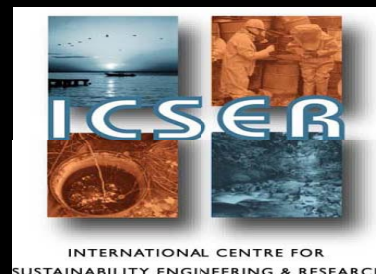


# Integrated Model for Assessing Sustainability of Complex Systems

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# Methodology


**Step 1:** Review complex systems literature to identify significant characteristics of complex systems = Criteria




**Step 2:** Use identified criteria to evaluate existing sustainability assessment methods and models



**Step 3:** Identify the most suitable existing methods with respect to the abilities of the methods to take the identified criteria into account



**Step 4:** Develop a new model for assessing sustainability of complex systems by combining the most suitable methods



**Step 5:** Test the model on case study product systems

# Step 1: Complex Adaptive Systems (CAS) review

- A complex system consists of large populations of independent, interacting and self-interested agents where behaviour of the whole cannot be explained by the behaviour of the individual parts (Sawyer, 2005).
- A Complex Adaptive System (CAS) is a system that is complex and adaptive giving it the ability to change and learn thus increasing chances of its survival.
  - The Earth system is an example of a CAS (Holland, 1995), and organisations are CAS within the Earth system (Waldrop, 1992).

# Sustainability of CAS

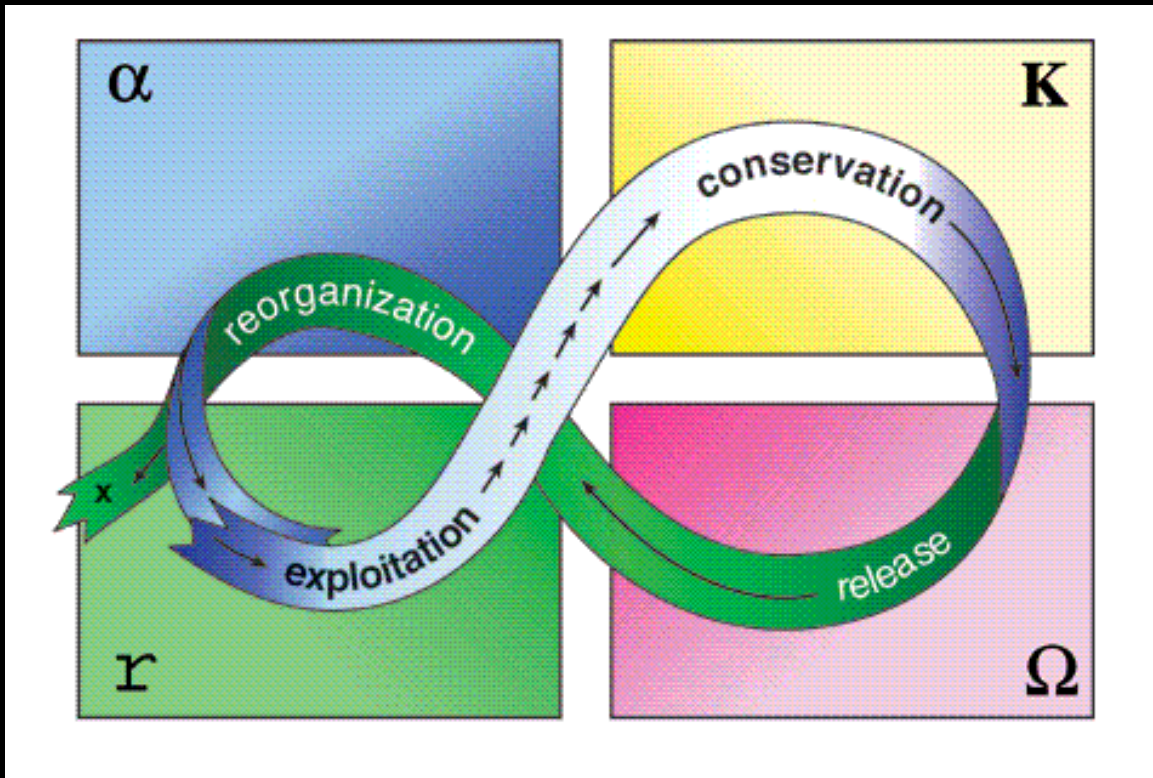
- “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987, p. 43).
- Sustainability of CAS depends on our understanding of how the complex systems function with their numerous and various interactions and interconnections.

# Properties of Complex adaptive systems

- Diversity
- Nonlinearity
- Dynamic
- Connectivity
- Self-organisation
- Emergence
- Co-evolution
- Resilience
- Holism

# Adaptive Cycle

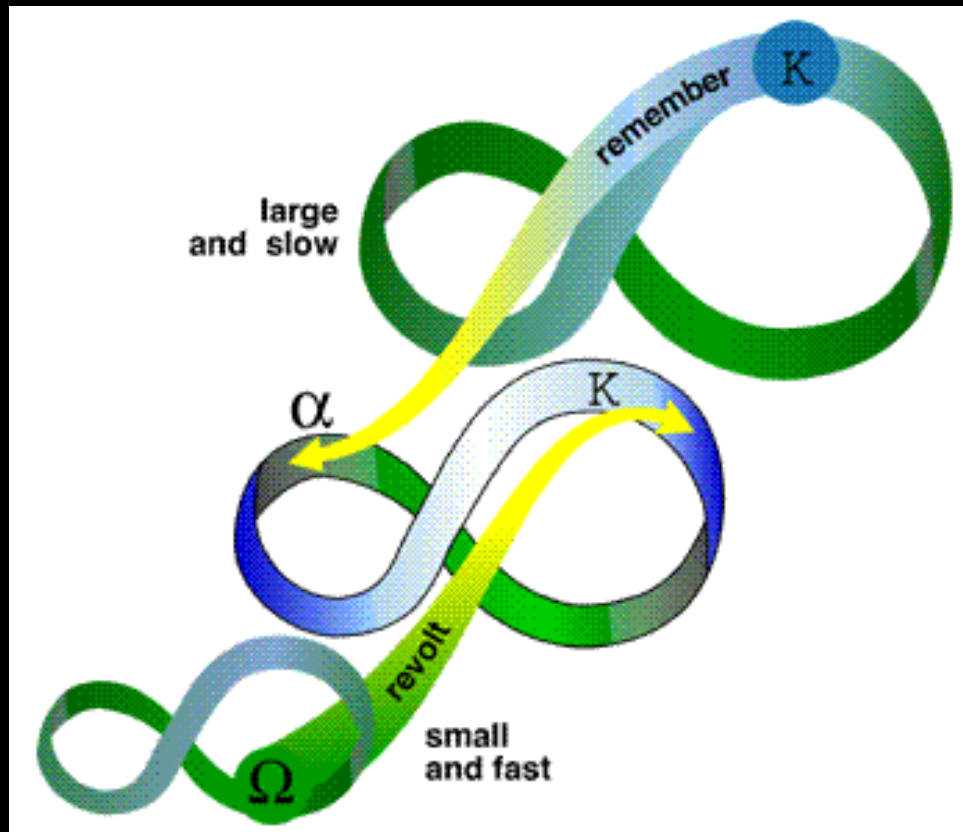
- “Fundamental unit of dynamic change”  
(Gunderson and Holling, 2002)



(Image: Holling, 2007)

# Panarchy

- Behaviour of adaptive cycles nested hierarchically within each other - interconnectedness





# Step 1 results: Criteria

- Take complexity of the system into account by:
  - Recognising the existence of multiple agents and system levels;
  - Recognising interconnections and interdependencies;
  - Taking system dynamics into account (time and space);
  - Recognising system limits or thresholds;
  - Recognising resilience and adaptive capacity; and
  - Being holistic; and
- Be based on science where appropriate
  - Help achieve scientific validity.

# Step 2: Sustainability Assessments

- 26 existing sustainability assessment methods were evaluated

Basic analytical methods	Integrated methods	Indicators	Tools for sustainability
Emergy	Triple Bottom Line	Well-being Index	Life Cycle Assessment
Exergy	The Natural Step	Sustainability Performance Index	Life Cycle Costing
	Sustainability assessment by fuzzy evaluation (SAFE)	Living Planet Index	Social Life Cycle Assessment
	Ecosystem Resilience	Product Sustainability Index	Risk Analysis
	Barometer of Sustainability	Environmental Sustainability Index	Critical Limits and Critical Natural Capital
	Ecological Footprint	Genuine Progress Indicator	Cost Benefit Analysis
		Genuine Savings Indicator	Multi-Criteria analysis
		Human Development Index	
		Sustainable Process Index	
		Carbon/water Footprint	
		Dow Jones Sustainability Index	

# Evaluating Sustainability Assessments

- The results of the evaluation showed that:
  - The existing assessment methods or models were well adapted at assessing what they were designed to assess.
- However...
  - Most existing methods did not take the criteria into account and hence were unable to assess sustainability of complex systems

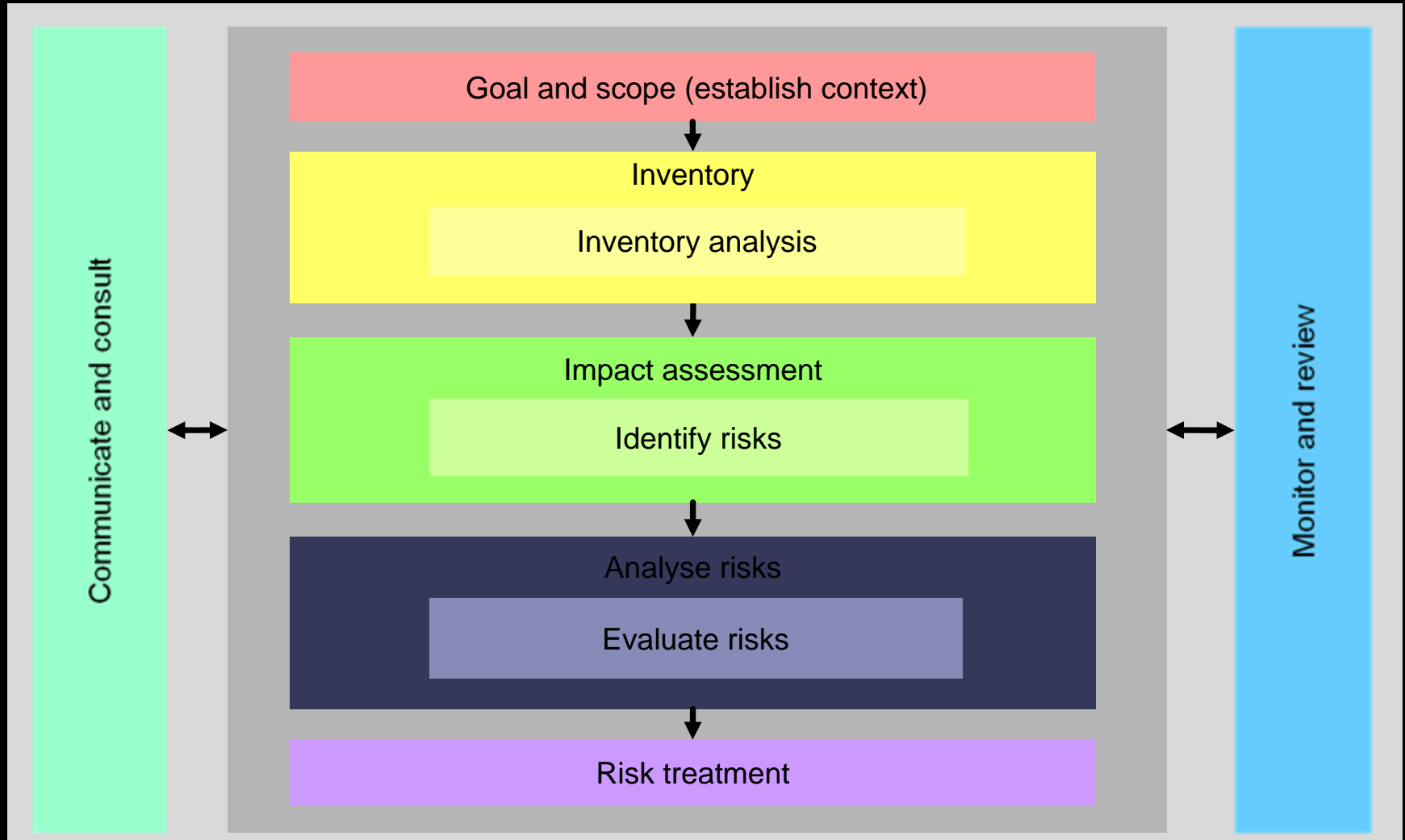
# Step 3: Suitable existing methods

- LCA and RA were chosen because:
  - They are both analytical tools and can be used to assess for the sustainability criteria identified ;
  - They have sufficient readily available literature and support including respective academic journals;
  - The assessment methods have been standardized;
  - Databases exist;
  - Both assessment methods have been standardised;
  - Both methods can be used to influence the future;
  - The methods and results are widely communicated and accepted; and
  - The methods have the necessary characteristics to be integrated where the two methods can complement each other.

# Step 4: New Model

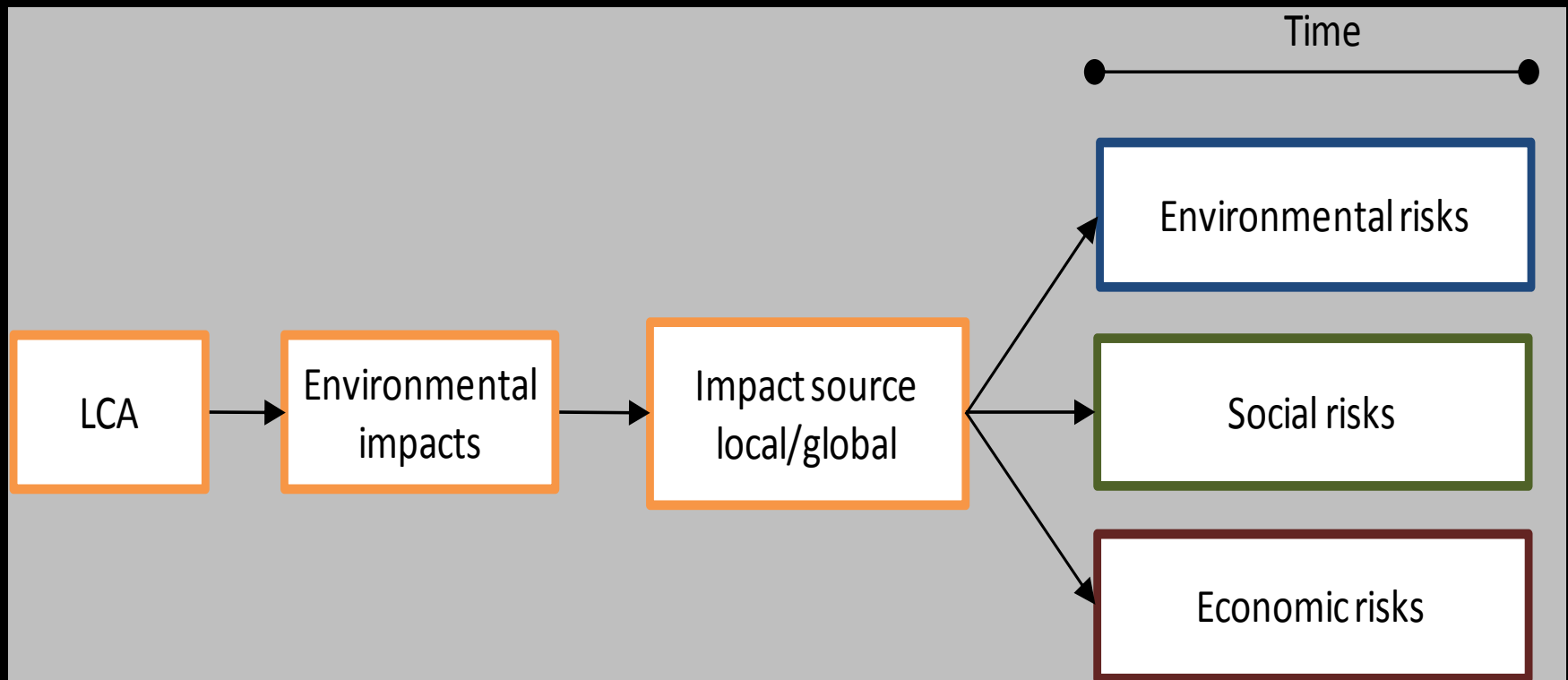
- Integration of LCA and RA can be carried out in numerous ways.
- For the resulting model to be fully integrated, components of both methods should connect seamlessly.
- The existing frameworks for both models assist in this procedure.

# Step 4: New Model

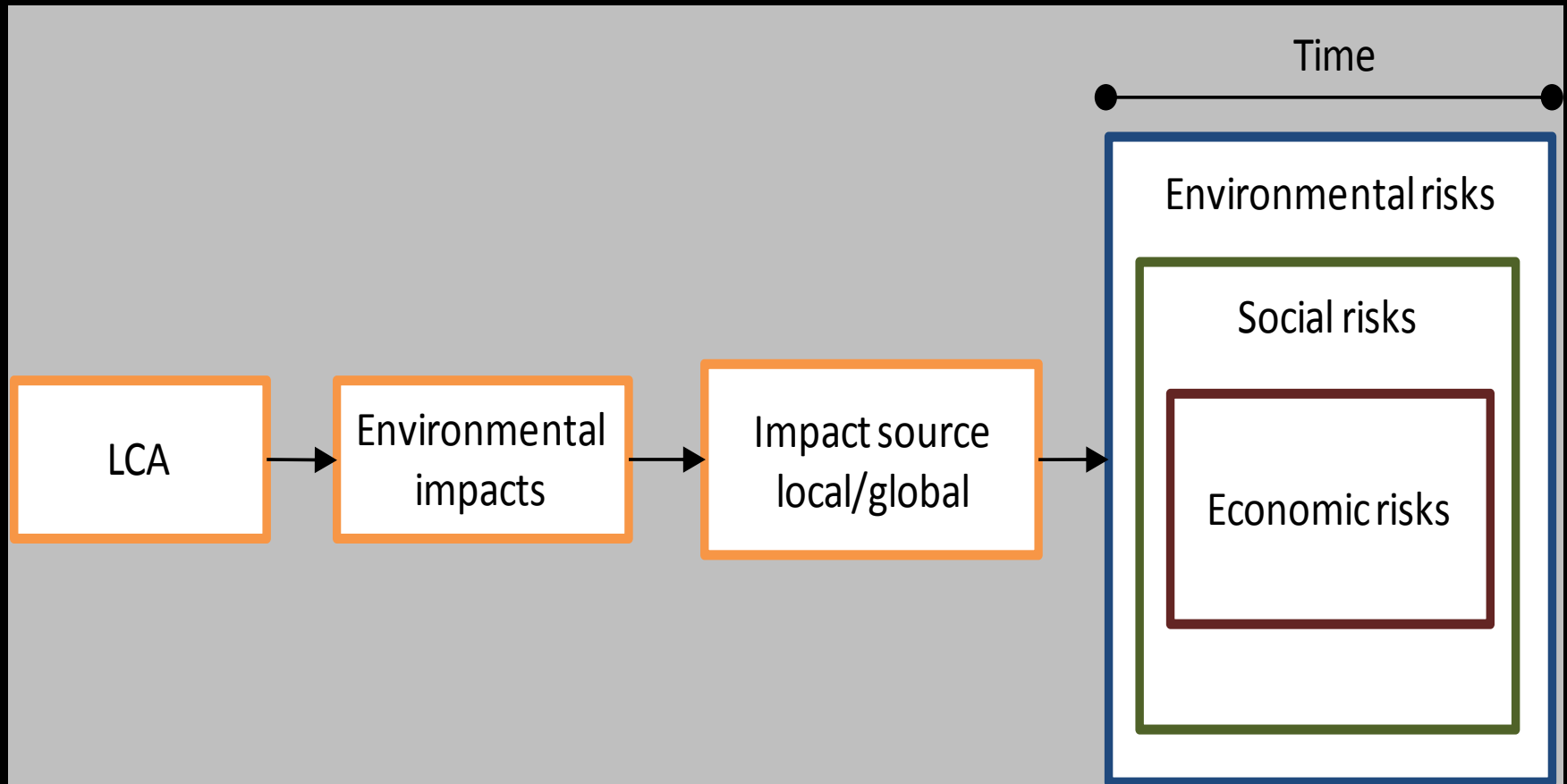


# The model: Streamlined

- Streamlined sustainability assessment – reduced to three systems



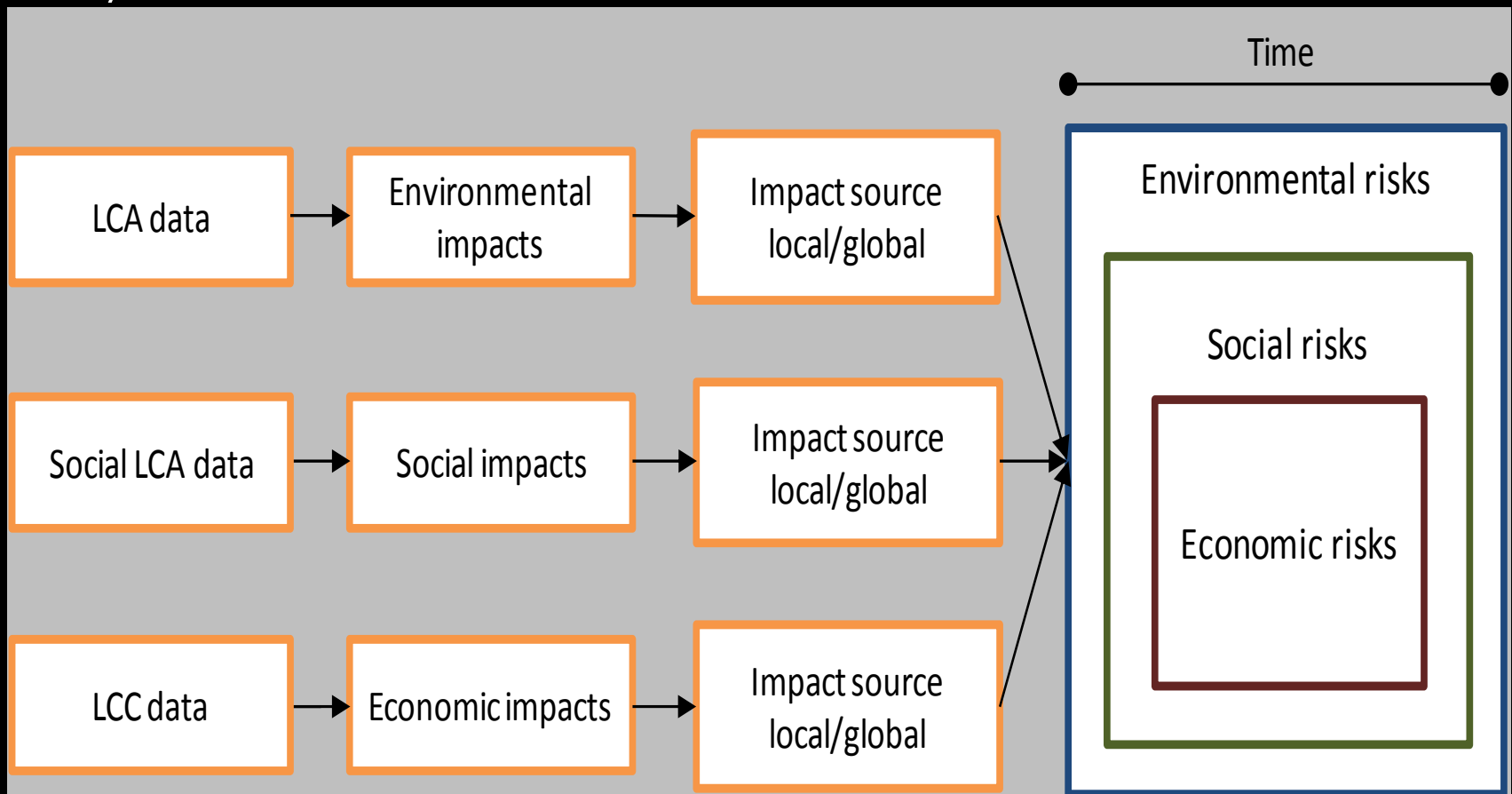
# The model: Streamlined





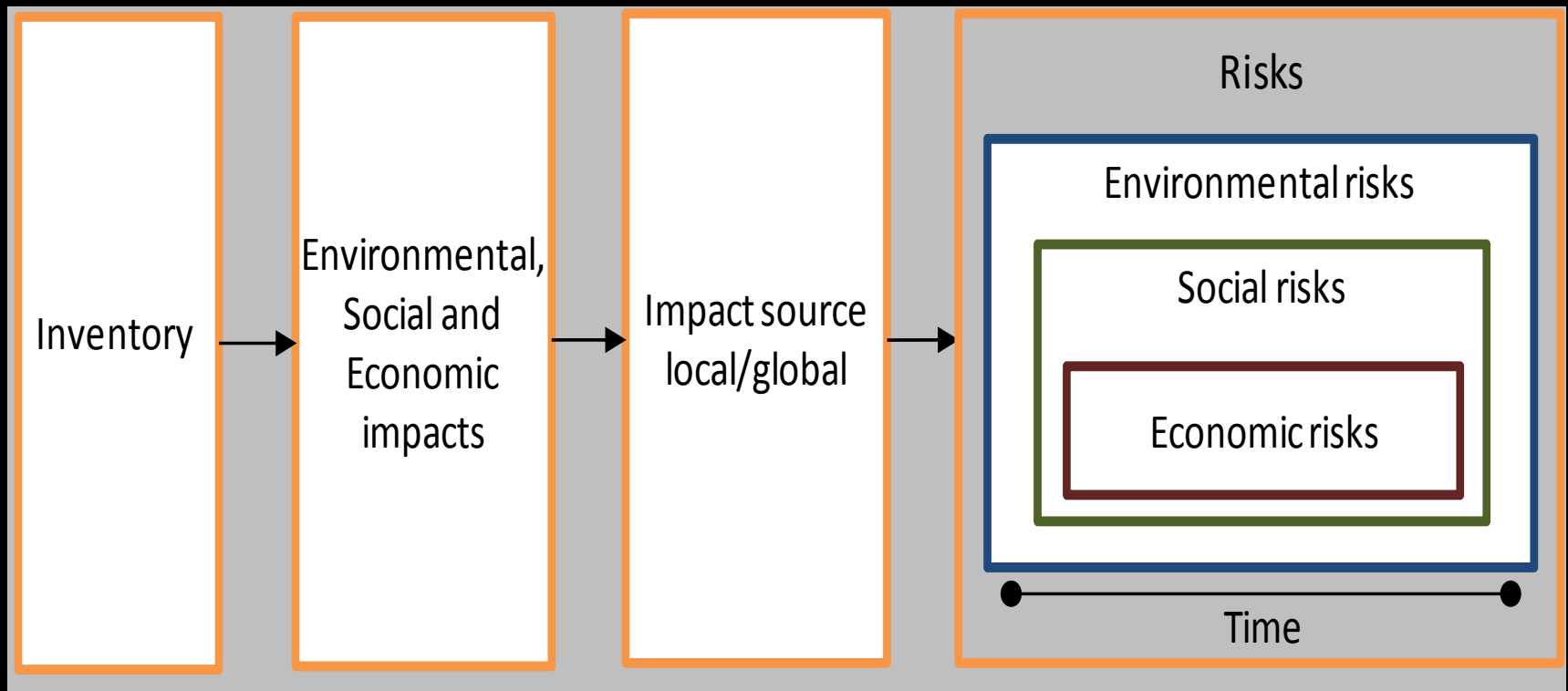
# The model: Streamlined -> Complete

- Sustainability assessment comprised of streamlined assessments per system



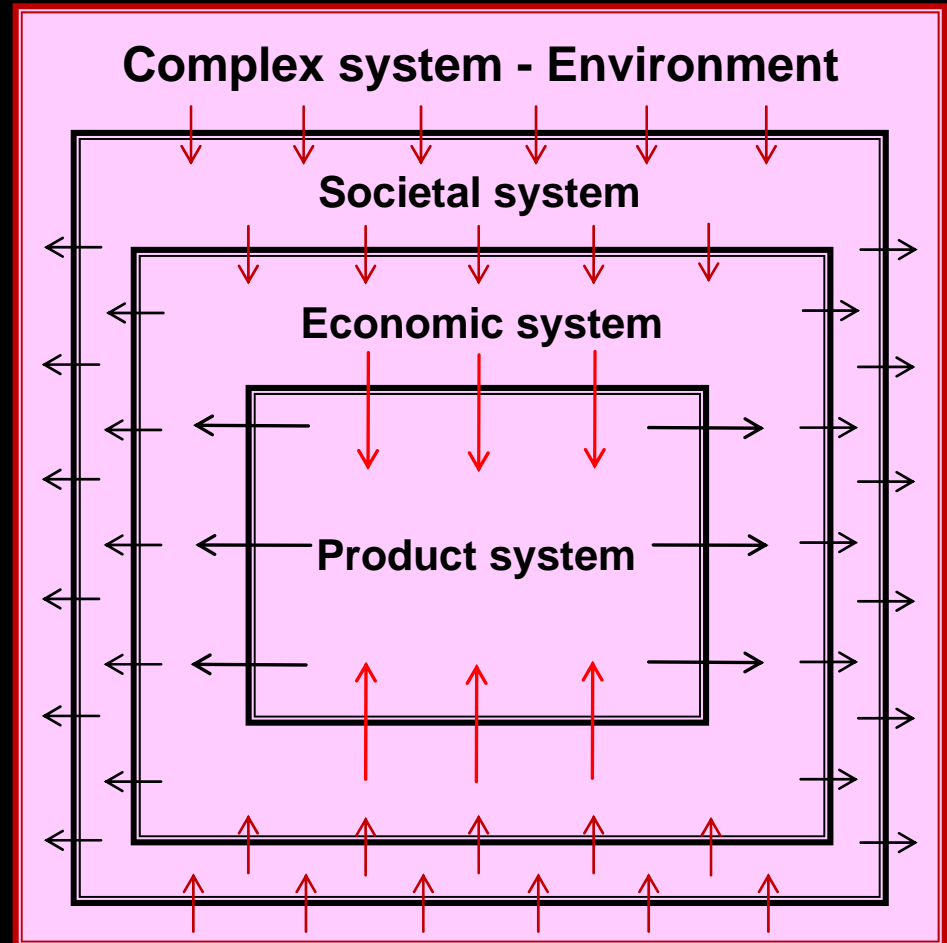
# Complete sustainability assessment

- In order to obtain a complete sustainability assessment, integration at each phase is required

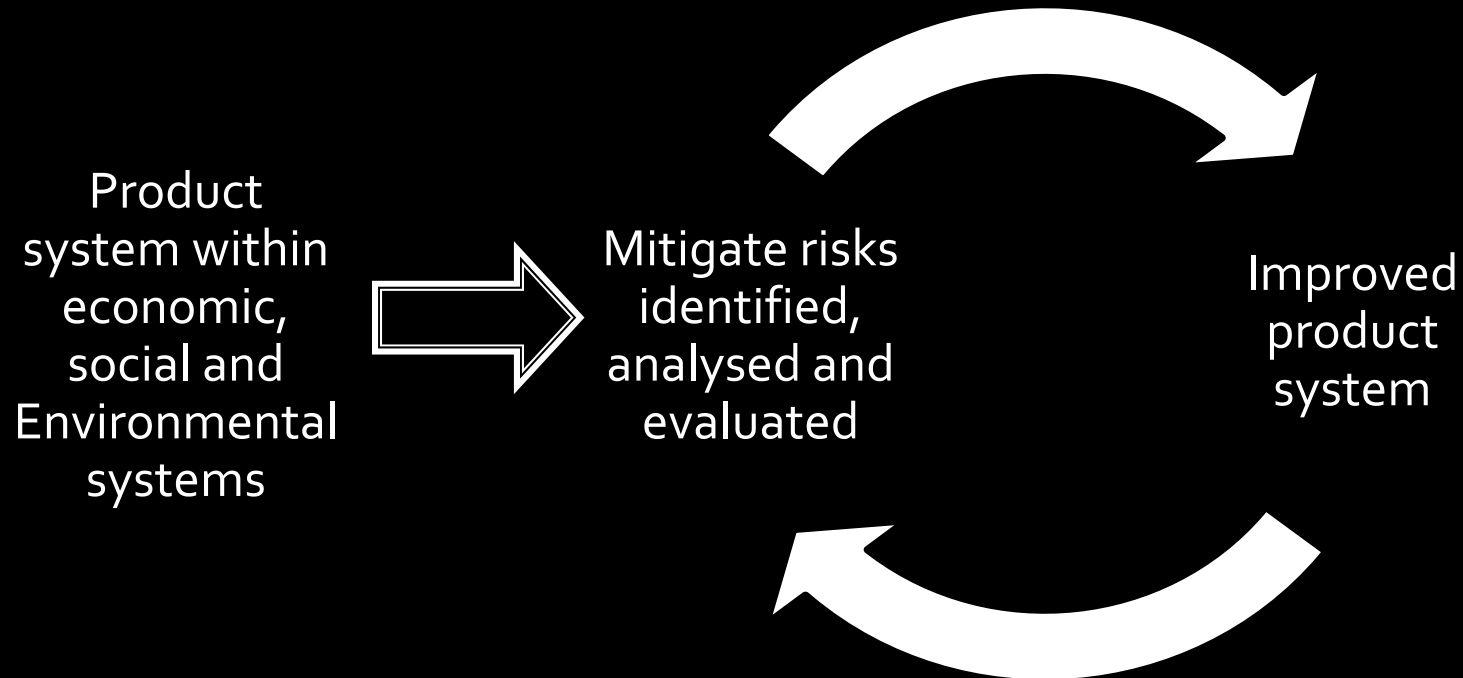


# Findings: Levels of risk

1. Risks from smaller lower level systems (micro level) - risks within the product system as well as risks to the product system from systems below;
2. Risks from the larger upper level systems (macro level); and
3. External risks from random disasters – risks from emergence.



# Risk - sustainability



# Conclusions

- LCA and RA have the ability to take sustainability criteria into account.
  - The hybrid model developed uses results from one component as input for the other and can be implemented on product systems, designs, etc.
- The model can be used as a streamlined version or more holistic (complete) version incorporating environmental, social and economic systems as per the strong sustainability concept.
- Treatment of risk may be instrumental in sustainability of product systems.
  - The different levels of risk that needs to be treated for sustainability correspond with the concept of panarchy.

# Future Work

- Future work may be based on empirically testing whether treatment of risk identified by the model would lead to sustainability of a CAS such as a product system.
- Development of software for the hybrid method.
- Application of the method on different systems.

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# Question Time

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# Thank you!