






Sustainability Assessment of Urban Systems

(ENV-461) – MA B1 11

8: Assessing the interactions among indicators: Influence Matrix

Lecturers:

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Program of the course

Lectures : BS 170 on Wednesdays, 13:15 – 16:00 (Lecture + Exercise)

n°	Date	Session	Milestones Project
1	19/02/2025	**Introduction** into sustainability and SA	
2	26/02/2025	**Sustainability issues** in **urban systems**	
3	05/03/2025	**Key steps in SA #1**: SSP, normative dimension, frameworks	**Groups formed**
4	12/03/2025	**Key steps in SA #2**: Systemic dimension	
5	19/03/2025	**Key steps in SA #3**: Participatory dimension	**Submission - Outline 19.03**
6	26/03/2025	**Deriving indicators (1/2)**	
7	02/04/2025	**Deriving indicators (2/2)**	
8	09/04/2025	**Influence matrix**	
9	16/04/2025	**Multi-Criteria Analysis**	
	23/04/2025	**Easter break**	
10	30/04/2025	**Deriving policy recommendations**	
11	07/05/2025	**Policy implications**	
12	14/05/2025	**Sustainability Assessment in practice**	
13	21/05/2025	**Exam**	
14	28/05/2025	**Presentation of semester work_2**	

* May be updated depending on the number of students enrolled

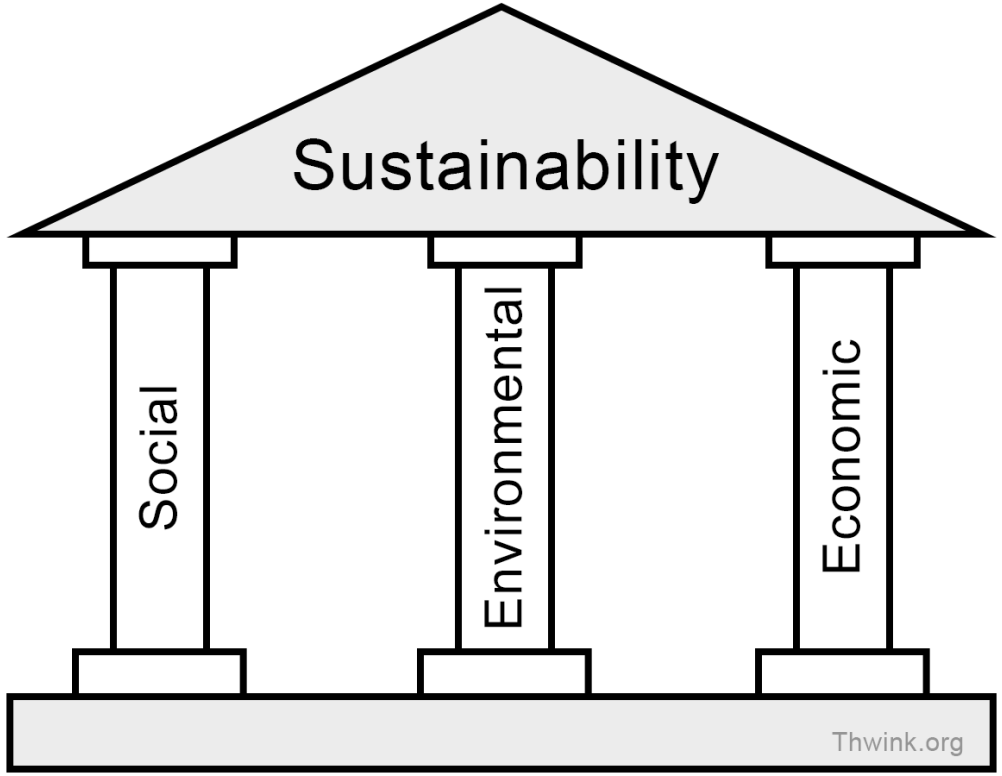
Influence Matrix

Laboratory on Human-Environment Relations in Urban Systems

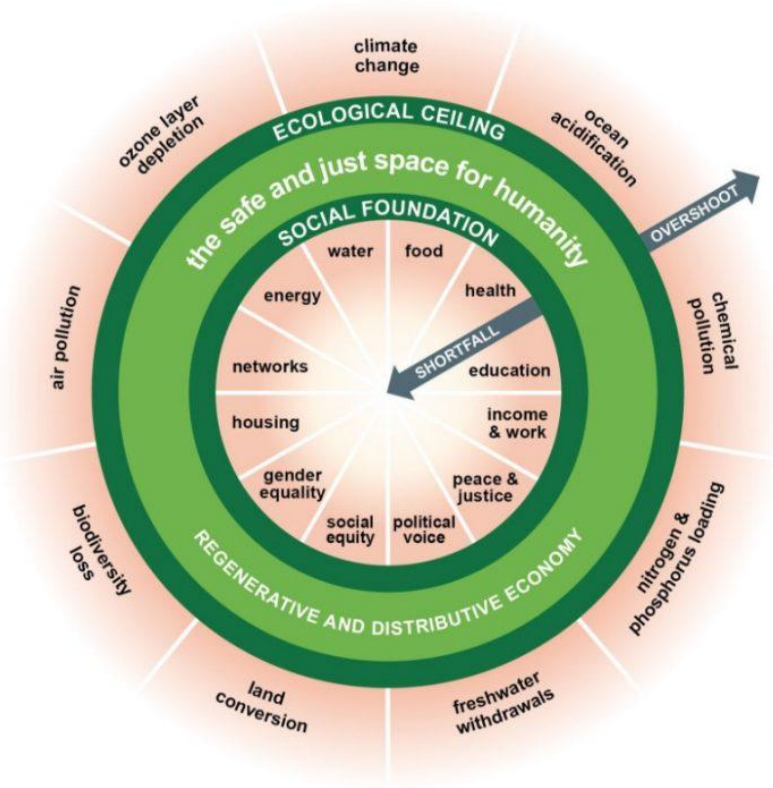
Goals of the Lecture

- Why do we need to study the interactions among the indicators?
- How can we assess the interactions among the indicators?
  - Influence Matrix
  - Activity-Passivity Plot (System Grid)
- Reflecting on the role and relevance of different categories of indicators for policymaking and strategic action

Why do we need to study the interrelations among the indicators?

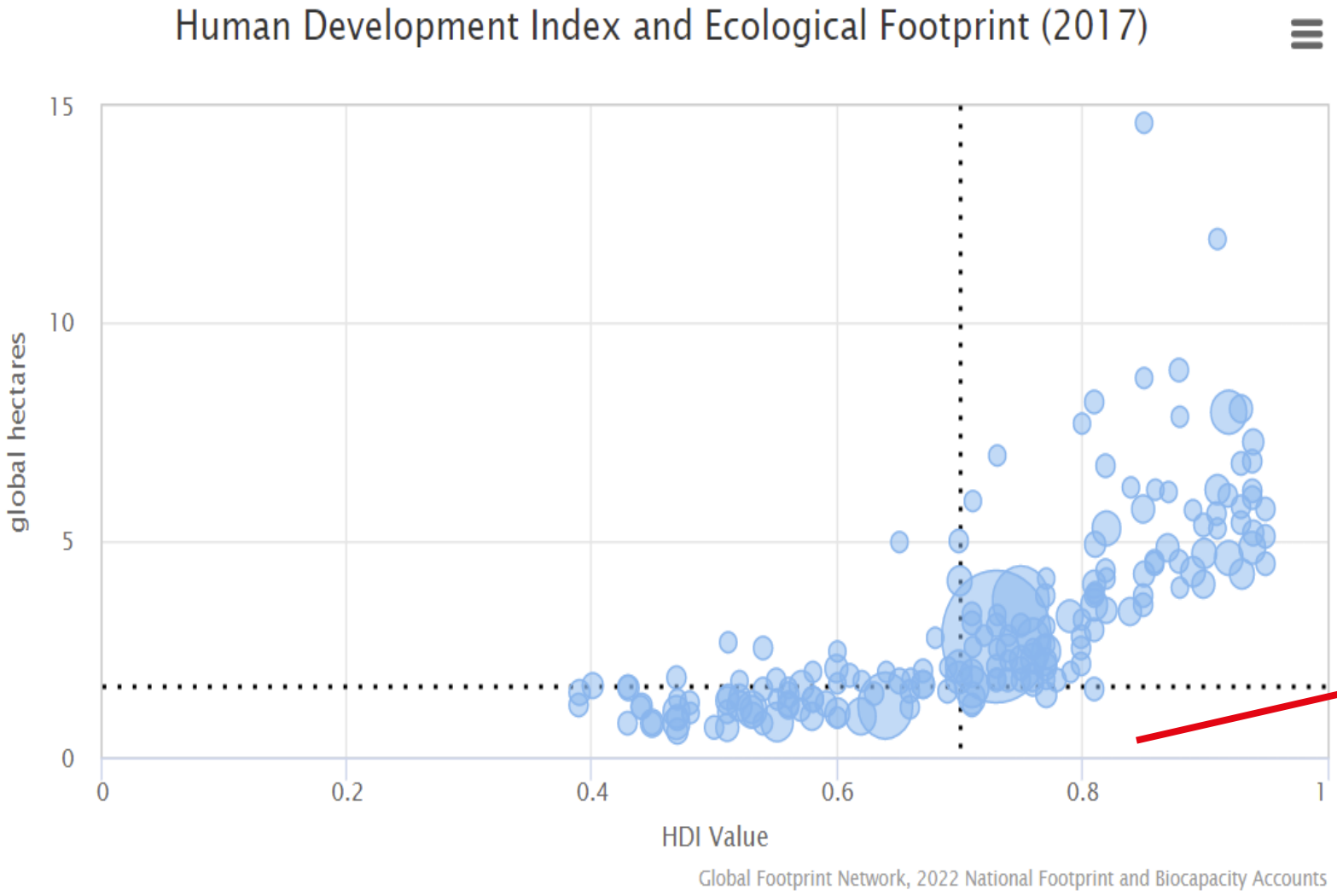


Adams, 2006



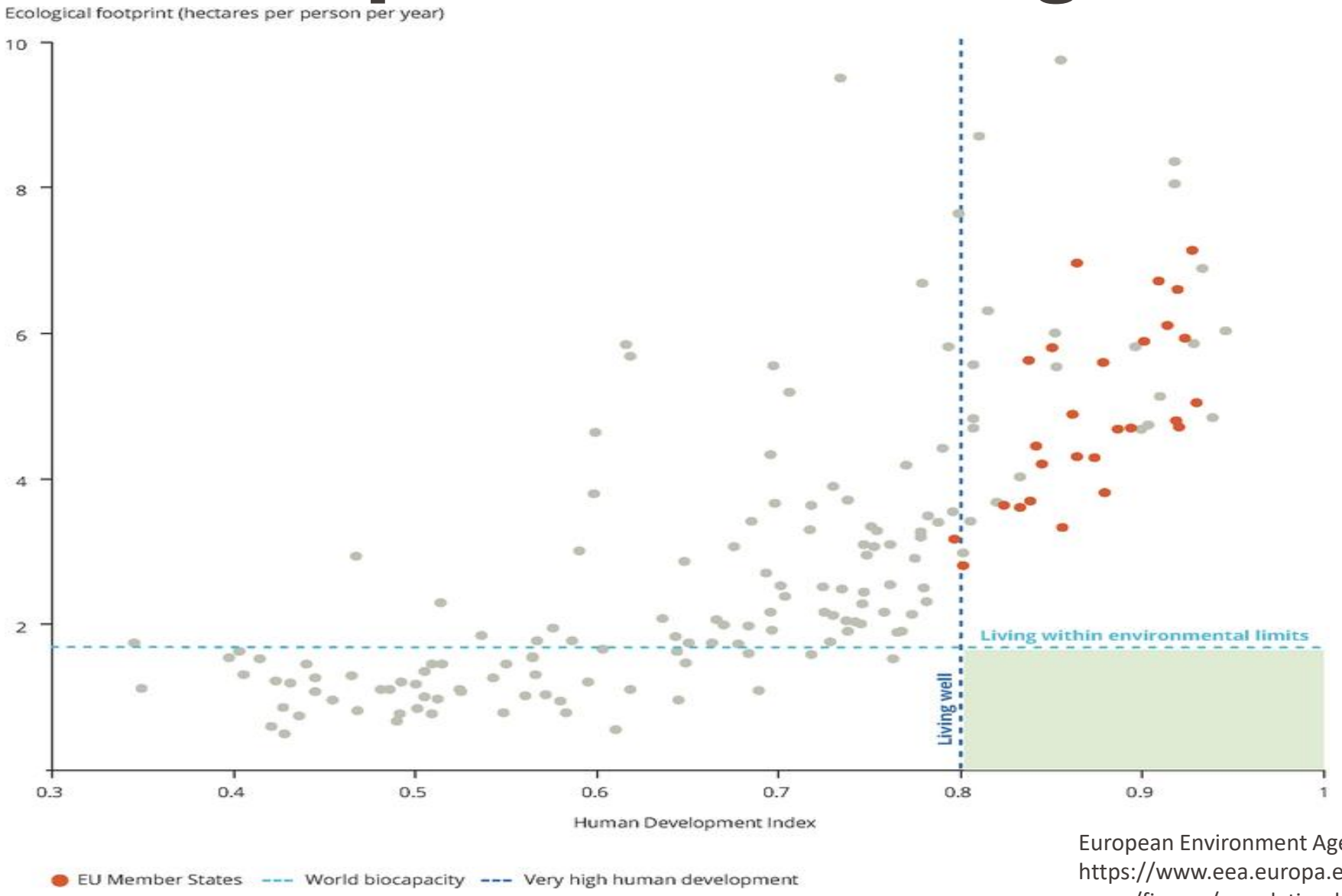
(Raworth 2012)

Human Development Index vs. Ecological Footrpint



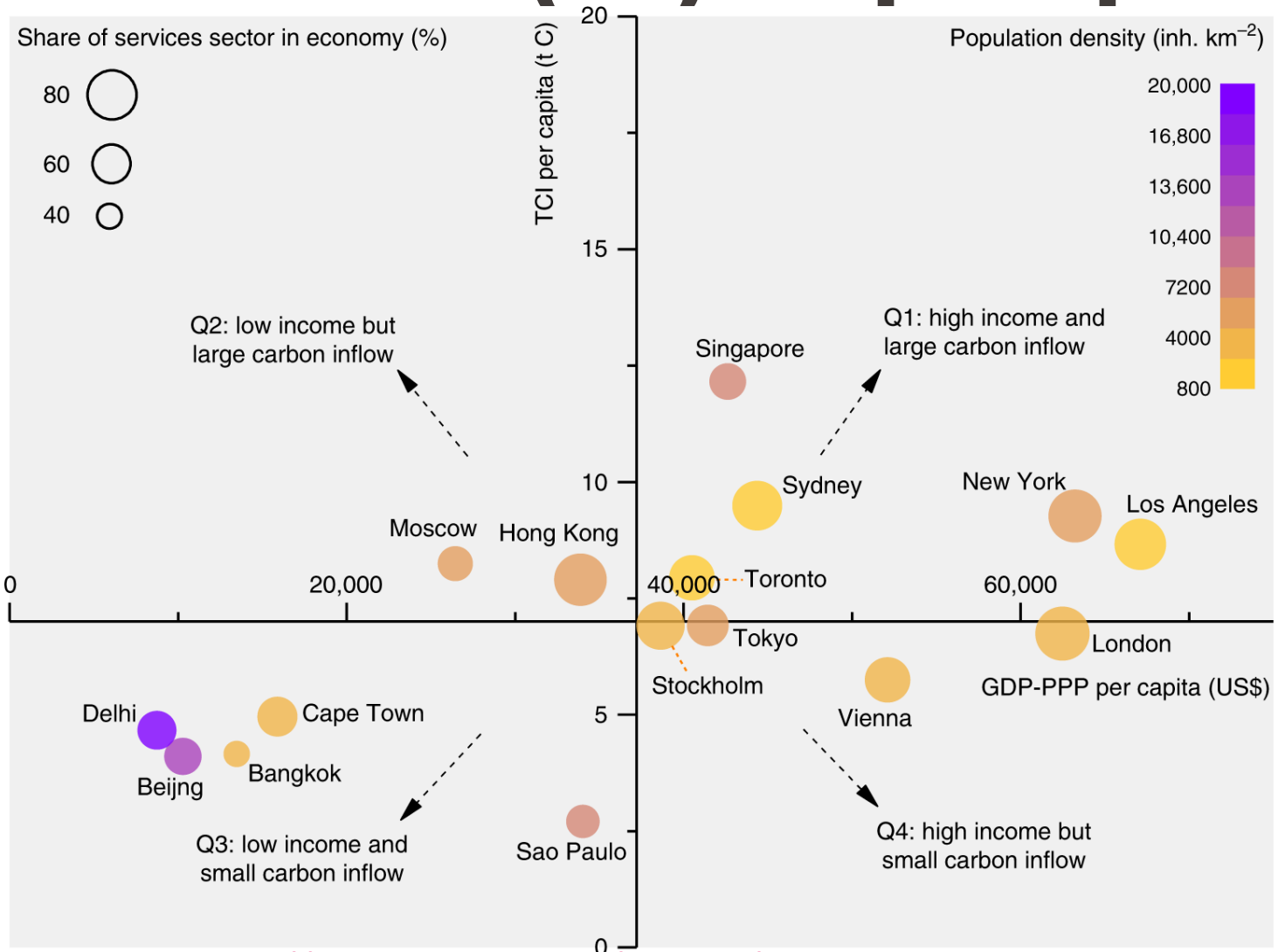
Algeria, Colombia, Cuba, Ecuador, Georgia, Jamaica, Jordan and Sri Lanka

Human Development Index vs. Ecological Footrpint



European Environment Agency, 2019 - https://www.eea.europa.eu/data-and-maps/figures/correlation-between-ecological-footprint-and

Distribution of 16 global cities by per capita total carbon inflow (TCI) and per capita GDP-PPP.



Shen et al. 2020

https://www.nature.com/articles/s41467-019-13757-3

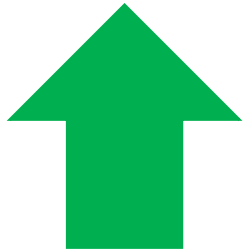
Promoting green spaces ?
The example of the High Line Park in NYC

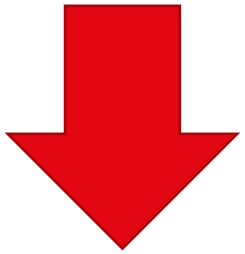
Disused railway line turned into a 2.5 km linear park

https://www.timeout.com/newyork/parks/highline

Praised as a pioneering project → Over 7 million visitors in 2009 → Rise in property values → Gentrification (displacement of local residents)

Promoting Urban Density – good or bad?





- More efficient use of energy and space
- Lower costs of service provision
- Less reliance on private vehicles
- Positive correlation with innovation

- Lower liveability
- Less green space, obstruction of daylight and airflow
- Worsening intensity of urban heat island effect
- Might lead to the loss of a community feeling

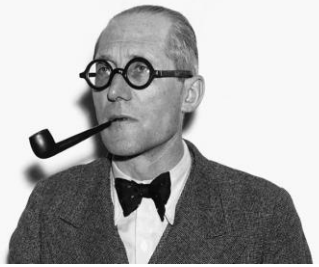
Slum cities of 19th century

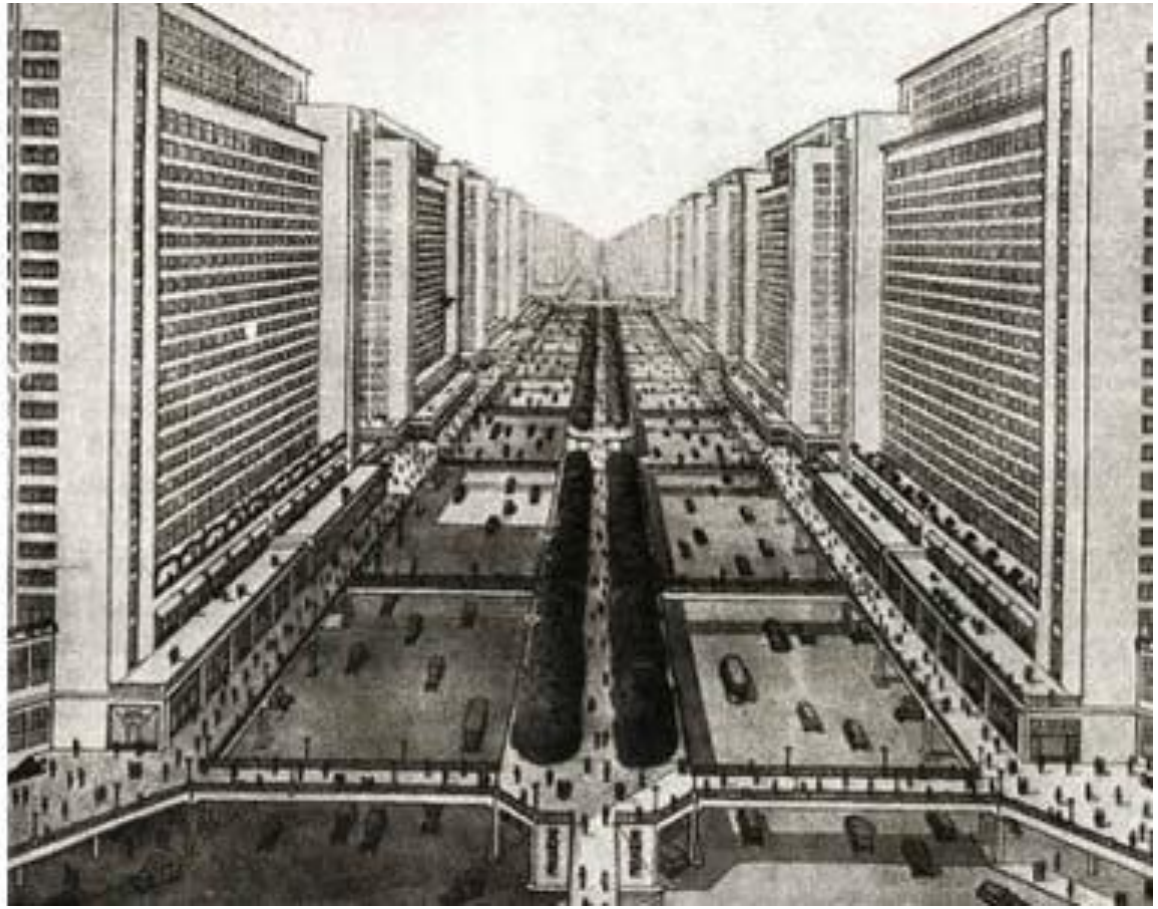
Building an affordable housing ?

https://www.historytoday.com/miscellanies/desolation-row-victorian-britain%E2%80%99s-sensational-slums

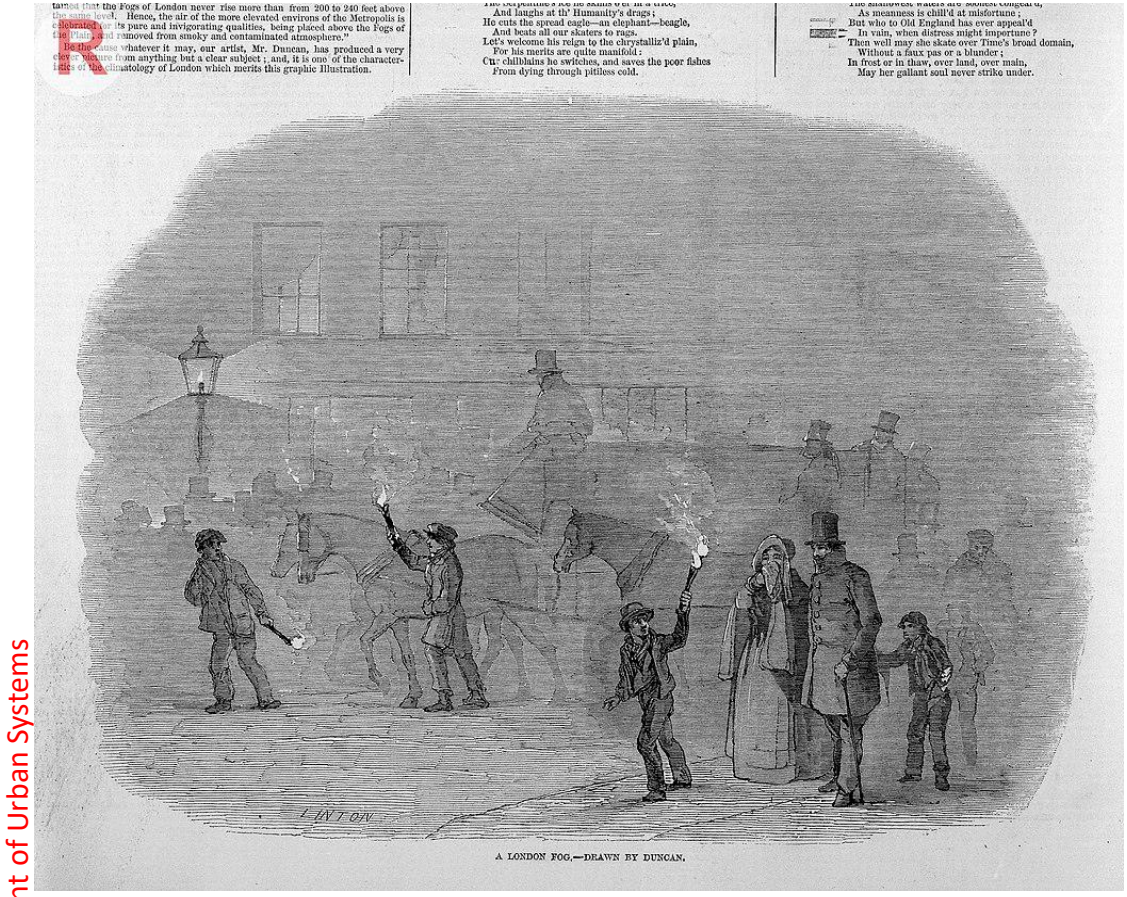
Building more affordable housing ?
The example of the high-rise social housing projects

Le Corbusier
(1887-1965)

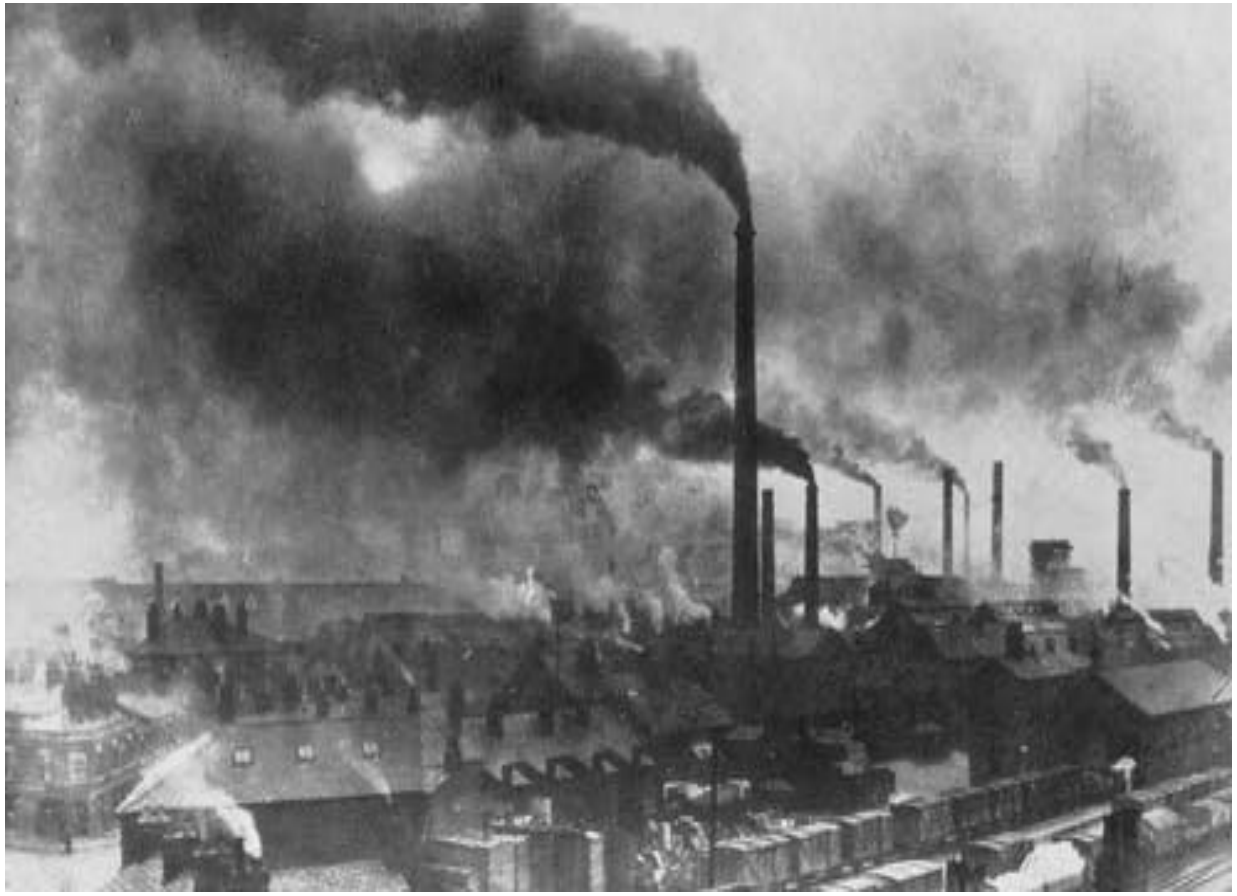




https://www.researchgate.net/figure/5-Two-scale-models-of-the-Radiant-City-Source-http-wwwcurbsandstoopscom-gaia-In_fig7_260038282



A LONDON FOG.—DRAWN BY DUNCAN.



“During the continuance of a real London fog—which may be black, or grey, or more probably orange-coloured—the happiest man is he who can stay at home...Nothing could be more deleterious to the lungs and the air-passages than the wholesale inhalation of the foul air and floating carbon which, combined, form a London fog.” (Charles Dickens, Dicken’s Dictionary of London, 1879).

High-rise social housing projects

Bijlmelmeer, Netherlands

The Bijlmermeer 1971: Queen Juliana visiting the functional town of the future; amazed or bewildered?

van Soomeren et al., 2014

High-rise social housing projects

Heygate Estate, London

Paris Banlieue

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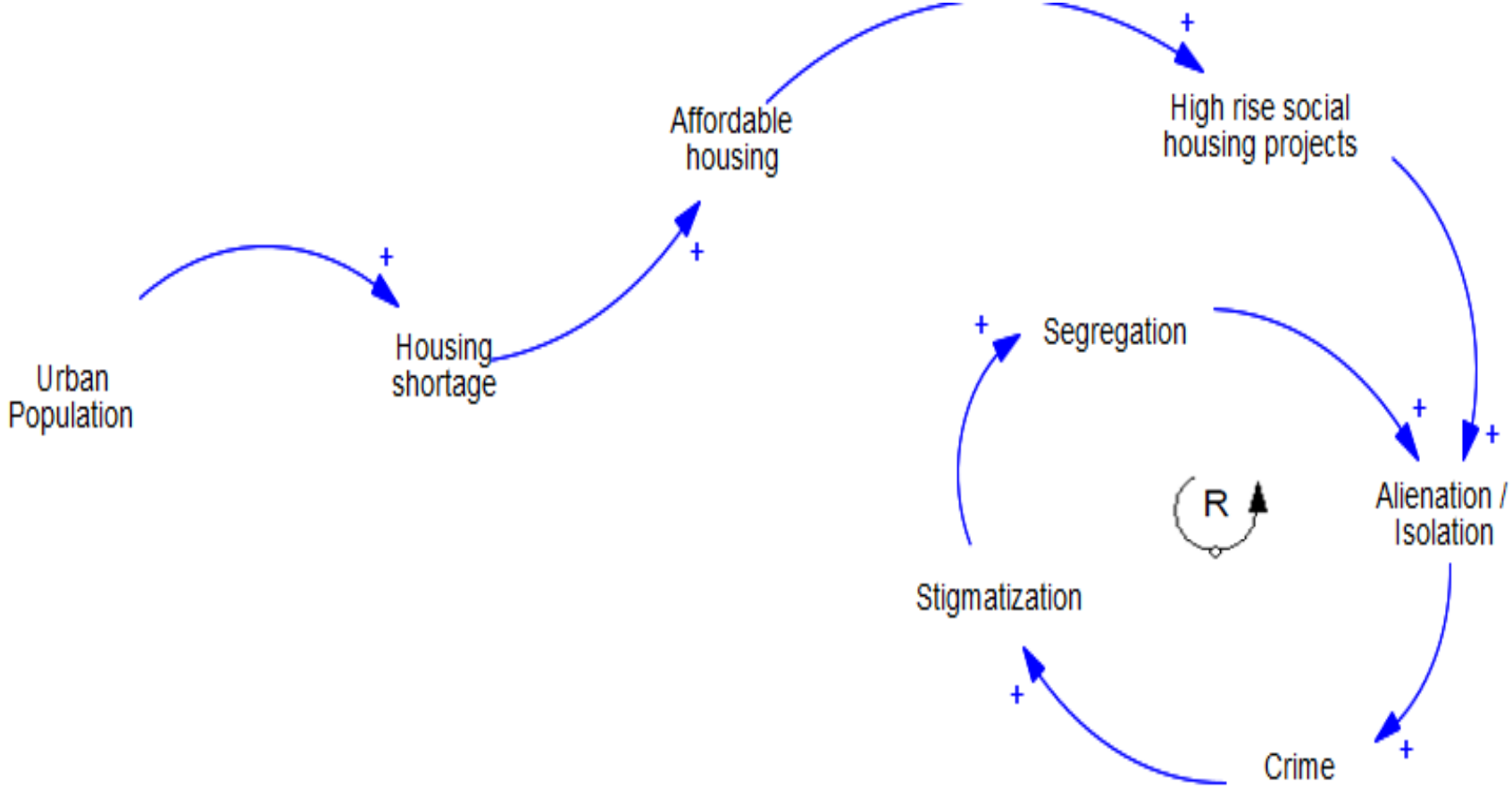
Interrelations between built environment and social aspects



Other examples ?

Consider policies designed to influence a specific indicator and analyze how they may also impact other indicators.

House retrofitting
→ Improve comfort
→ Reduce energy consumption and carbon emissions

But also
→ Rising rents
→ Risk of residential segregation

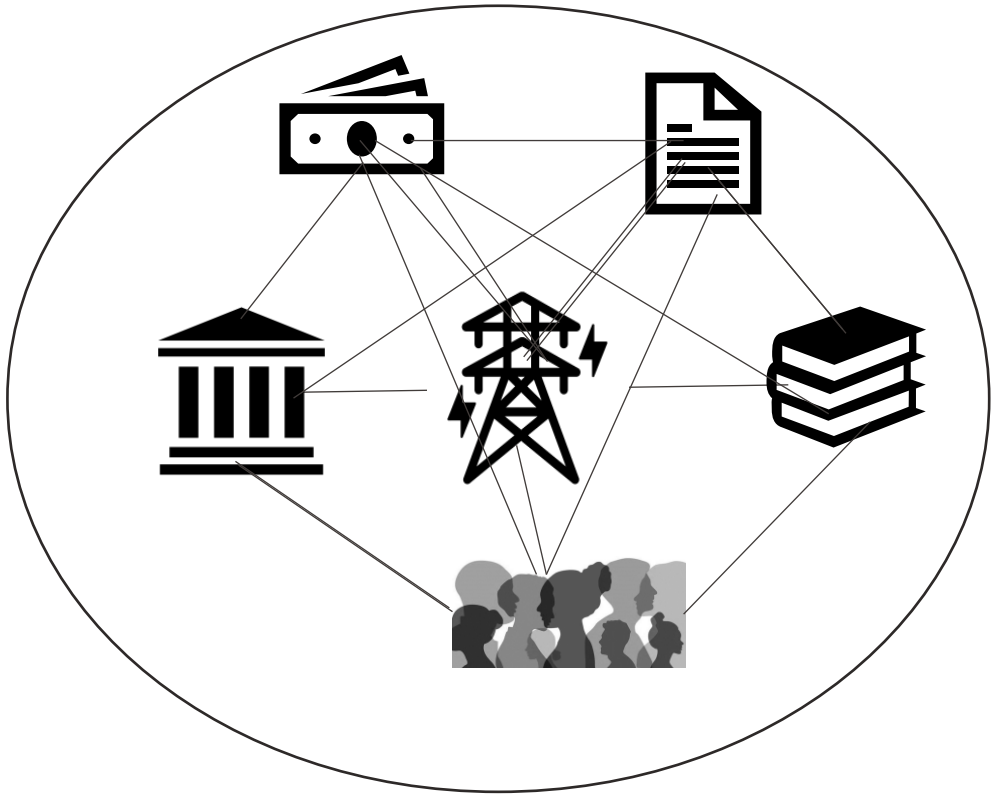
Creation of protected areas
→ Protect the biodiversity
→ Generate income from tourisme

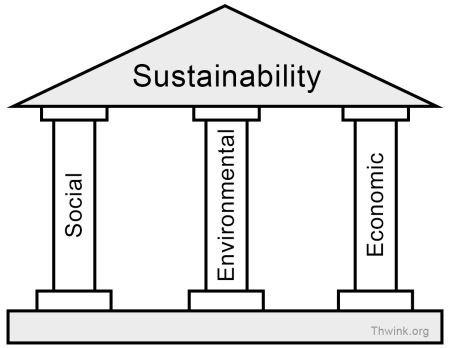
But also
→ Hindering the access of local residents to resources

...

Mangold, M., Österbring, M., Wallbaum, H., Thuvander, L., & Femenias, P. (2016). Socio-economic impact of renovation and energy retrofitting of the Gothenburg building stock. *Energy and buildings*, *123*, 41-49.

Cities as Complex Socio-Technical Systems





- Socio-technical systems made up of technical, economic, institutional, socio-political and cultural elements that are interrelated
- Cities as configuration of these elements
- Intervention on one element may have impacts on several other system elements
- Challenge: making sense of this complex system and change it towards a desired direction

Conclusion – Why do we study the interactions among the indicators?

- To identify the trade-offs
- Uncovering potential linkages between different issues
- Root causes of the problems – “treating causes, not symptoms”
- Avoiding unintended consequences, rebound effects
- Designing more effective interventions

How can we analyse interactions among the indicators?

Influence Matrix

- **Influence Matrix** is part of **Structural Analysis** which was developed in 1960s/70s

- **Structural Analysis** aims to describe a **system** and **its evolution** by analysing the interactions among its key elements:

  1) Identification of variables that define/characterise a system
  2) Assessing the interactions among the system variables
  3) Studying system dynamics (modeling the behaviour of the system)

Influence Matrix

- **Influence Matrix** is used to elicit the **"direct" influence** of **variables/indicators on one another** and thereby helps to **assess the interactions** among them

Source: Godet (1986), Godet (2000)

Structural Analysis

1. Conceptualisation of the system and identification of variables that characterizes the system
2. Assessment of the interactions between system variables
3. Studying system dynamics (modeling the dynamic behaviour of complex systems)

Sustainability Assessment

1. Conceptualisation of the system, identification of the issues and indicators that are pertinent for SA
2. Assessment of the interactions between sustainability indicators
3. Evaluating the sustainability performance (of cities), determining what needs to be changed, how it can be changed

Outcome: Identifying the drivers, causal flows and leverage points

Assessing the interaction among indicators

“Influence matrix” addresses the following questions:

1. How strong is the influence of indicator A (left) on indicator B?

0 = no direct influence

1 = weak direct influence

2 = strong direct influence

2. Is the influence positive (the more, the more; +) or is the influence negative (the more, the less; -)?

Interaction between the indicators – Influence Matrix

Influence matrix with direct influences between indicators (-2: strong negativ influlence; -1 weak negative influence; 0: no influence; 1: weak influence; 2: strong influence).

		Environmental aspects			Economic aspects			Social aspects		
	→	Indicator Env.1	Indicator Env. 2	Indicator Env. 3	Indicator Econ.1	Indicator Econ. 2	Indicator Econ. 3	Indicator Soc. 1	Indicator Soc. 2	Indicator Soc. 3
Environmental aspects	Indicator Env. 1		0	1	0	1	0	-2	1	0
	Indicator Env. 2	0		1	0	1	0	2	1	0
	Indicator Env. 3	1	1		0	1	0	-1	1	0
Economic aspects	Indi. Econ. 1	1	1	1		1	0	1	1	-1
	Ind. Econ. 2	-1	1	1	2		0	1	1	0
	Ind. Econ. 3	1	-1	1	2	0		1	0	0
Social aspects	Indicator Soc. 1	1	1	-2	0	0	0		1	0
	Indicator Soc. 2	2	2	2	1	0	0	2		1
	Indicator Soc. 3	1	1	1	1	1	0	2	1	

Interactions among indicators – Example 1

To what extent is cooperative housing in Geneva more sustainable than non-cooperative housing?

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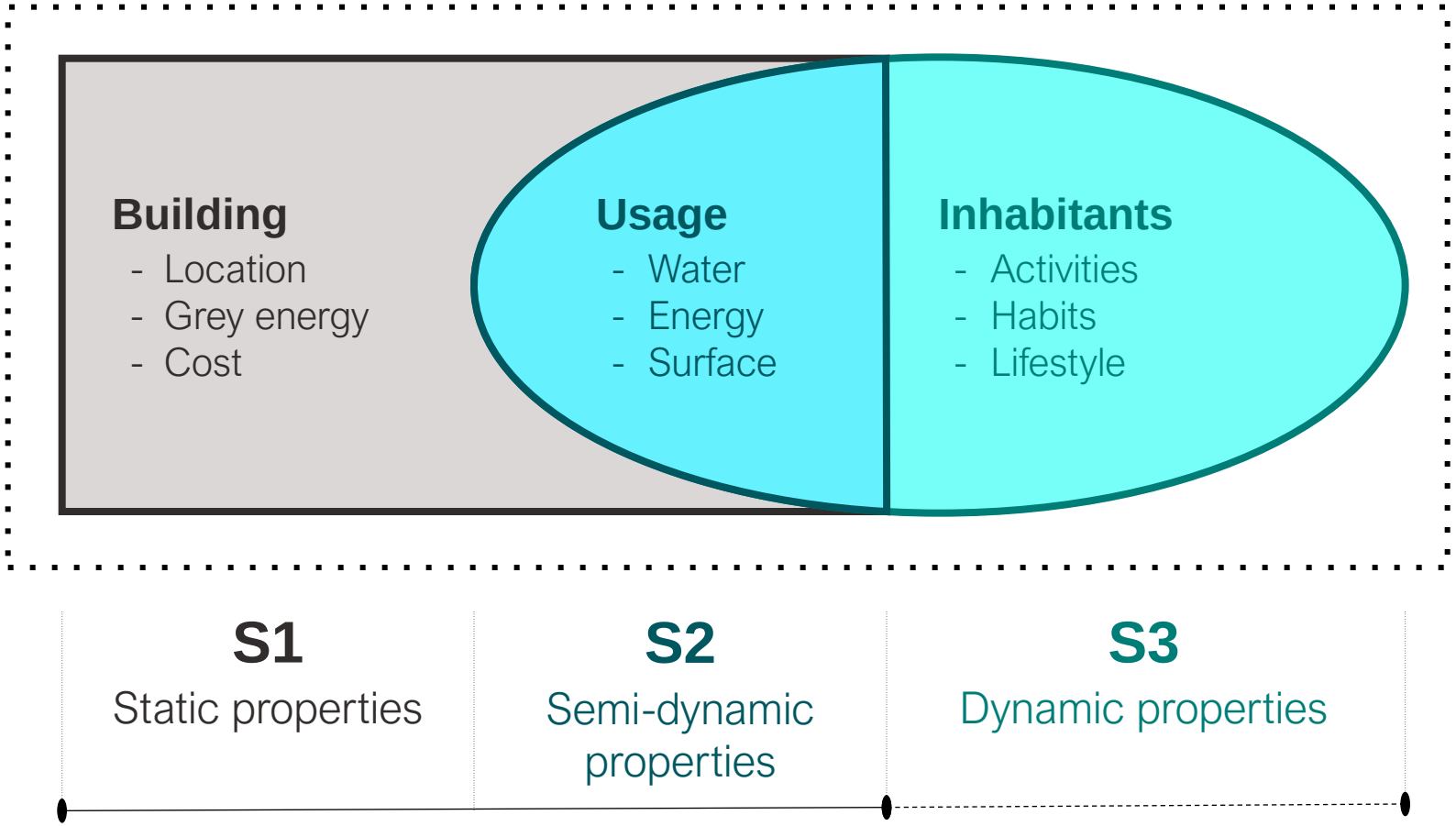
Interactions among indicators – Example 1



Interactions among indicators – Example 1

Indicator	Label	Definition	Units	Boun-daries	Topic
Building level					
Permeable surface	S1_a	Proportion of green surface or water surface where infiltration is easy, with respect to the total surface area of the parcel	%	75–90	Biodiversity
Waste water management	S1_b	Proportion of wastewater treated directly on site	%	35–100	Water
Grey energy	S1_c	Cumulative amount of non-renewable energy used for building one square meter of permeable surface per year	[kWh/m^2_{SP}/a]	26.5–0	Energy
Rental costs	S1_d	Monthly rental costs per square meter excluding electricity, heating, etc.	CHF/m^2	19.7–13	Living conditions
Shared spaces	S1_e	Sum of shared and polyvalent spaces with respect to the total number of rooms	m^2/rooms	0.3–1.5	Social cohesion
Proximity to public transportation	S1_f	Walking distance to the nearest public transport stop	m	400–0	Mobility

Gex 2018 and in Binder et al., 2020

Interactions among indicators – Example 1

Indicator	Label	Definition	Units	Boun-daries	Topic
Use level					
Water consumption	S2_a	Water consumption per person per day	l/cap/day	20–55	Water
Energy consumption	S2_b	Final energy consumption for heating and ventilating one square meter of living area for one year	[kWh/m^2 SRE/an]	35–0	Energy
Renewable electricity	S2_c	Share of electricity consumption covered by renewable energy production on site	%	40–100	Energy
Local food production	S2_d	Available space per apartment for gardening	m^2/apartment	2–10	Food
Surface per person	S2_e	Net space for living per person	m^2/cap	35–17.5	Living conditions
Intergenerational mix	S2_f	Number of age classes represented in the building (age class: 10 years)	Nr.	5–10	Social cohesion

Gex 2018 and in Binder et al., 2020

Interactions among indicators – Example 1

Indicator	Label	Definition	Units	Boun-daries	Topic
Inhabitants					
Incinerated waste	S3_a	Amount of waste incinerated per person per year	Kg/cap/year	75–0	Waste
Recycling	S3_b	Proportion of waste which is sorted and recycled (e.g., PET, organic waste)	%	75–100	Waste
Share of work performed in the home	S3_c	Ratio between paid work and work performed at home	%	1.9–0.1	Living conditions
Voluntary work	S3_d	Proportion of inhabitants who do at least one hour per week of voluntary work	%	50–100	Social cohesion
Life satisfaction	S3_e	Proportion of inhabitants satisfied with their life (>8 in scale of 1–10)	%	75–100	Satisfaction and comfort
Slow mobility	S3_f	Proportion of walking, biking, and public transport with respect to kilometres travelled per week	%	70–100	

Gex 2018 and in Binder et al., 2020

Interaction between indicators

The so-called “influence matrix” addresses the following questions:

1. How strong is the influence of indicator A (left) on indicator B?

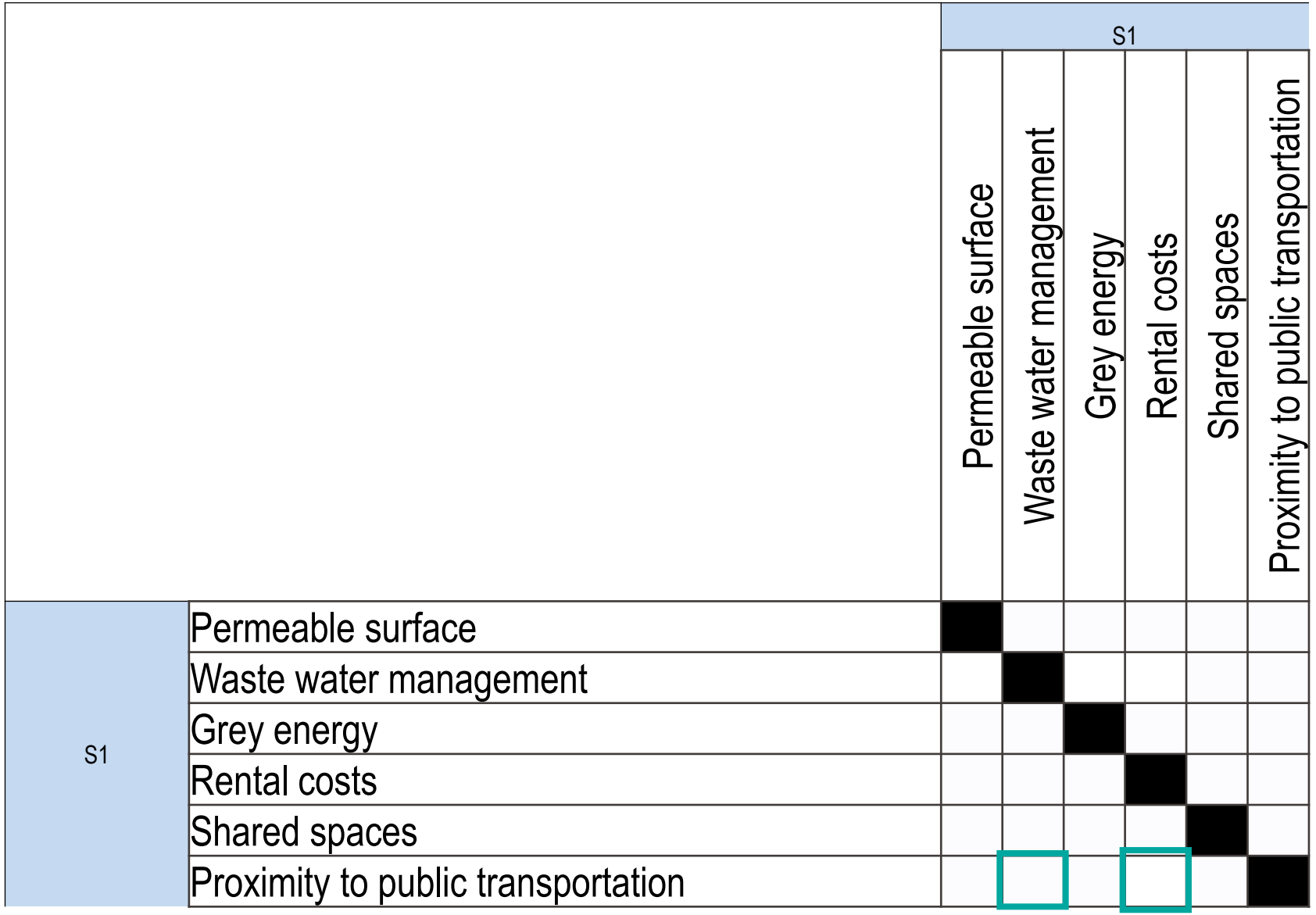
0 = no direct influence

1 = weak direct influence

2 = strong direct influence

2. Is the influence positive (the more, the more; +) or is the influence negative (the more, the less; -)?

Interactions among indicators – Example 1



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Interactions between the indicators – Example 1

		Permeable surface	Waste water management	Grey energy	Rental costs	Shared spaces	Proximity to public transportation
S1	Permeable surface		0	0	0	0	0
	Waste water management	2		1	2	0	0
	Grey energy	0	0		0	0	0
	Rental costs	0	0	0		0	0
	Shared spaces	0	0	0	0		0
	Proximity to public transportation	0	0	0	1	0	

Interactions among indicators - Example 2

How can we assess the sustainability of the housing system, considering both its material and social components?

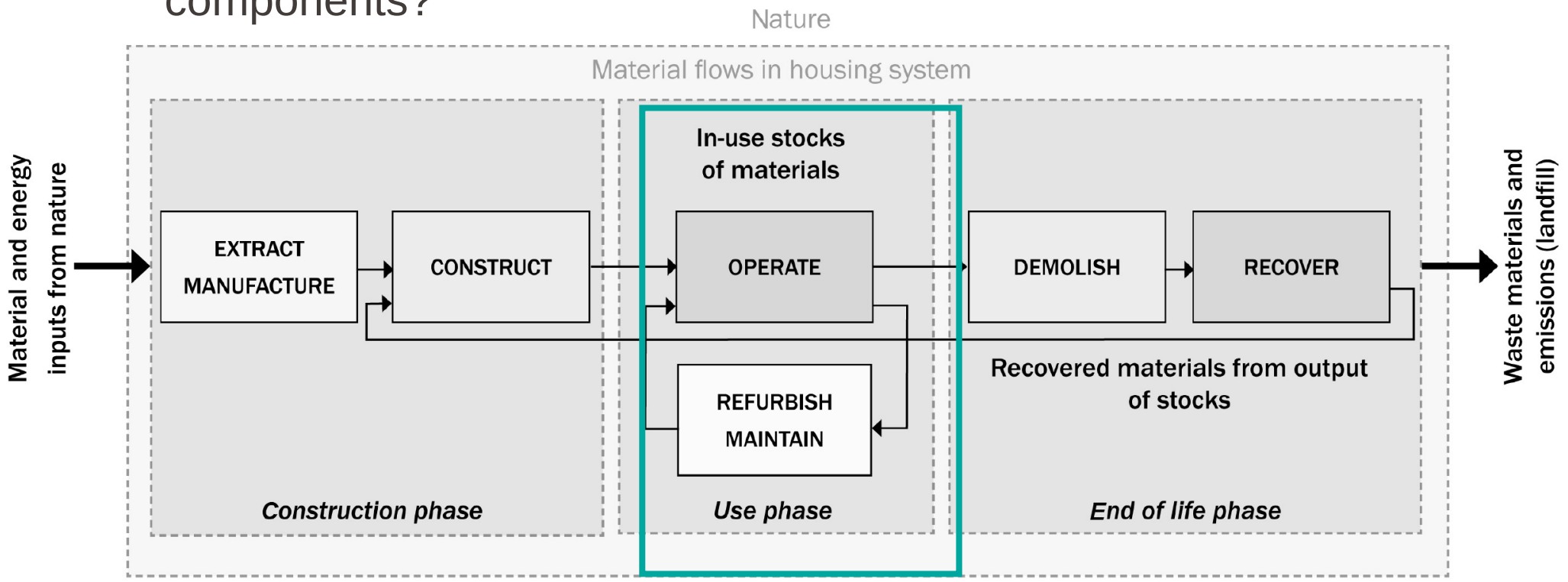
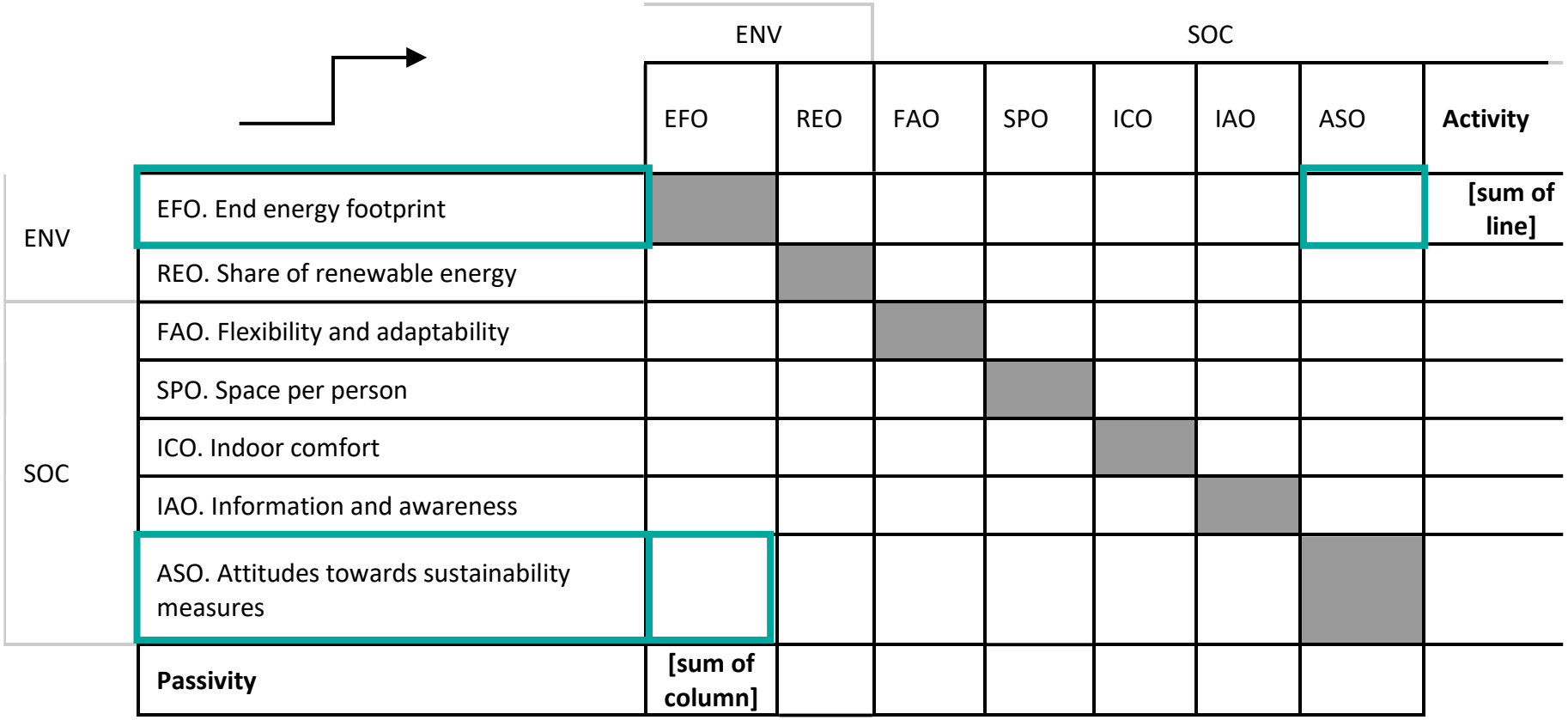


Figure 16.2 Aggregated material flows in housing system. Source: authors

Interactions among indicators - Example 2



		ENV		SOC					
		EFO	REO	FAO	SPO	ICO	IAO	ASO	**Activity**
ENV	EFO. End energy footprint								**[sum of line]**
	REO. Share of renewable energy								
SOC	FAO. Flexibility and adaptability								
	SPO. Space per person								
	ICO. Indoor comfort								
	IAO. Information and awareness								
	ASO. Attitudes towards sustainability measures								
	Passivity	**[sum of column]**							

Sustainability Assessment of Urban Systems

Laboratory on Human-Environment Relations in Urban Systems

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Pagani et al. 2020

Interactions among indicators - Example 2

		ENV				ECON		SOC						
		EFO	REO	WDO	CFO	RAO	IHO	FAO	SPO	SSO	VRO	ICO	IAO	ASO
ENV	EFO. End energy footprint		0	0	2	0	1	0	0	0	0	0	0	0
	REO. Share of renewable energy	0		0	-2	0	-2	0	0	0	0	0	0	0
	WDO. Water demand	1	0		0	0	0	0	0	0	0	0	0	0
	CFO. Carbon footprint	0	0	0		0	0	0	0	0	0	0	0	0
ECON	RAO. Rent affordability	0	0	0	0		0	0	0	0	-2	0	0	0
	IHO. Income spent on housing operation and maintenance	0	0	0	0	0		0	0	0	2	0	0	0
SOC	FAO. Flexibility and adaptability	0	0	0	0	0	0		-1	0	-2	1	0	0
	SPO. Space per person	2	0	0	0	-1	1	0		-1	0	0	0	0
	SSO. Shared space	-1	0	-1	0	1	-1	0	1		0	0	0	0
	VRO. Vacancy rate	0	0	0	0	0	0	0	0	0		0	0	0
	ICO. Indoor comfort	2	0	0	0	0	0	0	0	0	-2		0	0
	IAO. Information and awareness	-1	0	-1	-1	0	0	0	-1	1	0	0		1
	ASO. Attitudes towards sustainability measures	-2	0	-2	0	0	0	1	-2	1	0	0	0	

Visualizing and interpreting the influence matrix

How can we leverage the influence matrix to enhance our understanding and inform our assessment ?

Visualizing and interpreting the influence matrix

1. Role of indicators in the system

- Activity: Sum of absolute values of rows indicating the overall influence of an indicator on the other indicators
- Passivity: Sum of absolute values of columns indicating the extent of how much they are influenced by the other indicators

		S1						S2						S3						
		Permeable surface	Waste water management	Grey energy	Rental costs	Shared spaces	Proximity to public transportation	Water consumption	Energy consumption	Renewable electricity production	Local food production	Surface per person	Intergenerational mix	Incinerated waste	Recycled waste	Share of home-work	Voluntary work	Life satisfaction	Slow mobility	**Activity**
S1	Permeable surface		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	**2**
	Waste water management	2		1	2	0	0	-3	0	0	0	0	0	0	0	0	0	0	0	**8**
	Grey energy	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	Rental costs	0	0	0		0	0	0	0	0	0	-3	-3	0	0	2	-2	-2	0	**12**
	Shared spaces	0	0	0	0		0	0	0	0	0	0	3	0	0	0	3	2	0	**8**
	Proximity to public transportation	0	0	0	1	0		0	0	0	0	0	2	0	0	0	0	1	3	**7**
S2	Water consumption	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	**0**
	Energy consumption	0	0	0	0	0	0	0		-2	0	0	0	0	0	0	0	0	0	**2**
	Renewable electricity production	0	0	0	2	0	0	0	0		0	0	0	0	0	0	0	2	0	**4**
	Local food production	2	0	0	0	0	0	2	0	0		0	0	-2	1	0	1	2	0	**10**
	Surface per person	0	0	0	0	0	0	0	0	0	0		0	0	0	2	0	0	0	**2**
	Intergenerational mix	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	**0**
S3	Incinerated waste	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	**0**
	Recycled waste	0	0	0	0	0	0	0	0	0	0	0	0	-2		0	0	0	0	**2**
	Share of home-work	0	0	0	0	0	0	0	0	0	0	0	0	0	0		-2	0	0	**2**
	Voluntary work	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		2	0	**2**
	Life satisfaction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	**0**
	Slow mobility	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		**0**
	Passivity	**4**	**0**	**1**	**5**	**0**	**0**	**5**	**0**	**2**	**0**	**3**	**8**	**4**	**1**	**4**	**8**	**13**	**3**	

Visualizing and interpreting the influence matrix

1. Role of indicators in the system

- Activity: Sum of absolute values of rows indicating the overall influence of an indicator on the other indicators
- Passivity: Sum of absolute values of columns indicating the extent of how much they are influenced by the other indicators

2. System understanding (relations between the elements)

- Causal flows, Causal loops (analyses of parts of the system)

3. System consolidation (reduction of a set of indicators, if necessary)

4. Construction of (internally consistent) scenarios

Visualizing and interpreting the influence matrix

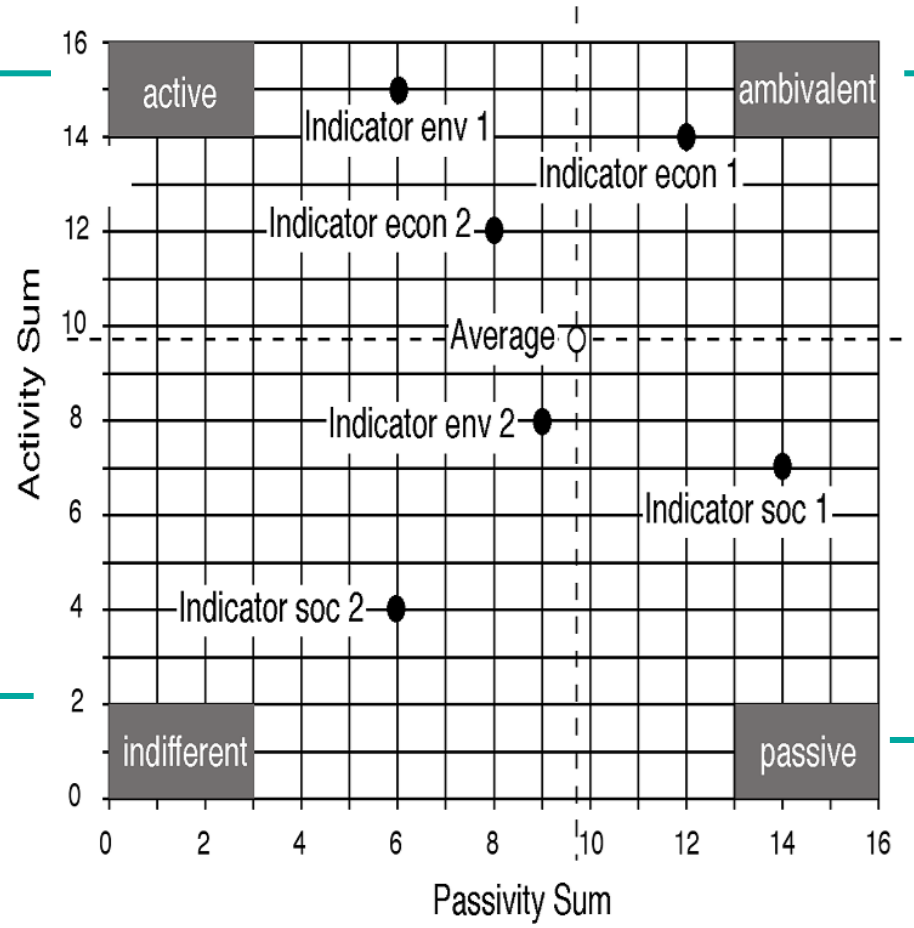
- Active indicators: strongly influence the system and are little influenced (sum rows>>>sum columns)
  - ➢ Considered as steering or driving indicators, important levers for changing the system
- Ambivalent indicators: strongly influence the system and are strongly influenced (sum rows ~ sum columns)
  - ➢ Considered as key indicators for the evolution of the system, important levers for changing the system
- Passive indicators: are influenced by the other variables (sum rows <<sum columns)
  - ➢Considered important for monitoring the system
- Indifferent (buffer) indicators: are little influenced and have little influence
  - ➢ Have low systemic relevance

Cole, A. (2006). The influence matrix methodology: A technical report. *Landcare Research Contract Report: LC0506/175*.

Visualizing and interpreting the influence matrix

strongly influence the system and are litte influenced

(sum rows>>>sum columns)



strongly influence the system and are strongly influenced

(sum rows ~ sum columns)

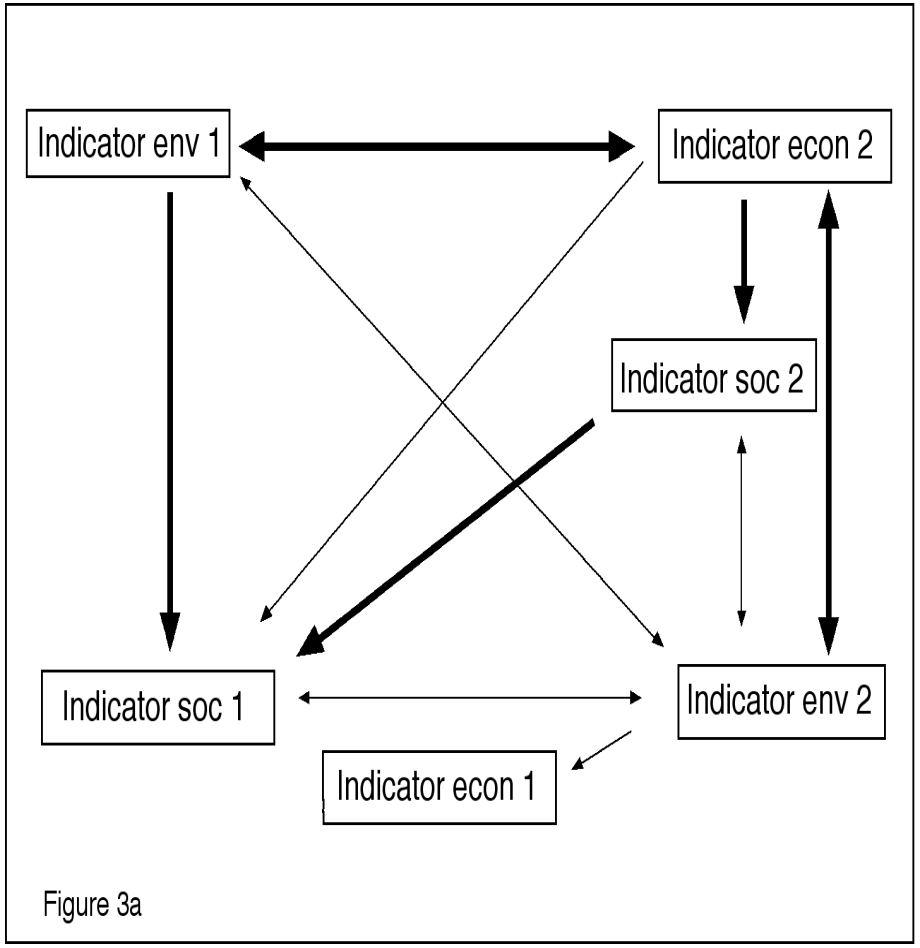
are little influenced and have little influence

are influenced by the other indicators

(sum rows <<sum columns)

Figure: example for system grid, also called activity-passivity plot (Wiek und Binder, 2005)

Visualizing and interpreting the influence matrix



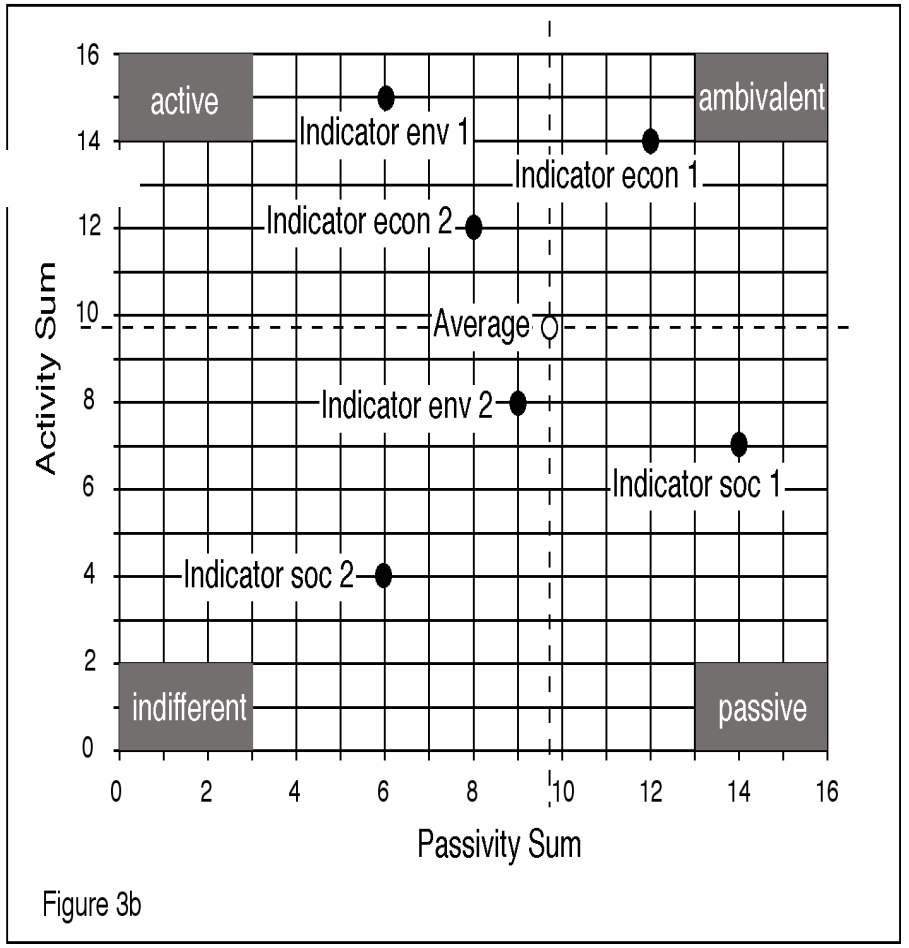


Figure: examples for system graph (left) and system grid, also called activity-passivity plot (right) (Wiek und Binder, 2005)

Activity-Passivity Plot – Example 1

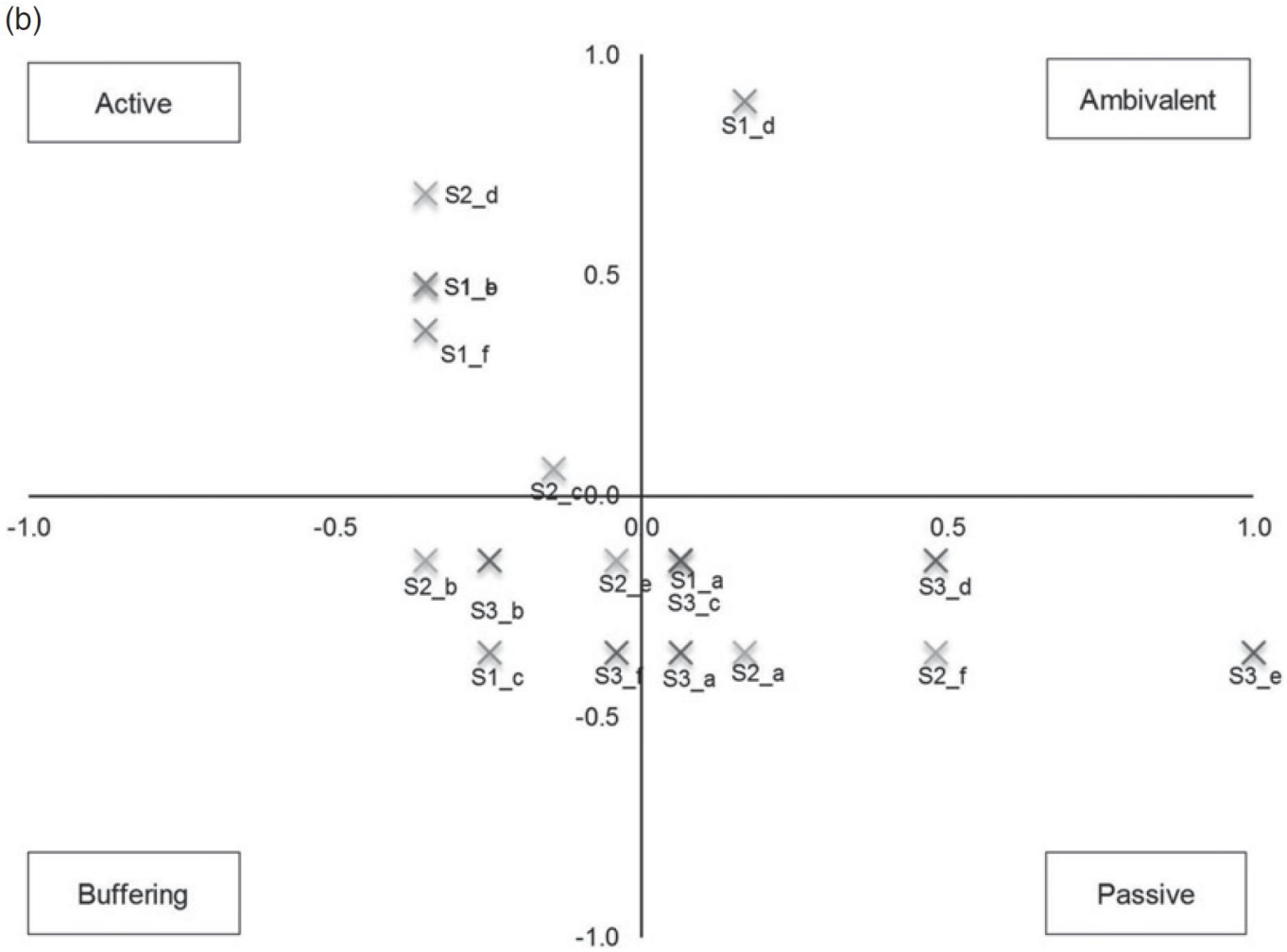
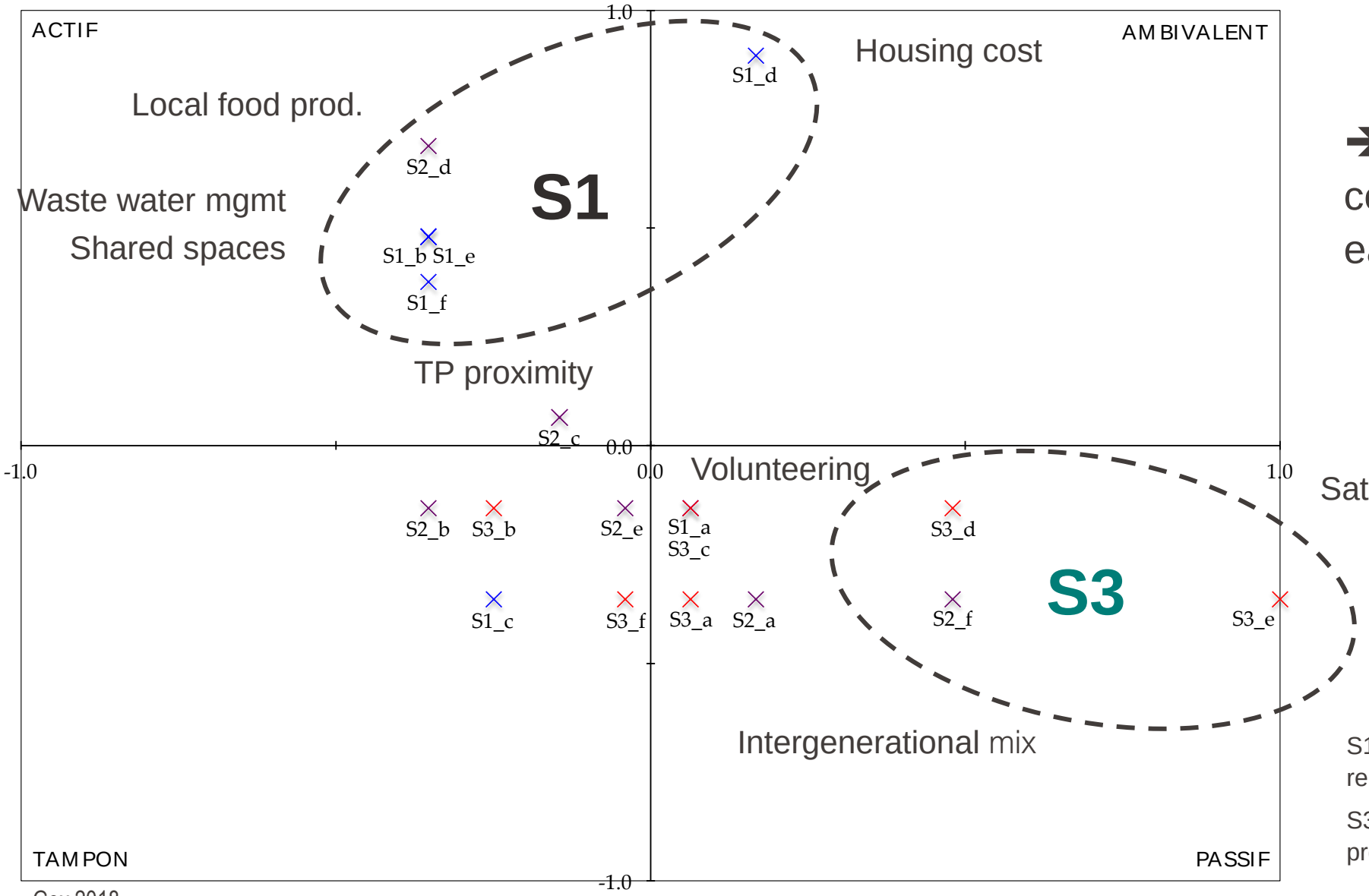


Figure 8.5 **(a)** Influence matrix of the Équilibre case study (right) and **(b)** impact grid for the Équilibre case study (left). The activity and passivity were normalized and plotted for each indicator. For the labeling, please see Table 8.5. Source: own illustration

Activity-Passivity Plot – Example 1



➔ Need to consider S1 early!

S1 static properties related to the building

S3 dynamic properties

Interactions among indicators - Example 2

How can we assess the sustainability of the housing system, considering both its material and social components?

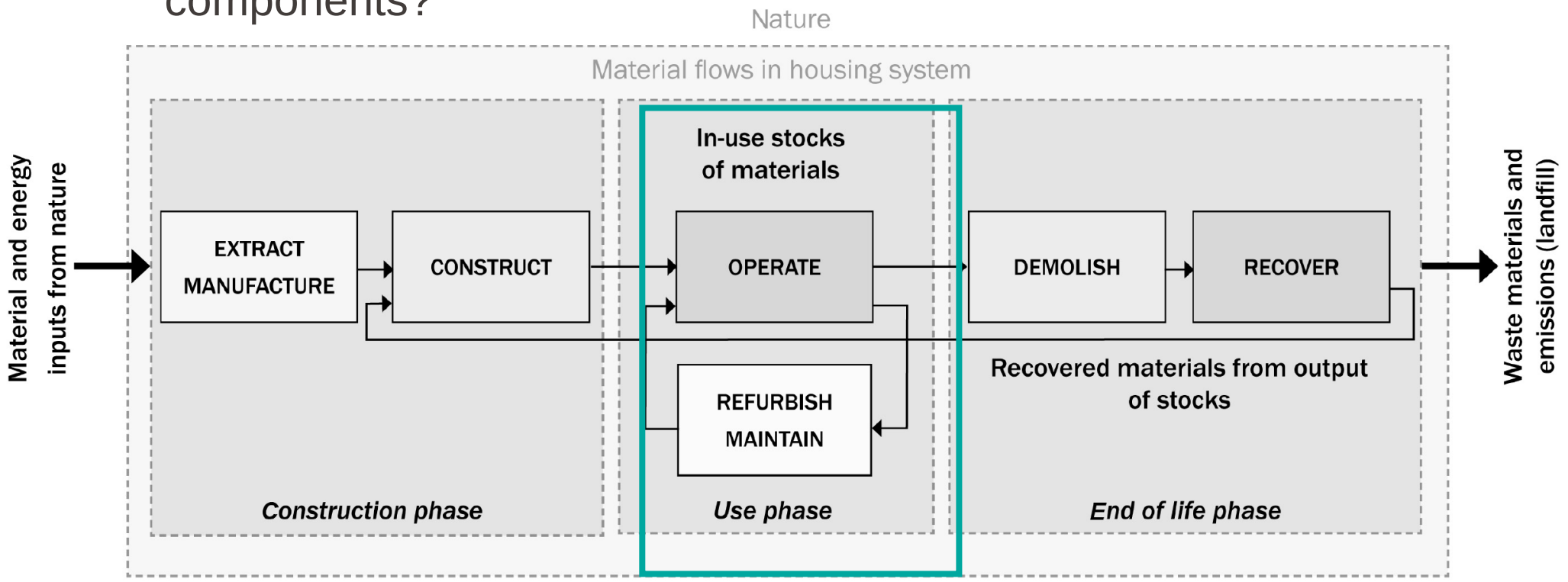


Figure 16.2 Aggregated material flows in housing system. Source: authors

Interactions among indicators - Example 2

		ENV				ECON		SOC						
		EFO	REO	WDO	CFO	RAO	IHO	FAO	SPO	SSO	VRO	ICO	IAO	ASO
ENV	EFO. End energy footprint		0	0	2	0	1	0	0	0	0	0	0	0
	REO. Share of renewable energy	0		0	-2	0	-2	0	0	0	0	0	0	0
	WDO. Water demand	1	0		0	0	0	0	0	0	0	0	0	0
	CFO. Carbon footprint	0	0	0		0	0	0	0	0	0	0	0	0
ECON	RAO. Rent affordability	0	0	0	0		0	0	0	0	-2	0	0	0
	IHO. Income spent on housing operation and maintenance	0	0	0	0	0		0	0	0	2	0	0	0
SOC	FAO. Flexibility and adaptability	0	0	0	0	0	0		-1	0	-2	1	0	0
	SPO. Space per person	2	0	0	0	-1	1	0		-1	0	0	0	0
	SSO. Shared space	-1	0	-1	0	1	-1	0	1		0	0	0	0
	VRO. Vacancy rate	0	0	0	0	0	0	0	0	0		0	0	0
	ICO. Indoor comfort	2	0	0	0	0	0	0	0	0	-2		0	0
	IAO. Information and awareness	-1	0	-1	-1	0	0	0	-1	1	0	0		1
	ASO. Attitudes towards sustainability measures	-2	0	-2	0	0	0	1	-2	1	0	0	0	

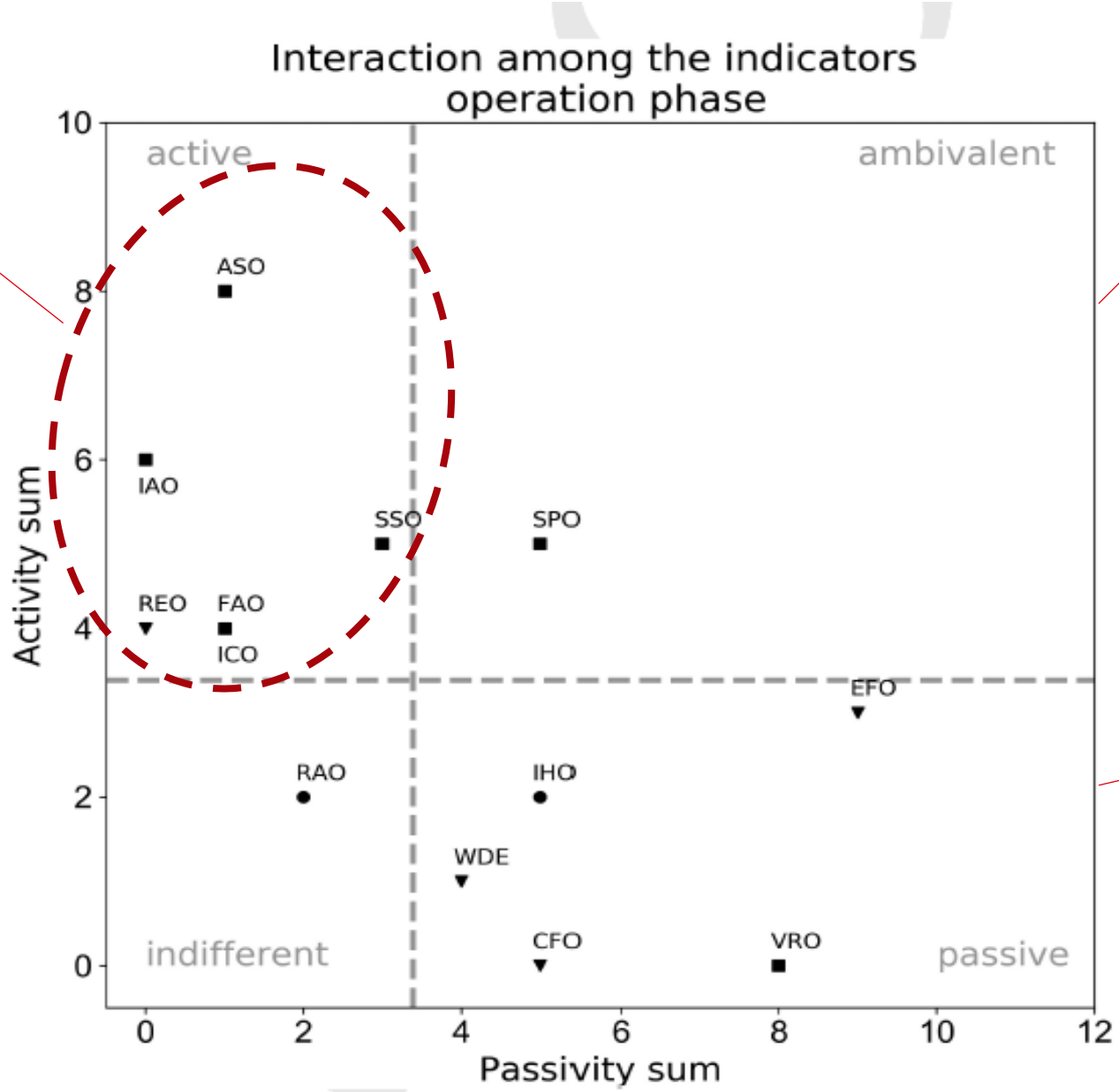
Interactions among indicators - Example 2

		ENV		SOC					
		EFO	REO	FAO	SPO	ICO	IAO	ASO	**Activity**
ENV	EFO. End energy footprint								**[sum of line]**
	REO. Share of renewable energy								
SOC	FAO. Flexibility and adaptability								
	SPO. Space per person								
	ICO. Indoor comfort								
	IAO. Information and awareness								
	ASO. Attitudes towards sustainability measures								
	Passivity	**[sum of column]**							

Binder | Heinrich

Activity-Passivity Plot – Example 2

Important leverage for increasing sustainability of the system, e.g. attitudes towards sustainability measures, indoor comfort, shared space, shared of renewable energy etc.



Space per person, influenced by e.g. attitudes towards sustainability measures, and influencing e.g. end energy footprint

Important to monitor e.g. end energy footprint, water demand, carbon footprint

Pagani et al. 2020

Conclusion: Influence Matrix and Activity-Passivity Plot

Strengths

- Flexible tool that can be applied to any case
- Integrative perspective, highlighting how indicators are interrelated
- Allows us to identify leverage points for changing the systems
- If trade-offs are elicited together with stakeholders it increases their system understanding

Challenges

- Potential “bias” depending on the people participating in the process (is knowledge-based, but leaves room for interpretation)
- Challenge of consolidating different participants’ perception of influence

Group projects

These methods can be used for different steps of your sustainability assessment, for example:

- **When finalizing the selection of indicators**: To reflect on the selection of indicators and to iteratively refine or further narrow down the selection on the basis of the activity-plot (e.g. what if most indicators are buffering ones?)
- **When performing the assessment**: characteristics of indicators/their positioning in the system can inform the weighting of indicator (e.g. should active and buffering indicators receive the same weight in your Multi Criteria Assessment?)
- **When discussing the policy implications of the assessment:** To identify leverage points for intervening in the system in order to move towards a more sustainable one (e.g. what should urban policymakers focus on?)

References

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- Godet, M., 2000. The art of scenarios and strategic planning: tools and pitfalls.Technol. Forecast. Soc. Change 65, 3–22.
- Scholz, R.W., Tietje, O., 2002. Embedded Case Study Methods: Integrating Quantitative and Qualitative Knowledge. Chapter 9, SAGE, London.
- Pagani et al.,(2020). Sustainability Assessment of the Housing System: Exploring the Interplay between the Material and Social Systems. In C. R. Binder, E. Massaro, & R. Wyss (eds.), *Sustainability Assessment in Urban Systems*.Cambridge University Press, pp. (384-416)