

The Future of Software Engineering

Lecture 9

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Based on some of Ruzanna Chitchyan's slides

Two key factors that will shape the future of software engineering

- Sustainability
- AI
- We'll mainly focus on sustainability in this lecture and we'll begin with some definitions

Sustainability in the Oxford English dictionary

NOUN

- 1 The ability to be maintained at a certain rate or level.

‘the sustainability of economic growth’

‘the long-term sustainability of the project’

+ More example sentences

- 1.1 Avoidance of the depletion of natural resources in order to maintain an ecological balance.

‘the pursuit of global environmental sustainability’

‘the ecological sustainability of the planet’

+ More example sentences

Sustainable use and sustainable development



Sustainable use of a system S
with regard to a function F and a
time horizon T
“use S in a way that does not
compromise its ability to fulfil F
for a period of T ”
[Hilty 2015]

compromise 妥协



Sustainable development is “meeting
the needs of the present without
compromising the ability of future
generations to meet their own needs”
[UN 1987]

The three pillars of sustainability 1

- This framework describes what sustainable development is
- It emphasizes that sustainability consists of environmental, social, and economic factors
- If one of the pillars is weak, then the sustainability of the whole system is compromised



The three pillars of sustainability 2

- **Environmental sustainability** is the ability of the environment to support a defined level of environmental quality and natural resource extraction rates indefinitely.
- **Economic sustainability** is the ability of an economy to support a defined level of economic production indefinitely.
- **Social sustainability** is the ability of a social system, such as a country, family, or organization, to function at a defined level of social well being and harmony indefinitely.

<https://www.thwink.org/sustain/glossary/ThreePillarsOfSustainability.htm>

The three pillars of sustainability 3

- How are the three pillars linked?
- If economic sustainability is disrupted, such as in the financial crash of 2008, then social well being is impacted and countries tend to focus on their budget deficits, rather than implementing stricter environmental policies
- If social sustainability is disrupted by war, then environmental sustainability is no longer a focus and economic sustainability is severely impacted
- If environmental sustainability is disrupted by climate change, then both economic and social sustainability are affected, for example, agriculture might fail and people might need to migrate
- This suggests that we need to take a **systems thinking** approach, where the world is viewed a set of interconnected systems

<https://www.thwink.org/sustain/glossary/ThreePillarsOfSustainability.htm>

How does sustainability relate to Information and Communication Technology (ICT)?

治理

- ICT can be harnessed in different ways to benefit sustainability:
 - Reduce the growth in ICT's own footprint
 - Find ways to use IT to reduce the footprint of production and consumption by society
 - Support broader sustainability goals, such as the 17 sustainable development goals that were adopted by UN member states in 2015
 - These include goals from each of the three pillars of sustainability: environmental; social; and economic.





“ Our whole economy is based on

Planned Obsolescence...

We make good products, we induce people to buy them, and then next year we deliberately introduce something that will make those products old fashioned, out of date, obsolete.

*We do this for the soundest
reason... to Make Money! ”*

— Brooks Stevens,
Industrial Designer. 1958

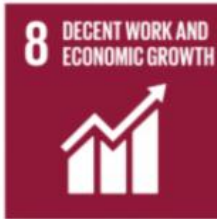


*Brought to you by the
Post-Landfill Action Network*

How are other UN goals related to ICT?



Goal 17.6. Enhance ... access to science, technology and innovation and enhance knowledge sharing ... and through a **global technology facilitation mechanism**



8.6: “..By 2020, **substantially reduce the proportion of youth not in employment, education or training.**”

8.7: “... by Increase Aid for Trade support for developing countries, ..., including through the Enhanced Integrated Framework for **Trade-Related Technical Assistance** to Least Developed Countries”

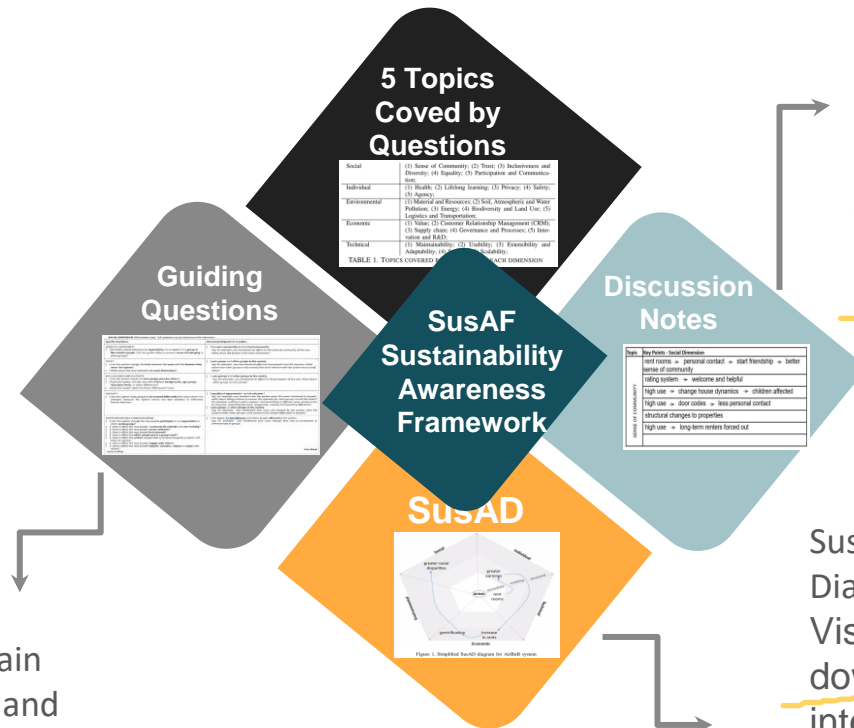


Goal 4.4: “...By 2030, substantially **increase the number of youth** and adults who have relevant skills, **including technical and vocational skills**, for employment, decent jobs and entrepreneurship”

Do we really know what we are building? Raising awareness of potential Sustainability Effects of Software Systems in Requirements Engineering (2019) Duboc et al (Ruzanna is an author)

***Abstract*—Integrating novel software systems in our society, economy, and environment can have far-reaching effects. As a result, software systems should be designed in such a way as to maintain or improve the sustainability of the socio-technical system of their destination. However, a paradigm shift is required to raise awareness of software professionals on the potential sustainability effects of software systems. While Requirements Engineering is considered the key to driving this change, requirements engineers lack the knowledge, experience and methodological support for doing so. This paper presents a question-based framework for raising awareness of the potential effects of software systems on sustainability, as the first step towards enabling the required paradigm shift. A feasibility study of the framework was carried out with two groups of computer science students. The results of the study indicate that the framework helps enable discussions about potential effects that software systems could have on sustainability.**

Sustainability Awareness Framework 1



Guiding Questions:
For each sustainability dimension, questions in plain text, examples, reminders and checkboxes.

Summary of Discussion Notes:
Identifying chain-of-effects
Reflection on impact of widespread and long-term use.

Sustainability Awareness Diagram (SusAD):
Visualisation tool, breaks down graph into **five** interrelated dimensions of sustainability.

Five dimensions of sustainability



Sustainability Awareness Framework 2

- The framework has sheets for each sustainability dimension, containing questions in plain text, examples, reminders and checkboxes.
- The sheet also suggests prompts to encourage the interviewee to think further, and examples to clarify some of the questions.
问题的目的是帮助发现可能的即时和长期影响。
- The questions are intended to help uncover possible immediate and longer-term effects.
elicit 引出
- To elicit the question sets, the research team used an adaptation of the Delphi method: the members of the Karlskrona Alliance on Sustainability Design acted as the panel of experts who were used to derive the questions. derive 获得
- Panel experts populated factors that affect the five dimensions of sustainability and questions that a requirements engineer should consider regarding these factors. After several round of discussion and elicitations, all panel members were satisfied with the derived questions set.

Sustainability Awareness Framework 3

Social	(1) Sense of Community; (2) Trust; (3) Inclusiveness and Diversity; (4) Equality; (5) Participation and Communication;
Individual	(1) Health; (2) Lifelong learning; (3) Privacy; (4) Safety; (5) Agency;
Environmental	(1) Material and Resources; (2) Soil, Atmospheric and Water Pollution; (3) Energy; (4) Biodiversity and Land Use; (5) Logistics and Transportation;
Economic	(1) Value; (2) Customer Relationship Management (CRM); (3) Supply chain; (4) Governance and Processes; (5) Innovation and R&D;
Technical	(1) Maintainability; (2) Usability; (3) Extensibility and Adaptability; (4) Security; (5) Scalability;

TABLE 1. TOPICS COVERED BY QUESTIONS IN EACH DIMENSION

Sustainability Awareness Framework 4

✓ Guiding questions

- **Individual:** Health, lifelong learning, ...
- **Social:** Sense of community, trust, inclusiveness, ... 包容
- **Environment:** Material & resources, energy, ...
- **Economic:** Value, CRM, supply chain, ...
- **Technical:** Maintainability, usability, security, ...

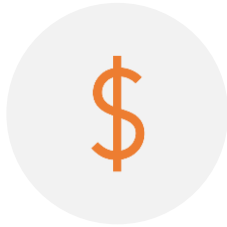
Trust: “Can the system change the **trust** between **users** and **the businesses that owns the system.**”

Inclusiveness and diversity: “Does the system include users **with different background, age groups, education levels, etc.**”

SOCIAL DIMENSION (Interviewer copy. Tick questions as you advance in the interview.)

Specific Questions	Remind participants to consider...
<p>SENSE OF COMMUNITY</p> <p>[] Normally people belong to an organization, to an area or to a group of like-minded people. Can the system affect a person's sense of belonging to these groups?</p>	<p>[] the user community and the local community. Say, for example: <i>you mentioned an effect on the sense of community of the user. What about the people in the local community?</i></p>
<p>TRUST</p> <p>[] Can the system change the trust between the users and the business that owns the system?</p> <p>[] What about the trust between the users themselves?</p>	<p>[] user groups and other groups in the society. Say, for example: <i>you mentioned an effect on how people trust the business. What about how other groups in the society that don't interact with the system trust each other?</i></p>
<p>INCLUSIVENESS AND DIVERSITY</p> <p>[] Can the system impact on how people perceive others?</p> <p>[] Does the system include uses with different backgrounds, age groups, education levels, or other differences?</p> <p>[] Does the system caters for these differences? How?</p>	<p>[] user groups and other groups in the society. Say, for example: <i>you mentioned an effect on the perception of the user. What about other groups on the society?</i></p>
<p>EQUALITY</p> <p>[] Can the system make people to be treated differently from each other? For example, because the system carries out data analytics or influences human decisions.</p>	<p>[] equality of opportunity¹ and of outcome². Say, for example: <i>you mention how the system gives the same treatment to people¹, what about taking actions to ensure the outcome for each person can be the same²? For example, putting in place support, communicating in different ways, giving access to resources, respecting decisions, recognizing, valuing and respecting differences.</i></p> <p>[] user groups or other groups in the society. Say, for example: <i>you mentioned how users are treated by the system. Does the system makes other groups in the society to be treated differently or equally?</i></p>
<p>PARTICIPATION AND COMMUNICATION</p> <p>[] Can the system change the way people participate in an organization or other social groups?</p> <p>[] Does it affect the way people communicate verbally and non-verbally?</p> <p>[] Does it affect the way people create networks?</p> <p>[] Does it affect the way people form bounds?</p> <p>[] Does it affect the effort people put in a group work¹?</p> <p>[] Does it affect the actions people take to achieve the goals, projects and tasks of a group?</p> <p>[] Does it affect the way people engage with others?</p> <p>[] Does it affect the way people support, consider, critique or argue with others?</p> <p>¹ social loafing</p>	<p>[] the users, the beneficiaries and other people affected by the system. Say, for example: <i>you mentioned how users change their way to participate or communicate in groups.</i></p> <p style="text-align: right;">Turn sheet</p>

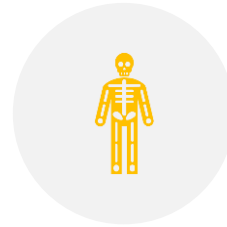
Motivating Example: Airbnb



NEW YORK:
HOMEOWNERS CAN
EARN 55% MORE
THAN THE MEDIAN
LONG-TERM RENTAL



ESTIMATED: AIRBNB
REMOVED 7,000 -
13,000 UNITS OF
HOUSING IN NY
→ INCREASE OF 1.4%
IN THE MEDIAN
LONG-TERM RENT



72% OF POPULATION
IN
NEIGHBOURHOODS
AT HIGHEST RISK OF
AIRBNB-INDUCED
GENTRIFICATION ARE
NON-WHITE
→ INCREASING RACE
SEPARATION

Visualising the impact of a software system on sustainability

相互关联

Each interrelated dimension of sustainability is divided into three types of effect that a software system can cause across time:

immediate (i.e., caused by the direct function of the system or its development) - centre

启用(即, 随着时间的推移由系统的应用产生)

enabling (i.e., arising from the application of a system over time) - middle layer

层结构(即, 指可以在宏观层面观察到的持续变化) - 外层

structural (i.e., referring to persistent changes that can be observed at the macro level) – outer layer

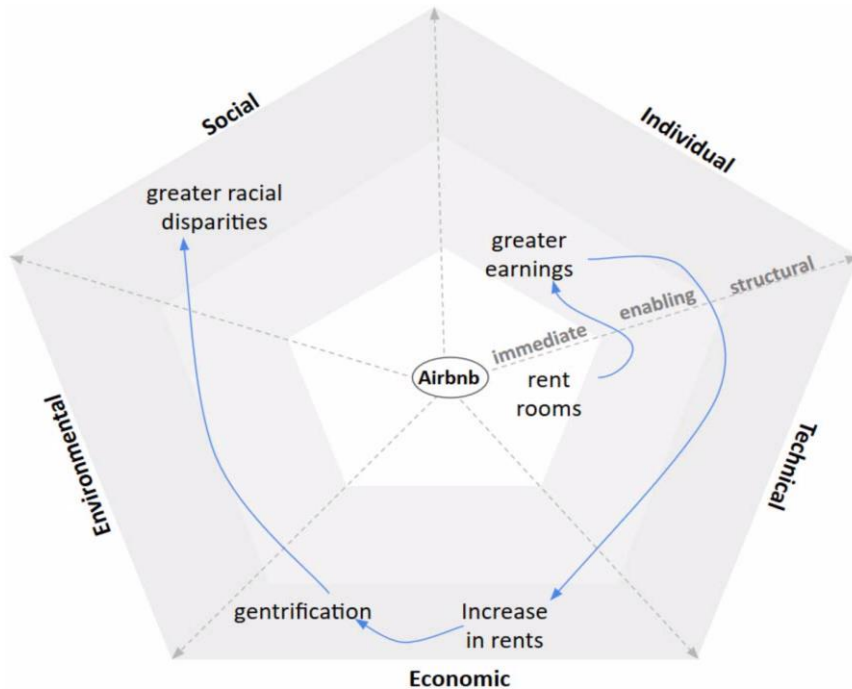


Figure 1. Simplified SusAD diagram for AirBnB system

Summary of Sustainability Awareness Framework

SusAF as a Systems Thinking activity:
Potentially high cost vs. few guiding questions

Systems vs Software Requirements Engineering:
Need to look at wider socio-economic system

Requirements Engineers as leads for Sustainability Engineering: timely consideration can help foster informed choices

AI and sustainability

- How does AI impact sustainability?
- We can think about this in terms of the three pillars of sustainability or the five dimensions of the sustainability awareness framework
- Let's use the example of Isambard-AI, which is currently being built at Bristol University

Isambard-AI 1



- Isambard-AI will be built from 5,448 NVIDIA GH200 Grace Hopper Superchips, which combine Nvidia's Arm-based 72-core Grace CPU with a Hopper-based GH100 AI and HPC GPU.
- It will cost around £220 M and be the fifth most powerful supercomputer in the world
- It is being built in north Bristol in the carpark of the National Composite Centre, partly because this facility has a 5 GW power supply
- The computer is water cooled and there are plans to supply the heated water to the local area for heating and electricity

Isambard-AI 2



- Isambard-AI is expected to achieve over 200 FP64 PetaFLOPS for high-performance computing that requires accurate calculations (10^{15} floating point operations per second)
- It will also deliver over 21 ExaFLOPS for AI inference and training workloads that use lower precision (10^{18} FLOPS)
- This performance is a tenfold improvement over the U.K.'s previous fastest supercomputer

Isambard-AI 3



- Isambard-AI has an environmental impact (the electricity bill per year will be over £10 M)
- It also has an economic impact as it will provide the UK with one of the most powerful AI supercomputers in the world
- To consider the social impact we can refer to the Sustainability Awareness Framework and ask:
 - Will it change the trust between users and the businesses that owns the system.Another relevant question is:
 - will users with different backgrounds, ages and education levels have access?(Inclusiveness and diversity)

How else can AI impact software engineering?

- Chat-GPT is good at generating code – will AI eventually replace programmers? AI still makes mistakes, so the role of developers could be to check and polish code
- AI, such as CodeWhisperer, is good at automating unit tests
- AI is not currently good at evaluating different architectural decisions, but it can support developers by suggesting appropriate cloud services
- One possible future is that humans use AI for support in the creative stage of software development and then AI takes a greater role in generating, testing and deploying code
- However, in the words of Niels Bohr, the physicist:
Prediction is very difficult, especially if it's about the future.



References

Becker, C., Betz, S., Chitchyan, R., Duboc, L., Easterbrook, S. M., Penzenstadler, B., ... & Venters, C. C. (2015). Requirements: The key to sustainability. *IEEE Software*, 33(1), 56-65.

Hilty, L. and Aebischer, B. "ICT for Sustainability: An emerging research field", in ICT innovations for sustainability, pp. 3-36 2015, Springer

Hilty, L. "A research agenda for ICT4S" 2014, keynote talk at the ICT4S conference, Stockholm, Sweden http://publicationslist.org/data/lorenz.hilty/ref-235/2014_Hilty_Keynote_ICT4S.pdf

Michael Braungart, William McDonough: "Cradle to Cradle: Remaking the Way We Make Things", 2002, Farrar, Straus & Giroux

Duboc, L, et al [Do we really know what we are building?](#), International Conference on Requirements Engineering, 2019

Duboc et al. (2019) Do we really know what we are building? Raising awareness of potential Sustainability Effects of Software Systems in Requirements Engineering. *IEEE 27th International Requirements Engineering Conference (RE)*