

Measuring Circularity

The Gordian Knot of the 21st century

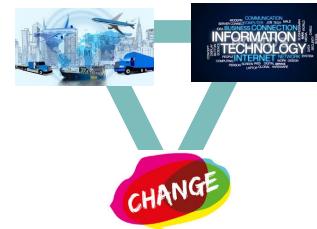
Arjen Wierikx

Vervoerslogistieke Werkdagen

November 16, 2023

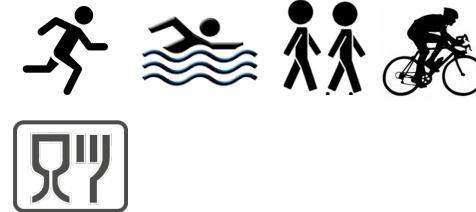
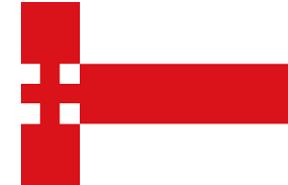
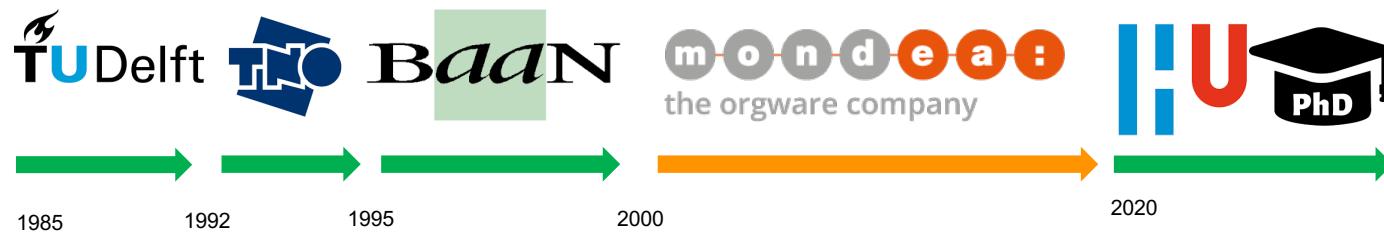


Passion For Logistics Allergic To Waste



SMART CIRCULAR
PASSION FOR LOGISTICS, ALLERGY TO WASTE

www.slimcircular.info



TU/e

Agenda

- ❖ Introductie
- ❖ Circulariteit meetbaar maken
- ❖ Model ontwikkeling
- ❖ Volwassenheid van circulaire prestaties
- ❖ Onderzoeksagenda

Circulair denken in de logistiek....

Logistiek is de motor van de circulaire economie

Logistiek en Circulariteit zijn welhaast synoniem

Logistiek

Jomini (1830), Christopher (1992) of Topsector Logistiek (2011)

- **Jomini (1830, p. 74)** ... de **kunst** om de marsen van een leger te ordenen, om de volgorde van de troepen in de kolommen, de tijd van hun vertrek, hun route, de communicatiemiddelen die nodig zijn om hun aankomst op genoemd punt te verzekeren ..
- **Christopher (2011):** Logistiek is het proces van strategisch beheer van de inkoop, verplaatsing en opslag van materialen, onderdelen en afgewerkte voorraad (en de gerelateerde informatiestromen) door middel van de organisatie en haar marketingkanalen zodanig dat de huidige en toekomstige winstgevendheid wordt gemaximaliseerd door de kosteneffectieve uitvoering van bestellingen.
- **Topsector Logistiek (2009):** De **kunst** van het slim organiseren

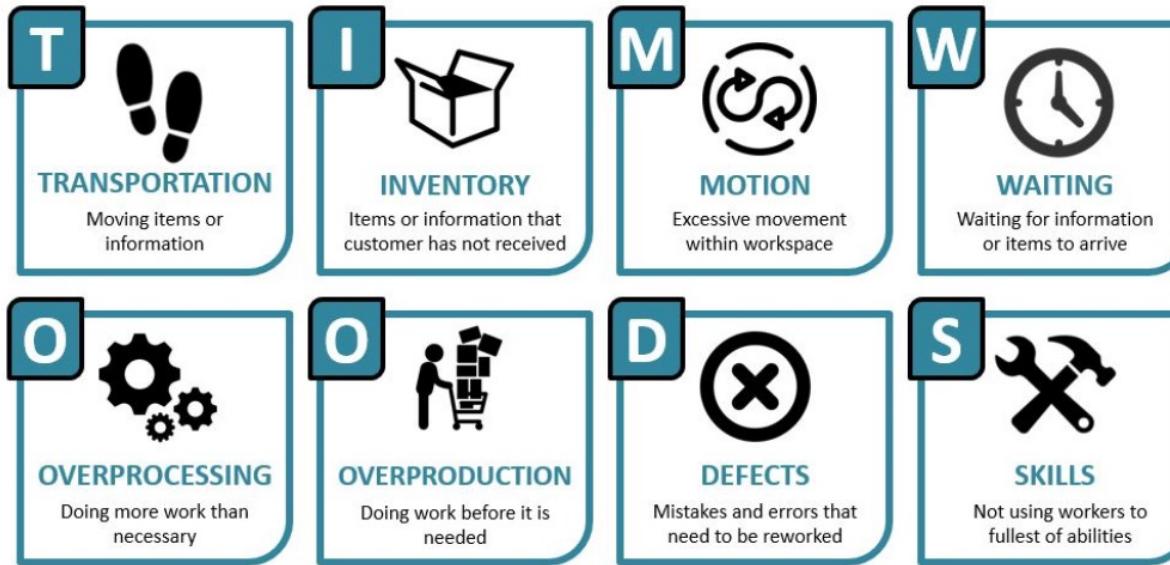
non à forces égales ou inférieures. 7) On voit donc que toutes les combinaisons d'une bataille consistent à employer ses forces de manière à ce qu'elles obtiennent le plus d'action possible sur celui des trois points qui offre davantage de chances , point qu'il sera facile de déterminer en le soumettant à l'analyse que nous venons d'exposer.

Art. 7. Des marches d'armées considérées comme manœuvres.

La **logistique** *) est l'art de bien ordonner les marches d'une armée , de bien combiner l'ordre des troupes dans les colonnes , le tems de leur départ , leur itinéraire , les moyens de communications nécessaires pour assurer leur arrivée à point nommé; c'est le fond des devoirs d'un officier d'état-major. Mais , outre ces détails tout matériels , il existe une espèce de

*) Autrefois les officiers de l'état-major se nom- 5

En als we de kunst van het slim organiseren verstaan...



Is er geen verspilling...

Is er geen sprake van waardelekken...



KennisDC Logistiek

En als er geen verspilling is..., we kunnen alles weer kunnen hergebruiken

Renewal
resource

Linear economy
Natural resources

Circular economy
Natural resources

En is logistiek daarmee dan
niet bij uitstek de motor van
de circulaire economie?

Landfill
and incinerate

Landfill
and incinerate

Transition towards a circular economy

Source: PBL 2016

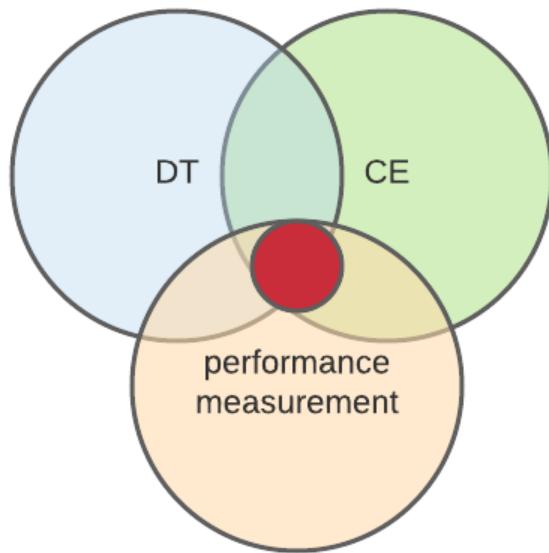
www.pbl.nl

jn we dan
et elkaar
et geweldig
circulair
bezig.



KennisDC Logistiek

Mijn promotieonderzoek



How can organizations use Digital Technology strategies to increase Circular Economy performance?

Broken down into:

1. How do we measure CE performance on a micro level?
2. How to determine DT strategies?
3. Impact of DT strategies on CE performance



Measuring circularity

SER: Make Raw Materials transition a priority



September 16, 2022:

SER (social economic board) exploration: Climate targets will not be achieved without accelerating the raw materials transition

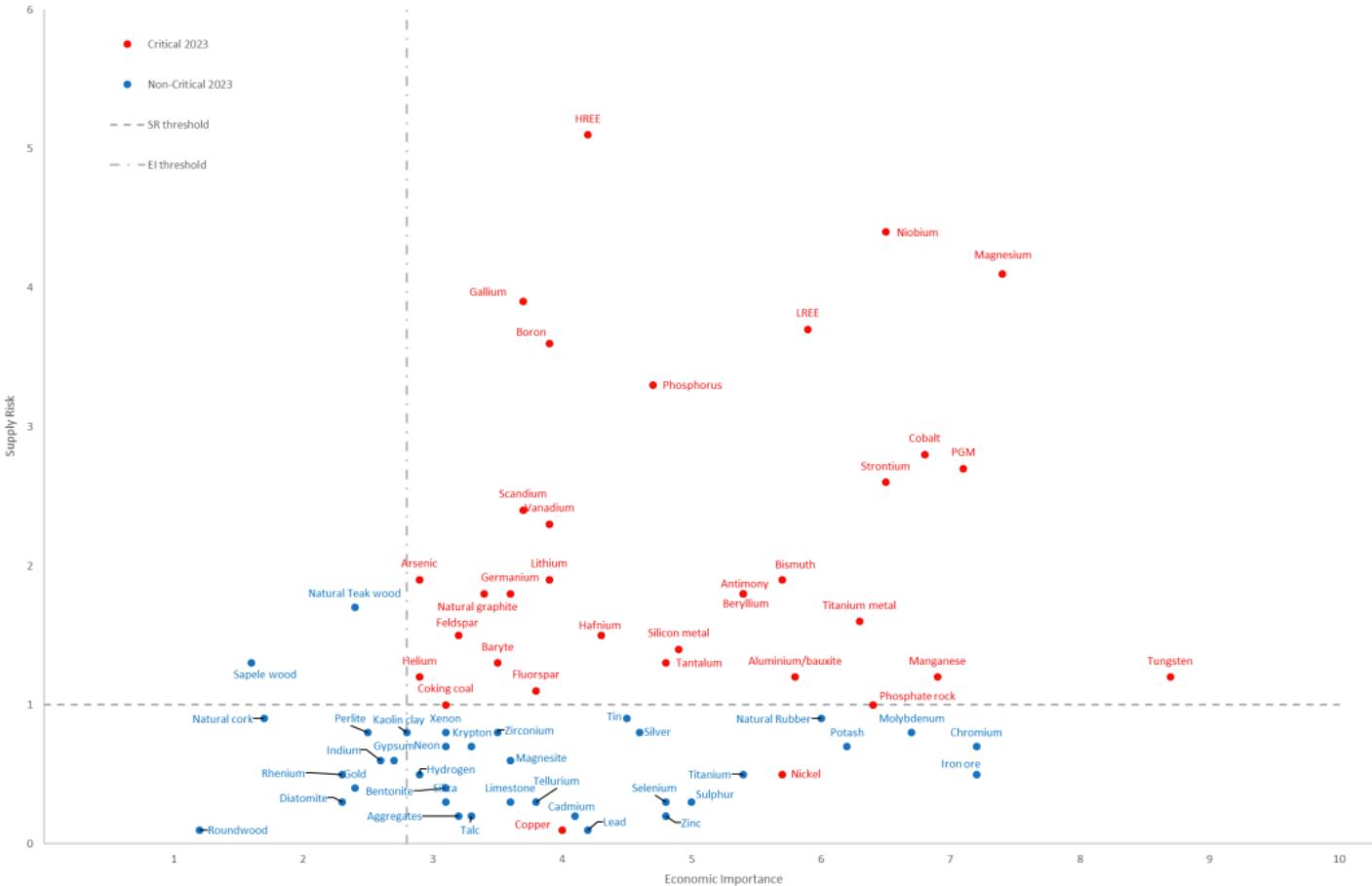
"High-quality reuse of raw materials and materials, high-quality use of bio-based raw materials and making international chains more sustainable are necessary conditions for both transitions. Cohesive policy is therefore crucial."

Ed Nijpels, chairman SER-commission Sustainable Development

- ❖ Energy transition and Raw materials transition are at odds;
- ❖ With CO₂ we can make the energy transition measurable. What about the raw materials transition / circularity?

The 5th List of Critical Raw Materials

From 14 in 2011 to 30 in 2020 and 34 in 2023



Materials

Supply Risk

(sorted largest to smallest)

Very high	LREEs HREEs
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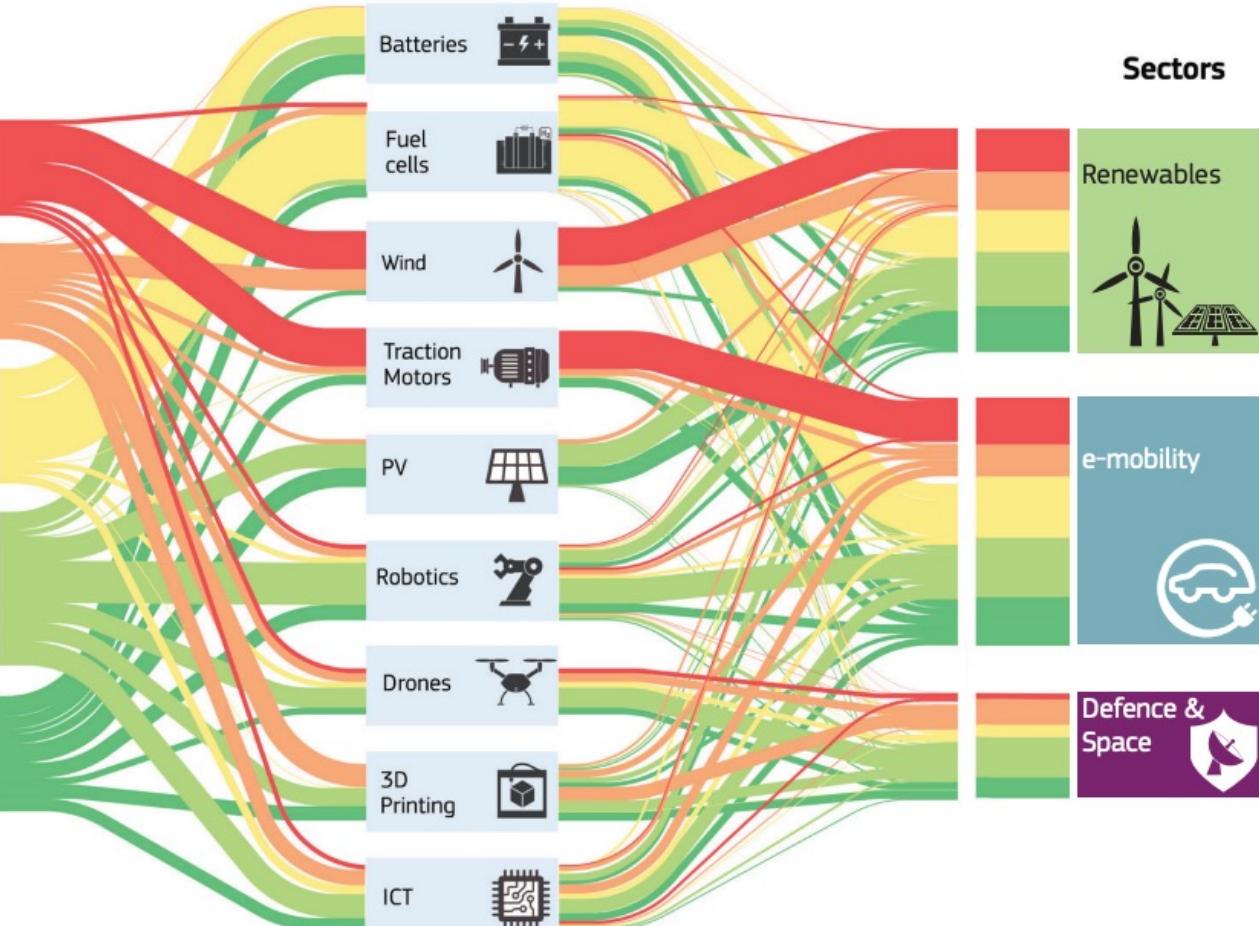
High	Magnesium Niobium Germanium Borates Scandium
------	--

Moderate	Strontium Cobalt PGMs Natural graphite
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Low	Indium Vanadium Lithium Tungsten Titanium Gallium, Hafnium Silicon metal
-----	--

Very low	Manganese Chromium Zirconium Tellurium Nickel, Copper
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Technologies



Where we are?



Governments worldwide are announcing that they want to be 100% circular by 2050 (EC, 2011).

Euhh, that is 27 (!!?) years from now.

To get an idea

source: Circularity Gap Report Initiative (<https://www.circularity-gap.world/>)

- World ▪ 7,2%
- EU ▪ 12%
- Denmark ▪ 4%
- Italy ▪ 18.4%
- Netherlands ▪ 24,5%
- Poland ▪ 10,2%
- Switzerland ▪ 6,9%
- UK ▪ 7,5%



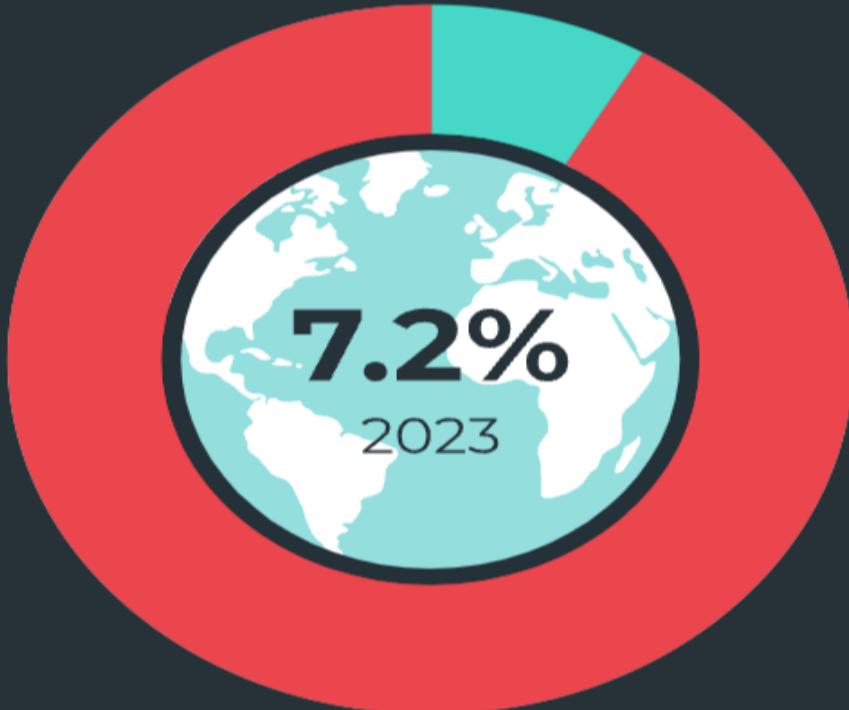
The Naked Truth.....

THE GLOBAL ECONOMY IS NOW ONLY 7.2% CIRCULAR

The global situation is getting worse year on year—driven by rising material extraction and use.

Rising material extraction has shrunk global circularity: from 9.1% in 2018, to 8.6% 2020, and now 7.2% in 2023. This leaves a huge Circular Economy Gap: the globe almost exclusively relies on new (virgin) materials.

This means that more than 90% of materials are either wasted, lost or remain unavailable for reuse for years as they are locked into long-lasting stock such as buildings and machinery.



Materials that are cycled back into the global economy after the end of their useful life, otherwise known as secondary materials, account for 7.2% of all material inputs into the economy—this is the Circular Economy Metric.

How do we measure circularity? ➔

How circular are you / is your organization?

- 0-5%
- 5-10%
- 10-15%
- 15-25%
- 25-50%
- 25-75%
- 75-100%





> 115 definitions
(Kirchher et al., 2017)

Een circulaire economie is een economie die herstellend en regeneratief is van opzet en tot doel heeft producten, componenten en materialen te allen tijde op hun hoogste nut en waarde te houden, waarbij onderscheid wordt gemaakt tussen technische en biologische cycli (EMF, 2013)

MINIMISE SYSTEMATIC
LEAKAGE AND NEGATIVE
EXTERNALITIES



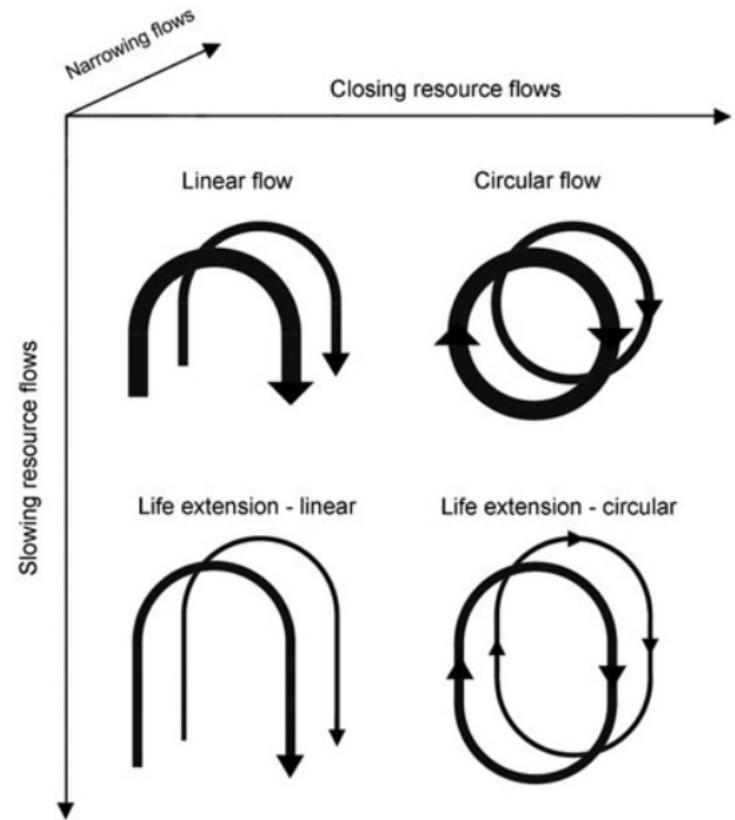
Strategies

R-strategies / narrowing, slowing, closing

o.a. Potting et al. (2017) and Bocken et al. (2016)



Strategies	
Smarter product use and manufacture	
R0 Refuse	Make product redundant by abandoning its function or by offering the same function with a radically different product
R1 Rethink	Make product use more intensive (e.g. by sharing product)
R2 Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials
Extend lifespan of product and its parts	
R3 Reuse	Reuse by another consumer of discarded product which is still in good condition and fulfils its original function
R4 Repair	Repair and maintenance of defective product so it can be used with its original function
R5 Refurbish	Restore an old product and bring it up to date
R6 Remanufacture	Use parts of discarded product in a new product with the same function
R7 Repurpose	Use discarded product or its parts in a new product with a different function
Useful application of materials	
R8 Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality
R9 Recover	Incineration of material with energy recovery

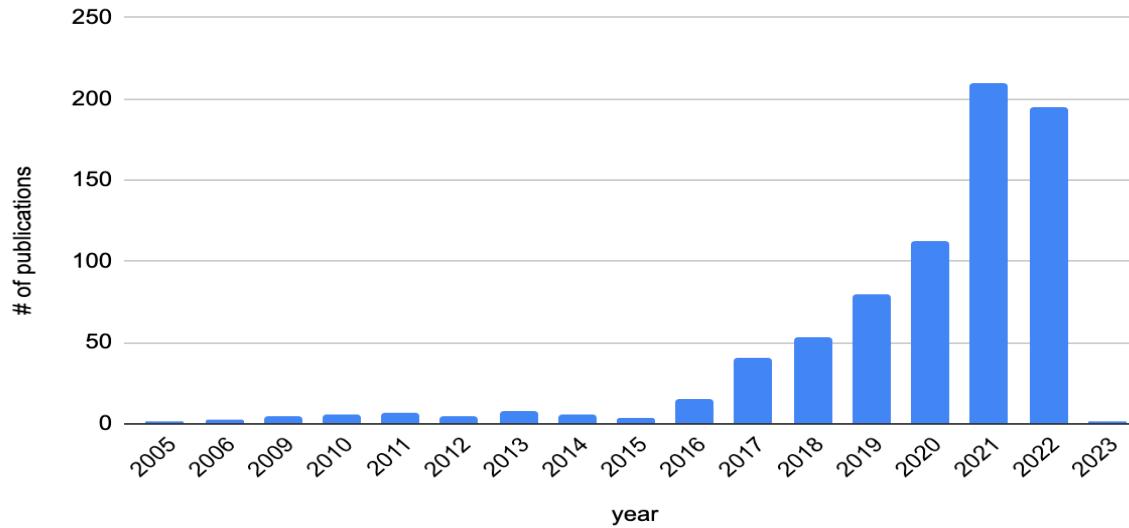


Publication explosion..

751 and counting

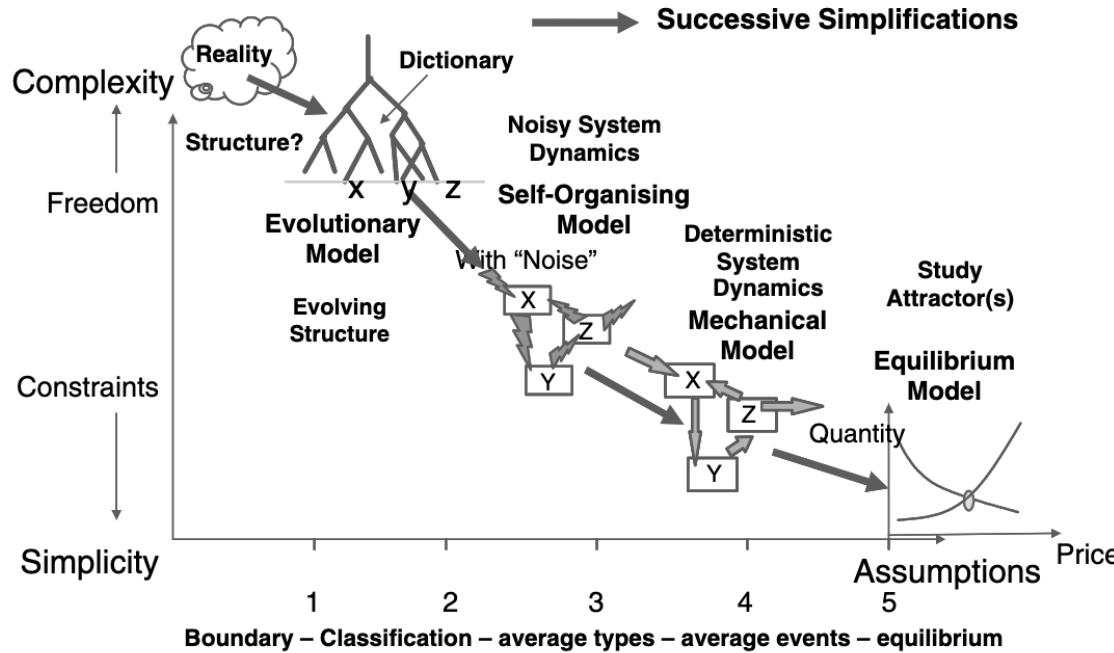


Publications on CE & Performance



Source: constructed by authors (Dec. 2022)

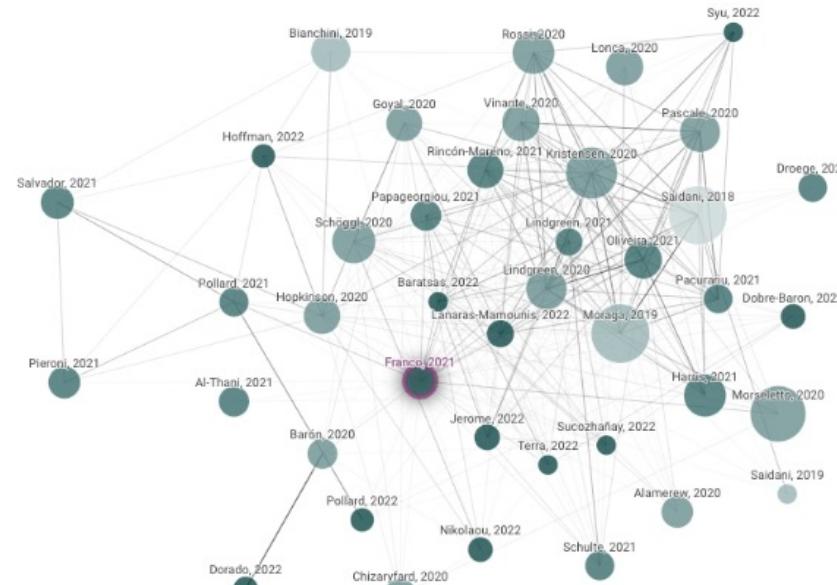
A co-evolutionary perspective on the Circular Economy



Source: Allen, P. M., & Varga, L. (2006)

Findings

Wierikx et al., 2022

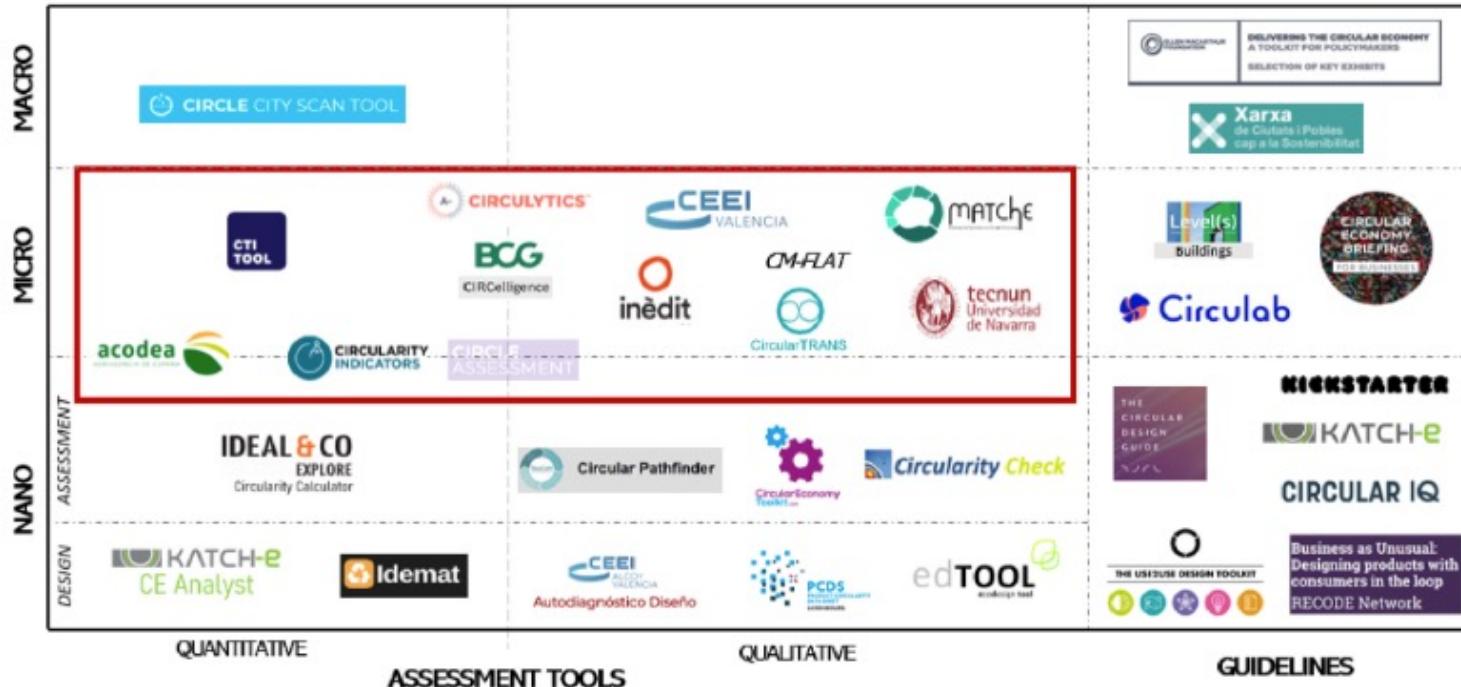


Reference	Approaches	Characteristic
(Valls-Val et al., 2022)	12	Tools capable of measuring the level of circularity of organisations.
(Vinante et al., 2021)		Focus on 365 different firm level metrics, classified in 23 categories.
(Kravchenko et al., 2020)		Review and ex-ante classification of sustainability performance indicators for proactive CE-strategies assessment
(Kristensen & Mosgaard, 2020)	30	Focus on micro level, zooming in on 'CE categories' and connection to Sustainable Development (SD) dimensions. Less attention for implementation perspective. Also includes grey literature.
(Lindgreen et al., 2020)	74	Newly constructed review framework, applying four review perspectives: A general, descriptive (methodological), normative (inclusion of SD/CE dimensions), and prescriptive (implementation-focused) perspective.
(Corona et al., 2019)	72	Zooms in on 'validity', 'reliability', and 'utility' of metrics, and connection to existing methodologies (Life Cycle Assessment (LCA)/Material Flow Analysis (MFA)), no focus on micro level.
(Moraga et al., 2019)	20	Introduces classification framework for CE indicators, both on macro- as well as micro level. Addresses different CE strategies captured by indicators.
(Parchomenko et al., 2019)	63	Applies Multiple Correspondence Analysis (MCA) to assess metrics. No distinction between different levels of assessment.
(Michael Saidani et al., 2019)	55	Proposes intricate taxonomy of indicators, applying 10 differentiation categories.
(Sassanelli et al., 2019)	45	Collects and reviews CE-performance assessment methods. Primary focus on methodological foundation. No specification of level of assessment.
(Elia et al., 2017)		Review, analyses, and comparison on how environmental assessment methodologies based on quantitative indicators are effective in measuring CE-strategies' level of application in companies, products and services.

- 11 meta studies
- Reference set of 731 papers

- 125(!) models to make CE measurable
- 365 (!) micro level parameters

Snapshot (semi) commercially available tools



Existing tools for the assessment of the circular economy (Valls-Val et al., 2022)

Interviews confirm the picture

- ❖ “We use CO2 because other units of measurement are not clear”;
- ❖ “Circular turnover is reported annually, based on four indicators that we measure company-wide”;
- ❖ “I have no idea how to measure, I had hoped that you would come and tell me”;
- ❖ “We really want to measure circular performance, but we feel enormously hampered by regulations, laws and OEMs”;
- ❖ “If my customers want this, I will pay attention to it”;
- ❖ “For a small part of the business, we use a simplified version of the CTI Tool”;
- ❖ “We separate waste”....

The Gordian knot

- ❖ Scientific transparency is lacking (Valls-Val et al., 2022) ;
- ❖ Varying substantiation (Sacco et al., 2021);
- ❖ Focus on in-& outflow / LCA & MFA;
- ❖ Inconsistent in purpose, scope and application (Saidani et al., 2019);
- ❖ Lack of standardization (Vinante et al., 2020; Kristensen et al., 2020);
- ❖ Terminology not formalized (Baratsas et al., 2022);
- ❖ Confusion and ambiguity (Vinante et al., 2020; Fiksel et al., 2012)

Hypothesis

There is not yet a really good tool for making circular performance holistically measurable



Tool development

Complexity science, design science, maturity thinking

The challenge

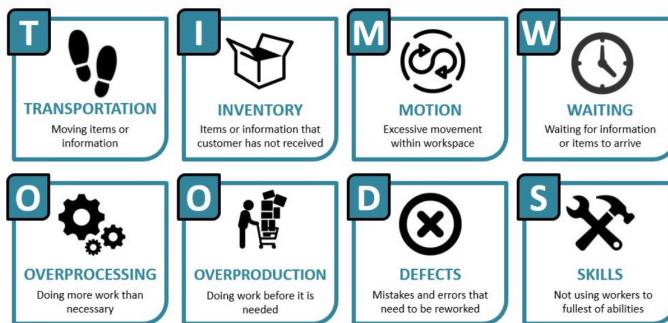
holistic, dynamic, accessible and longitudinal

- **Systemic / Holistic:** Circular performance is more than just a focus on material flows.
- **Dynamic:** Domain is in constant motion, capabilities can (will) change over time;
- **Accessible:** Attractive. Feeling invited to participate to increase response;
- **Longitudinal:** Being able to make visible what to do to develop to the next level based on a benchmark.

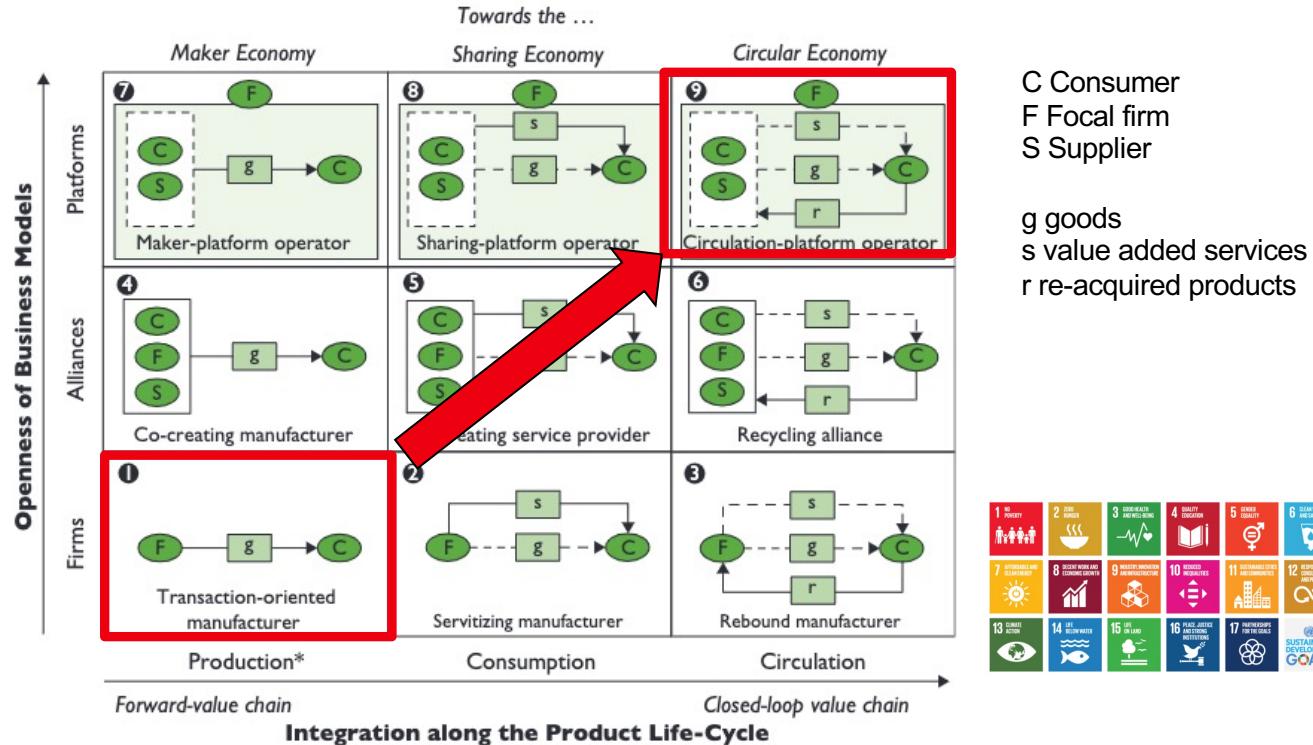
Inspiration: CMM & Prosci

Systemic ambitions

based on R-ladder, Porter & Lean



New initiatives... Eliminating leaks.. Thinking differently...

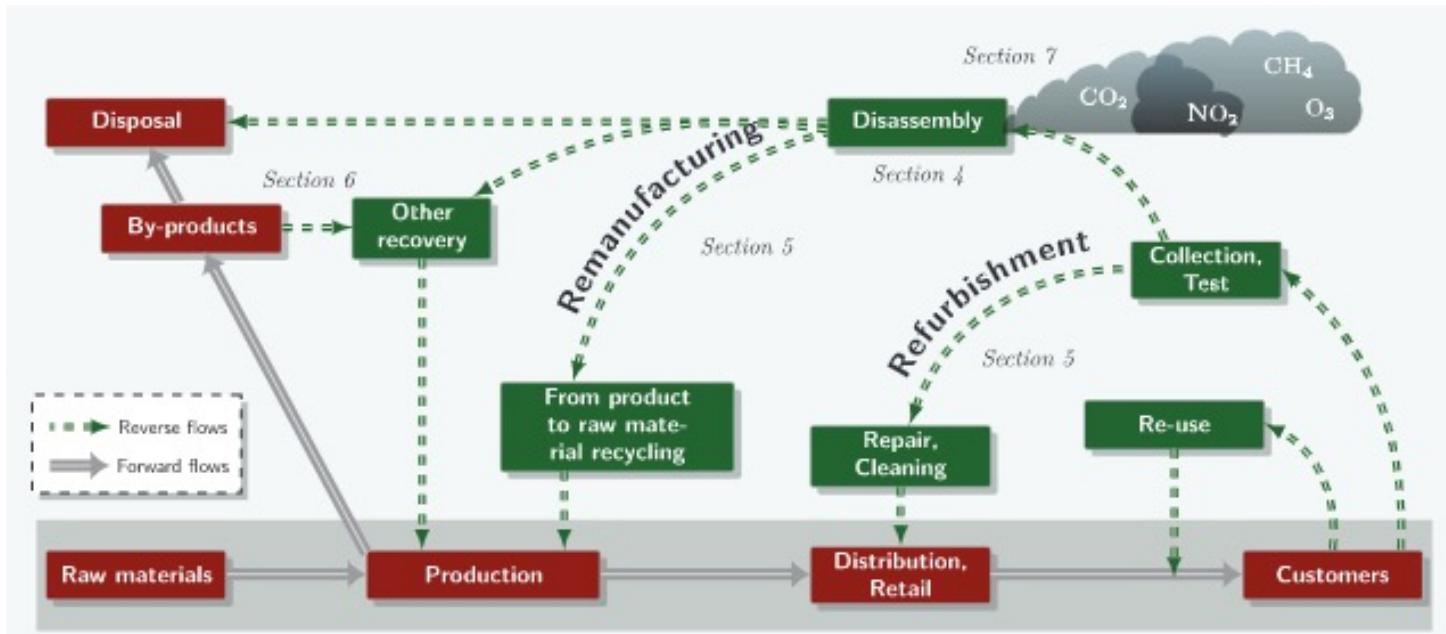


Anton Pieck



Schoenmaker blijf bij uw leest!

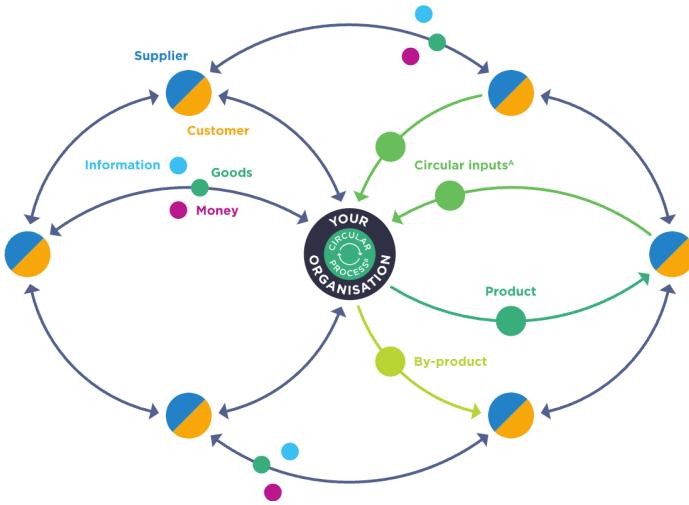
New entities in new networks



Source: Suzanne et al. (2020)

Stelling

Een closed loop supply chain bestaat niet, en als ie al zou bestaan, zou het niet je ambitie moeten zijn, met uitzondering van één...



What are circular supply chains?

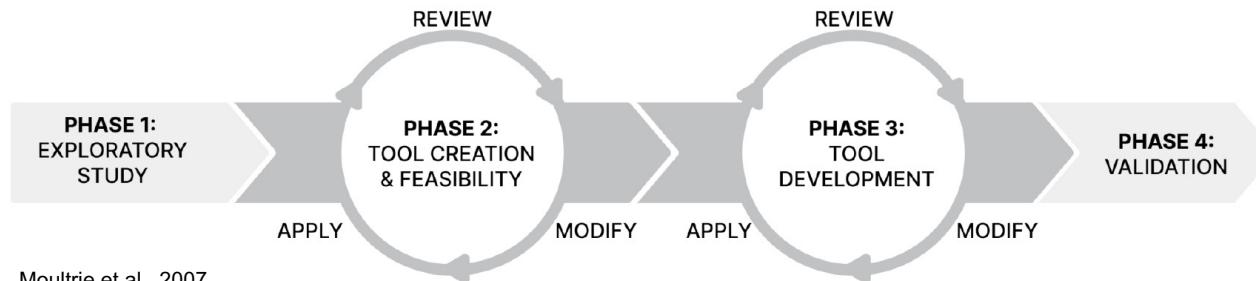
Circular supply chains require three things:

- Distributed and interconnected networks to leverage local and global partnerships with suppliers, customers, and industry peers
- Multidirectional flows of information, goods, and money to enable data — such as the location, material composition, and disassembly options of an item — to flow between network partners
- The ability to capture and deliver value by keeping products and materials in use

Model creation methodology

following Moultrie et al. (2007)

DSR as underlying perspective (Cross, 2001; Hevner et al., 2004)



Moultrie et al., 2007

- Balancing rigor & relevance
- Iterative
- Start gathering data

Exploratory study

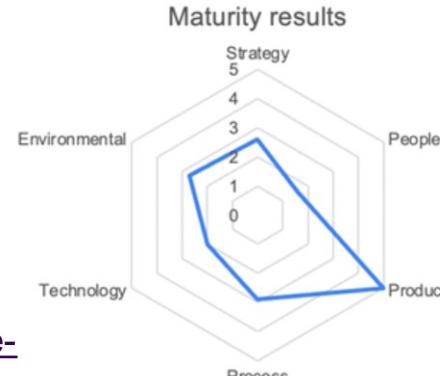
Minor project: Astrid van den Berg, Brent Rietveld, Jop de Winter



Likert, 1932

None	There is no circular awareness, elements of circular economy in strategies or related activities in the organization.
Basis	The organization appears to have a need for CE, and there are discussions about how and where to act.
Exploratory	Demonstration projects and pilots are being started within the various functions in the organization. This allows the value of a CE to be proven and organizational capabilities to be tested.
Systematic	Means for pursuing a CE are implemented throughout the organization. Successful pilots are also being carried out, after which scaling up is started.
Integration	Circular initiatives and ambitions are aligned throughout the organization and critical supply chain.
Regenerative	The organization is really engaged in CE and is regenerative and restorative by design.

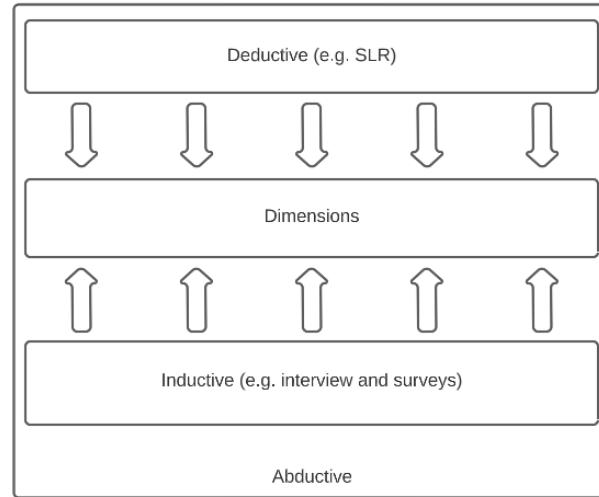
Uhrenholt et al., 2022



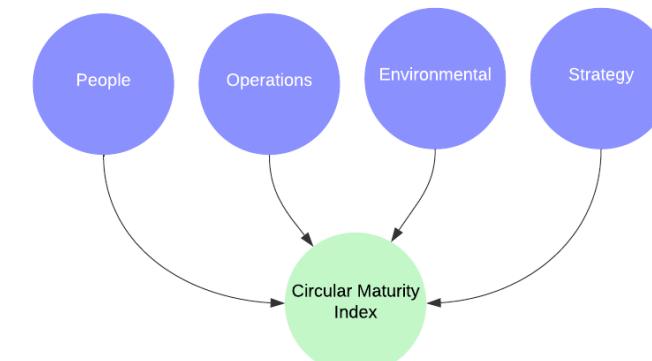
https://www.slimcirculair.info/1170474_prototype-circular-performance-maturity-model

Deriving dimensions

abductive research approach (Williams et al., 2019)



26 different studies



59 dimensions

25 company interviews





Lead to the creation of ten themes



1 Producten en diensten



In hoeverre er circulaire producten en/of diensten aangeboden worden.



2 Leiderschap en cultuur



In hoeverre circulariteit wordt uitgedragen en verworven in de bedrijfscultuur.



3 Vaardigheden



In hoeverre werknemers beschikken over circulaire vaardigheden en ze in staat zijn om kennis hierover op te doen.



4 Communicatie



In hoeverre er intern en extern gecommuniceerd wordt over circulaire onderwerpen.



5 Strategie



In hoeverre er een circulaire bedrijfsstrategie gehanteerd wordt.



6 Financiering



In hoeverre er gebruik gemaakt wordt van circulaire verdienmodellen.



7 Ketensamenwerking



In hoeverre er wordt gestreefd naar een circulaire samenwerking in product- of materiaalketens.



8 Innovatie en technologie



In hoeverre er gebruik gemaakt wordt van circulaire innovaties en technologie.



9 Interne bedrijfsvoering



In hoeverre er gestuurd wordt op hergebruik, recycling en energiebesparing bij interne bedrijfsvoering.



10 Milieu



In hoeverre de klimaatimpact zoals energieverbruik geminimaliseerd of verduurzaamd wordt.

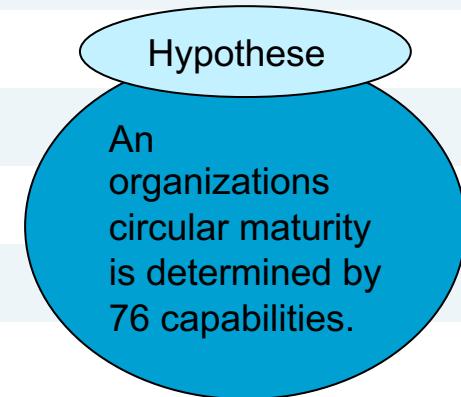


Item generation

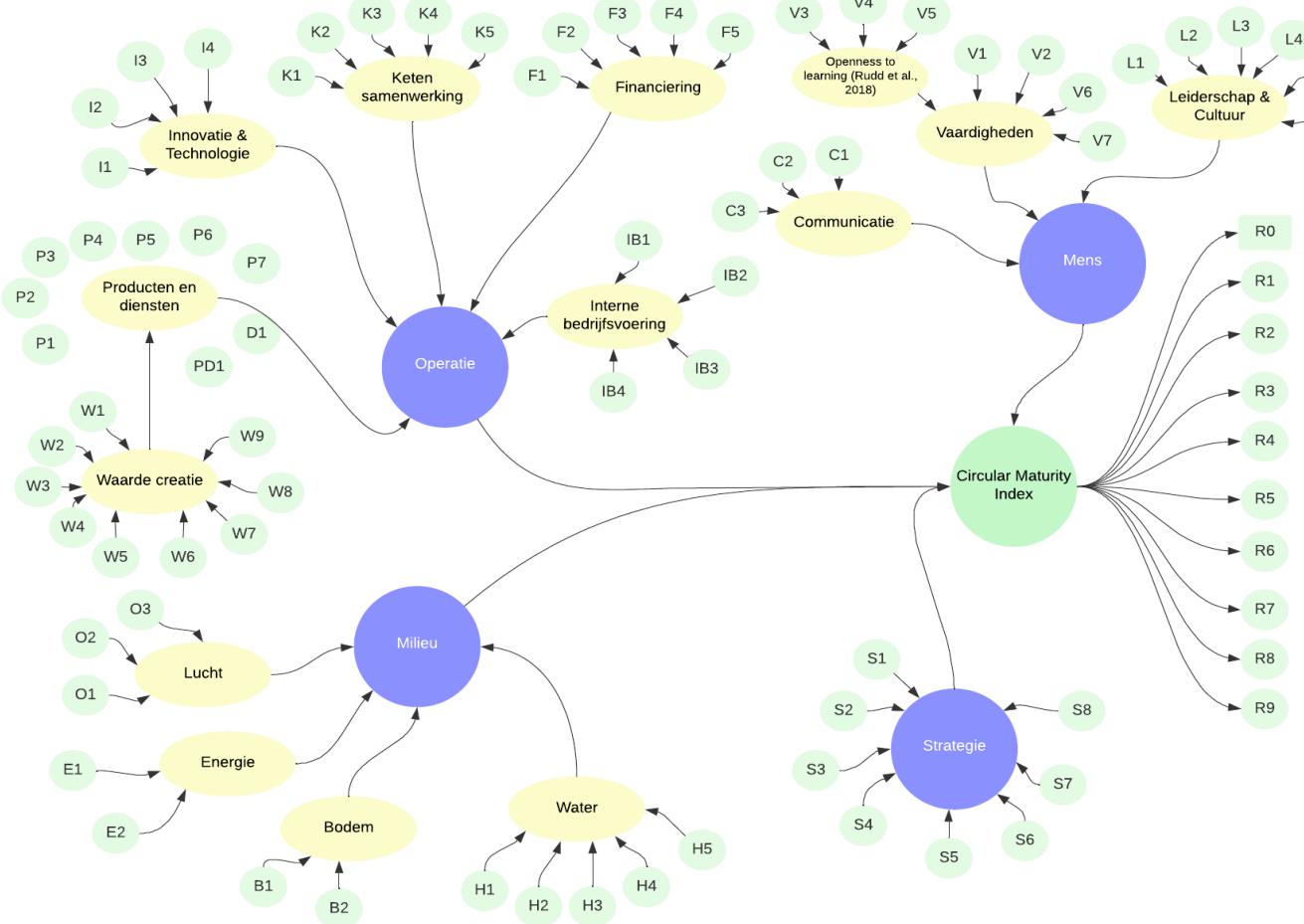
- ❑ Generate multiple items for each dimension to ensure reliability (Allen & Yen, 1979; Lee et al., 2015; Moore & Benbasat, 1991) and internal consistency (Nunnally, 1978);
- ❑ Whenever appropriate, items from existing scales which had been empirically tested were considered and adapted for the newly developed measure (Chang, 2001).
- ❑ The process established a pool of 107 items, which were subsequently refined and arranged in a sequence suitable for the purpose of content validation and to eliminate redundant or ambiguous items.
- ❑ Content validation with 3-panels leads to 76 items and 10 outcome variables

Capabilities (itempool)

Dimension	Subdimension	Capabilities
People	Communication	4
	Skills	7
	Leadership & Culture	6
Operations	Products & Services	16
	Innovation & Technology	7
	Value Chain Collaboration	5
	Financing	4
Strategy	Internal Business Operations	7
		8
Environmental		12



Conceptual model





Instrument creation & pilot application

Instrument creation

- Intuitive
- Time to complete
- Easy to use
- Language
- Typeform
- Klinkende Taal
- Do's & Don'ts'
- Example <-> Objectivity
-



Data Collection



Home Actueel ▾ Onderwerpen ▾ Politiek & Bestuur ▾ Organisatie ▾ Loket ▾

[Home](#) > [Actueel](#) > [Nieuwsoverzicht](#) > Circulaire volwassenheidsmeting – hoe staan bedrijve...

Circulaire volwassenheidsmeting – hoe staan bedrijven in de regio ervoor?

- ❑ Data collected from first half of 2023
- ❑ E-mail to 2.500 companies (selected by Province of Utrecht)
- ❑ Survey invitation distributed via LinkedIn and other social media
- ❑ Light cases / interviews with 6 organizations.

The Result platform



Producten en diensten

Niveau 5



0

1

2

3

4

5

Do's

Maak het gebruik van de 'R-ladder' strategieën standaard binnen je bedrijf door bijvoorbeeld 'rethink' of 'refuse' als kernstrategie te gebruiken waarbij een fysiek product vervangen kan worden door software oplossingen.

Maak bij het herontwerpen gebruik van workshops over circulair design. Voorbeelden van dit soort workshops zijn te vinden bij de Ellen MacArthur Foundation met onder andere een [Circulaire Strategie Workshop](#) en een [Product Herontwerp Workshop](#).

Implementeer duurzame productieprocessen met een focus op circulaire economie, zoals cradle-to-cradle en biomimicry. Kijk bijvoorbeeld eens bij [biomimicrynl](#) voor inspiratie.

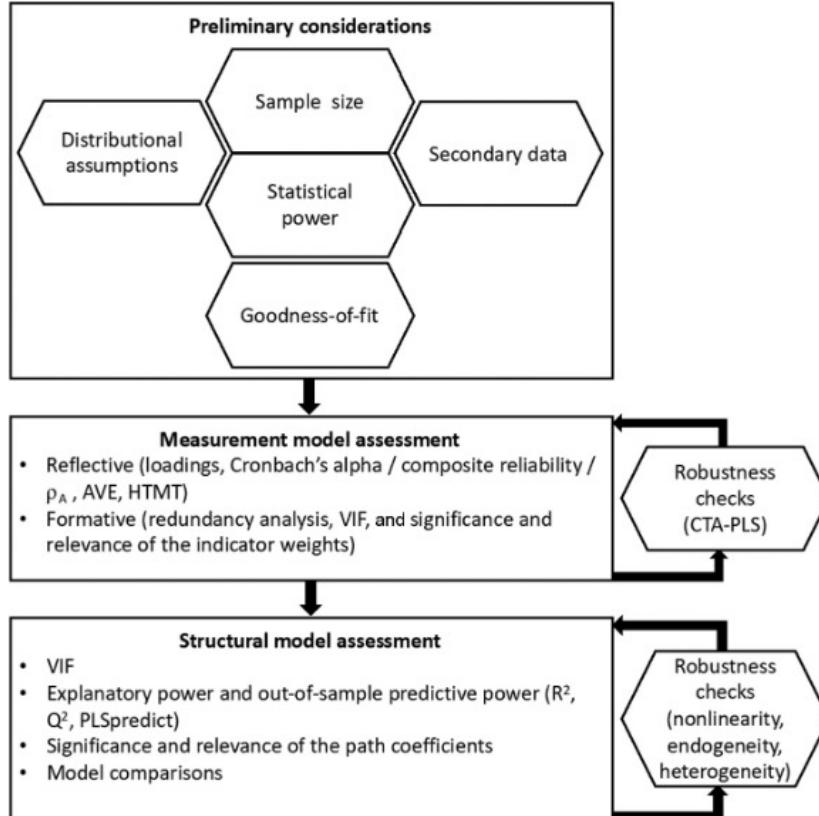
Don'ts

Vermijd het gebruik van recyclebare materialen in productontwerp, zoals enkelvoudig plastic of materialen die niet kunnen worden gerecycled.

Vermijd producten met een korte levensduur en stimuleer klanten om duurzame keuzes te maken, zoals het hergebruiken of recyclen van producten na gebruik.

Raak niet overweldigd, en heb niet het gevoel dat je per direct je gehele business strategie moet gooien. Je kunt klein beginnen, lees bijvoorbeeld eerst eens de hoofdstukken Circulaire Verdienmodellen en Financiering uit de "Reisgids naar een circulaire bedrijfsvoering". Gratis te downloaden via [Route Circulair](#).

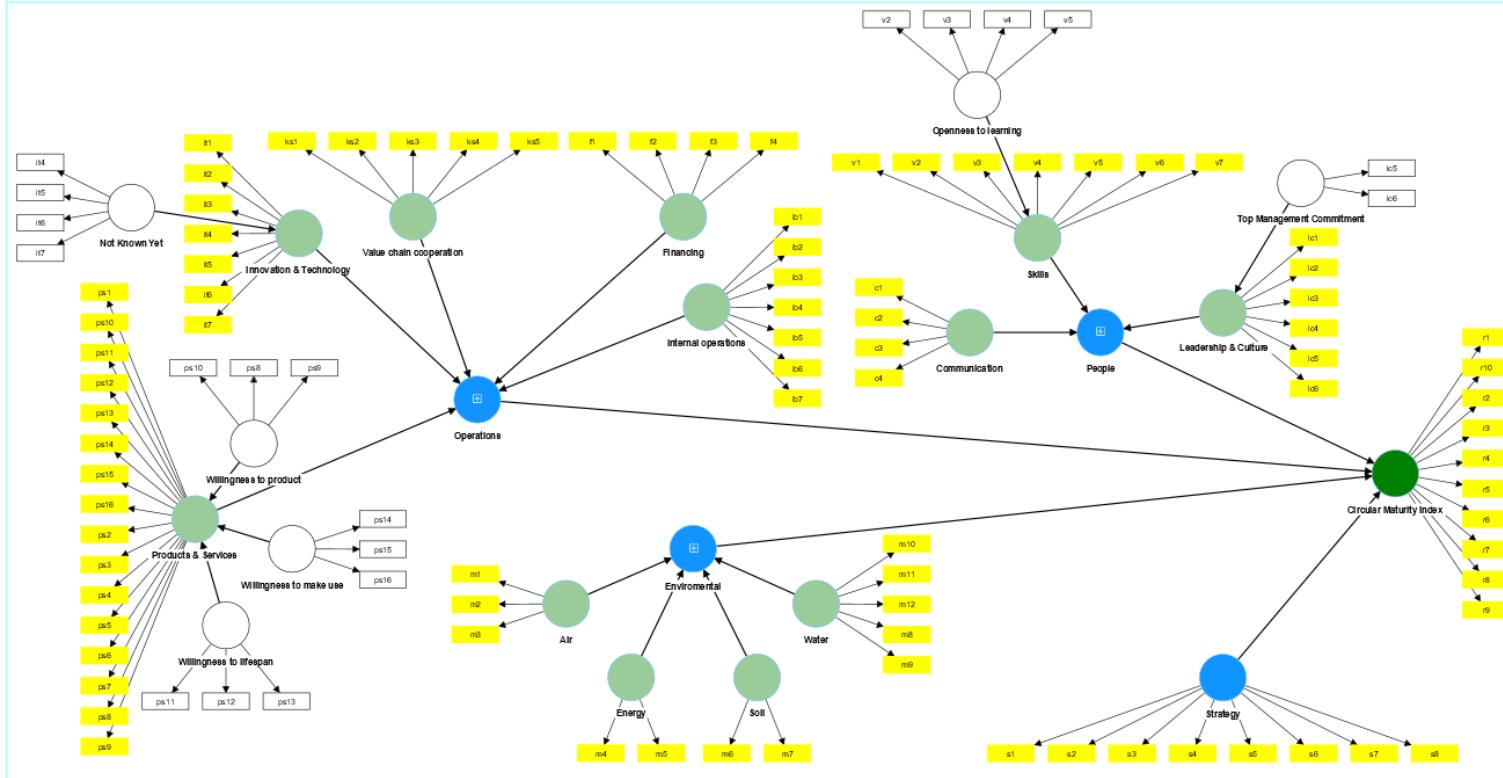
Advanced analytics using PLS-SEM



- To what extent are the items in the circular maturity model suitable for measuring the underlying latent variables?
- Construct comparisons

HTMT: heterotrait-monotrait ratio
 AVE: average variance extracted
 VIF: Variance Inflation Factor
 PLS: Partial Least Square
 SEM: Structural Equational Modeling
 CTA: Confirmatory Tetrad Analysis
 R^2 : coefficient of determination
 Q^2 : cross-validated redundancy measure

SmartPLS reflective model



Improving model performance

- ❑ To improve model performance, bad performing items are removed based on:
 - ❑ Outer loading must be $> 0,708$
 - ❑ Items part of earlier validation remain
- ❑ 27 items are removed
- ❑ Additional check using a control sample (70% of data + additional data from new city).
- ❑ All criteria are met when 24 items are removed.

Hypothesis

Examining circular performance from a systemic perspective, focusing on maturity, not only yields a thorough understanding of the present situation but also offers guidance on the trajectory for future growth.

Research agenda



Expliciete rol van logistiek in het circulaire bedrijfsmodel



Tuinstra et al., 2020

1.

Logistiek als **motor / enabler** om tot circulaire waardeketens te komen

2.

Logistiek als **functie / activiteit** binnen een onderneming circulair maken

Questions?



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