deeper analysis has to be performed to understand how tagging could be integrated in the part without mechanical interference in the assembly of the parts

The battery requires a on-metal tag because of the full metal piece. This is a 0,5mm thick inlay which needs to be taken into consideration when the battery is assembled into the phone. The use of inlays based on newer chip generation (Ucode 8 and M7000) could slightly improve the results.

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