

H2020 MSCA-ITN-2018

ReTraCE Project

Realising the Transition to the Circular Economy

Milestone 4 (M1.4)

Development of a set of mathematical models for solving decision-making problems related to the establishment of circular supply chains





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Circular Economy Indicators for Supply Chains: A Systematic Literature Review

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Milestone 1.4

- The current literature review represents the core part of D 1.1 (*Measuring the transition towards circular supply chains: insights from academic literature and industrial practice*)



Contents

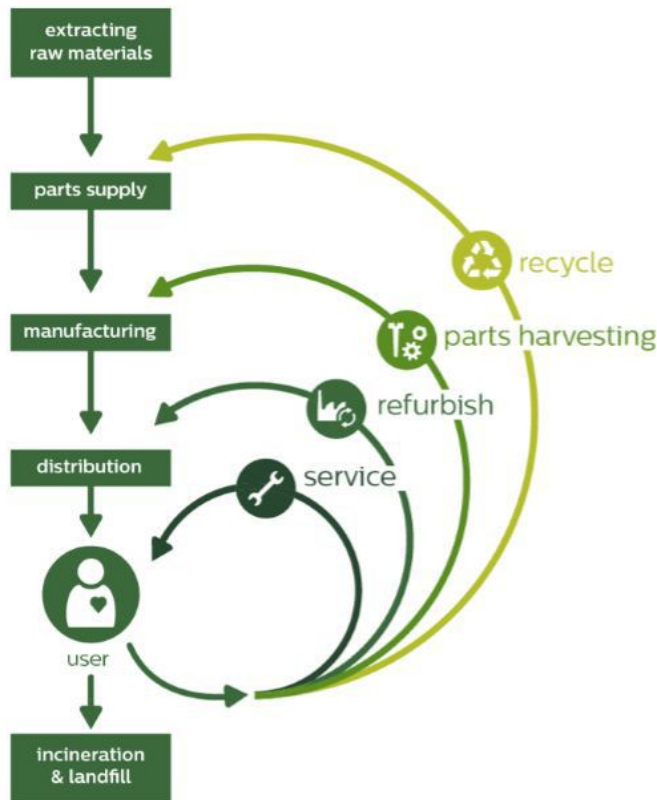
- Problem Statement & Research Objectives
- The Research Method
- Systematic Literature Review Findings
- Research Gaps
- Two synthetic CE indexes
- A suggested Research Agenda

Background

- Today's SCs are complex, global and linear
 - Lack of adequate penalties for their externalities (EMF, 2013; Ciardiello et al., 2018)
- Organizations are increasingly accounted for their environmental and social impacts (Acquaye et al., 2018)
 - Scarcity of natural resources,
 - increased generation of waste materials
- Closing the loop of products and materials is essential



Problem Statement



- Companies are adopting CE interventions along their SCs
- Tracking the effectiveness of the transition of SCs towards higher levels of circularity requires specific indicators
 - To go beyond organizational boundaries, taking a supply chain and lifecycle perspective
 - To take a systemic view on economic, social and environmental aspects
 - To assess the level SCs are able to reduce the waste streams they produce

Current Gaps

- Results from a preliminary analysis shows that there is not an established standard to measure the level of circularity of SCs
 - Highly fragmented field of study
 - Huge availability of environmental indicators, but no agreement on “what to measure”
- Need for an attempt to assess the state-of-the-art of current indicators, their uptake and potential developments

Research Objectives

1. To identify current indicators in the context of circular supply chains literature
2. To characterise them according to the dimensions they consider and the decision they aim to support
3. To identify a restricted set of key performance indicators which could be used to keep track of the effectiveness of CE interventions in CSCs

A SLR on CE Indicators for SCs

- To date, **no systematic review** has been carried out in the field of Circular Economy indicators at a supply chain level.
- A systematic review is useful to **locate** , **select** , **analyse** , **appraise** and **evaluate the literature** relevant to particular research question (Denyer and Tranfield, 2009).
- A systematic literature review offers **brief and holistic view of research outcomes** , in order to **clarify** the **general understanding** of a particular field and **identification of relevant gaps** in the previous literature (Pittaway et al., 2004; Tranfield; 2003).

Methodology

- **SCOPUS (and Web of Science)** . The review was conducted among international peer-reviewed journals
- Generic Keywords have been chosen to maximize the number of articles to be included in the analysis

Keyword String	Number of Results
(("Circular Economy" OR "Circular" OR "Closed-loop" OR "Reverse" OR "Industrial Ecology") AND "Supply Chain*" AND ("indicator*" OR "measure*" OR "assess*" OR "index"))	543
(("Circular Economy" OR "Circular" OR "Closed-loop" OR "Industrial Ecology") AND "Supply Chain*" AND ("indicator*" OR "measure*" OR "assess*" OR "index"))	345
(("Circular Economy" OR "Circular" OR "Industrial Ecology") AND "Supply Chain*" AND ("indicator*" OR "measure*" OR "assess*" OR "index"))	176
(("Circular Economy" OR "Circular") AND "Supply Chain*" AND ("indicator*" OR "measure*" OR "assess*" OR "index"))	91

A SLR on CE Indicators for SCs

- **543 relevant** peer-reviewed research papers
- **17years (2002 - 2018)**
- Body of literature concerned with the development of **indicators** and **metrics** , aiming to track the transition towards Circular Economy at **a supply chain level**
- This systematic literature review is used to **discover existing approaches** used by SCM scholars, which can help characterizing **Decision -Making** in a **Circular Supply Chain** context as well as to identify relevant **gaps**

Inclusion/Exclusion criteria

- Only include articles in English language
- Only include peer-reviewed studies
- Exclude articles that do not develop/employ any indicator
- Exclude articles that do not consider the circular dimension of SCs



Sample of Articles

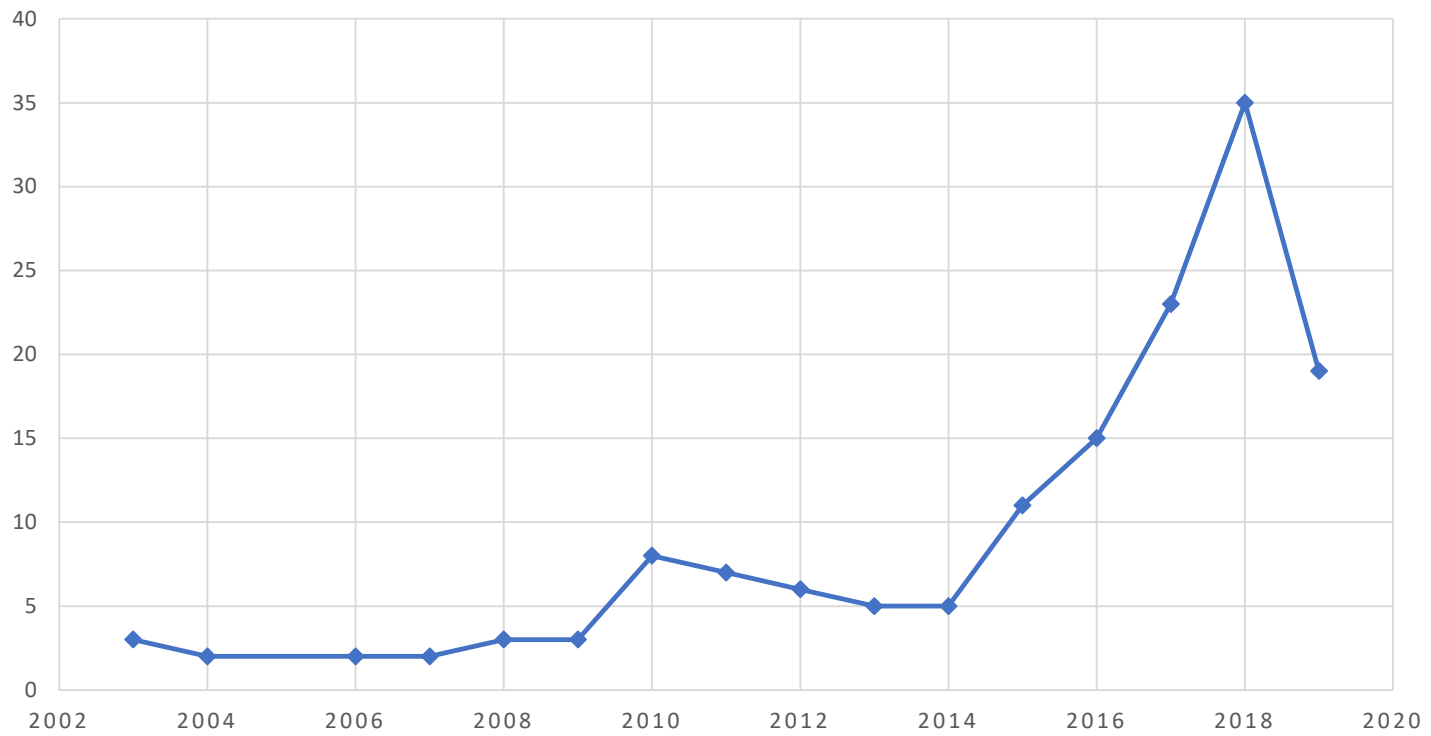
No	Study / Author(s)	Year	Journal	Supply Chain Decision Supported	Type of Supply Chain
1	Pelton et al, Hotspot Scenario Analysis: Comparative Streamlined LCA Approaches for Green Supply Chain and Procurement Decision Making Pelton and Smith Hotspot Scenario Analysis	2015	Journal of Industrial Ecology	SC Performance Assessment	Forward supply chain
2	YılmazBalamanet al, Network design and technology management for waste to energy production: An integrated optimization framework under the principles of circular economy	2018	Energy	SC Network Design	Circular Supply Chain
3	SaxenaL.K et al, Tactical supply chain planning for tyre remanufacturing considering carbon tax policy	2018	International Journal of Advanced Manufacturing Technology	SC Network Planning	Closed Loop Supply Chain

Relevance of Reviewed Articles

- 200 resulting articles
- **149 relevant studies ; 51 studies were not relevant** to the study objectives.
- Articles were evaluated based on: decision supported, industry of implementation, methodology employed.

Criteria	Number of Studies	Relevance
Studies developing an indicator/multiple indicators in order to explicitly evaluate the performance of CSCs	63	Included
Studies employing an indicator/multiple indicators for CSCs in the context of wider Decision-Making models and problems	86	Included
Studies contributing to the CE literature without developing any indicator	51	Excluded

Historical Series



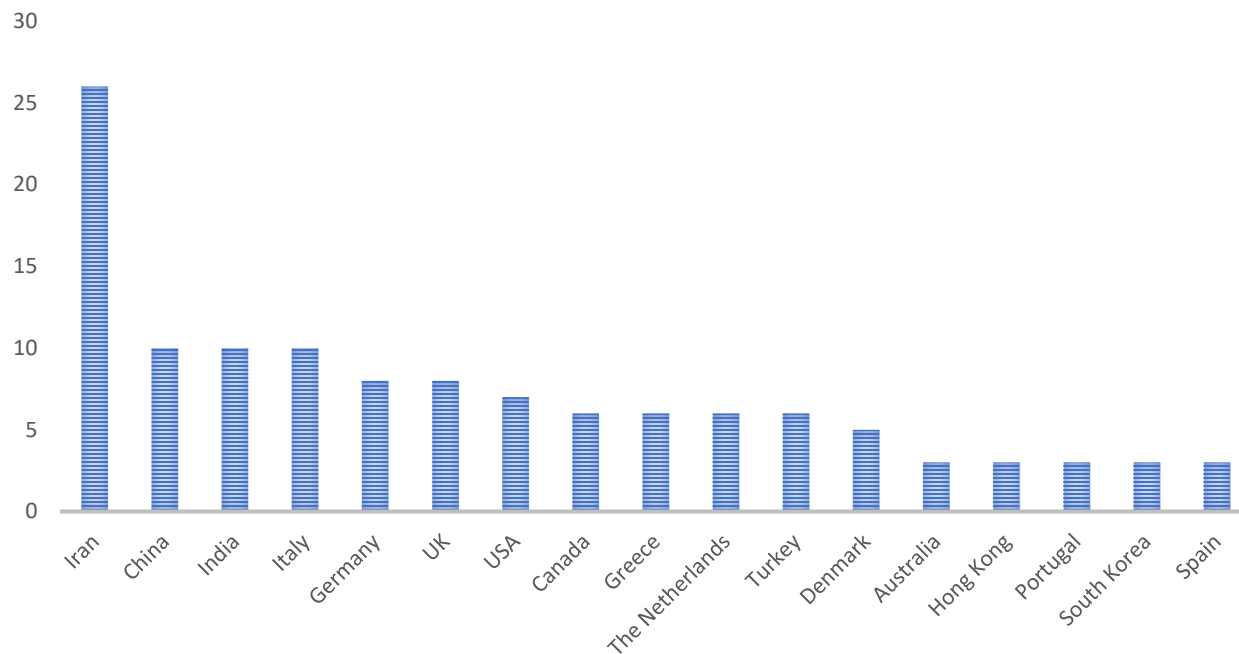
Journals

Journal of Cleaner Production	17
Sustainability (Switzerland)	11
International Journal of Production Economics	10
Resources, Conservation and Recycling	8
International Journal of Production Research	7
Applied Mathematical Modelling	6
Computers and Industrial Engineering	6
Science of the Total Environment	4

- The top contributors are the Journal of Cleaner Production and Sustainability, both of the academic field of Environmental Science
- Some contributions also from the MS/OM domain (International Journal of Production Economics, International Journal of Production Research)



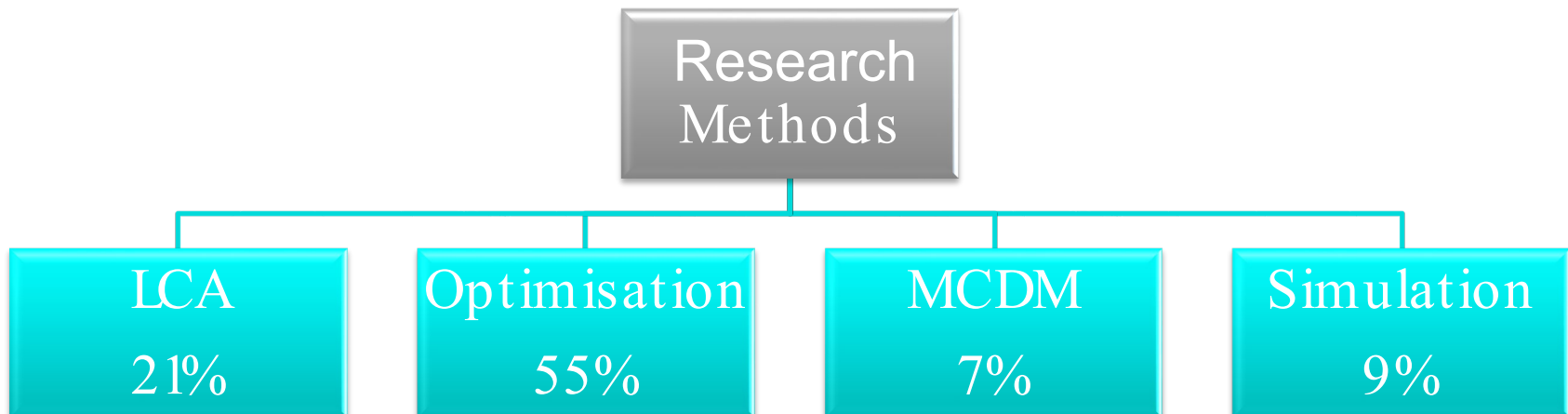
Countries of Origin



- Iran, China, and India countries with more contributions followed by some European countries.

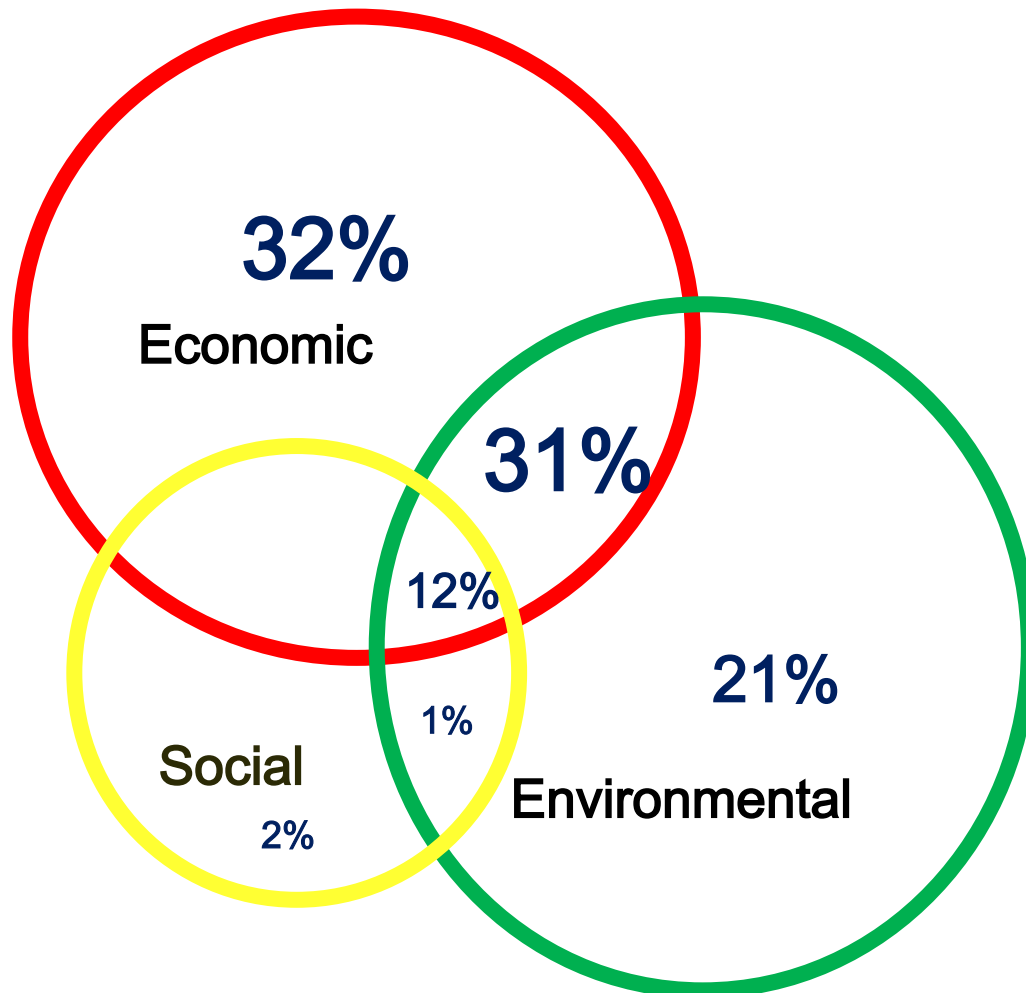


Research Methods



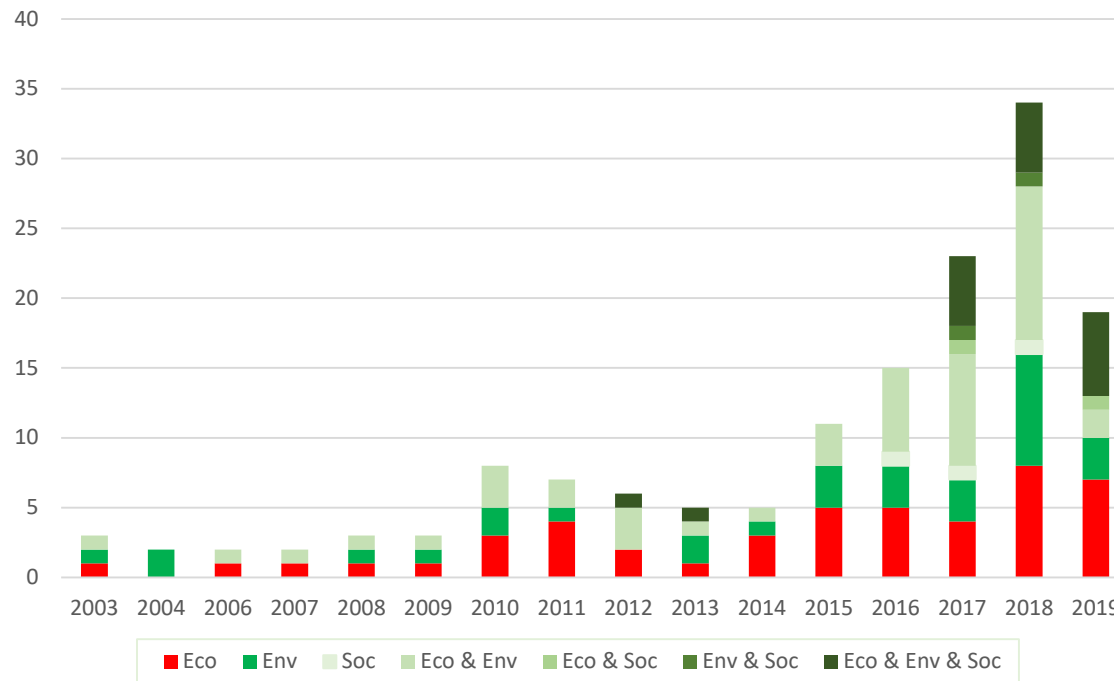


Sustainability Dimensions



- Only the 12% of the 149 papers consider the 3 dimensions simultaneously
- The great majority of the papers (84%) do not integrate social dimension indicators
- 35% of the papers do not consider the environmental dimension at all

Sustainability Dimensions



- Increasing number of indicators that integrate environmental and social issues, and that are characterised by a multi -criteria approach

Economic Dimension

SC Cost 69

SC Profit 32

Time responsiveness 8

Quality 5

Risk 5

NPV 4

Flexibility (FLEX) 3

GVA 2

- Prevalence of cost-based measures
 - Cost of Production
 - Transportation Cost
 - Facility Location Cost
- Mainly SC Network Design Optimisation models
- No indicator of the most frequent is related to CE

Economic Dimension - CE

Net sales of reuse, reusable, and recyclable products	1
Costs of used and returned materials	1
Total payroll and benefits for staff in reverse logistics procedures	1
Taxes paid broken down by country associated with reverse logistics procedures	1
Subsidies associated with reverse logistics	1
Business infrastructure development associated with reverse logistics systems	1
Indirect economic impacts regarding reverse logistics system	1

- Some economic measures directly linked to feedback loops
 - Net sales, Costs
 - Taxes, Subsidies
 - Infrastructure development and indirect impact of the reverse logistics system
- No established CE indicators

Environmental Dimension

CO2e emissions (CC, GHG, GWP)	62
Virgin resource use (MFRD)	22
Residual waste	19
Terrestrial acidification (TAP)	17
Energy use	15
Other emissions (PM, Ozone depletion, Respiratory inorganics)	14
Freshwater or marine eutrophication (FEP, MEP)	14
Water use	12

- 77 different indicators employed
- Are they all necessary?
 - Is there some correlation?
- No explicit measurement of process “circularity”
- Mainly efficiency and intensity measures

Environmental Dimension - CE

Material Circularity Indicator (MCI)	1
Circular Economy Indicator Prototype (CEIP)	1
Proportion of recycled materials to total material input	1
Proportion of recyclable materials to total material input	1
Utilization Rate of Resources	1
Attainment Rate of Waste Discharging	1
ENVIRONMENTAL LCC	1
CONVENTIONAL LCC	1

- Some papers develop specific indicators to measure
 - The proportion of waste and by-products reincorporated in the supply chain
 - the “closeness” of the supply chain
 - the environmental costs of externalities
- No established CE indicators

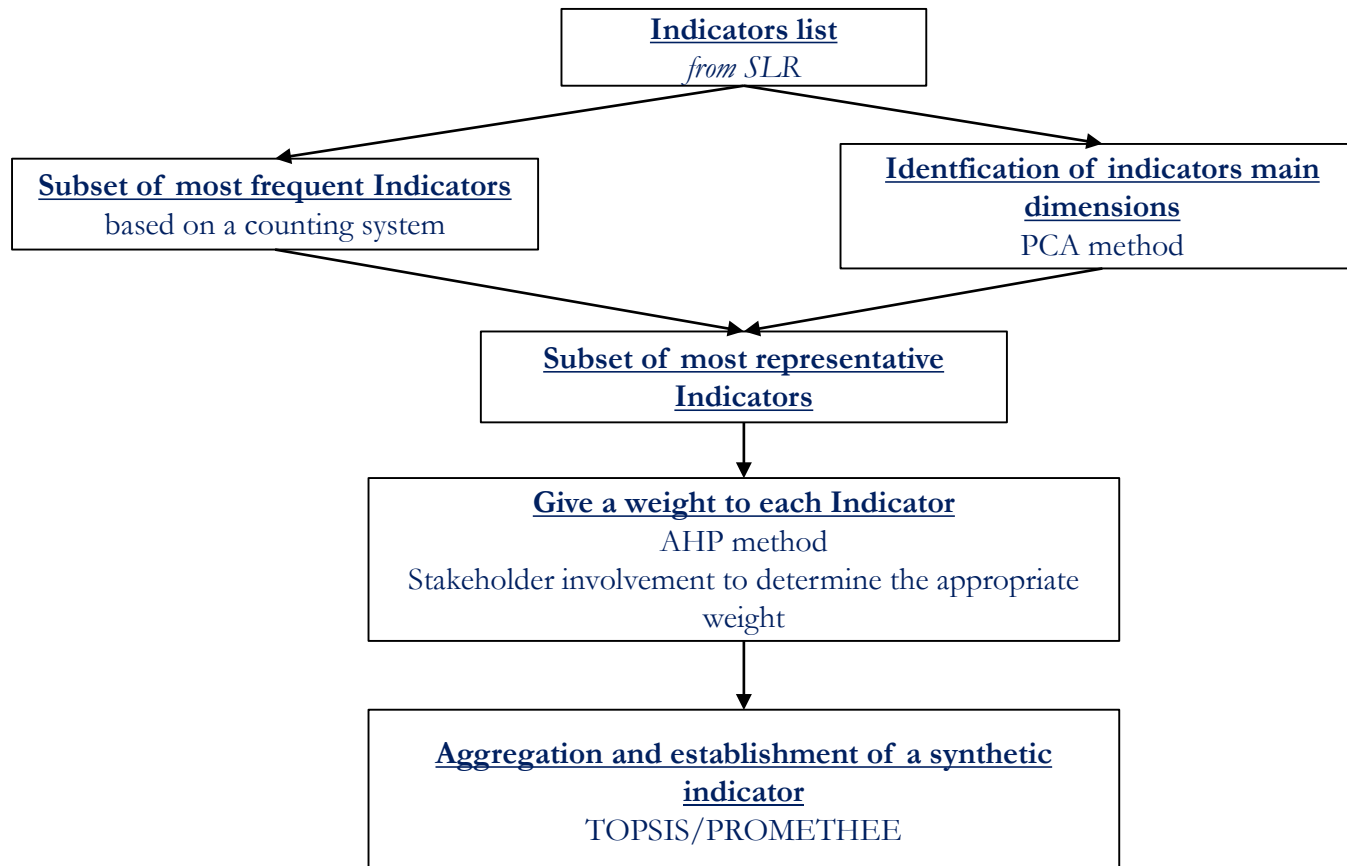
Social Dimension

Job creation	11	<ul style="list-style-type: none"> • No agreement on stakeholders to be involved <ul style="list-style-type: none"> • Employees? • Customers? • Suppliers? • Mainly measures of “quantity” rather than of “quality” <ul style="list-style-type: none"> • What kind of jobs? • Should it be “jobs associated with recycling, repairing, refurbishing”?
Compliance with the ILOcode/ ILO Guidelines for Occupational Health Management Systems	5	
Type of job (Fixed variable Jobs)	4	
Training (average hours of training)	4	
Decent Work, Work Conditions	2	
Stakeholders Commitment/ Involvement	2	

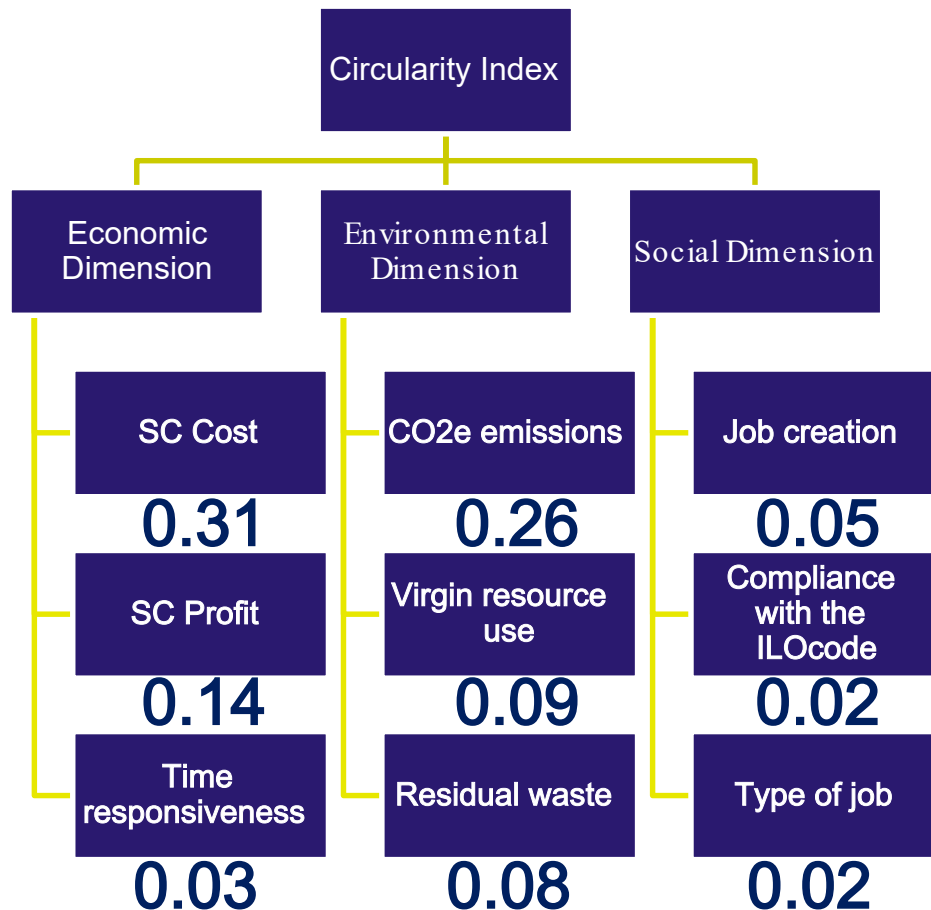
Research Gaps

- **Gap #1**– Most of the approaches does not account for the social dimension. Few very simplistic measures are adopted.
- **Gap #2**– A lot of environmental indicators employed. Are they correlated? Lack of measures of the circularity of the supply chain.
- **Gap #3**– Lack of a multi dimensional and established composite indicator.

A Potential Index



A Literature Based Index



- What literature suggests
- 3 most popular indicators for each dimension
 - Dimensions and indicators weighted on relative frequencies
 - Eco = 0.48
 - Env = 0.43
 - Soc = 0.09
- Little link to CE!

An ideal CE Index



- How can we valorise developed indicators directly linked with CE?
- Choice of the 3 most frequent indicators for each dimension explicitly linked to circularity
- Weight dimensions equally
 - Eco = 0.33
 - Env = 0.33
 - Soc = 0.33
- Weights indicators equally

Research Agenda

- Alternative definition of the synthetic CE index
 - of the subset of indicators for each dimension (PCA)
 - of the weights (involving different stakeholders)
- Test how the CE index behave both with secondary datasets in the accepted papers and in real world supply chains
- Mechanisms and drivers that drive an improvement of the CE index for a supply chain



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