Viktoria

GUIDELINES FOR IMPLEMENTING CIRCULARITY METRIC & RELATED ENVIRONMENTAL INDICATORS

PROJECT:
MEASURING PRODUCT CIRCULARITY AS A MEANS TO PROMOTE RESOURCE PRODUCTIVITY

Emanuela Vanacore & Marcus Linder – RISE Viktoria AB
Hanna Ljungkvist & Lisbeth Dahllöf – IVL Svenska miljöinstitutet

This handbook aims to provide some practical guidance for business people and practitioners on how to apply and use some circular and environmental indicators in their organisations.

The circularity metric was applied and tested in the “Measuring product circularity” project funded by Re:Source from August 2017 until June 2018. The project aimed to test the metric in the real world and compare it to other sustainability indicators. With that purpose the work was carried out in collaboration with 19 Swedish companies from a wide range of industries which received guidance from a research team including researchers from RISE Viktoria and IVL Svenska Miljöinstitutet. Conceptual development of the circularity metric was funded by the Marianne and Marcus Wallenberg Foundation in the related project “Measuring business circularity”.

This handbook is made of two sections. The first refers to the Circularity Indicator (pp.2-9) whereas the second part relates to environmental indicators that complement the circularity indicator.

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GUIDELINES FOR IMPLEMENTING CIRCULARITY METRIC

By Emanuela Vanacore & Marcus Linder, RISE VIKTORIA

INTRODUCTION

This guide aims to provide a useful tool to help understand and apply the circularity metric. Key definitions and practical examples will be given to support this step-by-step guide whilst highlighting the benefits of utilising the metric. Specifically, the text outlines how a company can estimate the circularity of a product using internal accounting data.

WHY A CIRCULAR ECONOMY? WHY MEASURING?

Our current “**linear**” economic model has sustained significant economic growth since the Industrial Revolution, which has been pursued on the assumptions of indefinite development, an endless stock of primary, virgin resources and non-renewable, polluting energy sources as well as on the production of vast quantities of waste.

However, our **economic system** is currently **under pressure** because of factors such as commodity price volatility, increasing scarcity of non-renewable resources, severe environmental damage, increasing global population and middle-class consumers. These factors are **exposing businesses to growing opportunities and risks**.

Therefore, a “Business As Usual” approach appears to be unsustainable in the long-term and the **alternative model** of a **Circular Economy** (CE) that could overcome the aforementioned issues and challenges whilst mitigating risks and ensuring long-lasting prosperity appears to be thus inevitable.

Indicators or **metrics** are key and effective **tools** for production assessment and informed decision making. This is particularly relevant in a transitioning scenario to a CE for business stakeholders given the old idiom: “What gets measured get managed”.

BENEFITS OF CIRCULARITY METRIC

[redacted]

DEFINITION OF THE CIRCULARITY METRIC

For the purposes of the circularity metric, product level circularity is defined as *the fraction of a product that comes from retired products*.

We define *fraction of a product* in terms of **economic value**. This is different from fraction in terms of mass. Economic value is calculated using **market prices** or **cost estimations** (for proprietary parts). Because the metric is focused on economic value, there is often no need to break down the analysis to the level of raw materials. A reused component can be entered in the calculation as it is, without considering the materials it is made from.

The circularity metric ranges between 0 and 1 (or 0% to 100% recirculated parts).

CIRCULARITY METRIC EQUATION

[redacted]

WHY to use the circularity metric?

The c-value measures cycle efficiency and that is how much of the product has cycled as measured in the economic value of the product. You could think of it as any other efficiency metric, e.g. energy efficiency on a fridge or sales per lead. Material cycles are important to environmental sustainability, but do not cover every single environmental impact of products. Therefore, in order to get a comprehensive assessment of a product you need to complement the circularity metric with other measures such as toxicity and climate change effects.

When to use the circularity metric?

The metric is designed to measure how much of a set of physical items (e.g. a product or set of products) have cycled previously. It works best for products with recycled content and refurbished or remanufactured products. It does not take long life into account, not maintenance for life extension. The metric gives a snapshot of a product circularity at a specific moment in time. Thus, it is not suitable to reward so-called sharing or service business models. However, we are developing and testing a new metric that describes the linear flow (i.e. *the rate of materials sourced from the natural environment at a rate higher than the current renewal rate of the material)* that is required to maintain product utility over time.

In summary, the present metric is a valuable tool for a company that is interested in understanding how much of a product has been on the market. Also, it is worthwhile mentioning that the circularity metric can be applied also at a company level.

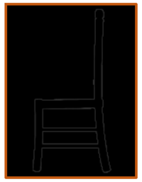
SIMPLE EXAMPLE

A chair is made of two parts. A frame made from recycled steel and a seat made from virgin wood.

The purchasing price of the frame is €10. The frame needs no further work before final assembly with the seat. The purchasing price of the wood is €0.5. The wood is turned into a seat through a workshop process. The estimated cost of making the wood into a wooden seat is according to internal accounting €4.5.

Because no additional products parts are added to this particular chair beyond the seat and frame, we can ignore any subsequent costs incurred by the chair. The economic value of recirculated parts is estimated as €10 for the steel frame. It is considered a recirculated part because the steel is 100% recycled steel. The economic value of all parts is €15 which results by adding €10 from the steel frame to €5 (€0.5 + €4.5) for the wooden seat. Product circularity is calculated as 10 divided by 15 which equals to 67%.

$$chair\ circularity = c = \frac{r}{r+n} = \frac{€10}{€10+€5} \approx 0.67$$



DATA

r = €10

n_1 = €0.5

n_2 = €4.5

n_{1+2} = €5

v = €(10 + 5) = €15

LEGEND

r = economic value of circulated parts

n_1 = economic value of part 1

n_2 = economic value of part 2

n_{1+2} = economic value of part 1 and part 2

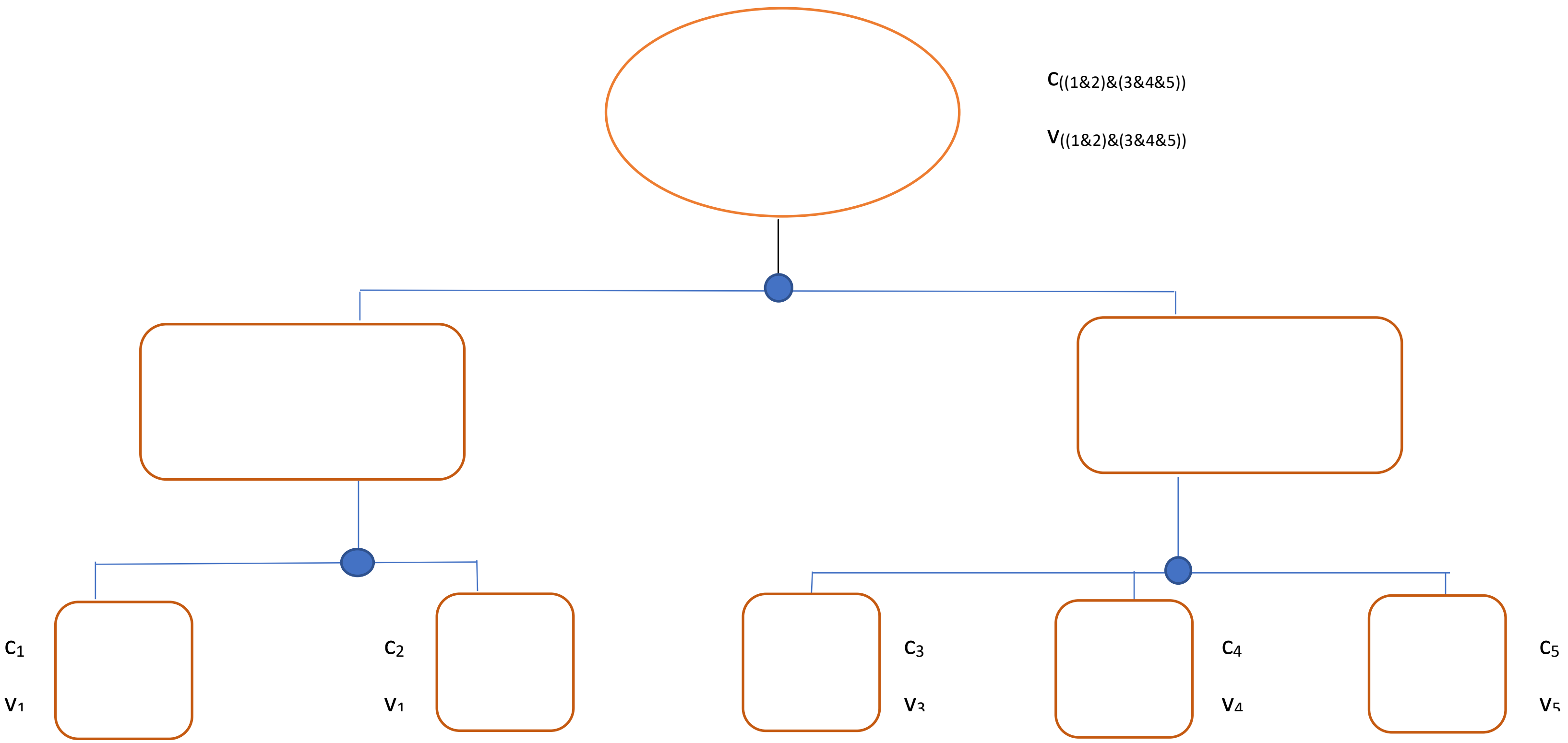
v = economic value of all parts

HOW IT WORKS AND FORMAL RULES

Here step-by-step instructions are presented to guide you through on how to operationalise the circularity metric.

1. The first step to do is to **select a product** whose circularity will to be measured;
2. The second step is to focus on the **product structure** that consists of the identification of the main product components and **draw a product tree**;
3. Then it is essential to specify the **origin of each component** (virgin or recirculated material?) and note the associated costs;
4. Also, it is important to create a "master structure" that maps out the **sequence** of activities to assemble the product;
5. Subsequently, it is important to identify the **main activities that have added value** to the product (e.g. procurement, labour costs, logistics, etc.);
6. The sixth and last step is to assemble all the collected data, preferably in an Excel spreadsheet (as shown in Figure 3) and **calculate** the final figure.

Figure 1. A PRODUCT AS A TREE OF PARTS



Circularity can be calculated by **iteratively applying some rules** for each combination of product parts and work applied to product parts in the value chain.

We use *capitalised product* to refer to the product for which we are calculating the circularity value.

There are **three rules** in total. Rule 1 explains with how to combine two parts into a larger part (e.g. $Part_A$ & $Part_B$ into $Part_{A\&B}$). Rule 2 explains how to enter parts from outside of the value chain you directly control into the calculations (e.g. a sub assembly or a raw material). Rule 3 explains how value adding activities affects the calculations (e.g. if you clean and inspect a used part).

For each step in the calculation, you will get two resultant values: *c* (circularity) and *v* (economic value).

RULE 1 – Used when combining two product parts and gives a resultant circularity value and economic value for the combination. The calculation of circularity can be therefore expressed as follows:

$$c_{1\&2} = c_1 \cdot \frac{v_1}{v_1 + v_2} + c_2 \cdot \frac{v_2}{v_1 + v_2}$$

Where the value of the combination of two product parts is $v_{1\&2} = v_1 + v_2$

The above equation can include several factors and therefore can be generalised as follows:

$$c_{1\&2\&\ldots\&n} = c_1 \cdot \frac{v_1}{v_1 + v_2 + \cdots + v_n} + c_2 \cdot \frac{v_2}{v_1 + v_2 + \cdots + v_n} + \cdots + c_n \cdot \frac{v_n}{v_1 + v_2 + \cdots + v_n}$$

Where the value of the combination of product parts is $v_{1\&2\&\ldots\&n} = v_1 + v_{2+\ldots+} v_n$

RULE 2 – Used when entering new parts or material into the production process for the first time.

The economic value of parts (v) sourced by the firms is calculated as follows:

v = maximum of

- cost of parts including handling costs such as procurement and logistics costs;
- sum of market prices for virgin materials contained in the product;
- second-hand market price for used material or component.

The ingoing circularity value of the pats (v) is given by the supplier or your knowledge of the part. If you go deep enough in the supply chain circularity of all parts are either 0 or 1, but in practice you will often get a reliable c-value before getting that deep. For instance, "recycled steel" may have 15% virgin steel in it, which would give *c*=0.85 for the "recycled steel" you bought.

When you source parts that come from *retired products* in this case refers to any part of the *product* which would no longer have been used for the purpose it was originally used for when first put on the market. For instance, a steering wheel from an old broken car put into a new car is here a part of the *Product* which comes from a retired product. If one takes 10 fully functioning cars, dismantles and mixes the components, and builds 10 new cars, those components are *not* considered parts that come from retired products. Discovering the boundaries of how rule 2 is applied (what is a circulated part in different industries) is a challenge so, document carefully and consider seeking external advice.

RULE 3 – Used when performing value adding activities on parts. For instance, sorting, washing or inspection.

When there is an activity which does not involve combining or consuming materials then the economic value of the parts increases by the cost of the activity.

If the estimated cost of the activity is Δv and the previous estimated economic value of the part on which the activity is performed in v, c and v after the activity are calculated as follows:

$$v_{\text{after activity}} = v_{\text{before activity}} + \Delta v$$

$$c_{\text{after activity}} = c_{\text{before activity}}$$

Rule 3 is always applied *after* Rule 1 since the combination of parts entails value adding activity. Rule 3 is sometimes included in Rule 2 (e.g. if the chosen max value included handling costs) and that economic value (*v*) should then not be counted twice.

ADVANCED EXAMPLE

It is always advisable to build a "product tree" that is a hierarchical diagram of components and process making up a product as shown in the following figures. This is particularly relevant for products that require several components and many processes.

Specifically, figure 2 shows an example of a product-tree, for a product that is made of two main components (Component I and Component II) and each component is made respectively of two parts (Part 1, Part 2) and three parts (Part 3, Part 4, Part 5). Figure 2 illustrates a numerical example for a (simplified) bike. This can be thought as having two main components, wheels and frame.

The wheels can be made of two key parts (rubber and spokes) whereas the frame can include three parts (clean steel structure, seat and break-shifting levers). First the wheels are assembled. In order to calculate the value of the two components (rubber and spokes) rule 1 is applied:

$c_{1\&2} = 0.33 = 1 \cdot \frac{2}{2+4} + 0 \cdot \frac{4}{2+4}$ and $v_{1\&2}$ = €6 = €2+€4.

Rule 1 is always followed by Rule 3, so that $v_{(1\&2)} = v_{1\&2} + \Delta v$ = €6 +€5 = €11. $v_{(1\&2)}$ includes also the assembly activity needed to produce the wheels. Rule 3 does not affect circularity, so that $c_{(1\&2)} = c_{1\&2} = 0.33$.

Focusing on the frame, it is worth noting that the recirculated steel structure has a value of €5 resulting from an initial value of €4 to which the value of cleaning €1 (Δv) has been added. Similarly to the wheels, the circularity (c) of the three parts making up the frame is calculated utilising Rule 2. In this case, the Δv could be included using either Rule 2 (first bullet) or Rule 3, but not both (see v_3 in figure).

To calculate the circularity of the combined parts making up the frame, Rule 1 is applied giving $c_{3\&4\&5}=0.50 = 1 \cdot \frac{5}{5+8+3} + 0 \cdot \frac{8}{5+8+3} + 1 \cdot \frac{3}{5+8+3}$.

To obtain a full frame, logistics and assembly activities worth respectively €4 and €5 are put into the calculation using Rule 3. By Rule 3, the value of the assembled frame ($v_{(3\&4\&5)}$) increases from the €16 (value of parts, €5+€8+€3) to €25 (value of parts plus value adding activities, €16 + €9).

Finally wheels and frame are put together. By applying Rule 1 the resulting circularity metric $c_{(1\&2)\&(3\&4\&5)} = 0.45 = 0.33 \cdot \frac{11}{11+25} + 0.5 \cdot \frac{25}{11+25}$ or 45% and $v_{(1\&2)\&(3\&4\&5)}$ = €36 = €11+€25. The assembly activity worth €3 is added using Rule 3 for a cumulative product value $v_{((1\&2)\&(3\&4\&5))}$ of €39. The final circularity metric of the full product, $c_{((1\&2)\&(3\&4\&5))}$ remains unaffected by Rule 3 for the assembly activity, so that the final circularity metric for the bike is:

$c_{((1\&2)\&(3\&4\&5))} = c_{(1\&2)\&(3\&4\&5)} = 45\%$.

Figure 2. THE TREE EXAMPLE

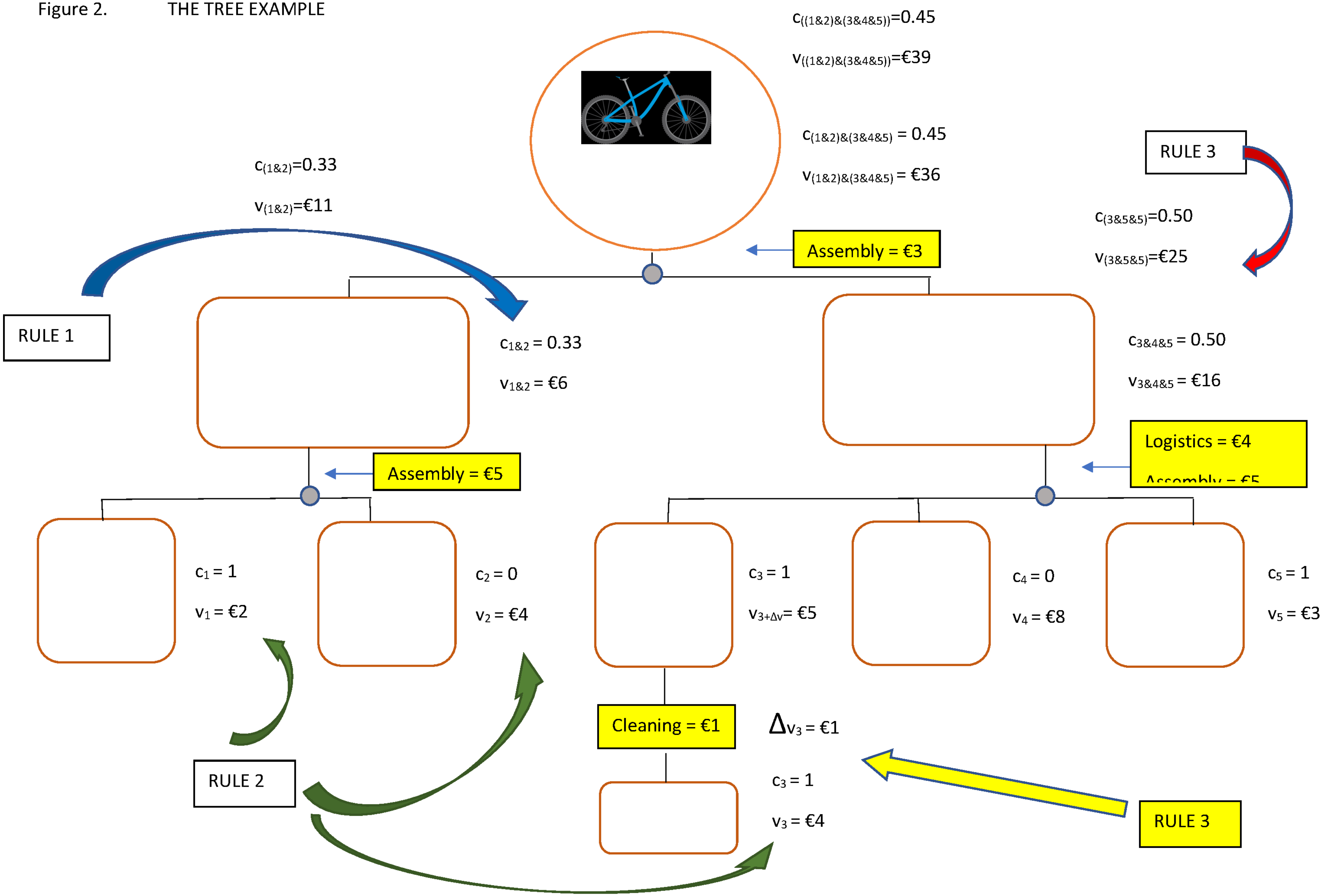
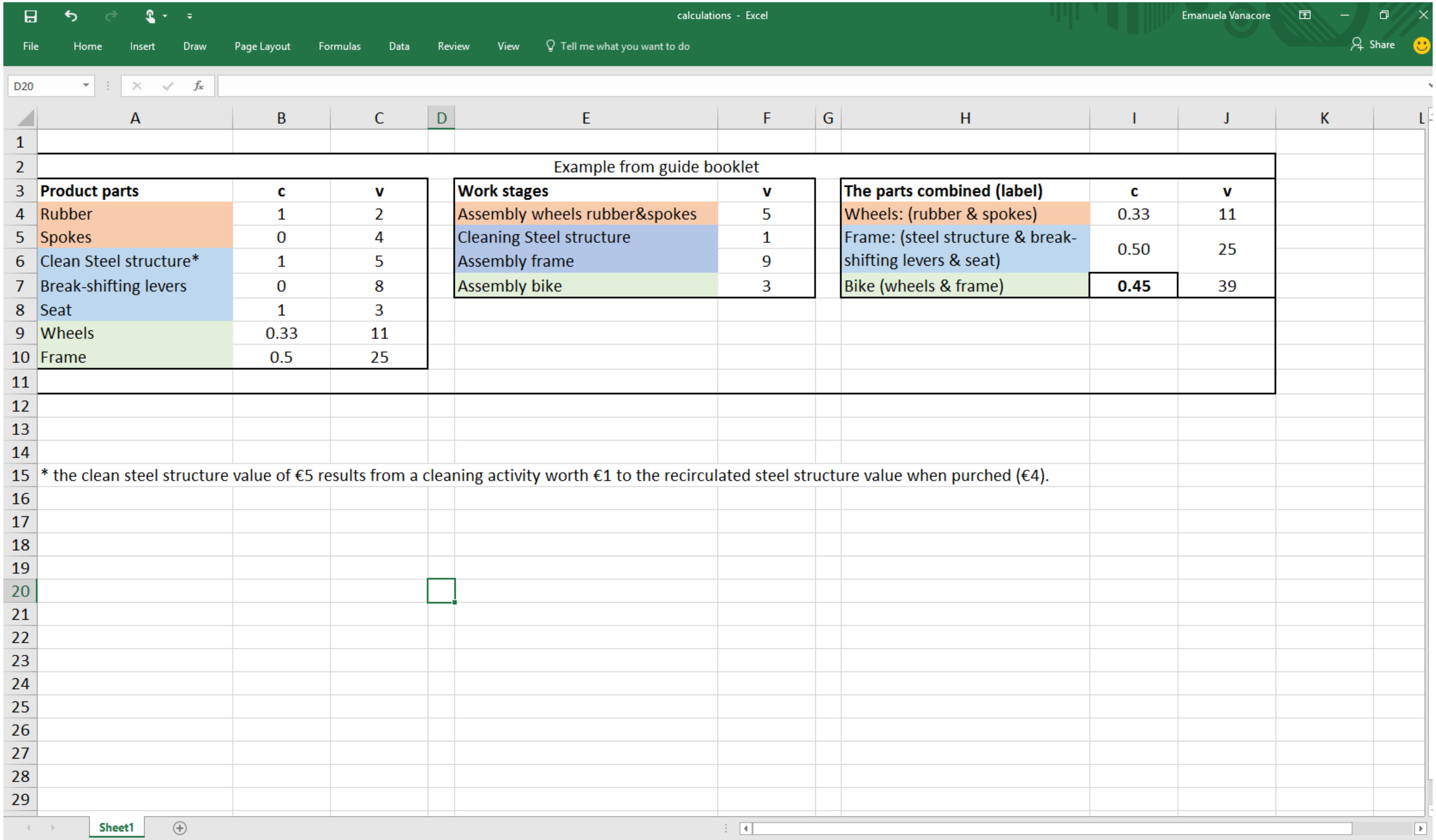


Figure 3. THE EXCEL SPREADSHEET



Example from guide booklet

Product parts	c	v
Rubber	1	2
Spokes	0	4
Clean Steel structure*	1	5
Break-shifting levers	0	8
Seat	1	3
Wheels	0.33	11
Frame	0.5	25

Work stages	v
Assembly wheels rubber&spokes	5
Cleaning Steel structure	1
Assembly frame	9
Assembly bike	3

The parts combined (label)	c	v
Wheels: (rubber & spokes)	0.33	11
Frame: (steel structure & break-shifting levers & seat)	0.50	25
Bike (wheels & frame)	**0.45**	39

* the clean steel structure value of €5 results from a cleaning activity worth €1 to the recirculated steel structure value when purched (€4).

CALCULATIONS OF ENVIRONMENTAL IMPACT

A high circularity metric does not per definition mean that the environmental impact is low. For instance, a product that has high impact in its use phase or when it is discarded can still have a high circularity metric. The same holds true for products with unusually short life expectancy. The circularity metric is a measure of resource cycle efficiency and can as such be a first approximation together with a basic toxicity (legislation), recyclability and raw material scarcity check with for example indexes from EPS 2015d or a useful complement to a full Life Cycle Assessment (LCA). But circularity is not enough on its own to fully assess the environmental impacts of a product.

When fully assessing the environmental benefits of a circular business model we recommend a Life Cycle Assessment (LCA) together with assessment of toxicity and design for recycling and if applicable remanufacturing. The level of detail of the LCA determines the cost and precision. If the use phase is the same as for the reference and if the reference and your product have similar design, it is possible to calculate only the environmental impact from the material use, since the difference in environmental impact from transports and manufacturing is small compared to the difference in material use regarding environmental impact. Polluter pays principle, as for example used for calculation of Certified Environmental Declarations (EPD 2017) approach for the LCA study would be acceptable to use.

To assess the environmental impact for specific products with LCA there is also a need to compare with something, One way to normalize the LCA score is to compare with a reference case. When we evaluated the circular products in the project, we chose to compare with a typical similar product with the same function in Sweden where most business models are linear.

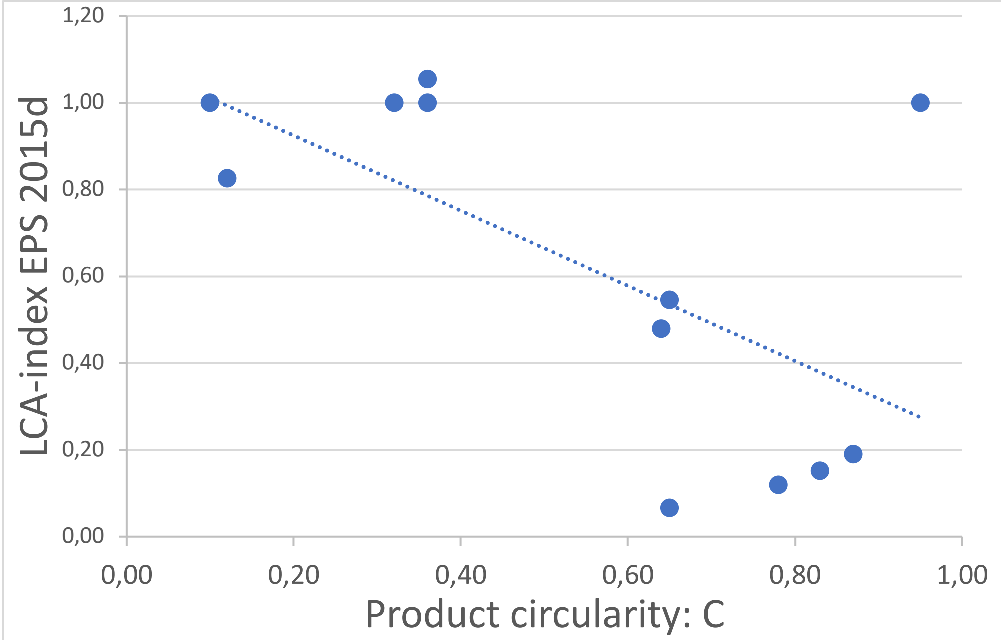


Figure 4 - Scatter plot of relative LCA (weighting by EPS 2015d) and circularity metric for 11 cases. LCA scores are normalized against a typical Swedish reference case specific to each product category.

In our evaluations, we considered the most important impact categories to be climate change and abiotic resource use. To express the total environmental impact in one number, one needs to select a weighting method. We chose EPS, which is a monetary method, calculating environmental damage costs. We recommend the characterization factors calculated by CML (2001) revised 2016 for the impact categories global warming (GWP 100 years) and abiotic resource use (ADP elements). For weighting we chose the monetary method EPS 2015dx – Excl impacts from secondary particles (2015). Thus our assessments do not include some potentially important environmental impact categories, such as the use and emissions of toxic materials.

If the use phase is the same for the product under study and the reference, the recommended equation when transports and manufacturing data are not included is: $1- I_c/I_{ref}$. I_c/I_{ref} scores are plotted in figure 4 above, together with the corresponding circularity scores.

For the twelve cases for which we had complete circularity metric and LCA calculations, the correlation between LCA scores and circularity metric was high. Specifically, Pearson correlations between the Circularity metric and relative LCA scores were for EPS 2015dx: -0.65 (-0.87 when excluding one particular and arguably controversial case). The relation is similar for global warming potential and abiotic resource depletion.

If the use phase differs between your product and your reference you must include the function in your calculations. Also if you want to assess selling a service instead of a product, you must include the life cycle of the service achieved by your product including all refurbishment, repair and remanufacturing that is needed. It may for example be the case that the reference requires 5 new products for the same function as what your product can give including the refurbishment, repair and remanufacturing and therefore all must be included in the scope. It is also important to monitor if the design for recycling is different and if there is a difference in occurrence of toxic substances compared to the reference as additional information.

References

EPD (2017). General program instructions for the international EPD® system. Version 3.0. 2017-12-11

CML (2001, updated 2016). https://www.universiteitleiden.nl/en/research/research-output/science/cml-ia-characterisation-factors Retrieved from the internet 2018-05-25.

EPS 2015d – Excl impacts from secondary particles (2015). https://www.ivl.se/english/startpage/pages/focus-areas/environmental-engineering-and-sustainable-production/lca/eps.html Retrieved from the internet 2018-05-25.

Data for LCA calculations are found in commercial LCA programs such as GaBi or SimaPro. OpenLCA is a freeware which can be used as an alternative.

FURTHER INFORMATION

This guide outlines the context and the practical application for Circular Metric. For any **further information** please, contact

Emanuela Vanacore – Email: emanuela.vanacore@ri.se, Mobile: +46 (0)72-210 78 00

Marcus Linder – Email: marcus.linder@ri.se, Mobile: +46 (0)70 874 51 85

Hanna Ljungkvist – Email: hanna.ljungkvist@ivl.se, Mobile: +46 (0)10 788 68 99

Lisbeth Dallhöf – Email: lisbeth.dahllof@ivl.se, Mobile: +46 (0)10 788 6853

For a more **formal description of the metric** and underlying theory and assumptions, please see Linder M, Sarasini S and van Loon P, 2017, A metric for quantifying product-level circularity, Journal of Industrial Ecology, Early view, DOI: 10.1111/jiec.12552.