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Design optimization of modular mobility assistive devices via generative AI

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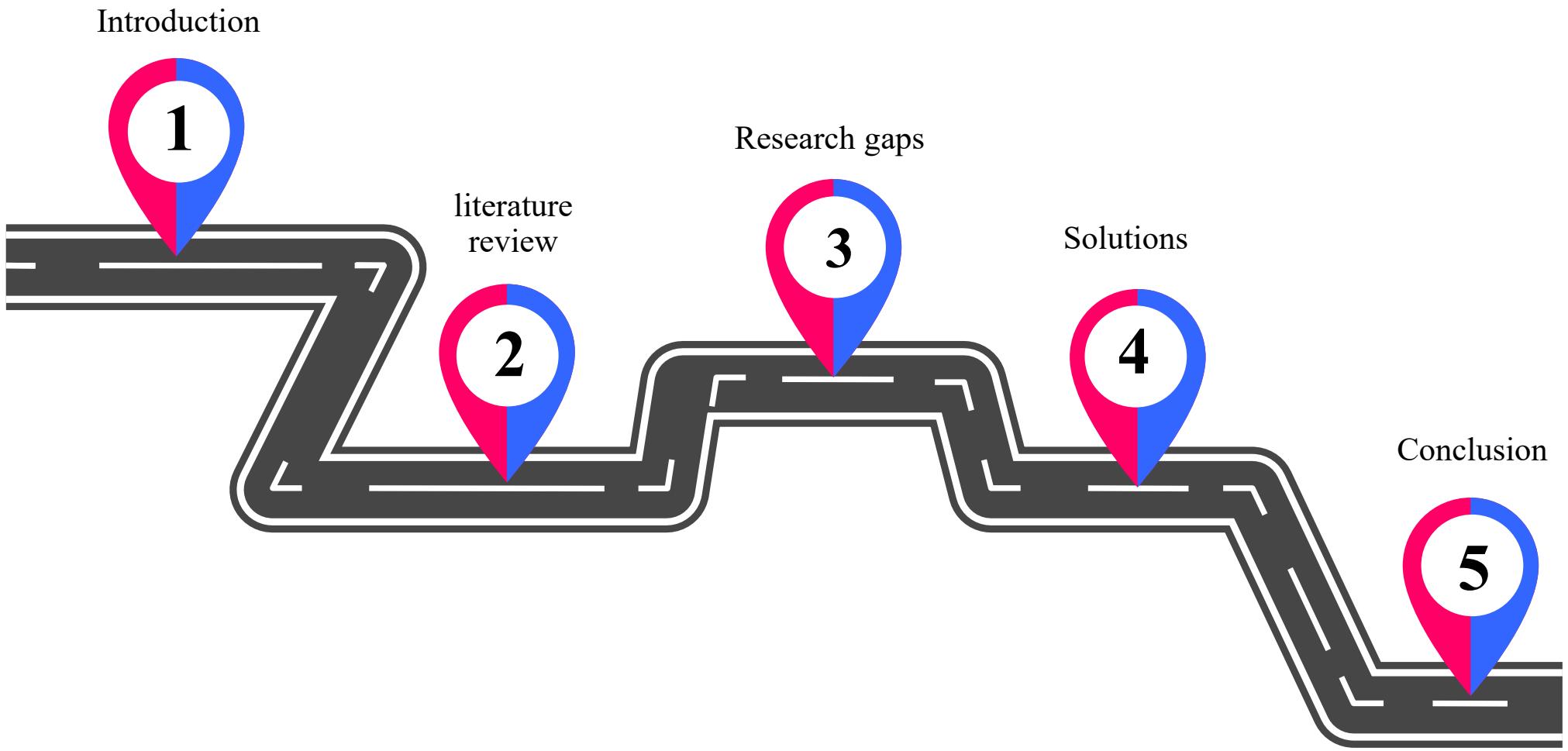
Optimization Day 2025

Design Optimization of Modular Mobility Assistive Devices via Generative AI

Maryam Ashkbous

Samira Keivanpour

May 12, 2025


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Introduction

Introduction

Eco-design

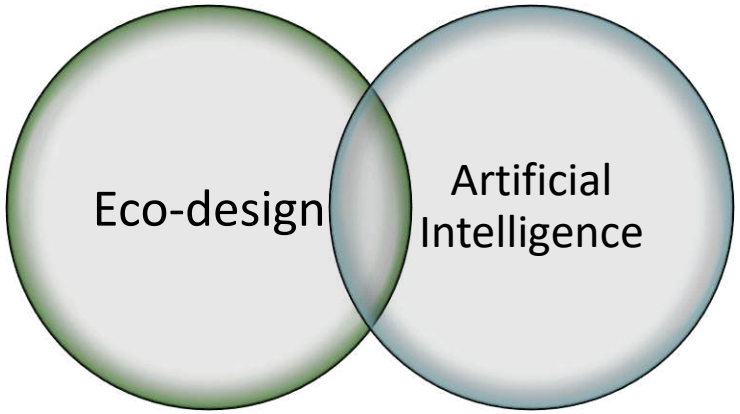
Circularity

personalized products

These concepts could be implemented via artificial intelligence (AI)

Literature Review

PRISMA systematic review



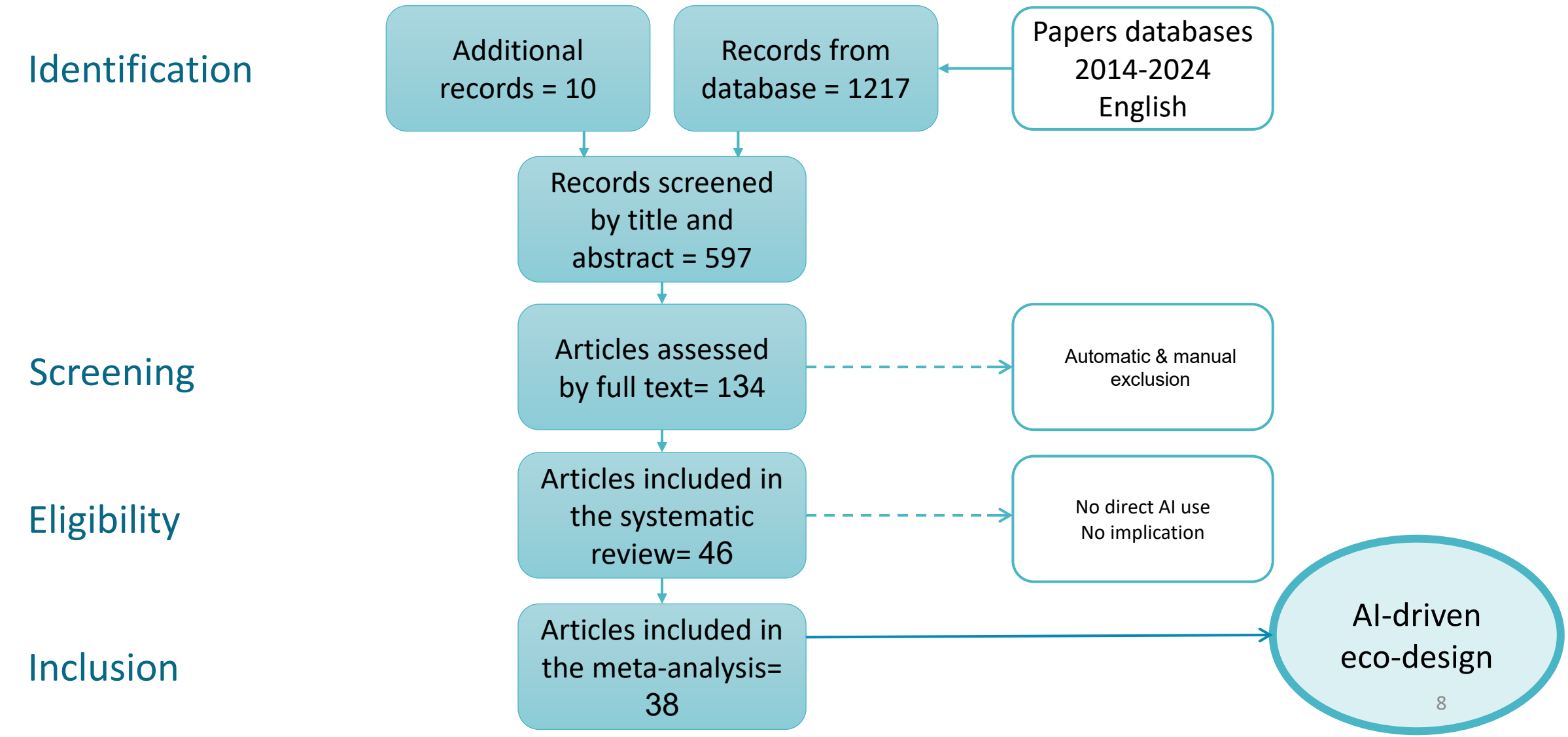
Eco-design keywords	("ecodesign" OR "eco-design" OR "green design" OR "circular design" OR "cradle-to-cradle design" OR design NEAR/1 sustainab* OR design NEAR/1 environment* OR "Eco-friendly Design" OR design NEAR/1 recycl* OR "design for energy*" OR design NEAR/1 disassembl* OR design NEAR/1 remanufactur*)
Operator	**AND**
AI keywords	("artificial intelligence" OR "machine learning" OR "neural network*" OR "deep neural network*" OR "reinforcement learning" OR "deep learning" OR "deep Q learning" OR "actor-critic" OR "DDQN" OR "data-driven" OR "large language" OR "LLM" OR "GPT" OR "transformer network" OR "attention mechanism" OR "multi-head attention" OR "vision language" OR "generative AI")

PRISMA systematic review

- Exclusions

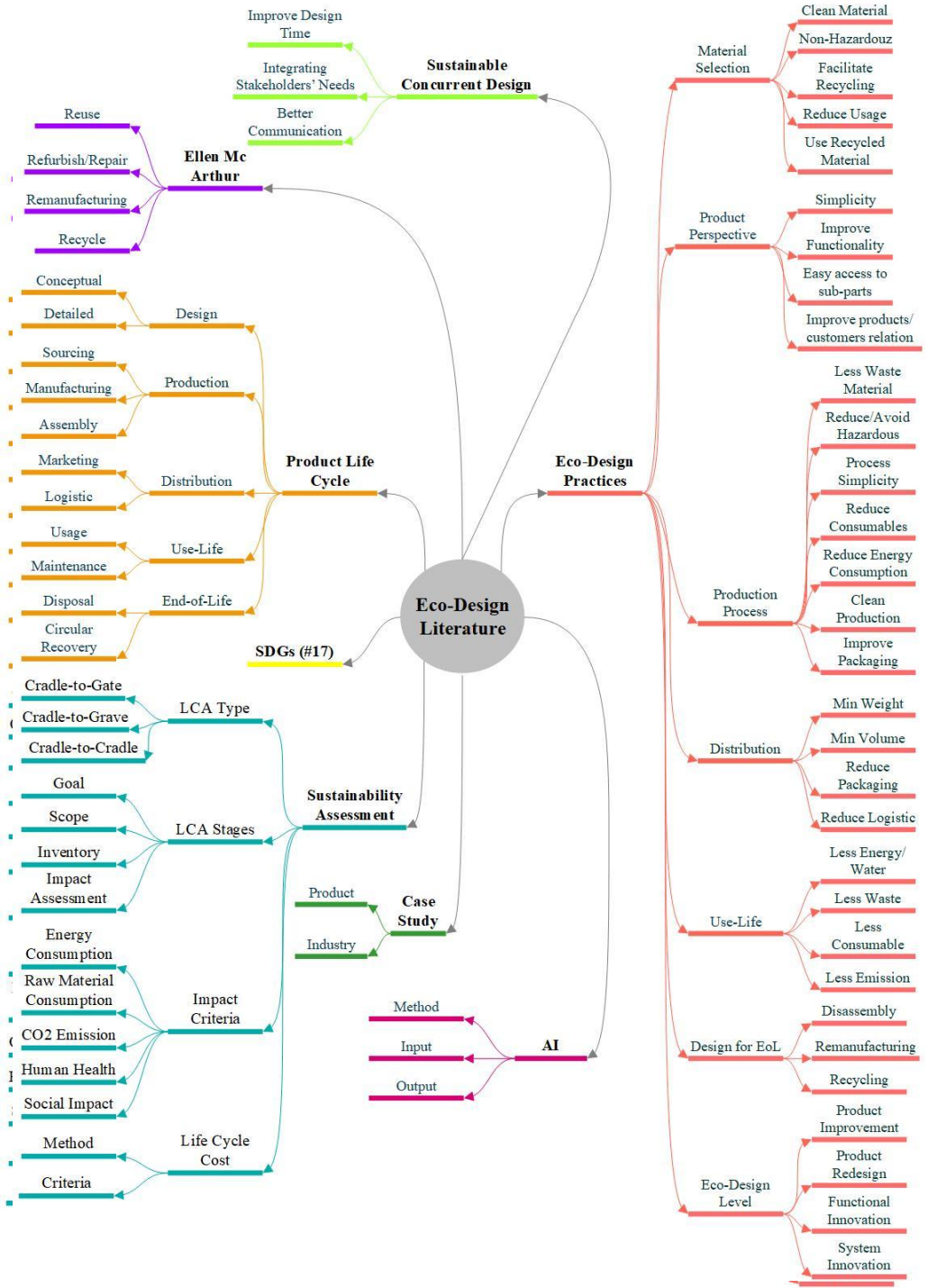
Automatically excluded	Manually excluded
- Intelligent building - Construction industry - Architectural design - Engineering Civil - Construction building technology - Architecture - Urban studies - Regional urban planning	- Social media - Agriculture - Waste management - Fuzzy - AHP - Computer vision - Image processing

PRISMA systematic review

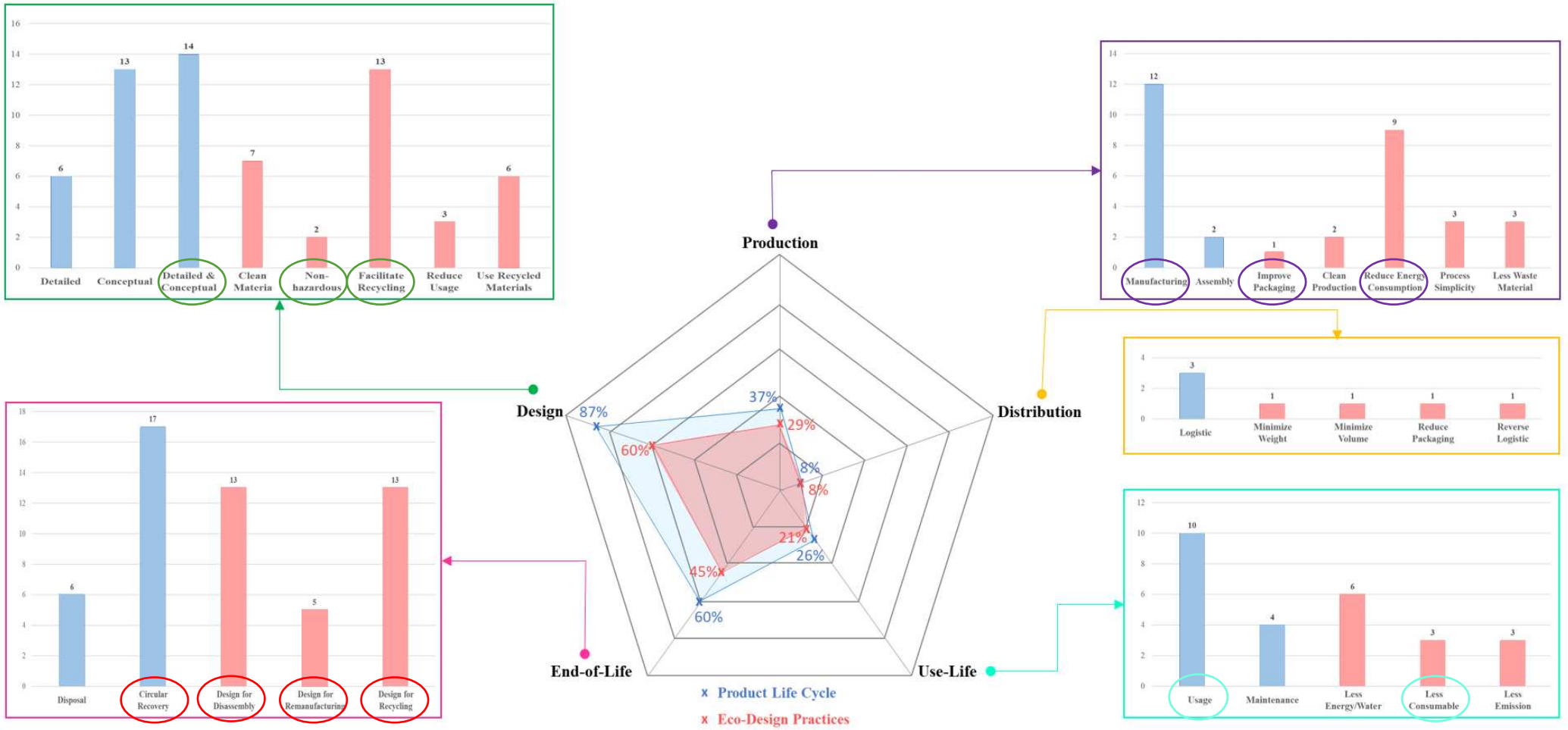


Papers classification framework

- Product life cycle (PLC)
- eco-design practices
- Sustainability assessment
- circularity (Ellen MacArthur principles)
- sustainable concurrent design
- Artificial intelligence (AI)
- case study
- sustainable development goals (SDGs)



Product life cycle and eco-design practices



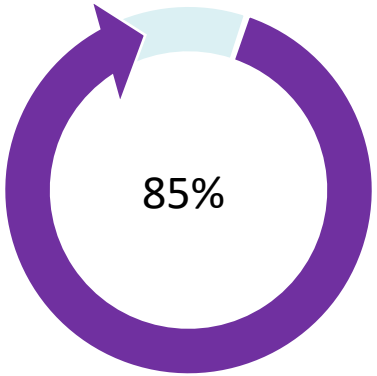
Product life cycle and eco-design practices

	Product life cycle										Eco-design practices						
Ref	Design		Production		Distribution		Use-life		EoL		Material selection	Product perspective	Production process	Distribution	Use-life	Design for EoL	Eco-design practices
	Conceptual design	Detailed design	Manufacturing	assembly	Marketing	Logistic	usage	maintenance	Disposal	Circular recovery	CM* NhM* FR* RU* URM*	IF* IPCR* MD*	IP* CP* REC* RC* PS* RH* LWM*	MW* MV* RP* RL*	LEW* LC* LE*	DfD* DfRem* DfRec*	PI* PR* FI* SI*
Penciuc et al.		✓	✓	✓						✓	URM		REC LWM PS	RL			
Bertoni Et al.		✓	✓				✓	✓		✓	CM URM		REC		LC LE		PI PR
Yang et al.		✓					✓	✓		✓					LC	DfRem	PI PR

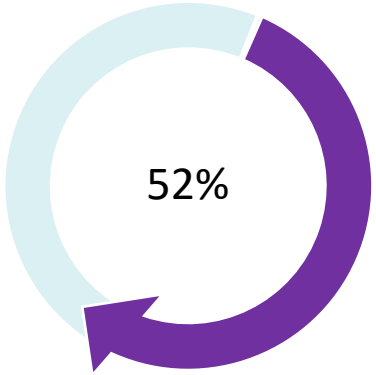
- No full life cycle coverage
- Heavy simulation and limited adaptability to real-world application

AI in eco-design

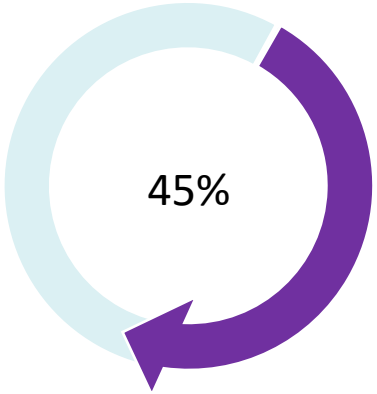
Product design
& manufacturing



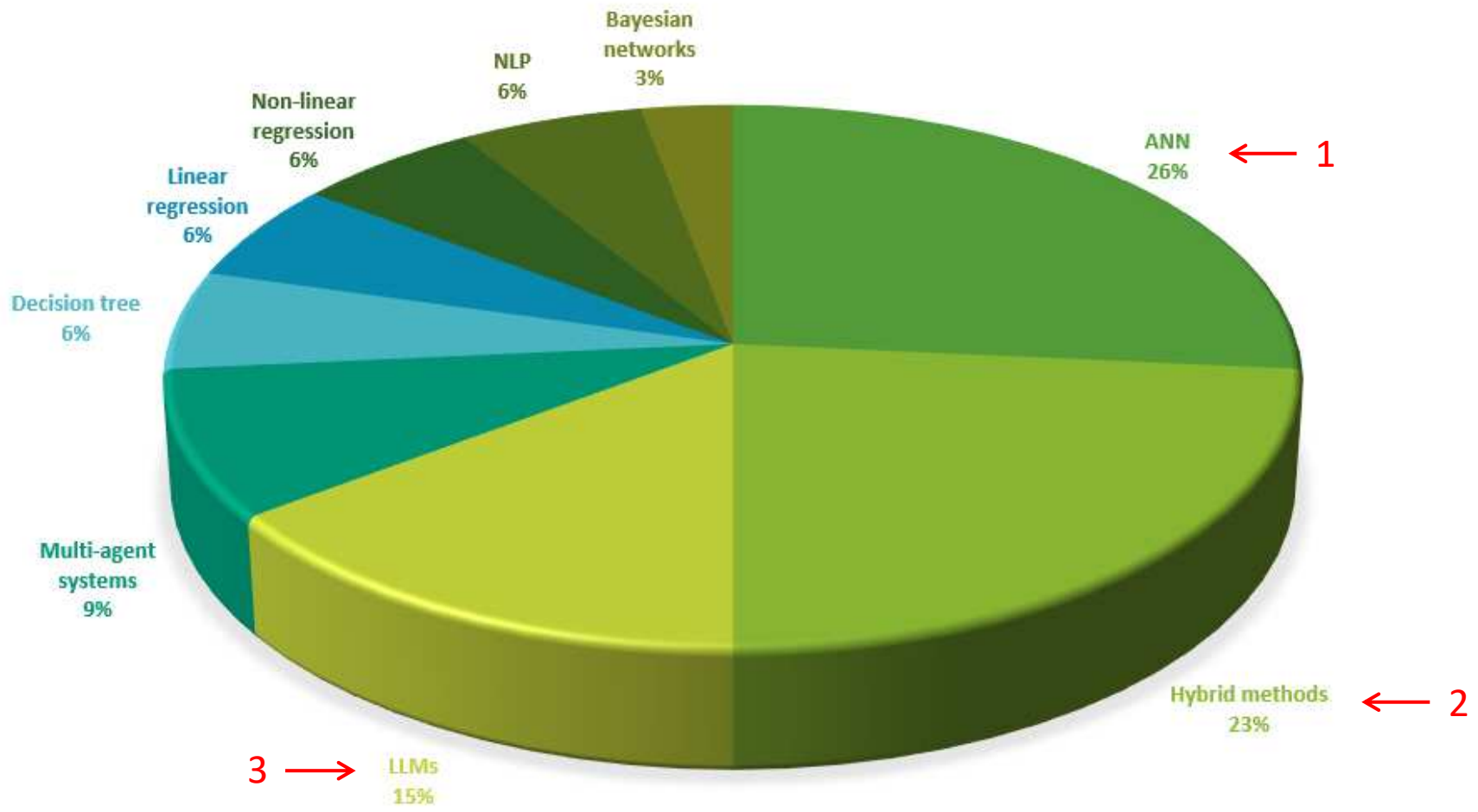
Circularity
Practices



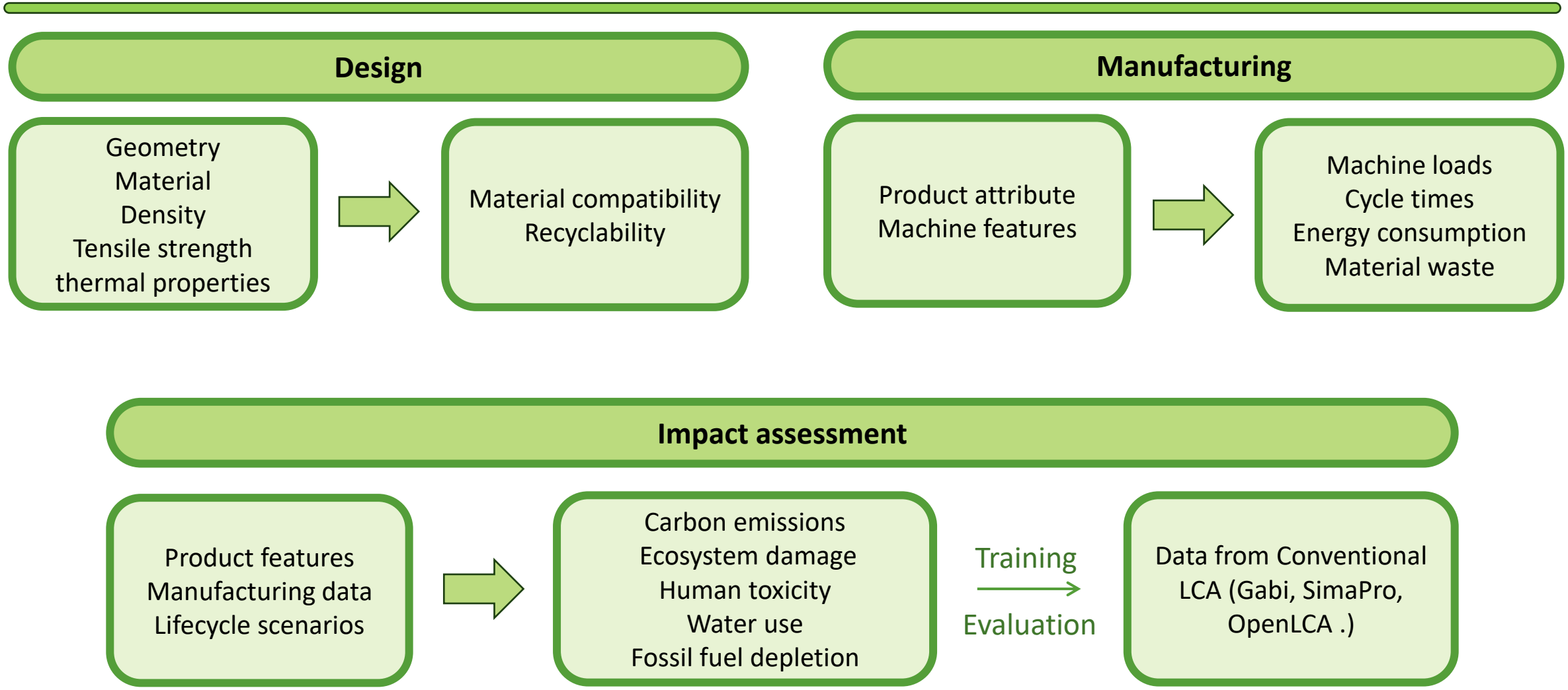
Environmental
Impact assessment



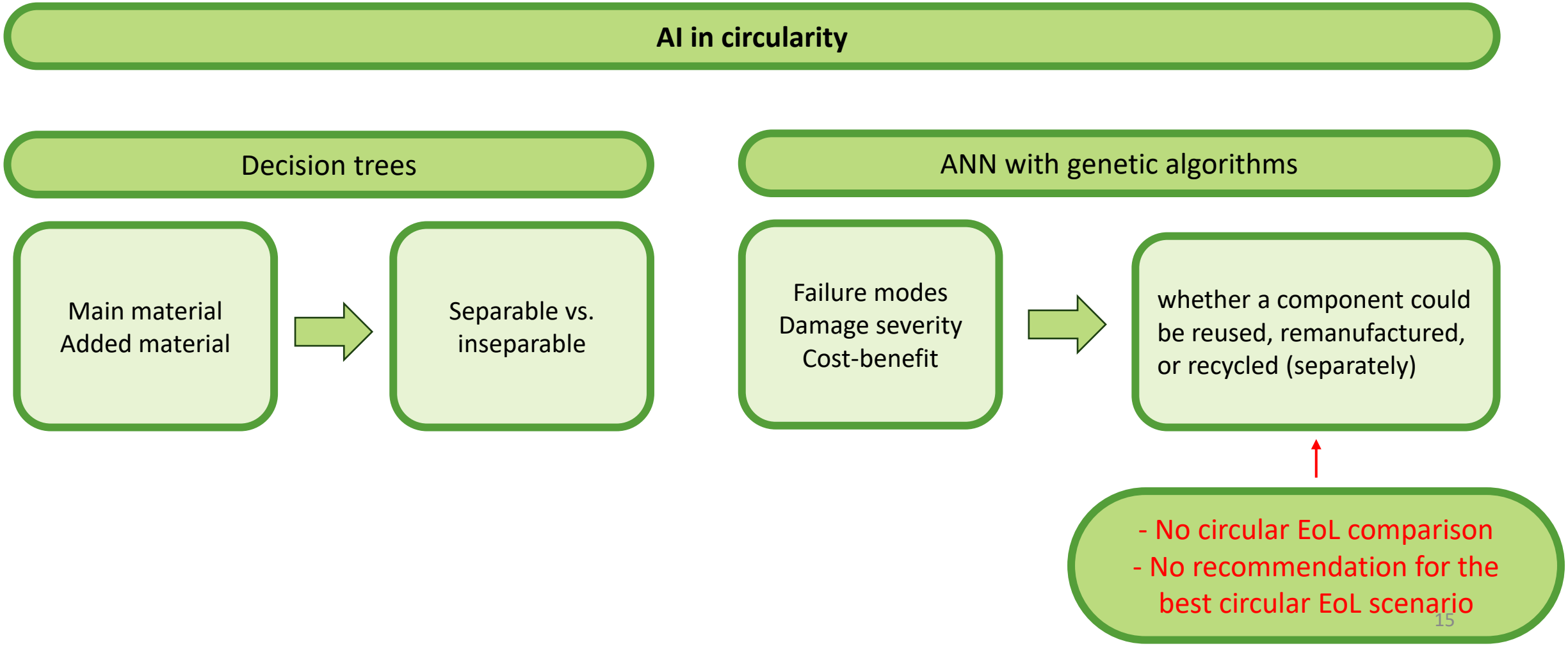
AI methods in eco-design



AI inputs & outputs in eco-design



AI in circularity

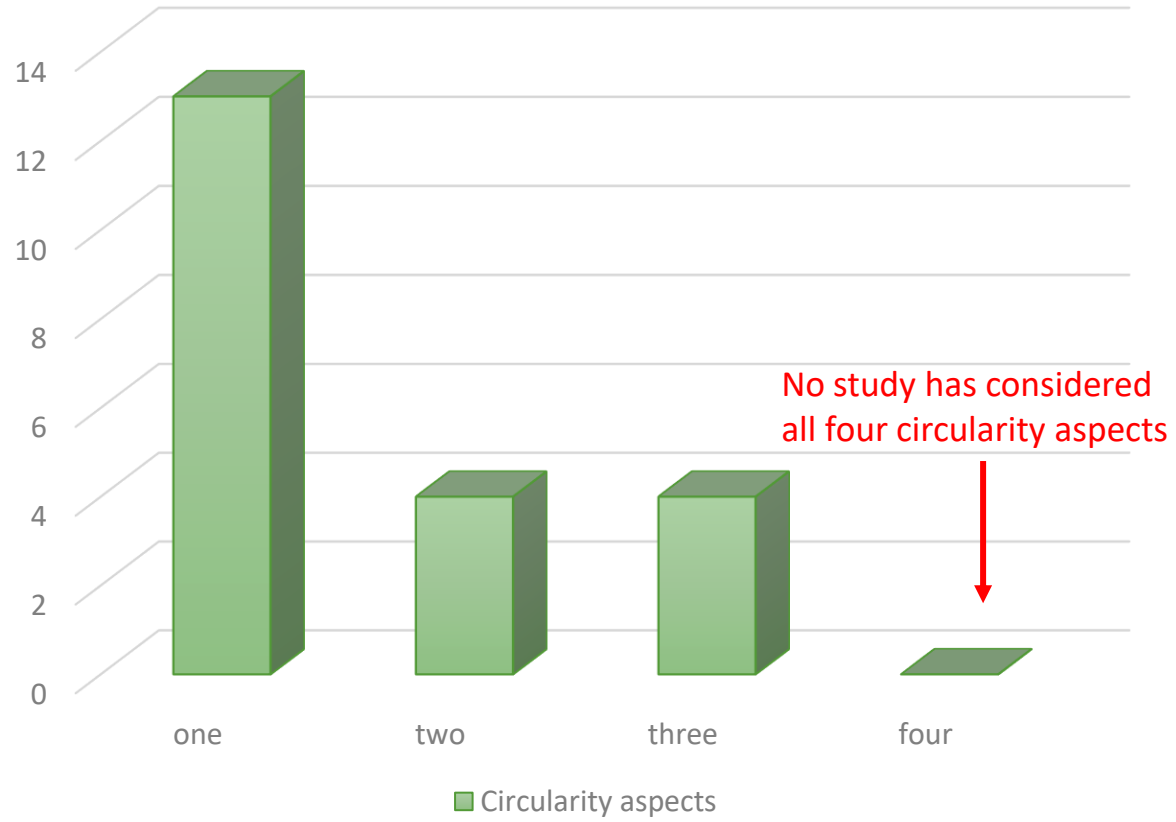


Ellen McArthur principals for Circularity

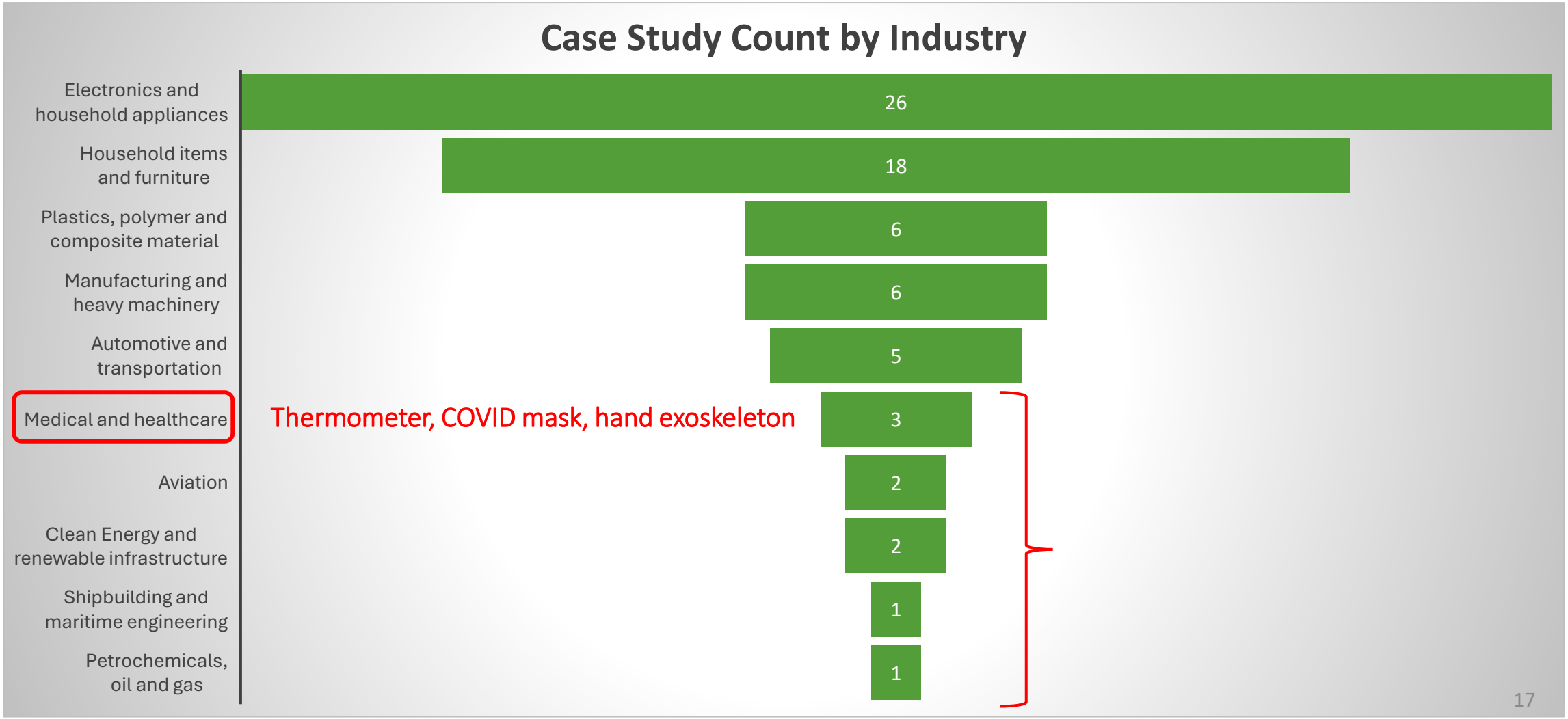
Ellen McArthur principals covered in each study

Ref	Reuse	Repair / Refurbish	Remanufacture	Recycle
[38]				✓
[37]	✓	✓		✓
[9]				✓
[28]				✓
[29]				✓
[35]				✓
[36]				✓
[25]				✓
[26]			✓	✓
[40]	✓		✓	✓
[27]				✓
[33]		✓	✓	
[34]	✓		✓	✓
[48]	✓			✓
[10]	✓		✓	
[14]				✓
[3]	✓			✓
[52]				✓
[1]				✓
[7]				✓
[57]				✓
[2]			✓	

Circularity aspects count by studies



Case studies



Research Gaps

Major Research Gaps and objectives

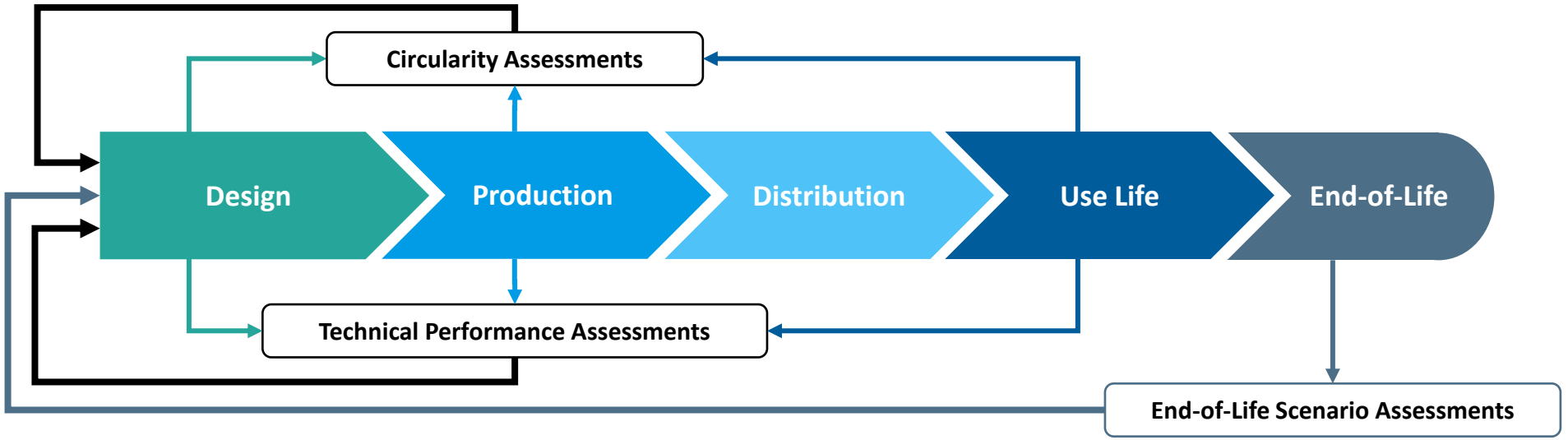
1. No full Life cycle stages coverage
2. Limited LLM applications
3. No full circularity aspect consideration
4. Limited health and medical case studies

1. Develop an eco-design framework for all PLC stages
2. Circularity ranking for different design alternatives
3. Design optimization via iterative feedback loops
4. Medical personalized device (AFO)
5. Automate framework via LLM

Solutions

Eco-design framework

- Full life cycle circularity framework



Case study

- Personalized modular ankle-foot-orthosis (AFO)







Case study

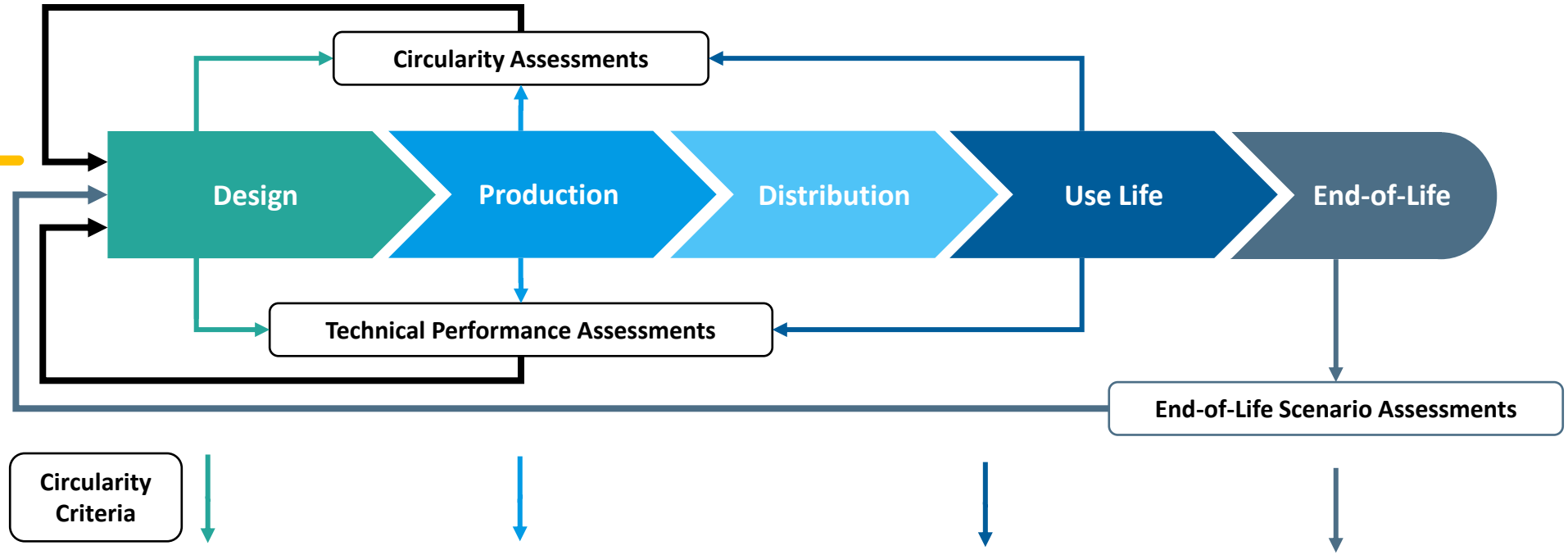
- Modular design

Module type	Examples
Common	Straps, fasteners
Customized	Rocker type, toe coverage
Personalized	Foot plate curvature



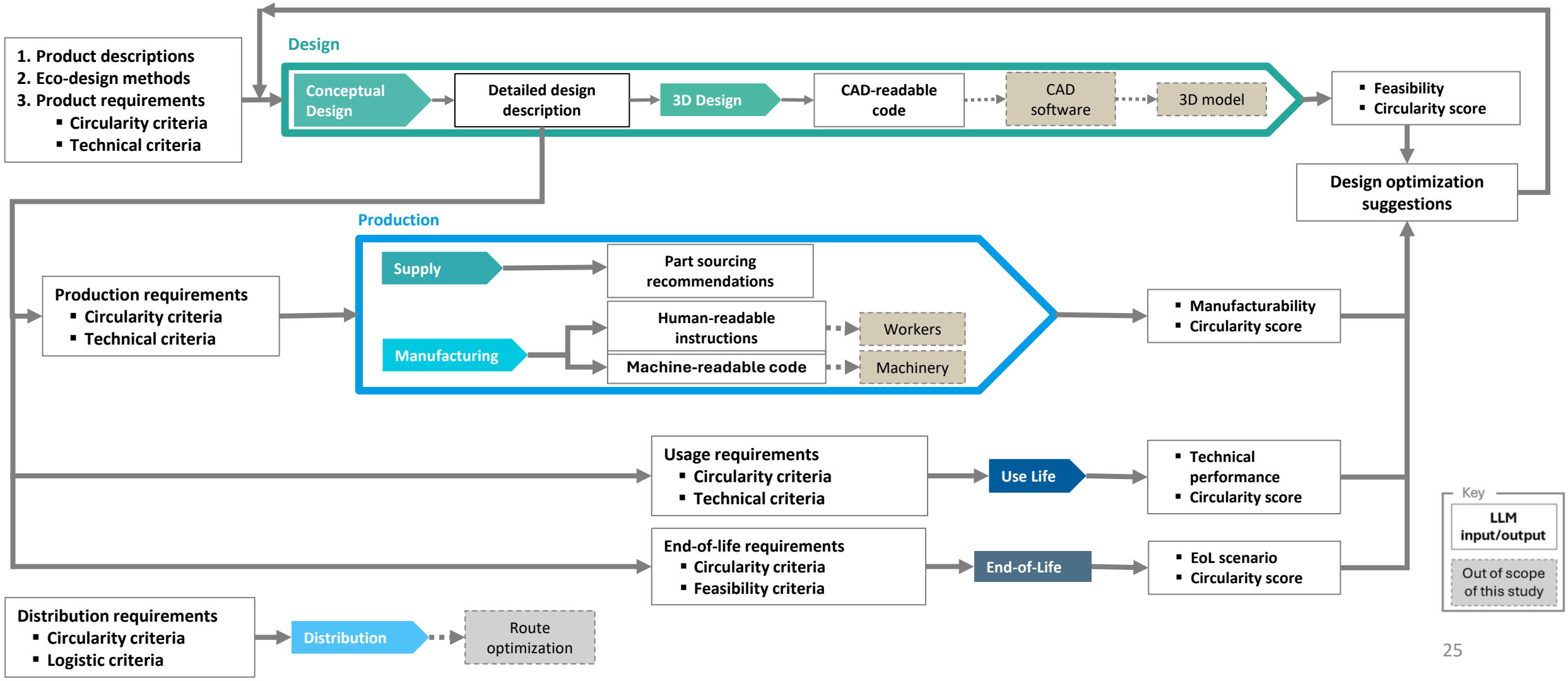
Circularity

- Circularity criteria for each PLC stage



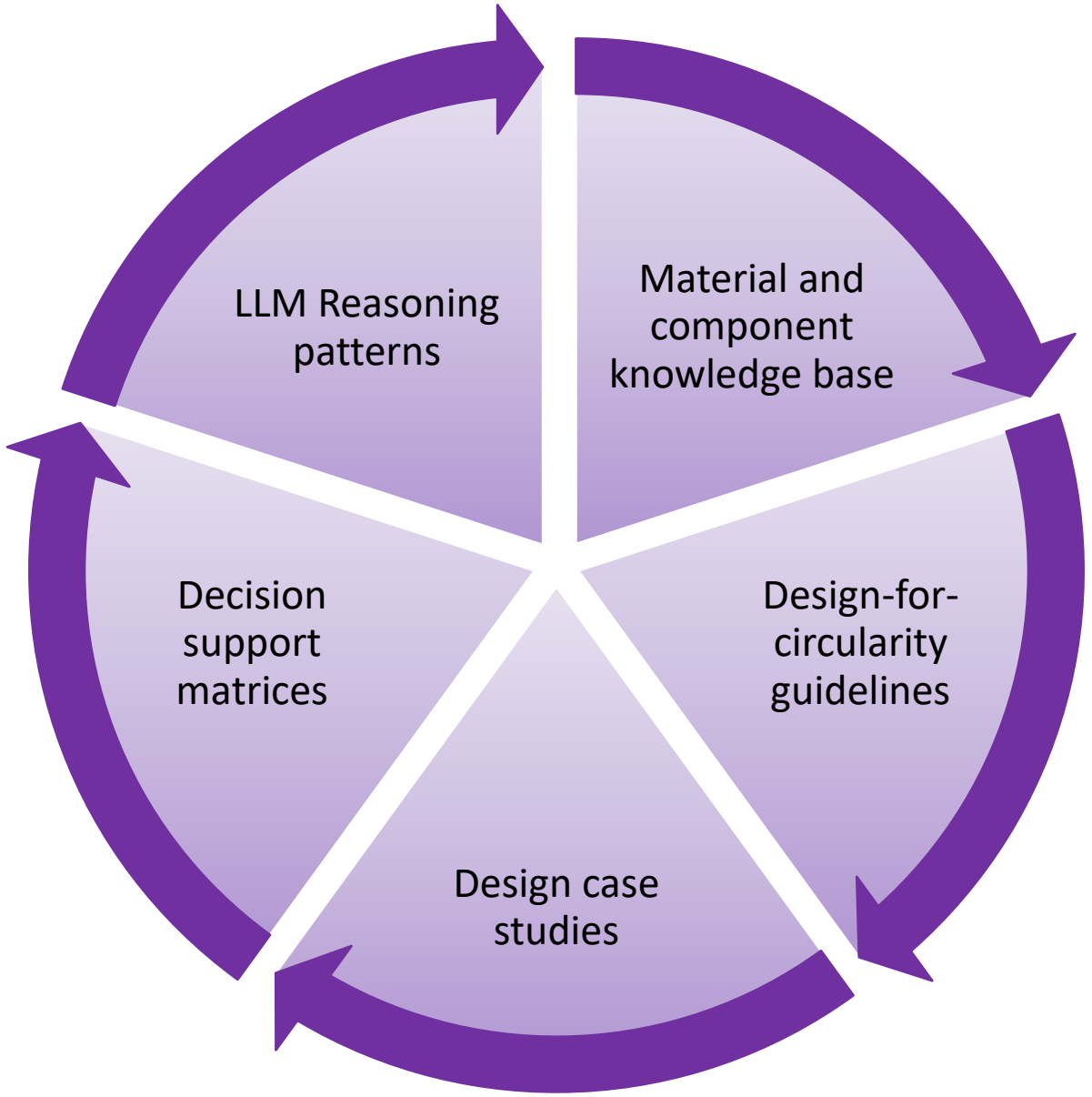
Design	Production		Use Life	End-of-Life
-Simplicity -Modular design -Easy access to sub-parts -Improve functionality -Improve products/customers relation -Clean Material -Non-hazardous -Facilitate Recycling -Reduce Usage -Use Recycled Materials	-Improve Packaging -Clean Production -Reduce Energy Consumption -Reduce Consumables -Process Simplicity -Reduce/Avoid Hazardous -Less Waste Material		-Less Energy/Water -Less Waste -Less Consumable -Less emission	-Design for disassembly -Design for recycling -Design for remanufacturing

LLM Prompt Inputs and Responses



Conclusion

- Prompt library



Thanks for your attention