Digitalisation as threat to resilience: what if there are no more semiconductors?

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ICTs: the present, the future and a driver of transition

- Present: ICT in every economic sector
- Future: ICT keeping growing + ICT as a driver to transition

Figure: Some future ICT benefits according to[GeSI, 2015].

Can ICT solve all problems?

3 important criticisms:

1. The environmental damages related to ICT are not so easy to manage
   - Rebound Effect [Bol et al., 2021]
   - Impact shifting
2. The social injustices related to ICT
   - Armed conflict in global South (e.g. in Democratic Republic of Congo) [Maenda Kithoko, 2023]
   - Precarious digital labour [Casilli, 2019]
   - Traffic of e-waste from the global North to the global South [Baldé et al., 2022]
3. ICT as threat to resilience

What is resilience?

Resilience

Ability of a system to

1. Absorb and resist adverse events,
2. Quickly recover from failure and
3. Evolve in front of a changing environment.[4]

Vulnerability **[∼ the opposite of resilience]**:

> *"The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt." – [IPCC, 2014]*

[4] See [Qi and Mei, 2023][Hosseini et al., 2016], [Sterbenz et al., 2010] for review and definition with a focus on engineering system and ICT networks.

Academic research about resilience?

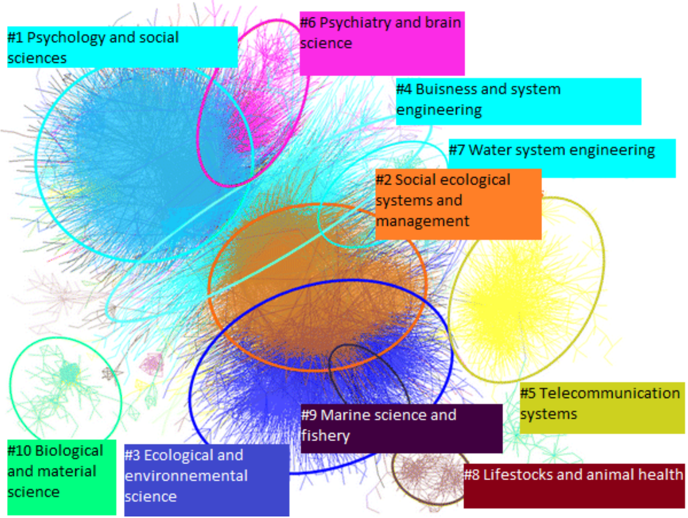
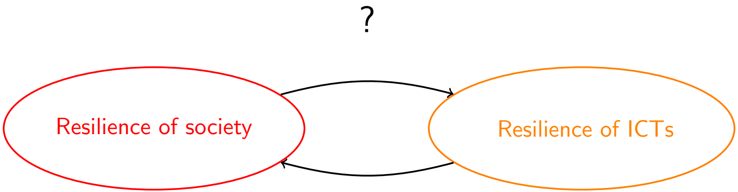


Figure: Adapted from [Xu and Kajikawa, 2018]

Resilience of what?



What is the link between research on resilience of ICT and resilience of society?

Resilience among ICT research communities

- Research focuses on [Sterbenz et al., 2010]:
  - Internal errors (fault-tolerance, dependability, availability, reliability)
  - Random adverse environment events (traffic tolerance, disruption tolerance)
  - Natural disasters (survivability)
  - Malicious attacks (security)

[Sterbenz et al., 2010] is a reference article that provides a summary of disciplines, axioms and principles involved in resilience of Communication networks.

Some principles for resilient communication networks

- Normal behaviour knowledge (P2) Knowledge of the expected behaviour of the system when there are no challenges and errors.
- Complexity management (P7) Control of the level of complexity.
- Diversity (P12)

  > *"Diversity consists of providing alternatives so that even when challenges impact particular alternatives, other alternatives prevent degradation from normal operations. " - [Sterbenz et al., 2010]*

  Example: n-version programming.
- Evolvability (P17) Ability to evolve in front of a changing environment.

Resilience of ICTs, and then?

Research mostly focuses on resilience of ICTs systems in isolation.

Exception: research related to ICT and natural disasters.

- Adaptation measures for more resilient ICT infrastructures in front of natural disasters amplified by climate change [Yang et al., 2018, Ali et al., 2021].
- ICT solutions for management of natural disaster situations (e.g. portable cellular network based on a group of drones [Ishigami and Sugiyama, 2020] [Hayajneh et al., 2016] [Naqvi et al., 2018])

Research about ICT in a resilient a society

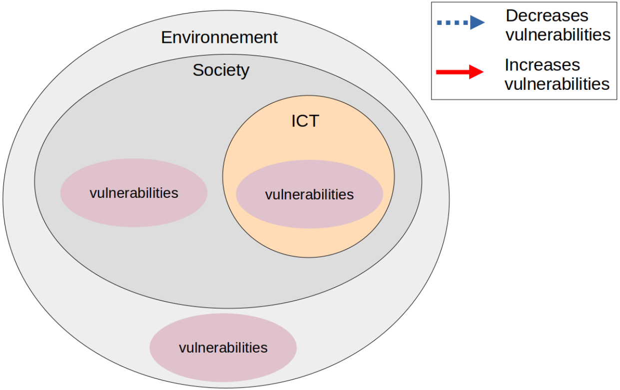
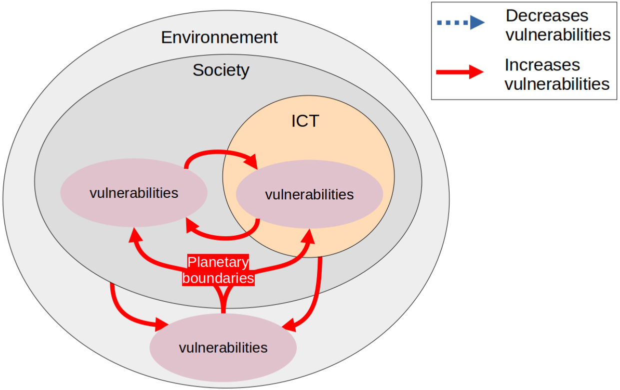


Figure: Schematic representation of research subjects related to ICT, resilience and sustainability. Inspired by the *strong sustainability* concept (see [Ruggerio, 2021]).

Research about ICT in a resilient a society



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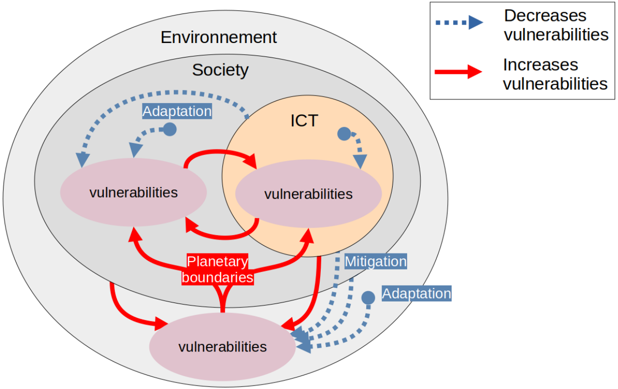

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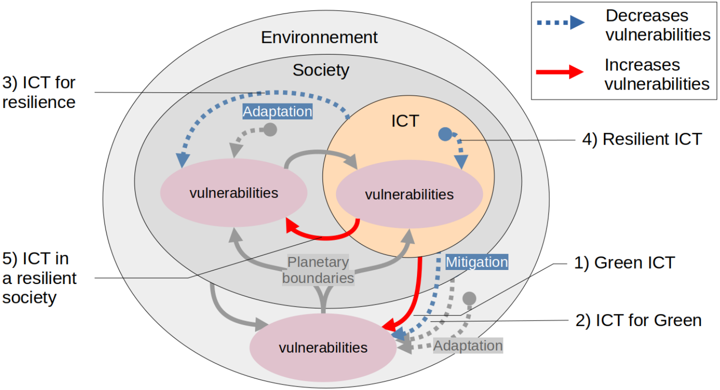

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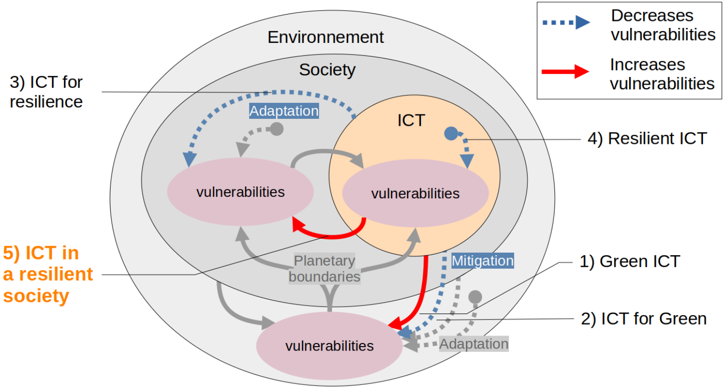

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→ Study how the vulnerabilities of ICT may impact the resilience of our societies.

Why study the impact of ICT vulnerabilities at a larger scale?

Based on the principales from [Sterbenz et al., 2010] previously presented:

- Resilience issues of systems relying on ICT:
  - Lack of diversity in the nature of tools
  - Lack of normal behaviour knowledge
  - Additional complexity
  - Dependence to ICT: evolvability outside of ICT reduced

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- Resilience issues of the ICT value chain: complexity, a lack of transparency on the involved flows and a lack of diversity in its actors and geography.

Thus, ICTs value chain have vulnerabilities and our extensively digitalised societies may be very sensitive to failures in ICTs.

Our research topic

Our research topic: the resilience of cellular networks under long term limitations on semiconductor availability.

Research questions:

- What would be the consequences for mobile networks of a long term semiconductor shortage leading to the nonreplacement of ageing hardware?
- What level of quality of service could be maintained and for how long?
- What network guarantees would we need to ensure the resilience of our societies?

→ These questions require a systemic approach.

- Combination of mobile network modeling and evaluation tools with STS methods such as socio-technical survey.

Conclusion

- We aim at studying how the vulnerabilities of ICT may impact the resilience of our societies.
- We believe that addressing resilience issues is complementary with studying environmental impacts and social injustice to underline the risks and drawbacks of ubiquitous digitalisation.
- ICT resilience and its consequences under long-term semiconductor scarcity is one example of the type of research the ICT community could tackle.

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Impact Shifting

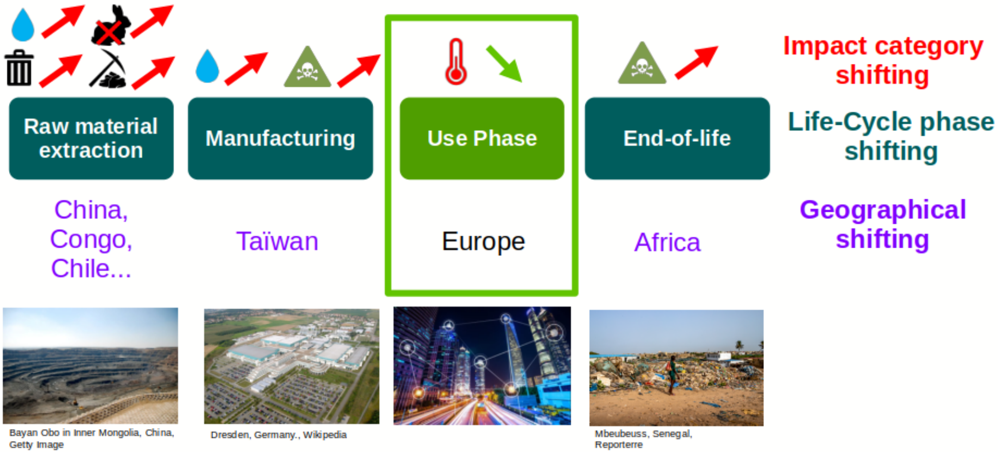

Figure: Illustration of impact shifting

Diversity (P12) 1/2

1. **ICT everywhere = lack of diversity in the nature of our tools.**
   (systems relying on ICT)
   - A semi-conductor shortage may have a global and huge impact on economy. [Voas et al., 2021][Dachs, 2023]
   - At smaller scale, fully-digital services act as single points of failure. (See examples of attacks against hospitals and universities).
     Diversity adaptation measures examples: keeping files in paper format, manual mode on shutters and doors.

2. **Lack of diversity among ICT manufacturing and services actors.**
   (ICT value chain) (see next slide)

Diversity (P12) 2/2

2. **Lack of diversity among ICT manufacturing and services actors.** (ICT value chain)
   - Lack of geographical diversity: The semiconductor manufacturing industry is dominated by countries located in South-East Asia [Ren et al., 2023]
   - Few countries dominates the value chain of semi-conductors [Ren et al., 2023]
   - Few companies dominates the semiconductor manufacturing market (TSMC)
   - Few Big Tech companies dominates the everyday services used by the majority of the population (Google, Meta, Microsoft). They represent significant concentration of power threatening the sovereignty of countries [Mhalla, 2023].

Normal behaviour knowledge (P2)

3 levels of lack of normal behaviour knowledge:

1. Comprehension of ICT tools by their designers. In some cases, designers of ICT tools are not able to explain the normal behaviour of their tool.
   - This is one aspect of the "Weapons of Math Destruction" concept [O'neil, 2017].
   - This is the issue explored by explainable AI research [Arrieta et al., 2020].

2. Comprehension of ICT tools by the users.
   ICTs are presented to users as black boxes
   - User can detect failures but neither faults nor errors
   - In some cases, monitoring by sensors or test mechanisms is provided, but it is only effective in cases anticipated by designers.

3. Comprehension of ICT value chain by designers. Actors of the ICT value chain (like Fairphone) face difficulties in knowing the origin of the material resources they work with.

Complexity management (P7)

“complexity itself makes systems difficult to understand and manage, and thereby threatens resilience. ” - [Sterbenz et al., 2010]

→ Adding ICT in a tool means adding complexity.

Examples:

- In cars, embedded ICT make repair harder [Caillard et al., 2024] [Vanderseypen and Swaen, 2018].
- Tools for agriculture (see [L’Atelier Paysan, 2021]).

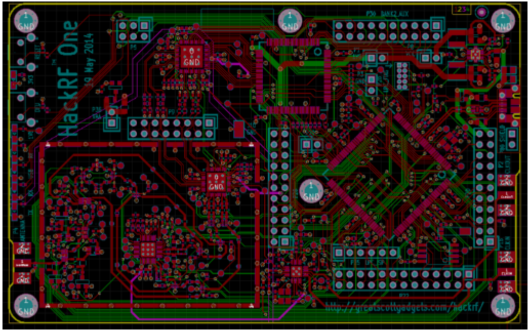

Figure: 4 layer board in KiCad PCB editor. Credit: wikimedia Commons

Evolvability (P17)

> *'Evolvability [154] is needed to refine (S6) future behaviour to improve the response to challenges, as well as for the network architecture and protocols to respond to emerging threats and application demands. " - [Sterbenz et al., 2010]*

Ubiquitous digitalisation of an economic sector cause:

→ Loss of skills (notion of "*prolétarisation*" by Bernard Stiegler)

→ Restructuring the work ecosystem

→ Increasing dependency to ICT (pointed by the European Chip Act [Dachs, 2023])

→ Evolvability outside of ICT is reduced.