RESEARCH GROUP
PROCESS INNOVATION & INFORMATION SYSTEMS

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Measuring Circularity

The Gordian Knot of the 21st century

Arjen Wierikx

June 22, 2023

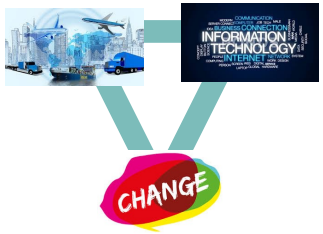
Route Circulair

SMART CIRCULAR
PASSION FOR LOGISTICS, ALLERGY TO WASTE

Agenda

- Introductie
- De circulaire uitdaging
- State of art
- Model ontwerp
- Regio Utrecht onderzoek
- Volgende stappen

Passion For Logistics
Allergic To Waste



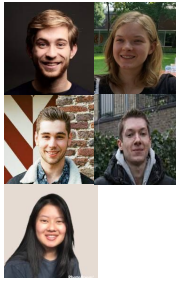
SMART CIRCULAR

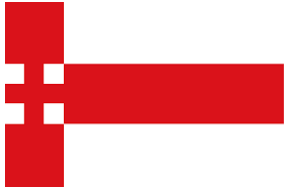
PASSION FOR LOGISTICS, ALLERGY TO WASTE

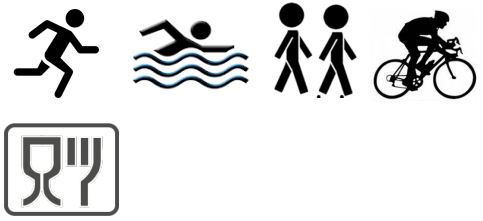
www.slimcirculair.info

TU Delft TNO BaaN mondeal the orgware company TU PhD

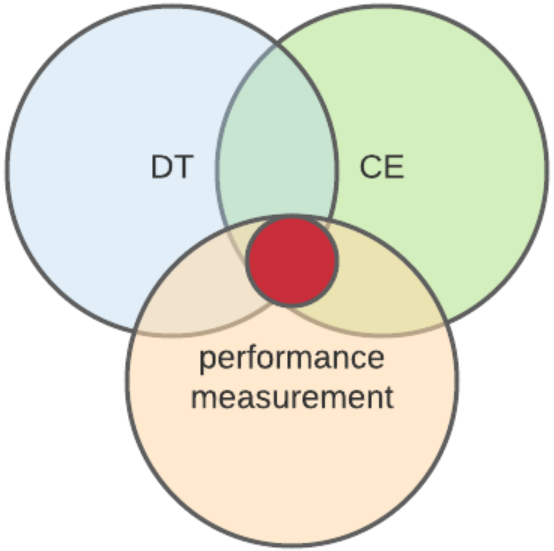
1985 1992 1995 2000 2020







Research question



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

SER: Make Raw Materials transition a priority

September 16, 2022:

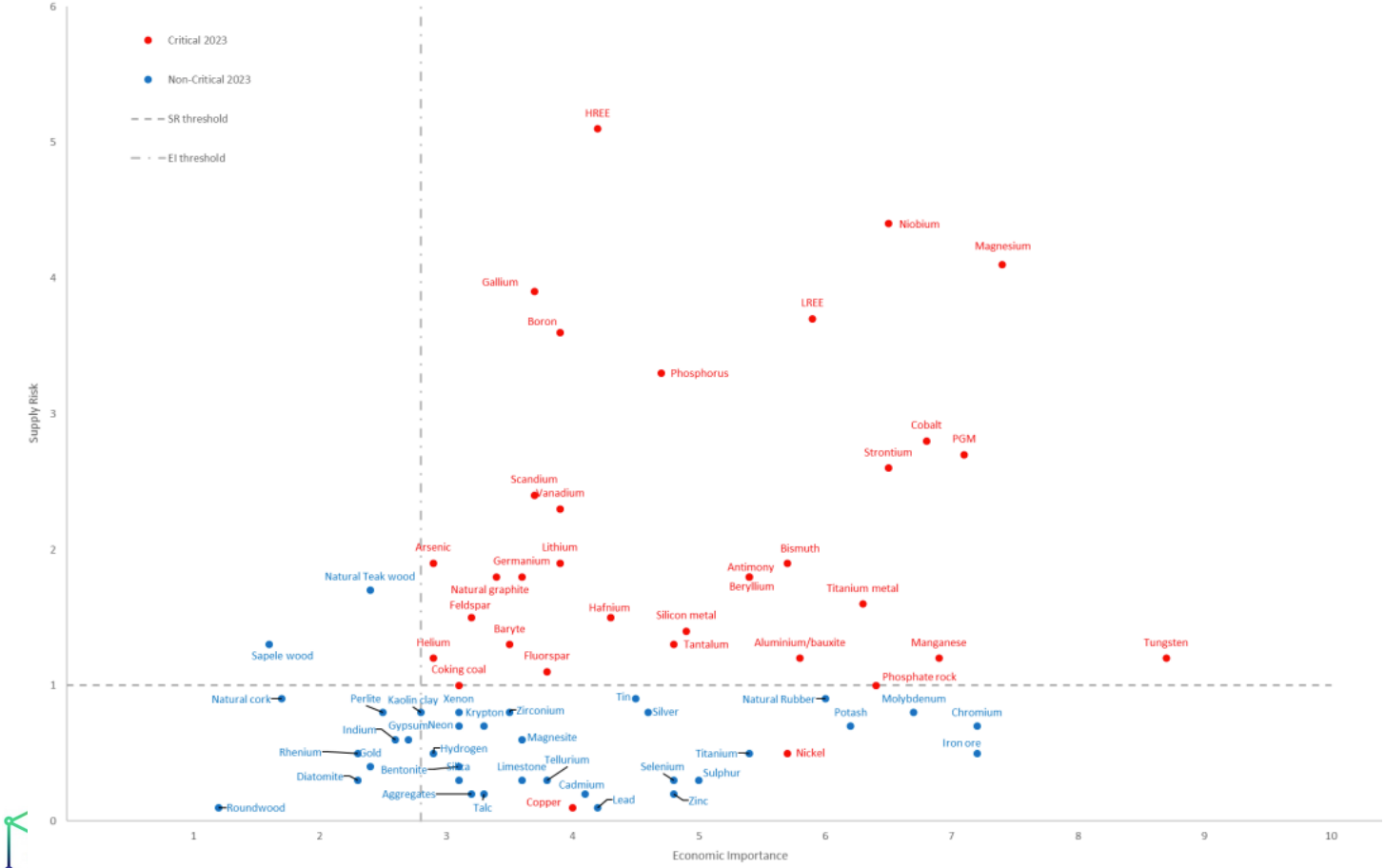
SER (social economic board) exploration: Climate targets will not be achieved without accelerating the raw materials transition

"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

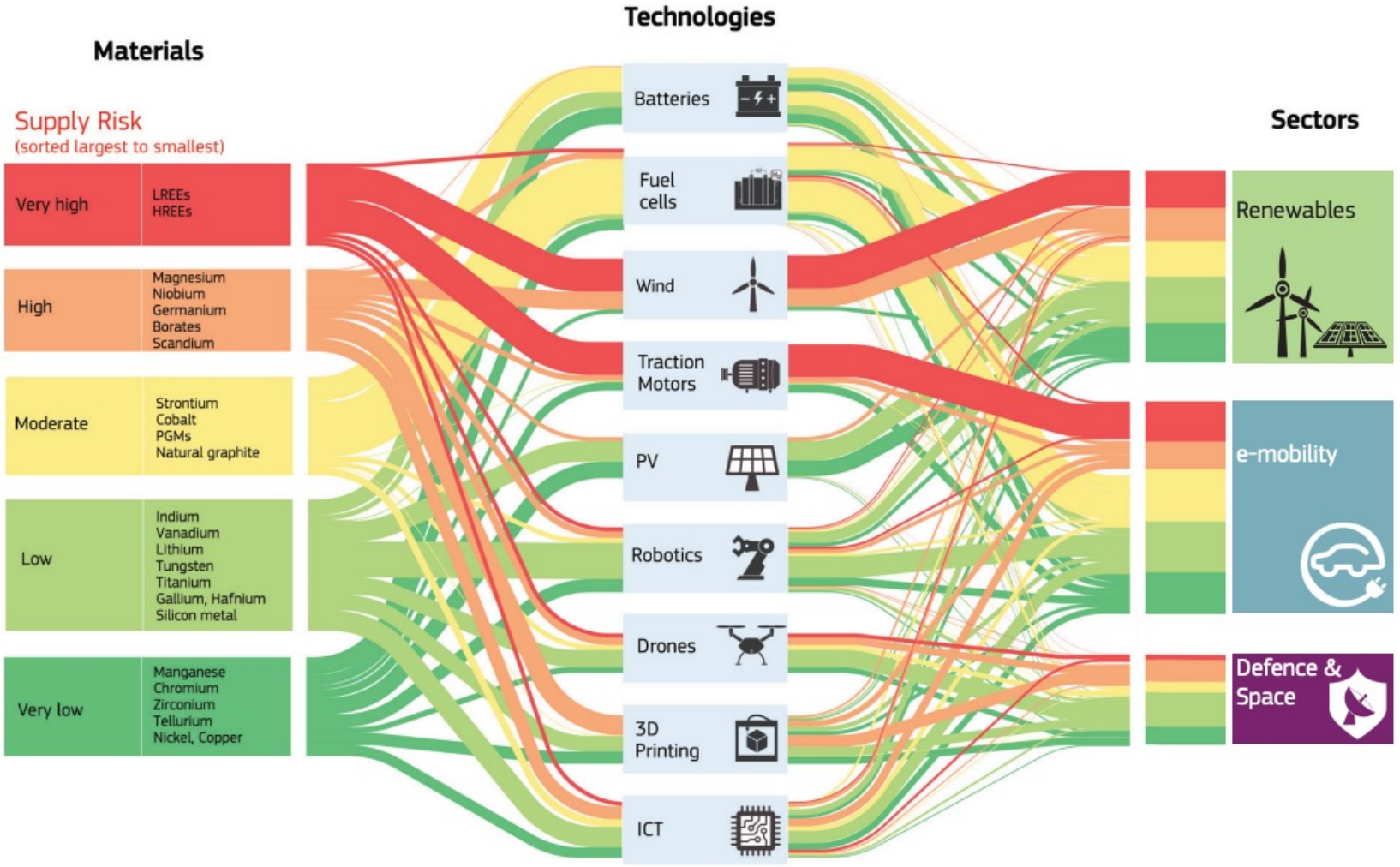
- Energy transition and Raw materials transition are at odds;
- With CO2 we can make the energy transition measurable. What about the raw materials transition / circularity?

The 5th List of Critical Raw Materials

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



Source: EU Science hub, Raw Materials Information System



Source: https://rmis.jrc.ec.europa.eu/uploads/CRMs_for_Strategic_Technologies_and_Sectors_in_the_EU_2020.pdf

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.

https://www.circularity-gap.world/2023

The Naked Truth……

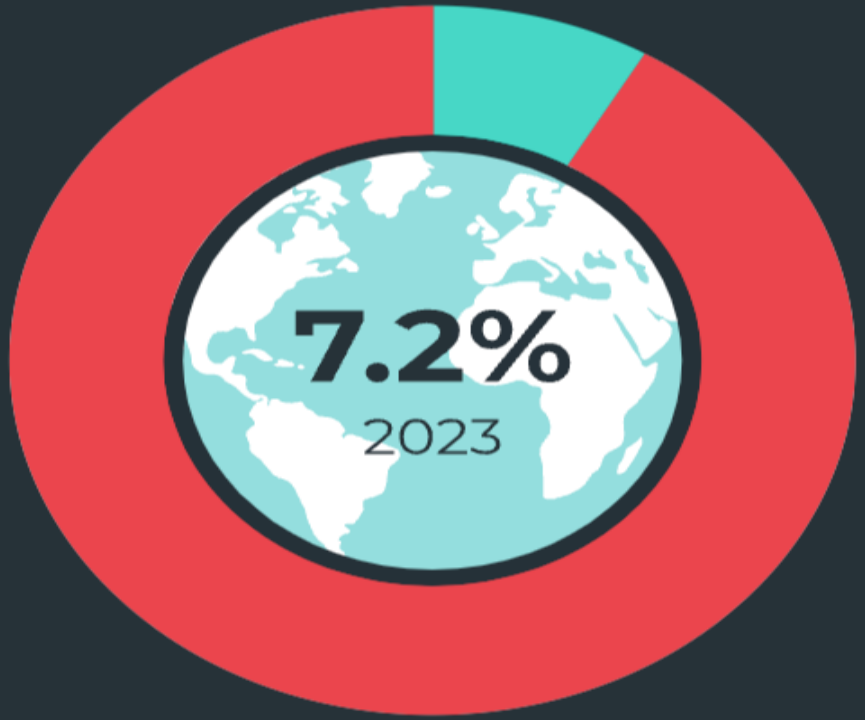
THE GLOBAL ECONOMY IS NOW ONLY 7.2% CIRCULAR

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 Circularity Gap: the globe almost exclusively relies on new (virgin) materials.

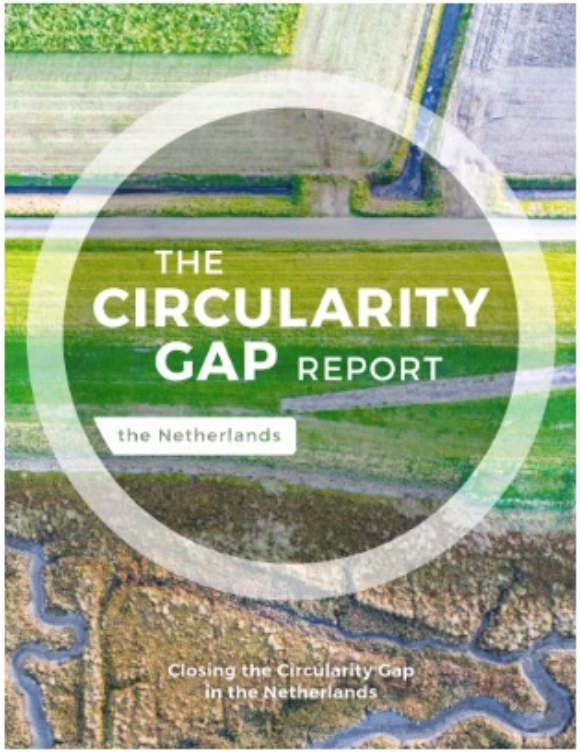
This means that more than 90% of materials are either wasted, lost or remain unavailable for reuse for years as they are locked into long-lasting stock such as buildings and machinery.

How do we measure circularity? ↗



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 Circularity Metric.

A little better for the Netherlands



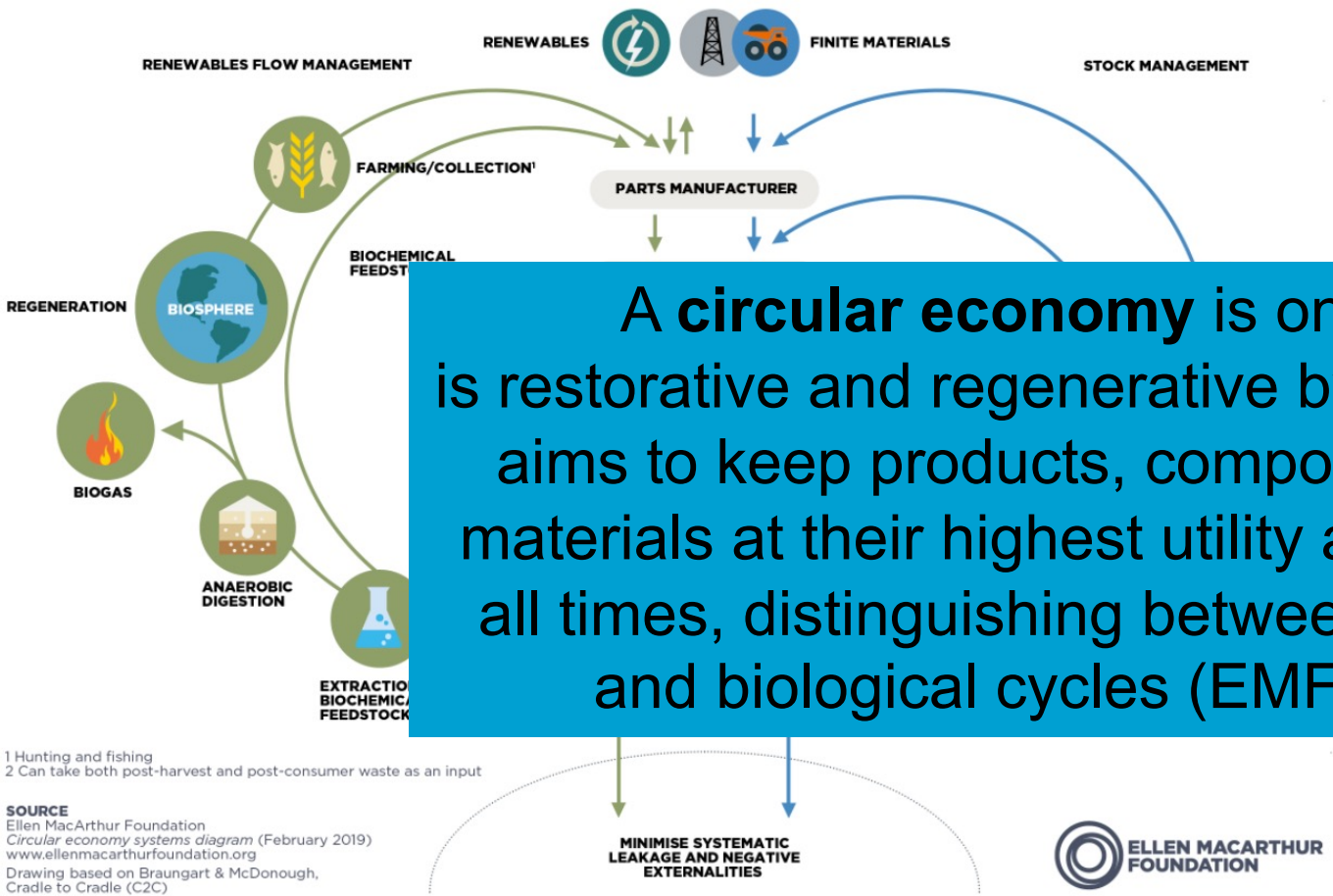
The Netherlands is a global frontrunner in the race to circularity with a Circularity Metric of 24.5%. However, the government has ambitious goals: an economy that is 50% circular by 2030 and 100% circular by 2050. The Circularity Gap Report, the Netherlands, recommends wide-ranging ways in which the economy can pivot away from its linear habits across four key sectors: agriculture, construction, manufacturing and energy. The suggested strategies could triple the Dutch metric from 24.5% to 70%.

Explore the full report

https://www.circularity-gap.world/countries

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)

A **circular economy** is one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles (EMF, 2013)

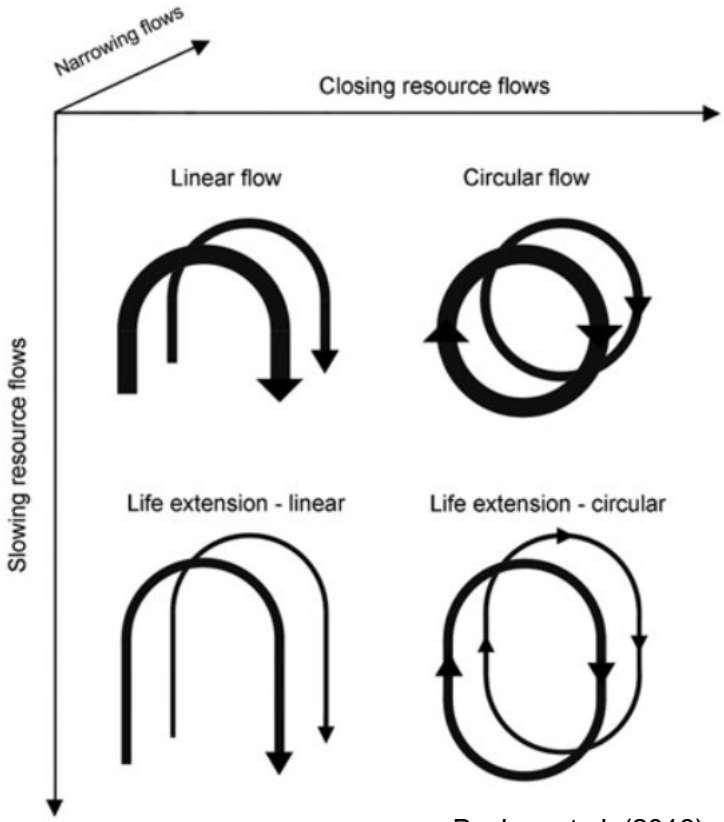
Strategies

R-strategies / narrowing, slowing, closing

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

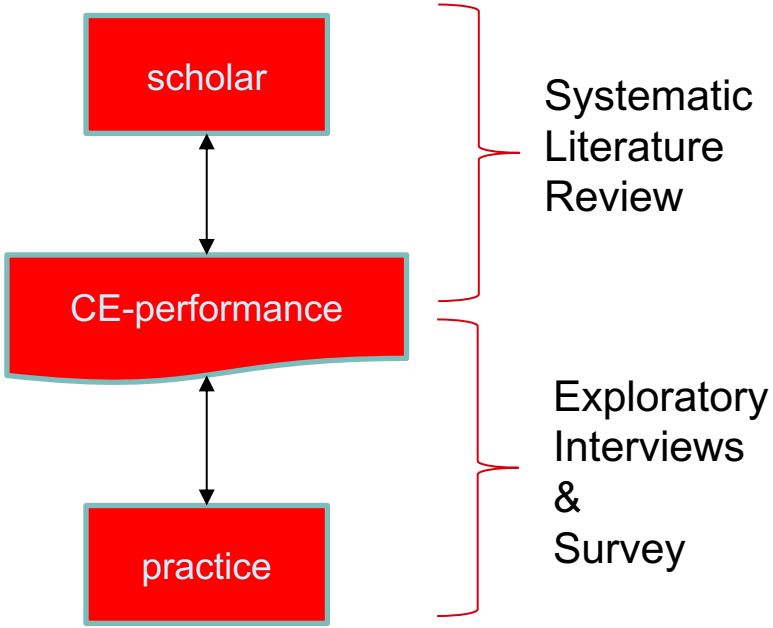
Circular economy	Strategies		
Increasing circularity	Smarter product use and manu-facture	R0 Refuse	Make product redundant by abandoning its function or by offering the same function with a radically different product
		R1 Rethink	Make product use more intensive (e.g. by sharing product)
		R2 Reduce	Increase efficiency in product manufacture or use by consu-ming 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
Linear economy	Useful application of mate-rials	R8 Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality
		R9 Recover	Incineration of material with energy recovery

Kirchherr & Piscicelli (2019)



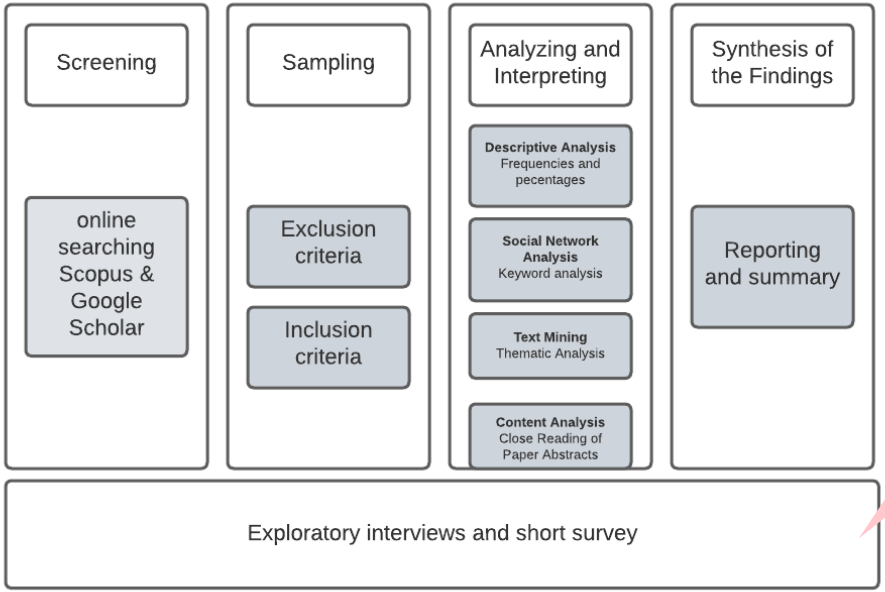
Bocken et al. (2016)

Exploring Circular Performance
Current State of art



SLR & Exploratory interviews/survey

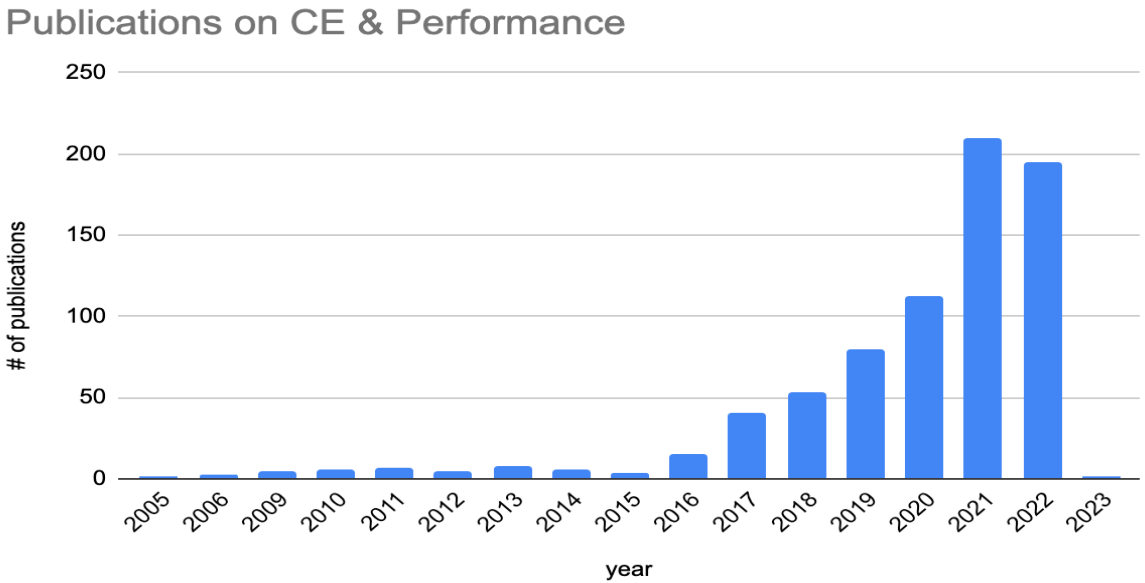
Systematic Literature Review following Denyer & Tranfield (2009)



- 40 interviews (manufacturers, wholesale)
- Survey (http://www.slimcirculair.info/1126611_circulariteit-meetbaar-maken)

Publication explosion..

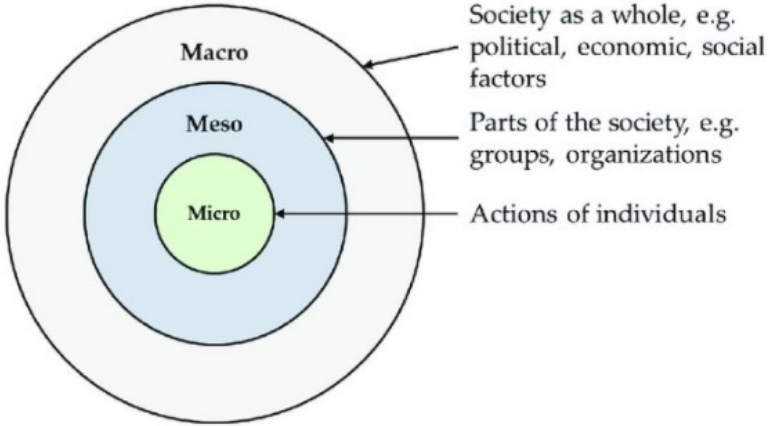
751 and counting



Source: constructed by authors (Dec. 2022)

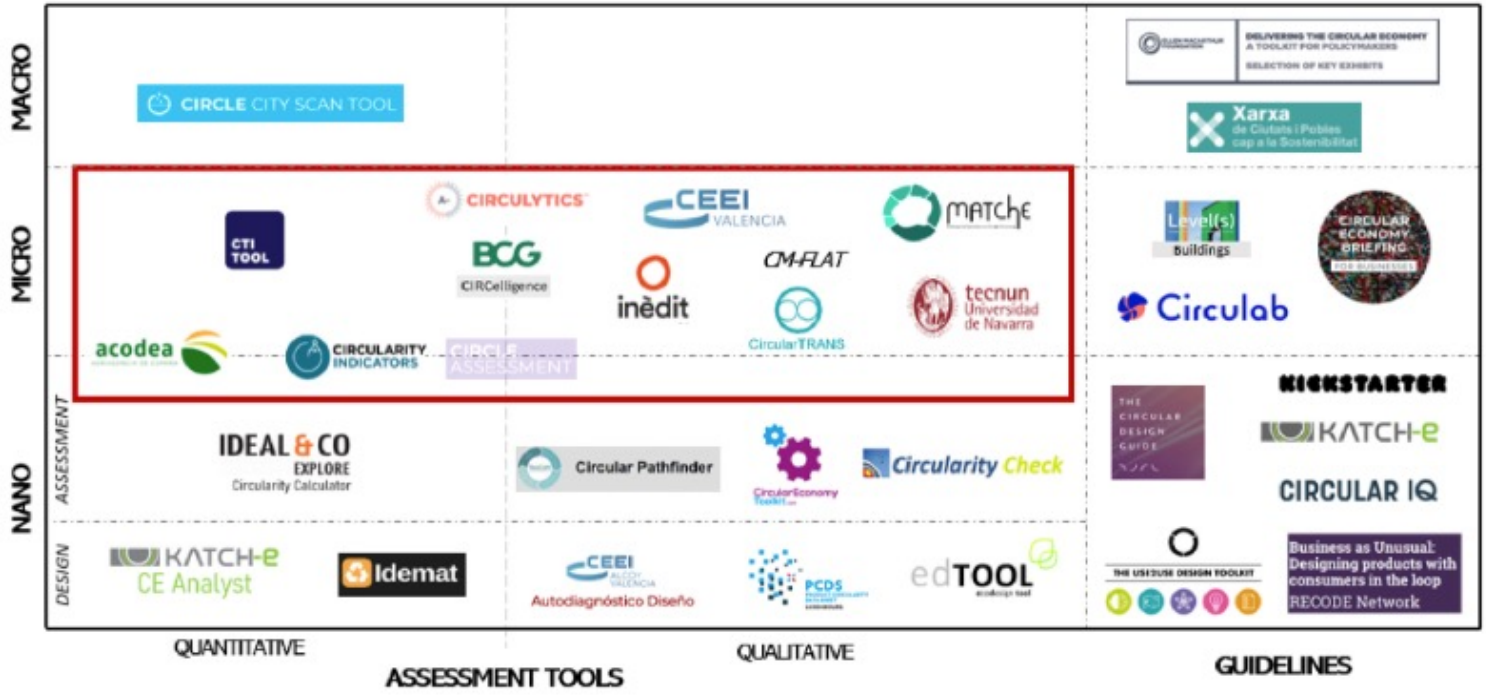
macro, meso, micro thinking in de circular economy

Focus on micro: ”what’s in it for me?”



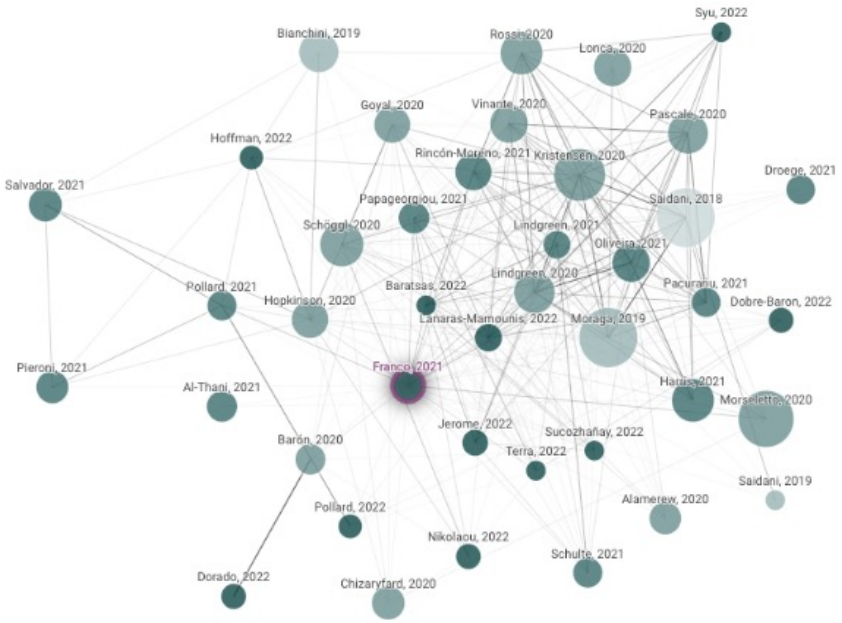
Macro, meso and micro level overview (Javaid, Javed & Kohda, 2019)

Snapshot (semi) commercially available tools



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

Findings



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

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)

Some results of the survey

Significant visibility, response not representative

- 75% of respondents is NOT measuring circularity (lack of expertise and or tooling (90%))
- Measuring circularity should be done once a year (62,5%) by top management (37,5%) or external consultants (37,5%)
- Strong desire to link current performance with growth scenario’s (87,5%)
- Max time to complete circular maturity scan: 1 hour
- Circular quality label?: (50/50)

Interviews confirm the picture

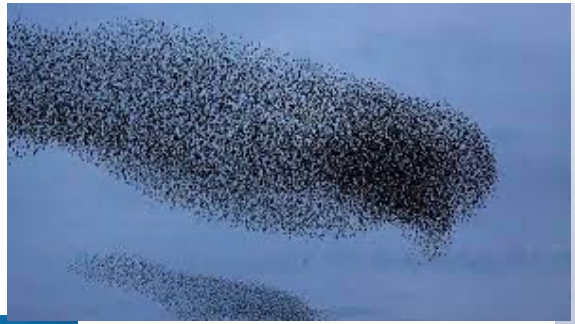
- “We use CO2 because other units of measurement are not clear”;
- “Circular turnover is reported annually, based on four indicators that we measure company-wide”;
- ”I have no idea how to measure, I had hoped that you would come and tell me”;
- “We really want to measure circular performance, but we 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”….

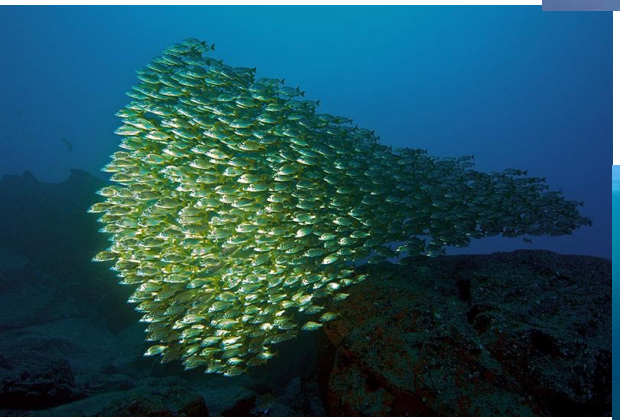
Hypothesis

There is not yet a really good tool for making circular performance holistically measurable that can also be used in SMEs in the Netherlands.

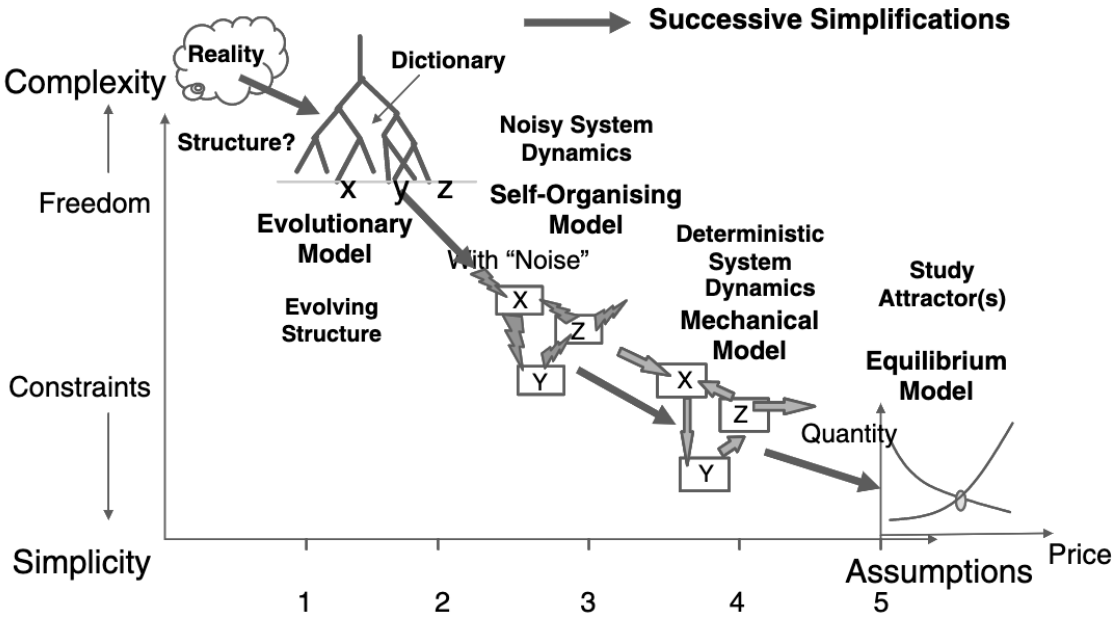
Co-evolution / complexity science

the one influences the other



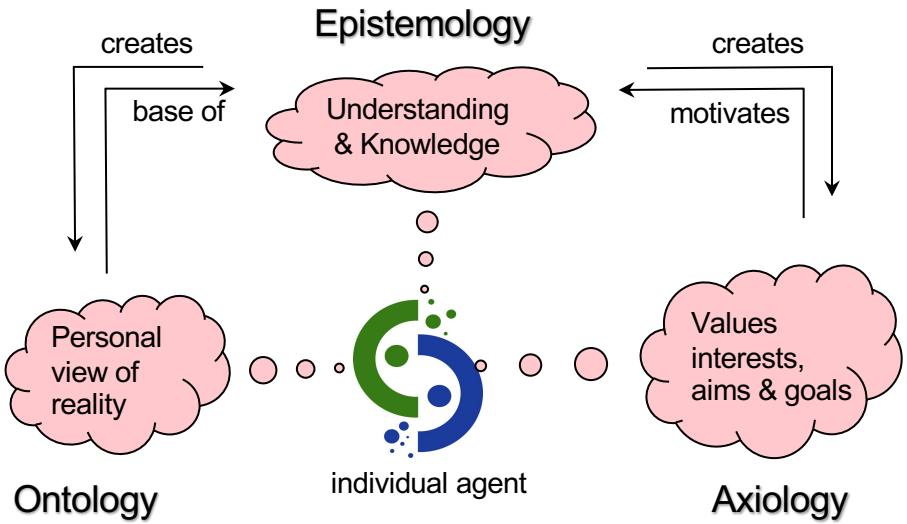


A co-evolutionary perspective on the Circular Economy



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

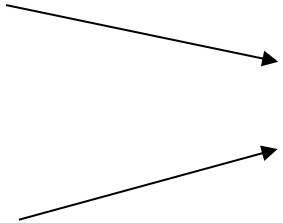
Co-evolutionary development of CE



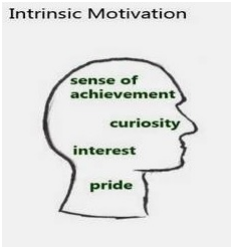
Source: created by Walraven, P. (2022) based on Allen, P. M., & Varga, L. (2006) and adjusted by author.

We are getting there

Converging knowledge



Intrinsic motivation



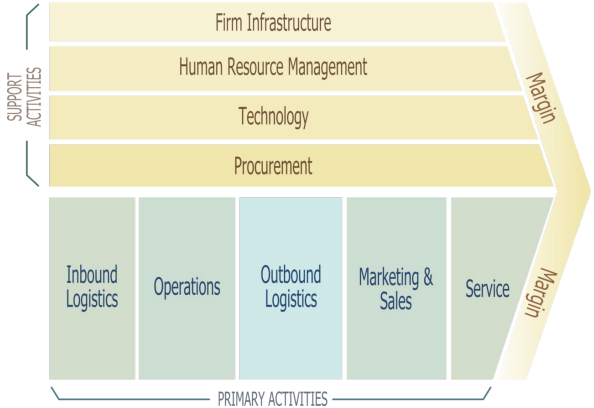
ISO

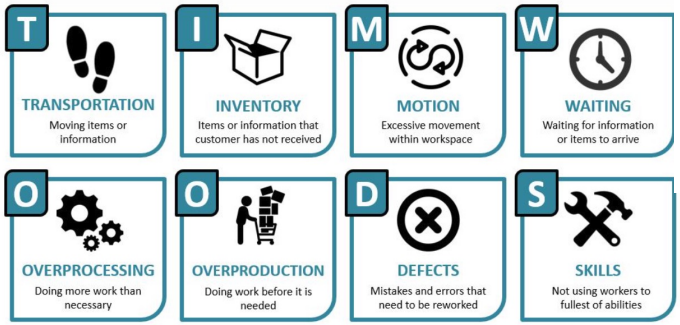
Standardization & Normation

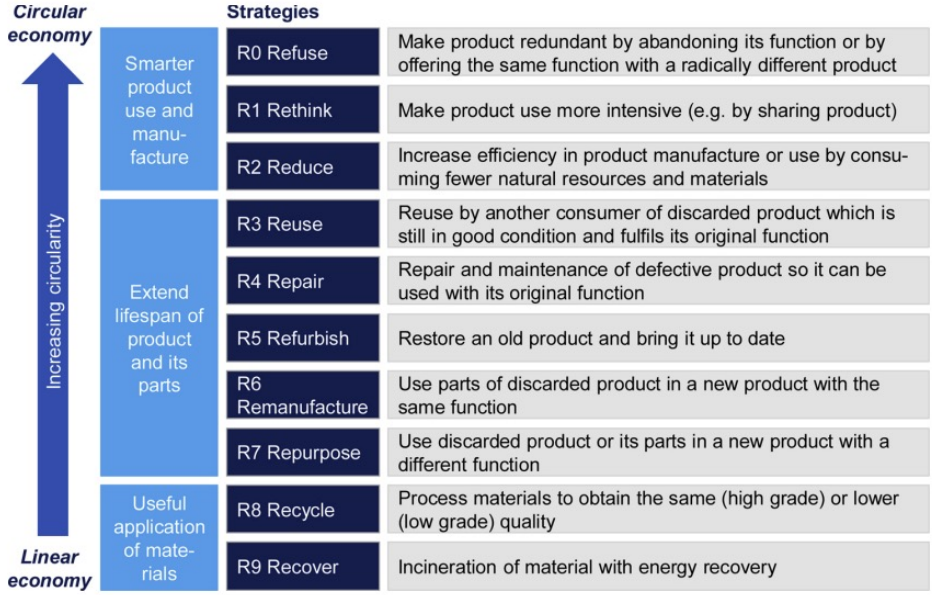
Regulations

Systemic ambitions

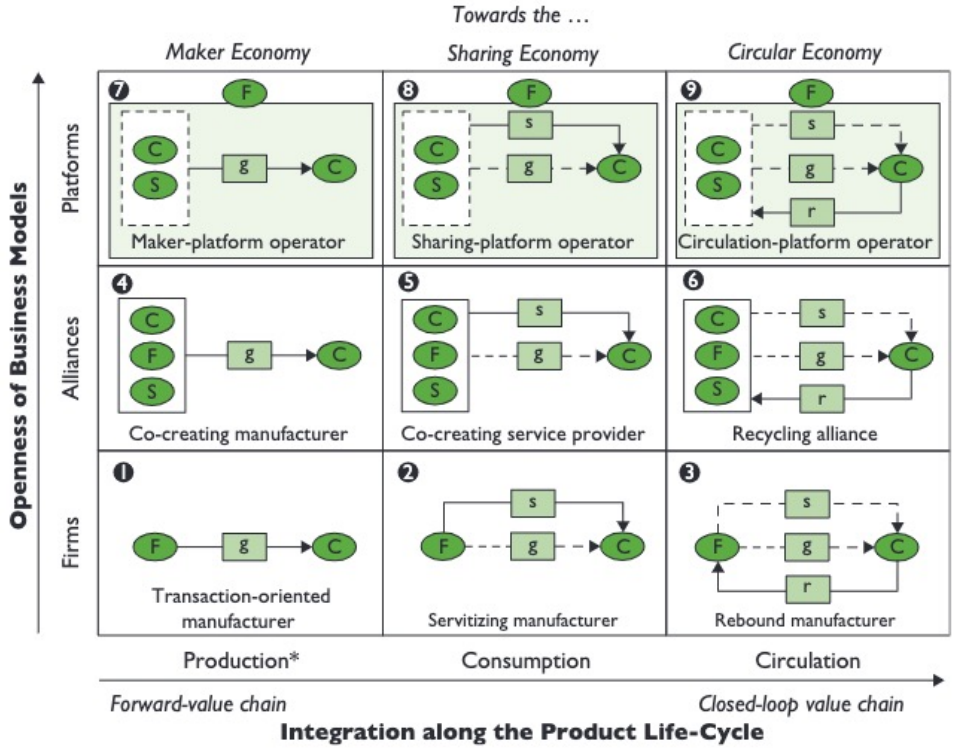
based on R-ladder, Porter & Lean







New initiatives…
Eliminating leaks..
Thinking differently…

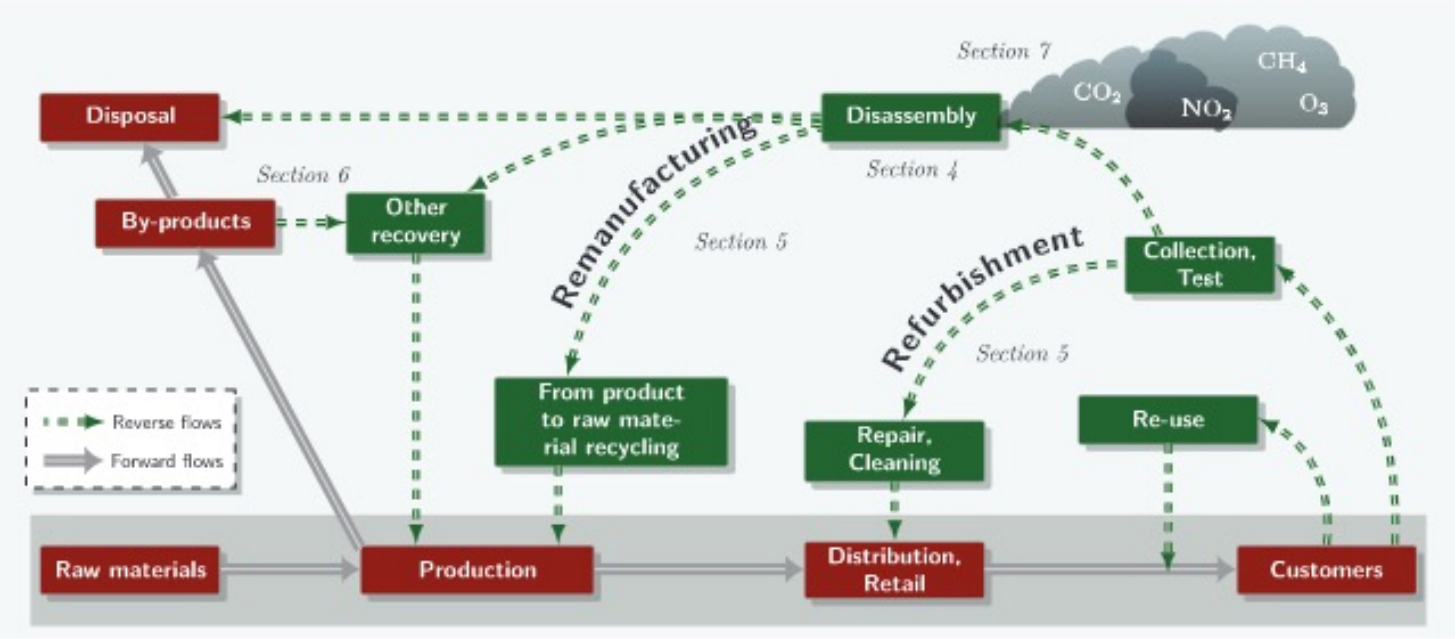


C Consumer
F Focal firm
S Supplier

g goods
s value added services
r re-acquired products

Source: Kortmann & Piller (2016)

New entities in new networks



Source: Suzanne et al. (2020)

Hypothesis

Closed loop supply chain do not exist, and if they do, it should not be the ambition, except for one….

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;
- Longitidunal: Being able to make visible what to do to develop to the next level based on a benchmark.

Inspiration: CMM & Prosci

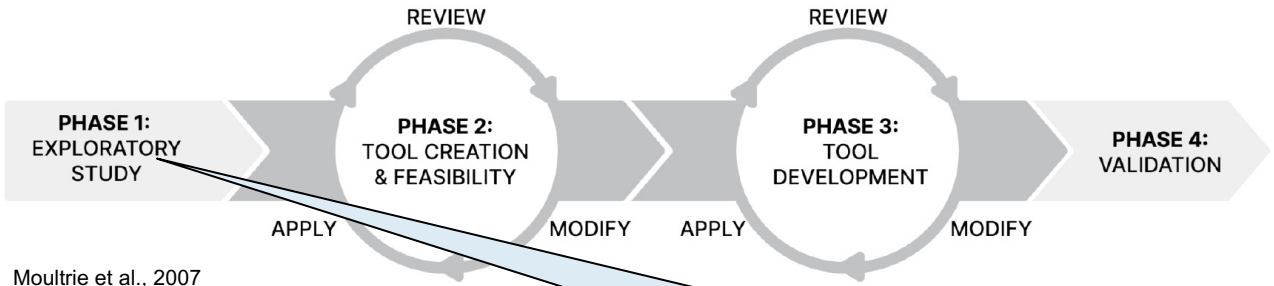
Systems Perspective / Design Science / Maturity Lens Untangling the Gordian Knot

Steenbergen et al, 2013; Cleven et al., 2012; Poeppelbuss et al., 2011; Mettler et al., 2010 / 2011; Scott, 2007; Rosemann and De Bruin, 2005

- Systems perspective: Approaching an organization as living organism and acknowledging relations (Kayikci et al., 2022);
- A holistic methodology is required to include all sustainability aspects of a given system (Walzberg et al., 2021);
- The concept of maturity proposes a suitable structure for explicating the elements of CE transformation and how they relate to organizational change (Uhrenholt et al., 2022)

Model creation methodology

following Moultrie et al. (2007)
DSR as underlying perspective (Cross, 2001; Hevner et al., 2004)



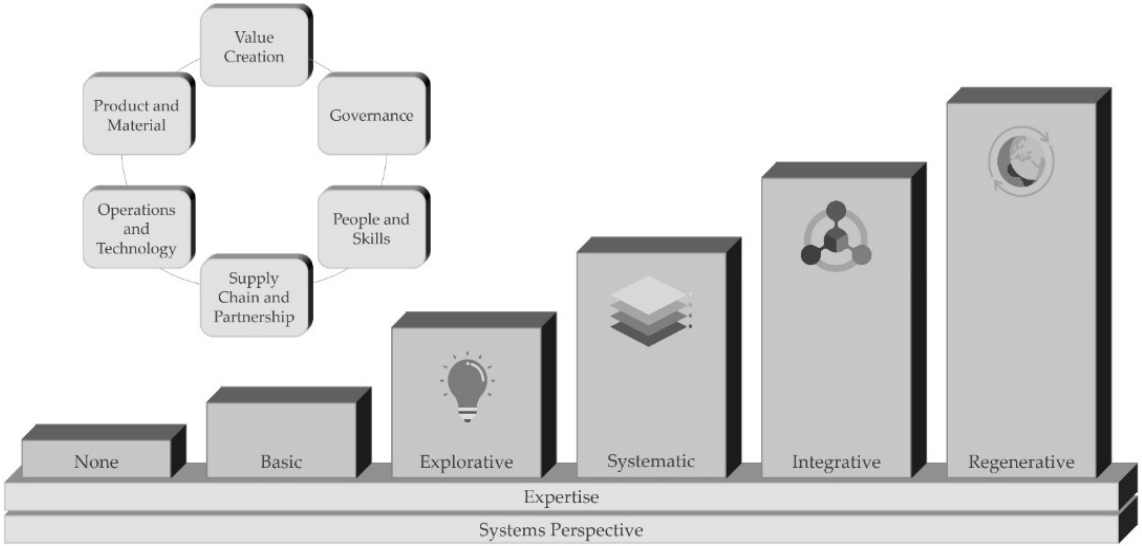
Moultrie et al., 2007

- Balancing rigor & relevance
- Iterative
- Start gathering data

Experiment (minor student project):

- Capability identification with reps. from 5 companies in Delphi workshop
- Prototype Circular Performance Maturity Model based on literature

Circular Performance through the lens of maturity



Source Uhrenholt et al. (2022)

Experiment: dimension selection

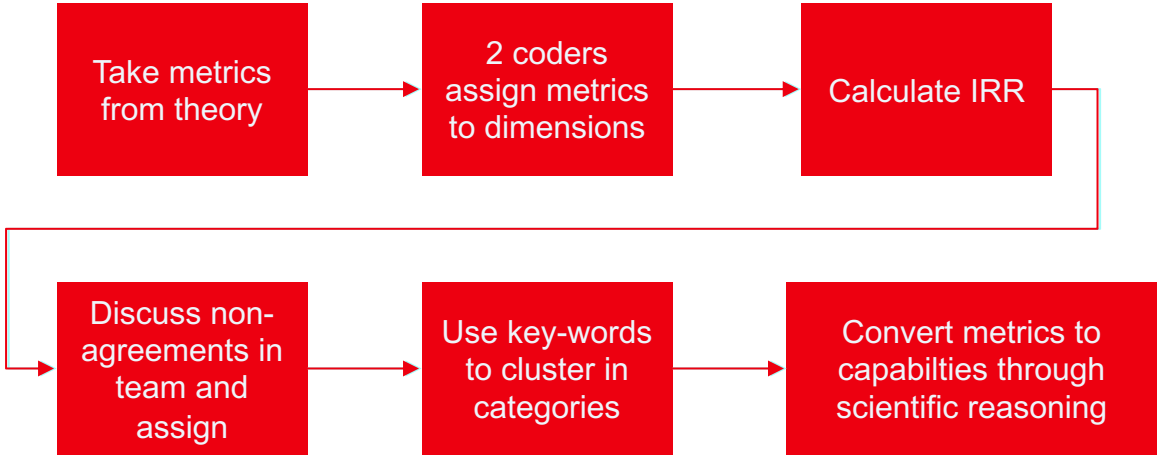
1. strategy, 2. products/services, 3. technology, 4. people and culture, 5. management 6. processes	1. Strategy & policy 2. Management & control 3. Organization & process 4. People & culture 5. Information technology	1. Strategy 2. Leadership 3. Customers 4. Product 5. Operations 6. Culture 7. People 8. Governance 9. Technology	1. Value creation 2. Governance 3. People & Skills 4. Supply Chain & Partnership 5. Operations & Technology 6. Product & Material	1. Economic 2. Environmental 3. Social 4. Policy 5. Process 6. Product 7. Strategy 8. Technology
Williams et al., 2019	Paavel et al., 2017	Mittal et al., 2018	Uhrenholt et al., 2022	Kayikci et al., 2022

Dimension selection

1. Strategy
2. People
3. Product
4. Process
5. Technology
6. Environmental

Experiment: capability identification

Steenbergen et al, 2013; Cleven et al., 2012; Poeppelbuss et al., 2011; Mettler et al., 2010 / 2011; Scott, 2007; Rosemann and De Bruin, 2005



Prototype

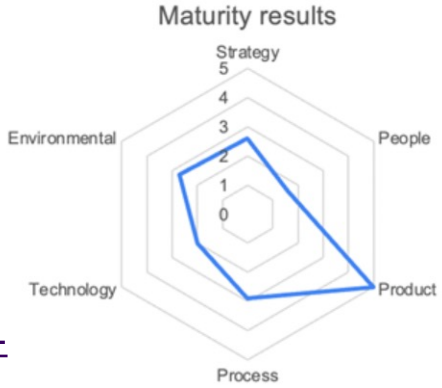
Astrid van den Berg, Brent Rietveld, Jop de Winter

Strategy	People	Product	Process	Technology	Environmental
capability	capability	capability	capability	capability	capability
capability	capability	capability	capability	capability	capability
capability	capability	capability	capability	capability	capability
capability	capability	capability	capability	capability	capability
capability	capability	capability	capability	capability	capability
capability	capability	capability	capability	capability	capability
capability	capability	capability	capability	capability	capability
capability	capability	capability	capability	capability	capability
capability	capability	capability	capability	capability	capability
capability	capability	capability	capability	capability	capability

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

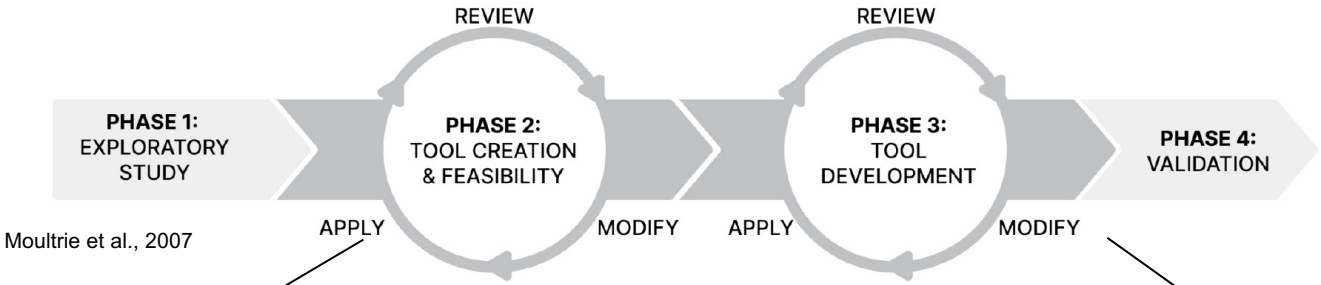


https://www.slimcirculair.info/1170474_prototype-circular-performance-maturity-model

Model creation methodology

following Moultrie et al. (2007)

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

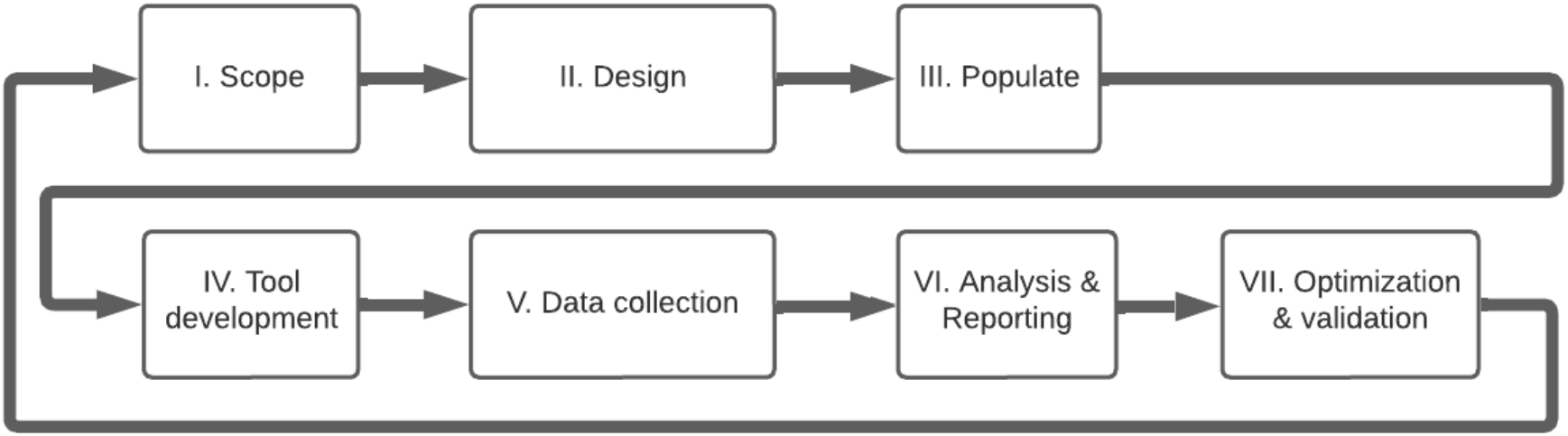


Moultrie et al., 2007

De Bruin et al., 2005

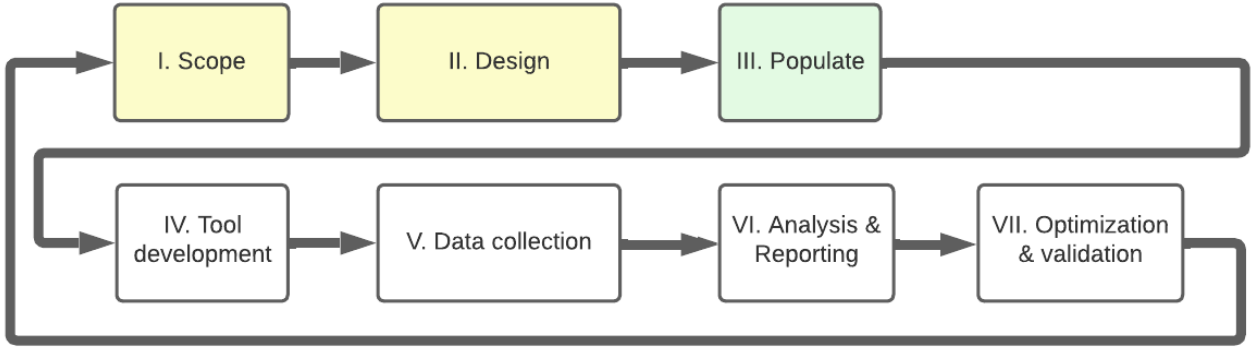
Circular Performance Maturity Model

our model, based on Moultrie et al., 2007 and De Bruin et al., 2005



Circular Performance Maturity Model v1.0

our model, based on Moultrie et al., 2007 and De Bruin et al., 2005

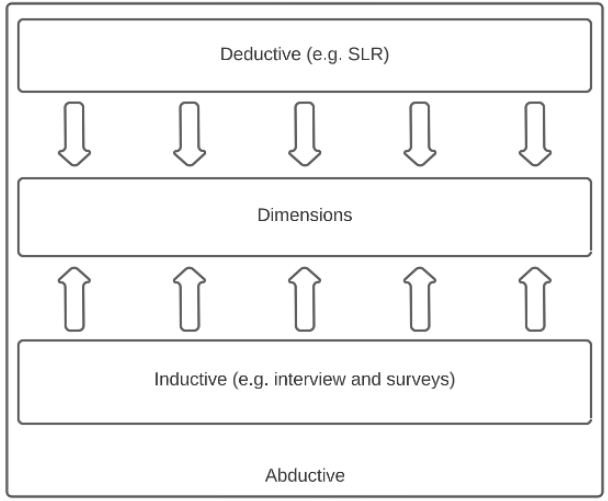


Populate

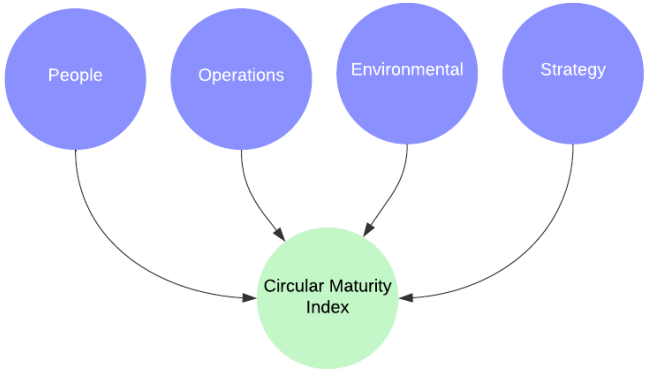
- Dimensions
- Sub-dimensions
- Capabilities
- Scoring capabilities
- Maturity levels

Populate

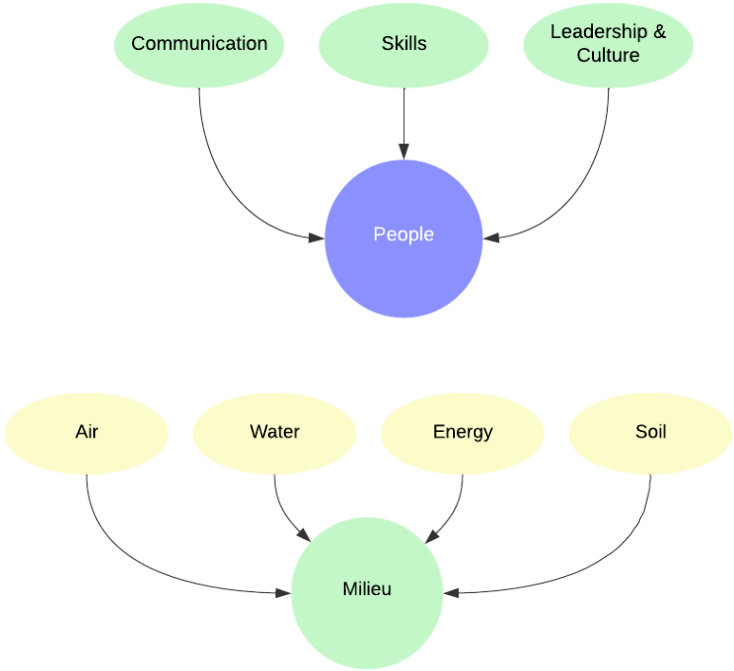
abductive research approach (Williams et al., 2019)

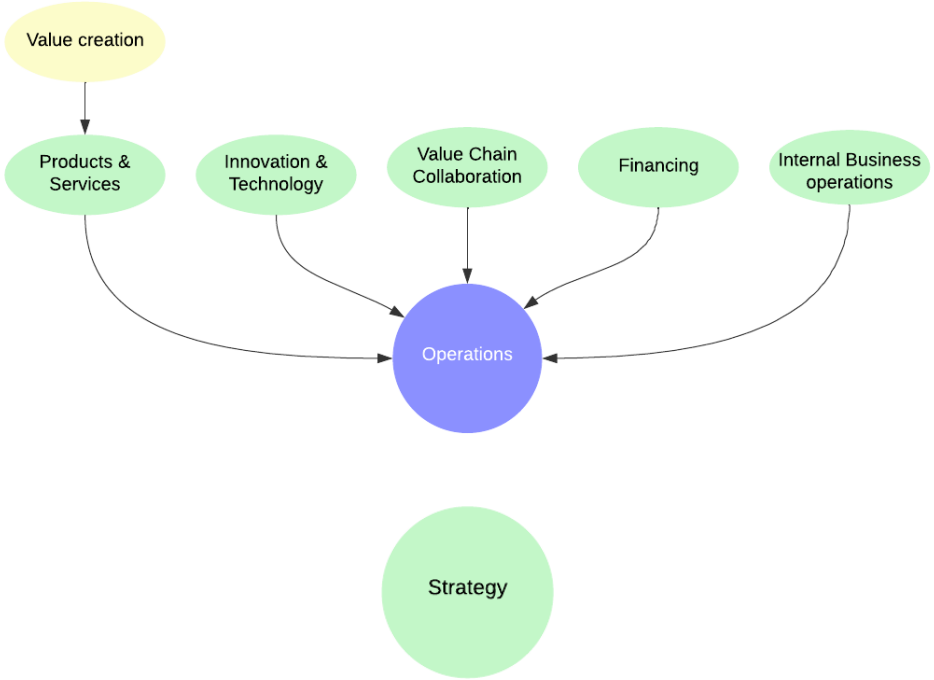


59 dimensions out of 26 different studies

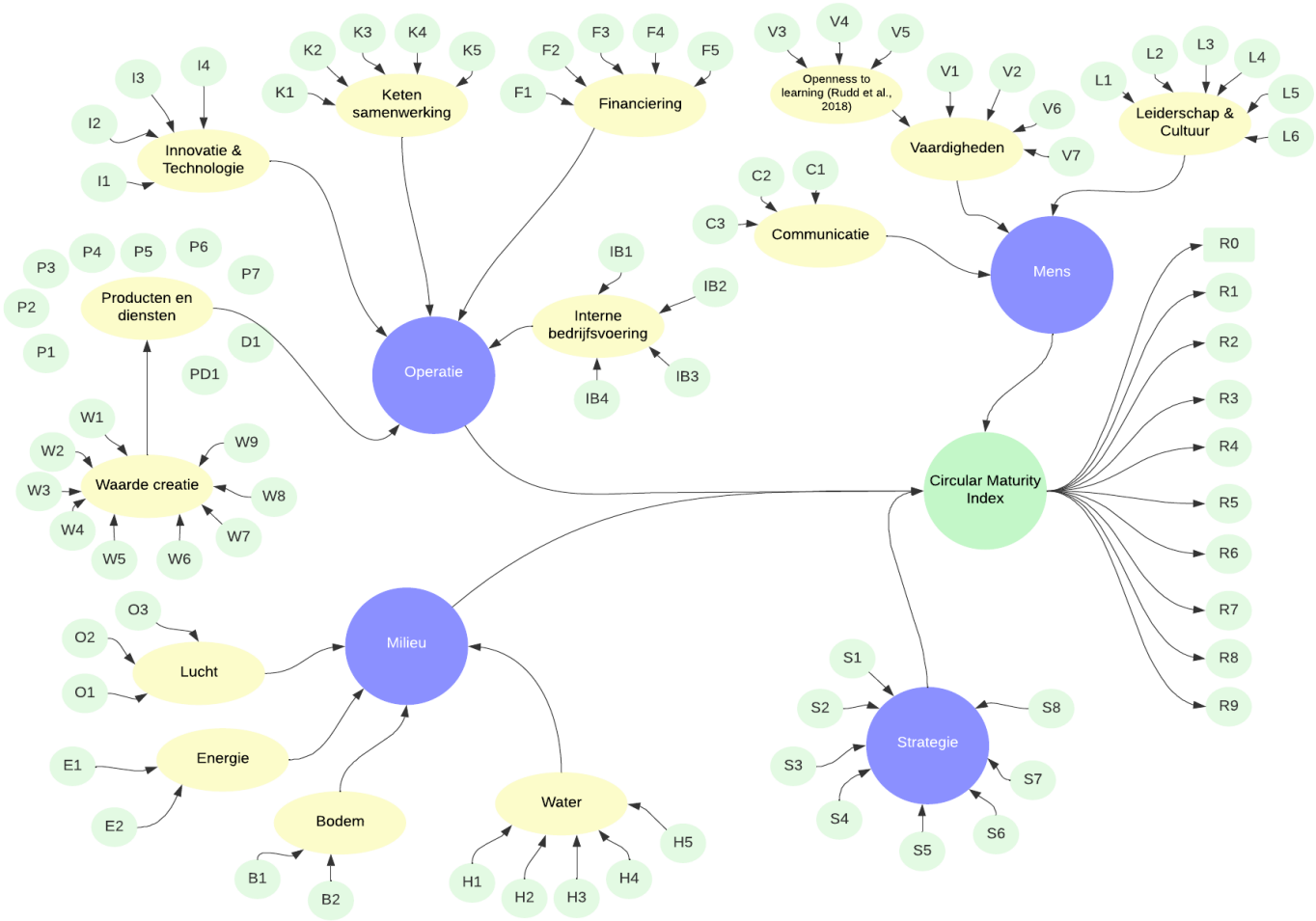


Dimensions and subdimensions



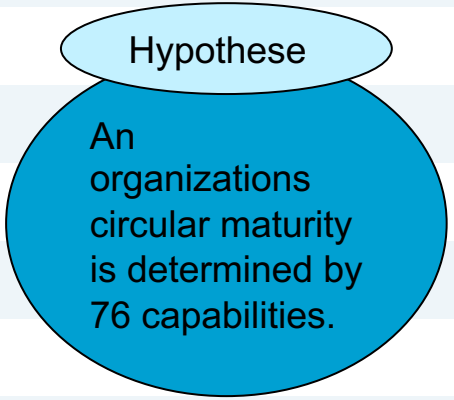


Conceptual model



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
	Internal Business Operations	7
Strategy		8
Environmental		12

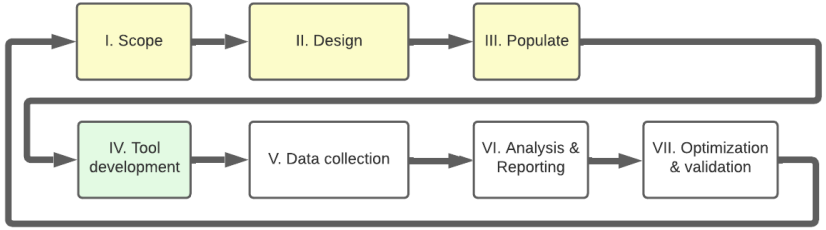


Scale & levels

- 7-point Likert scale (Preston & Colman, 2000; Oaster, 1989; Wakita et al., 2012; Tarka, 2017)
- Rescale 7-point Likert to 5 maturity levels following Dawes (2002)

- L_{min} = Minimum Likert Score (1)
- L_{max} = Maximum Likert Score (7)
- L_{mid} = Midpoint Likert scale = $(L_{min}+L_{max})/ 2$ ((7+1)/ 2 = 4)
- M_{min} =Minimum Maturity Index (1)
- M_{max} =Maximum Maturty Index (5)
- M_{mid} = Midpoint Maturity Index = $(M_{min}+M_{max})/2$ ((1+5)/2 = 3)
- L_d = Average Likert Score on dimension d
- M_d = Maturity Index of dimension d
- $M_d = M_{mid} + ((L_d - L_{mid}) * (M_{max} - M_{min})) / (L_{max} - L_{min})$

Tool development



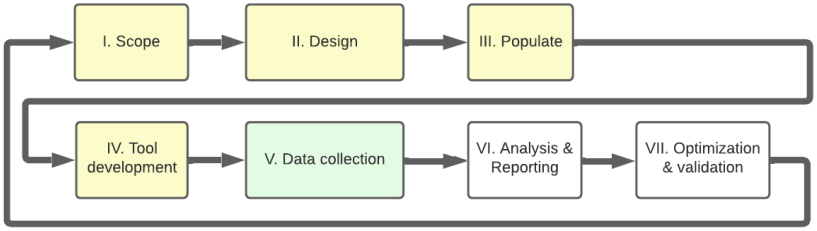
Tool development
- Intuitive
- Time to complete
- Easy to use
- Language
- …..

Tool development
- Typeform
- Klinkende Taal
- Do’s & Don’ts’
- Example <-> Objectivity

Scope Region Utrecht Survey

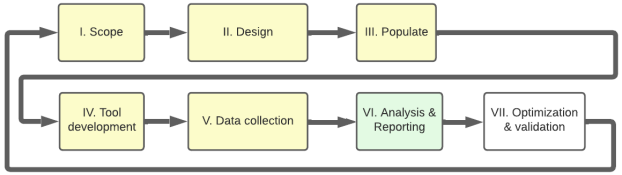
- Also SME:
  - SME's account for over 90% of the businesses (Filipe et al., 2016)
  - SME's are accountable for over 70% of industrial waste (Dey et al., 2022).
  - SME is fewer than 250 employees and turnover < € 50 million (EU)
- Products and Services
- OEM, tier 1, 2 and 3
- Focus Utrecht (region)
- Survey
- Light Cases

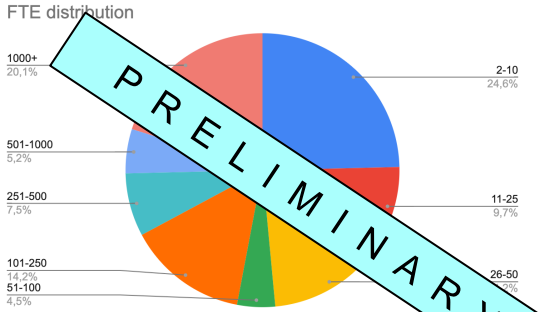
Data Collection

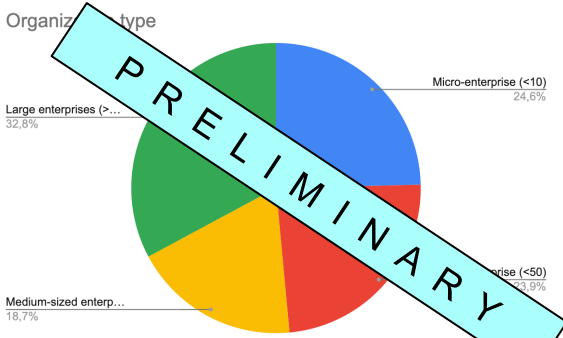


- Data collected from May 10, ‘23 until June 12, ‘23
- E-mail to 629 companies (selected by Province of Utrecht)
- Survey invitation distributed via LinkedIN and other social media
- Light cases / interviews with 6 organizations.

Analysis & Reporting – 134 respondents







PRELIMINARY

PRELIMINARY

PRELIMINARY

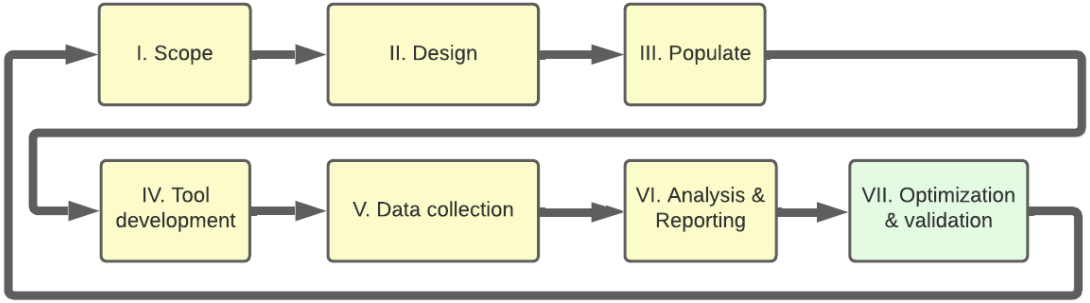
PRELIMINARY

FTE	records	CMI	strategy	skills	leadership & culture	communi-cation	products & services	value chain collabor…	…ncing	innovation & technology	internal business operations	environ-mental
2-10	33		2,58	3,36	3,39	2,94	2,70		2,45	2,85	3,24	2,61
11-25	13	3,31	…69	3,54	3,38	3,23	3,54	3,4…	…15	3,69	3,38	2,77
26-50	19	3,11	…47		3,47	2,84	2,95	3,21		3,21	3,42	3,26
51-100	6	3,00	2…		3,33	3,00	2,67	3,00		2,83	2,83	2,50
101-250	19	3,42	3,16		3,42	3,58	3,21	3,32	3,37	3,42	3,26	2,95
251-500	10	3,50	3,40	4,0…	3,70	3,20	3,40	4,00	3,20	…0	3,90	2,80
501-1000	7	3,71	3,43	3,71	…1	3,86	3,71	4,00	4,00		4,14	3,43
1000+	27	2,85	2,70	3,30		2,81	2,48	3,22	2,78	2…	3,00	2,22
Eindtotaal	134	3,13	2,89	3,46	3,…	3,09	2,95	3,30	2,98	3,13	3,31	2,74

Route Circulair

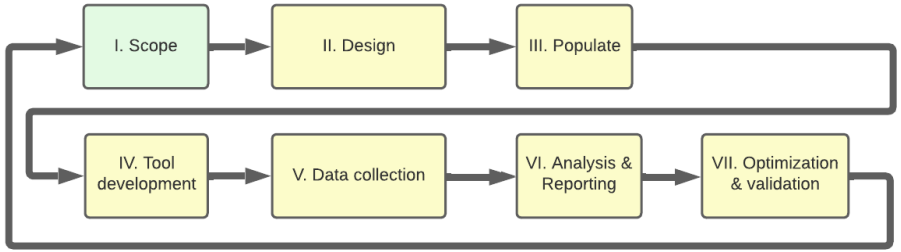
TU/e

Optimization & Validation



- Validation of dimensions and subdimensions (constructs)
- Are we asking the right questions?
- Do the items represent circular maturity?
- SmartPLS evaluation

V2 – September ‘23



- Outcome variables for services only
- Possibility of reducing # of items (< 30 minutes)
- Start researching Impact Interventions
- Lowering drop off rate
- ……
- ….

Hypothesis

Viewing my CE performance from a systemic perspective, through the lens of maturity, will not only provide me with insight into where I stand today, but also offer direction on how to grow tomorrow.

RESEARCH GROUP
PROCESS INNOVATION & INFORMATION SYSTEMS

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Questions?

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PASSION FOR LOGISTICS, ALLERGY TO WASTE