CECAN Webinar: Trophic Analysis of Directed Networks

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Tuesday 22nd September 2020, 13:00 - 14:00 BST

Presenter: Professor Robert MacKay, University of Warwick

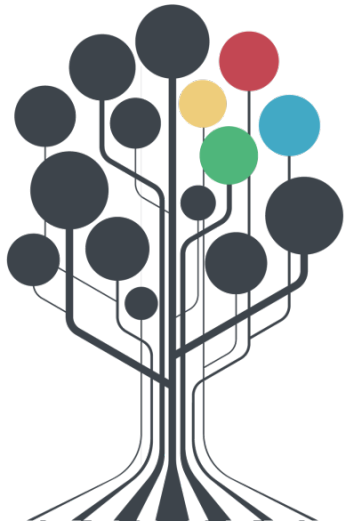
Welcome to our **CECAN Webinar.**

All participants are muted. Only the Presenters and CECAN Chair can speak. The webinar will start at **13:00 BST.**

Robert will speak for around 45 minutes and will answer questions at the end.

Please submit your questions at any point during the webinar via the **Q&A** box in the Zoom webinar control panel.

Today's webinar will be recorded and made available on the CECAN website.



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Trophic Analysis of Directed Networks

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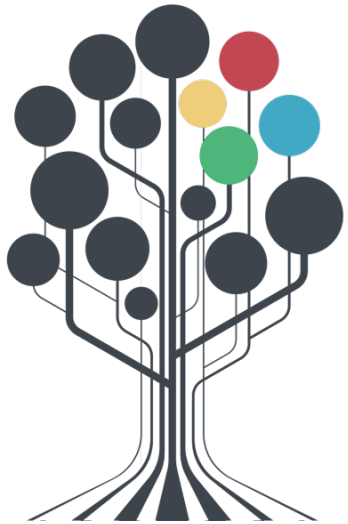
- Joint work with Bazil Sansom and Sam Johnson
- Supported by the Economic & Social Research Council (ESRC) via the Instability hub of the Rebuilding Macroeconomics programme managed by the National Institute of Economic and Social Research.
- Will concentrate here on its potential relevance to systems maps and related themes for evaluation of complex systems



Example directed network: from Alex Penn's Participatory Systems Mapping guide

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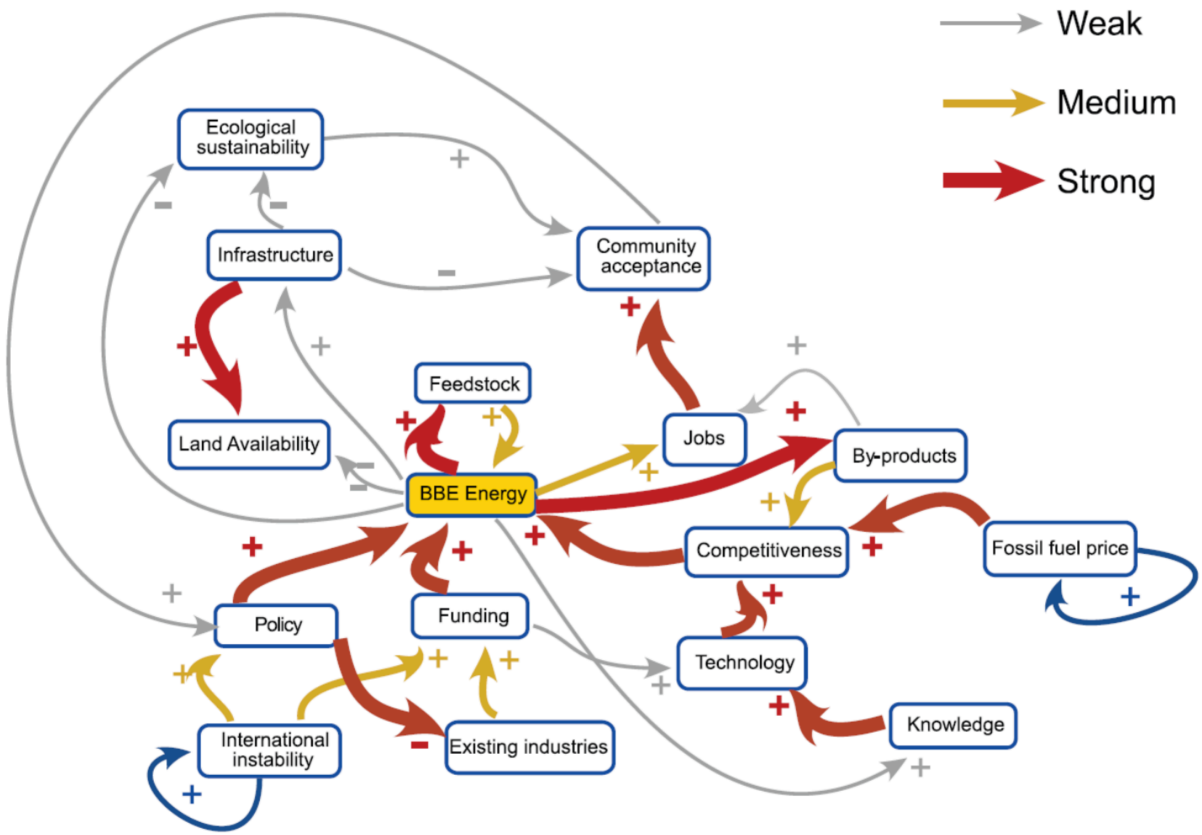

A system map indicates relevant factors and causal relationships between them

BBE=bio-based economy

Trophic analysis reveals position of factors along the flow of influence and quantifies the (in)coherence of the flow

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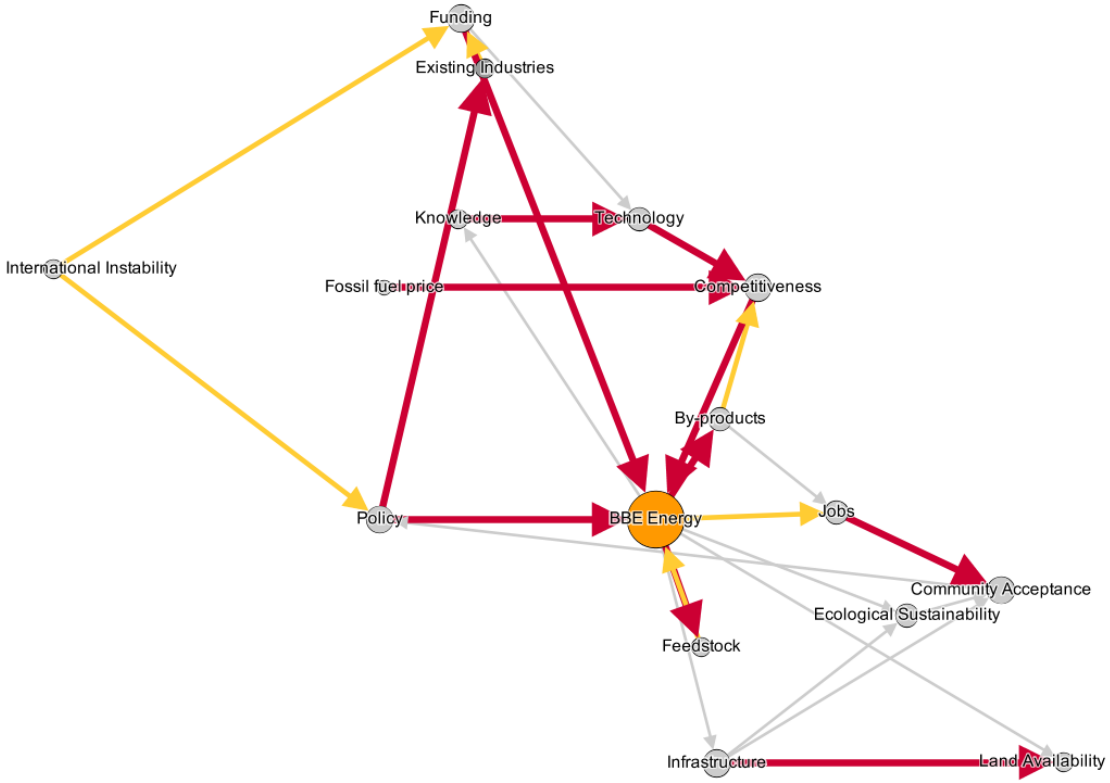
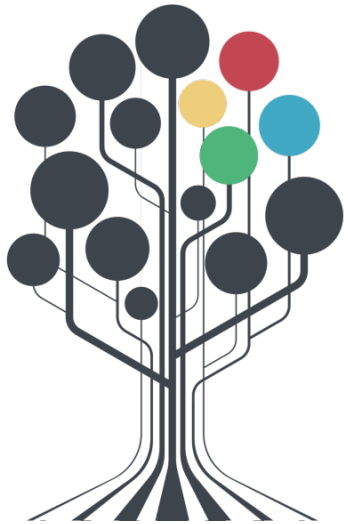


Edge weights coded as
Strong=1,
Medium = 2/3,
Weak=1/2

Incoherence
$F_0 = 0.6$



How does trophic analysis work?

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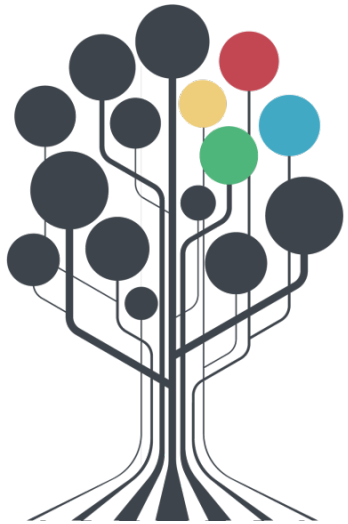
- It tries to assign levels to the nodes so that the level increases by 1 along each edge
- More precisely, let $w_{ij} > 0$ be the weight of edge from i to j, and minimise $\Sigma_{ij}\, w_{ij}\, (h_j - h_i - 1)^2 / \Sigma_{ij}\, w_{ij}$ over vector h. Then let incoherence F_0 be the minimising value.
- Get a unique solution h, up to adding an arbitrary constant in each weakly connected component
- It is given by solving linear system L h = v, where L is the symmetrised weighted graph-Laplacian and v is the imbalance vector $v_j = \Sigma_i\, w_{ij} - \Sigma_i\, w_{ji}$.
- There are other versions: Levine; Shuaib et al; and equivalent formulation by Iyetomi et al



Example 2: Renewable heat incentive system map from Pete Barbrook-Johnson

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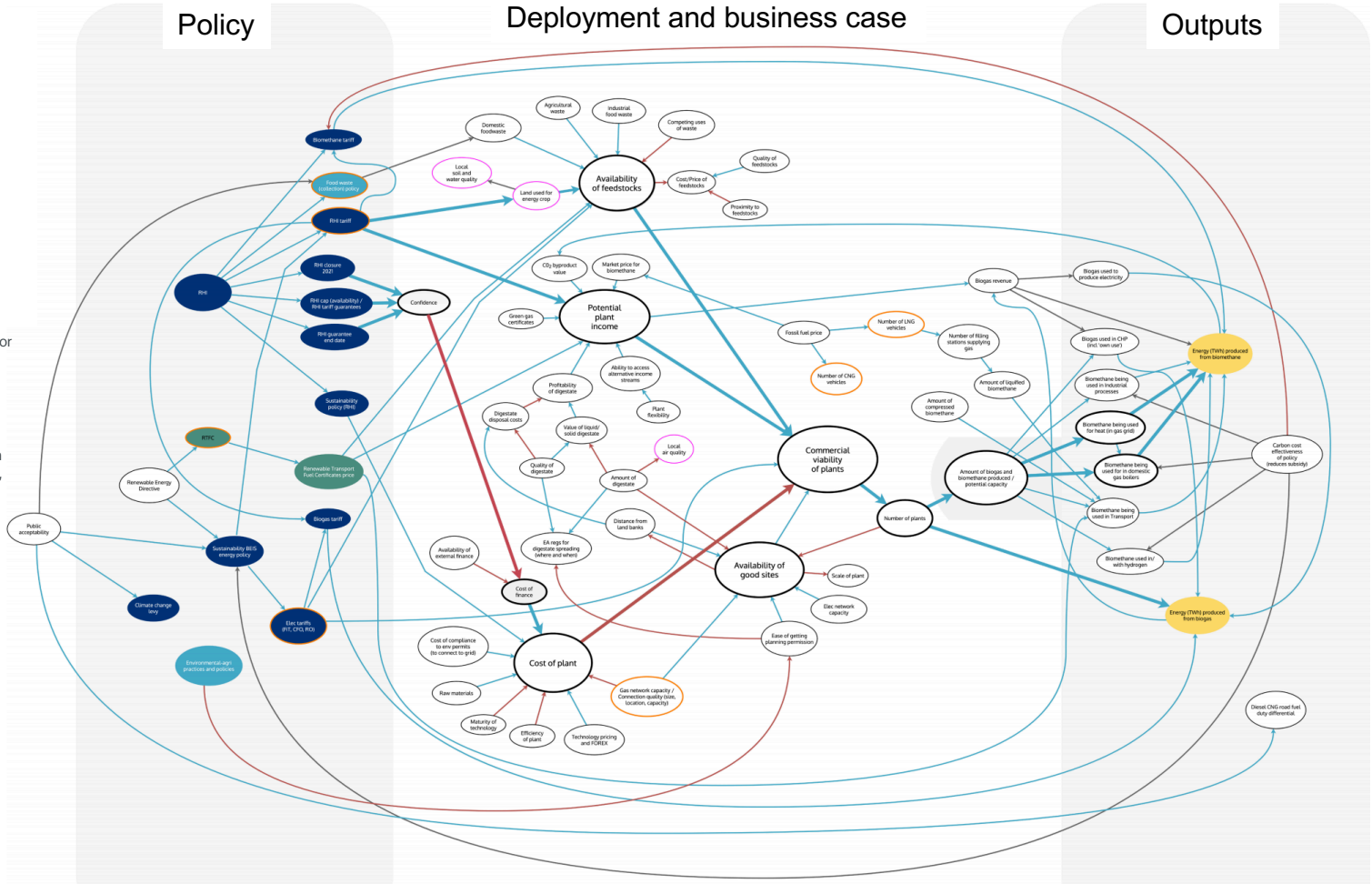
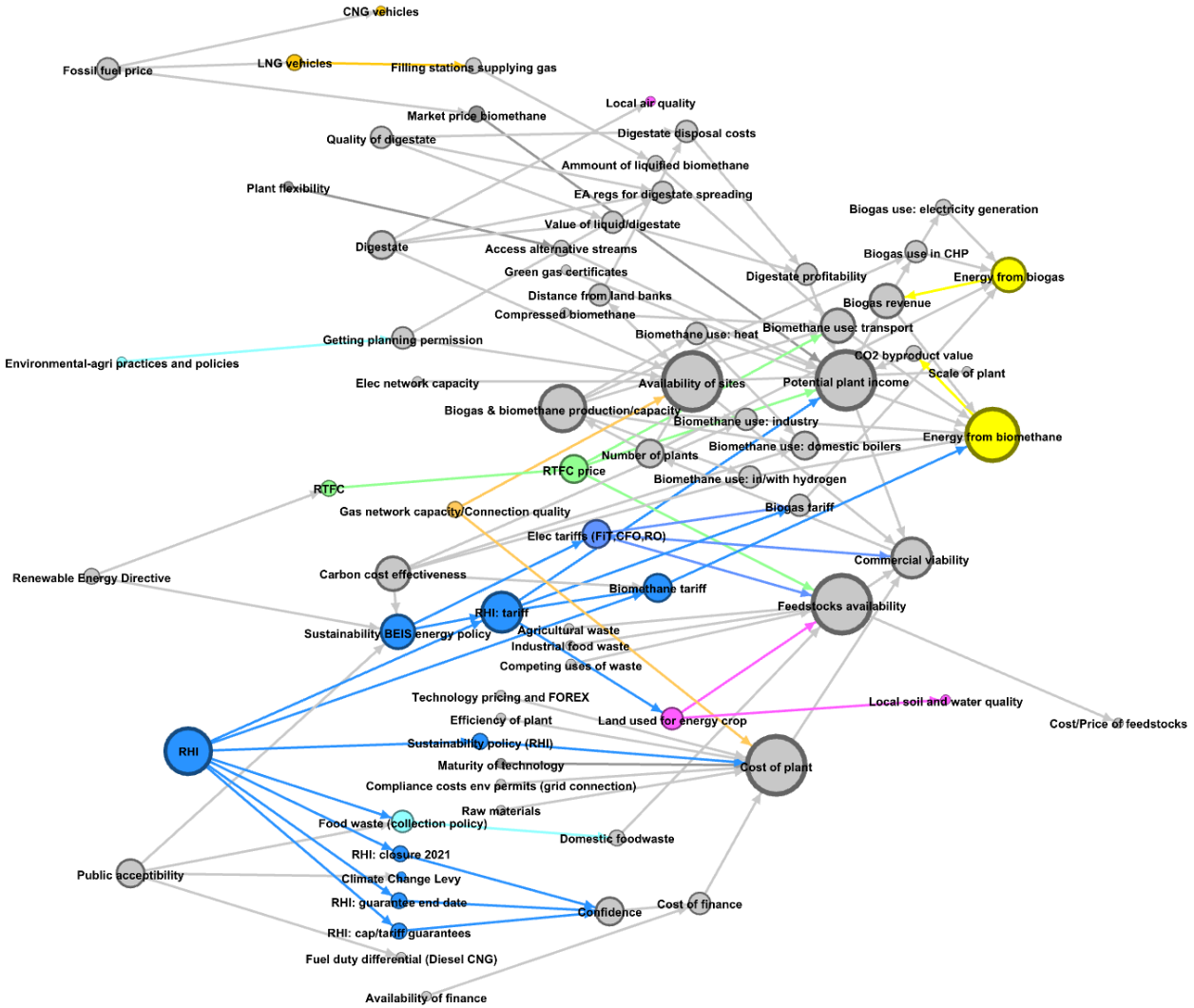
CECAN Note 17
(April 2020)



Replotted with trophic level on horizontal

- BEIS Policy
- DfT Policy
- Defra Policy
- Focal factor
- Risk
- Volatile



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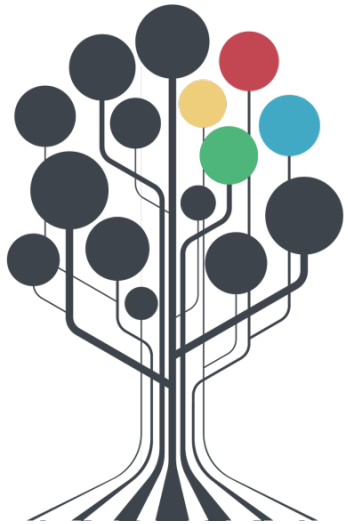
Incoherence
$F_0 = 0.2$



What does incoherence F_0 measure?

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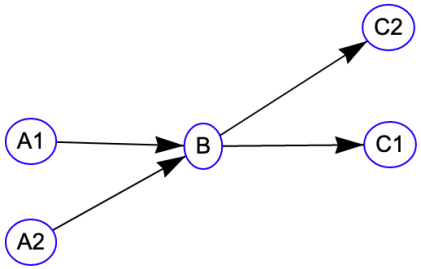
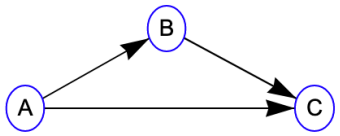
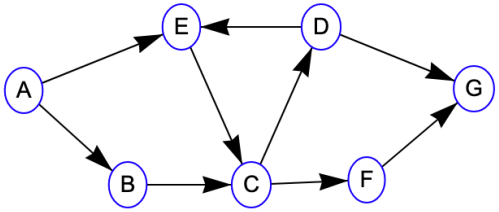
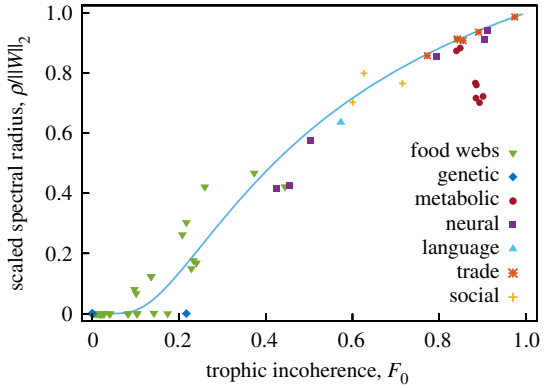




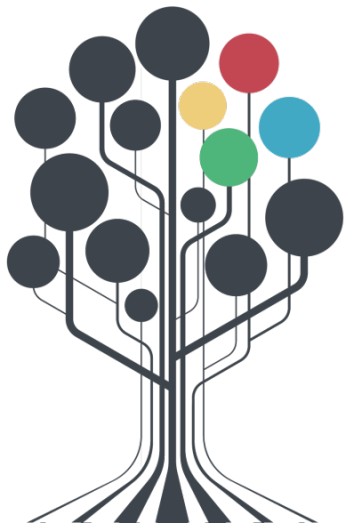




F_0 = 0 1/9=0.11 2/5=0.4 1

Networks drawn using PRiSM, thanks to Nigel Gilbert et al; equal weights assumed for calculation of F_0.

F_0 measures the failure of level differences to all be +1.
Some call it “circularity”. In particular, existence of a cycle forces $F_0>0$ and $F_0=1$ implies every edge is in a cycle, but $0<F_0<1$ does not imply any cycles.
Nonetheless, we conjecture that a quantification ρ_s of cyclicity behaves typically like $\rho_s = \exp((1-1/F_0)/2)$.



Example 3: fuzzy cognitive map based on stakeholder workshop in Bolivia

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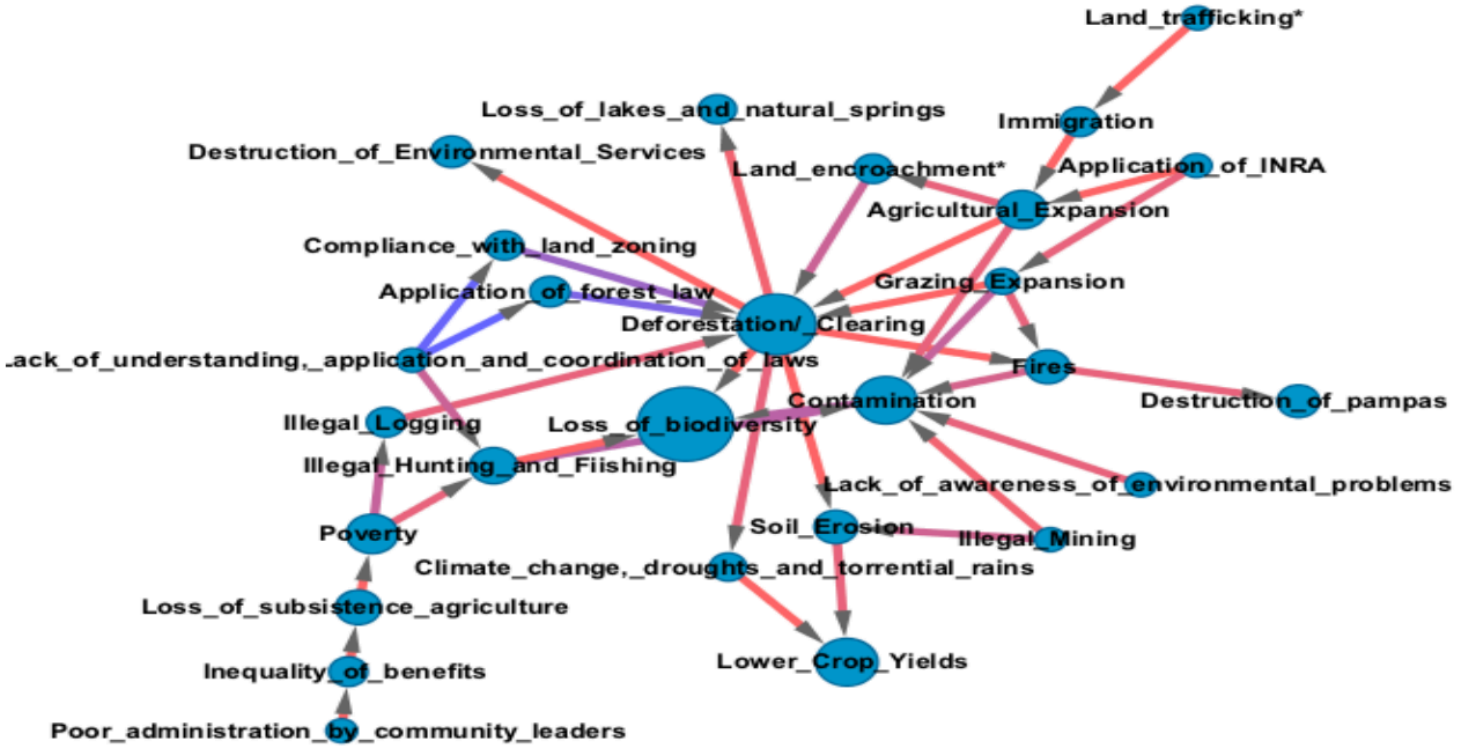

Replotted with trophic levels

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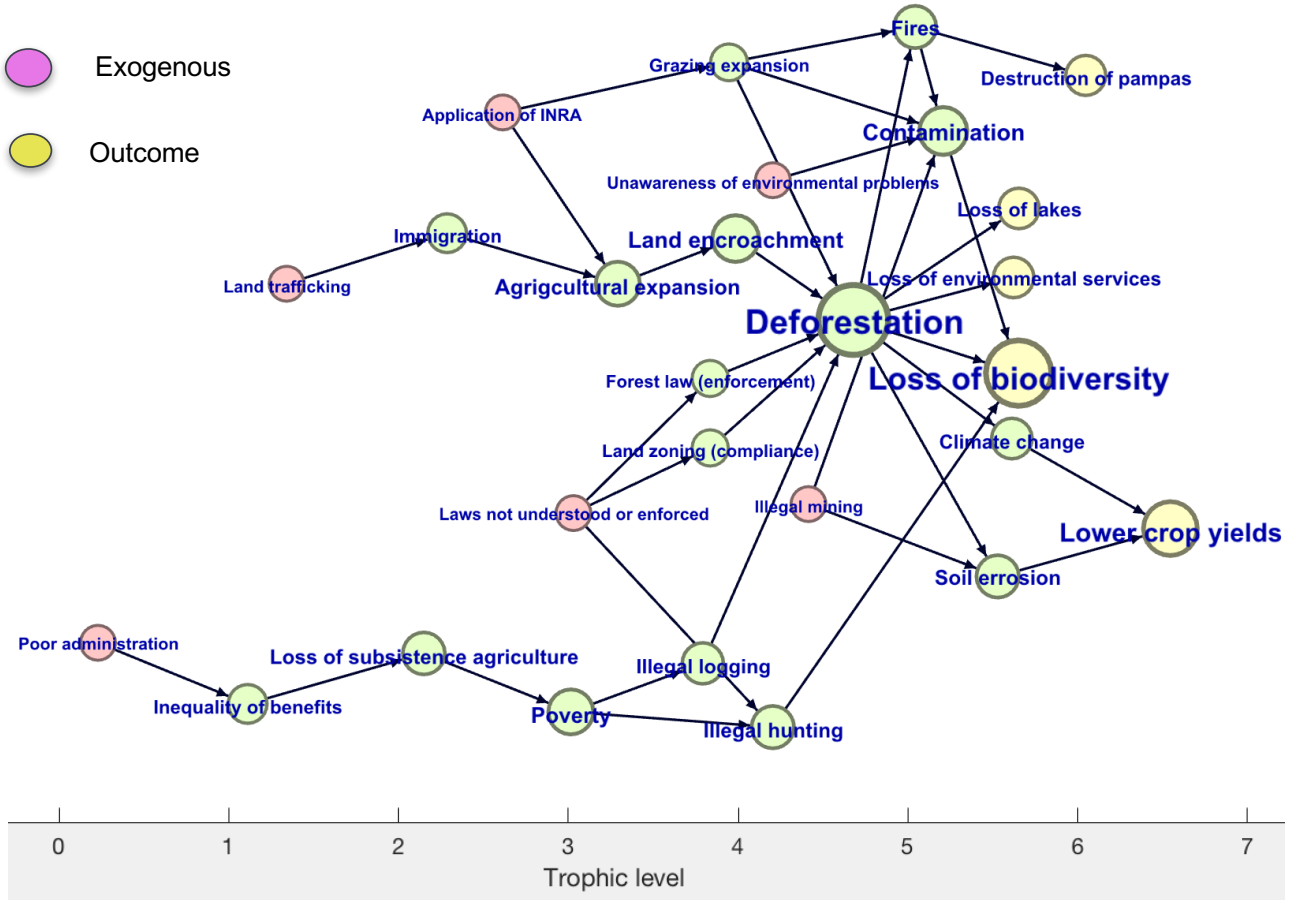

Incoherence
$F_0 = 0.06$

Systems map for the article “Garden instead of concrete: how Paris meets climate change”

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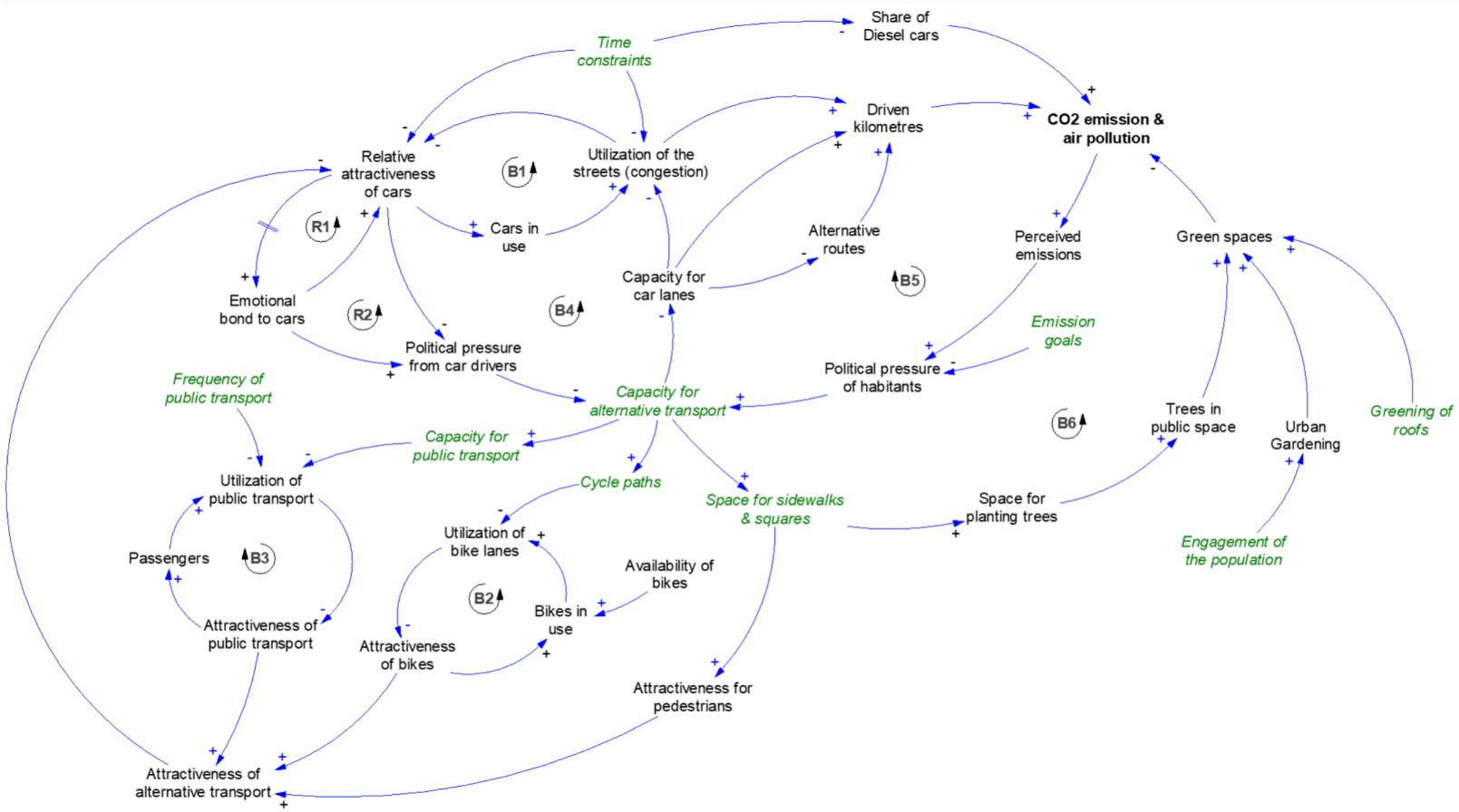

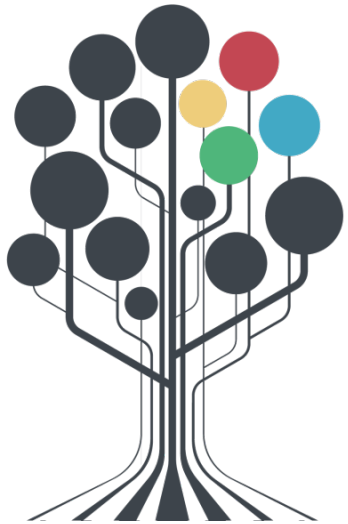

Replotted with trophic levels

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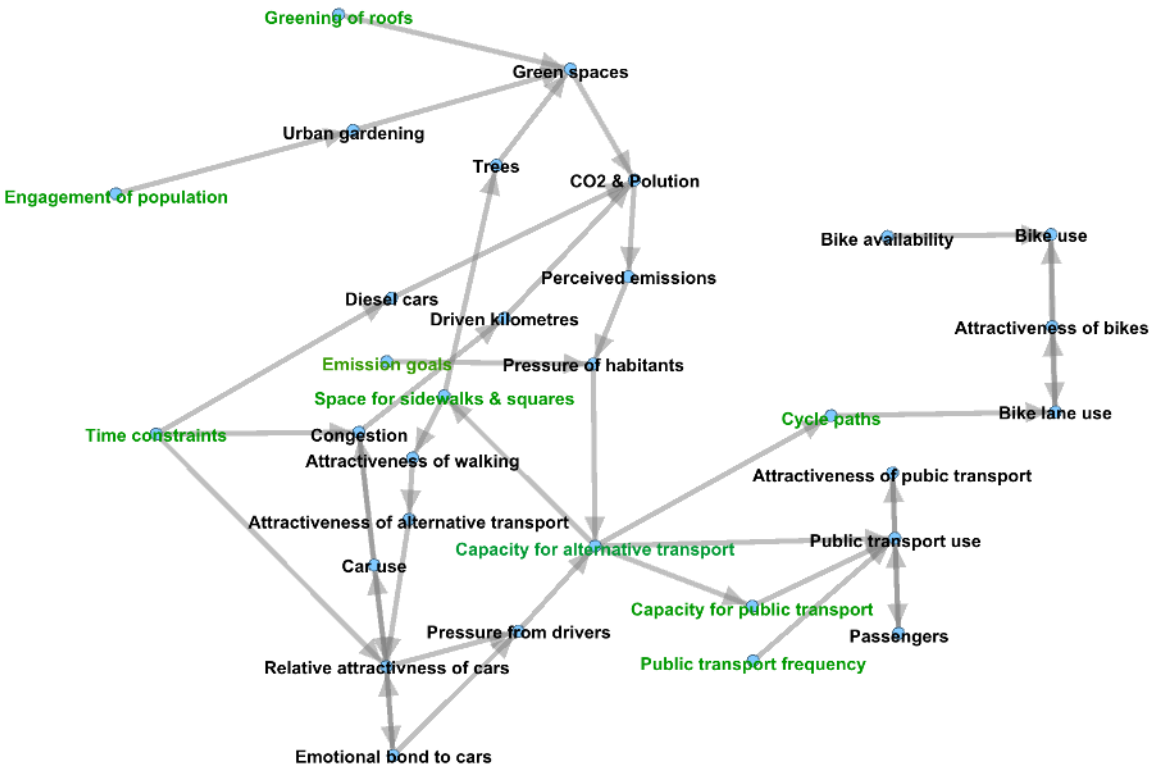
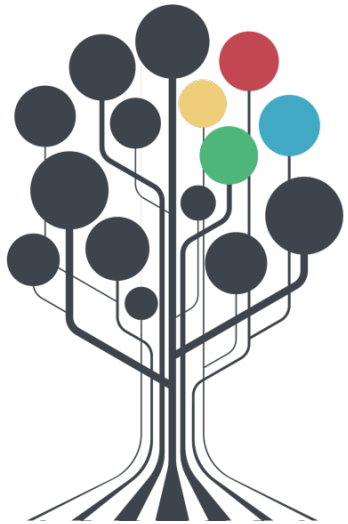
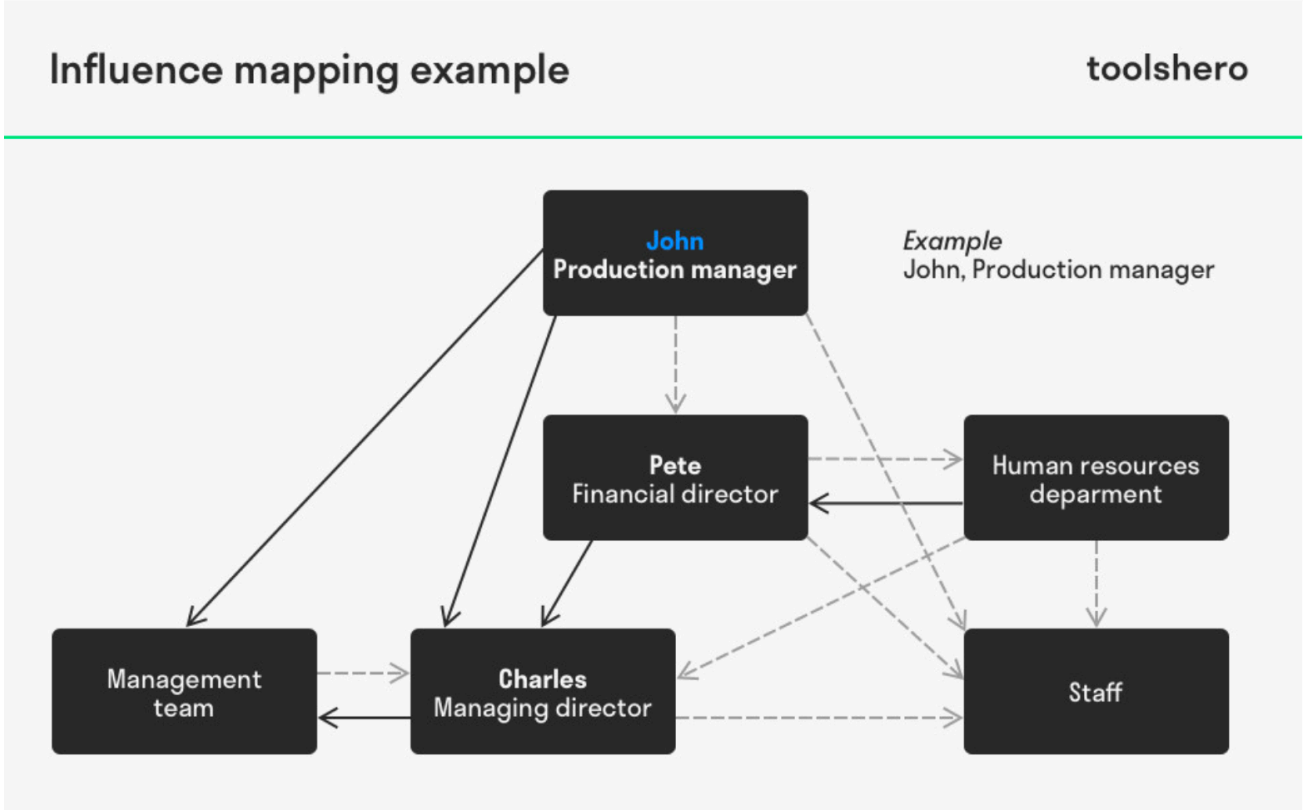


Incoherence
F_0=0.57



Alternative terminologies, e.g.



Mulder, P. (2012). *Influence Mapping*. Retrieved from ToolsHero: https://www.toolshero.com/project-management/influence-mapping/

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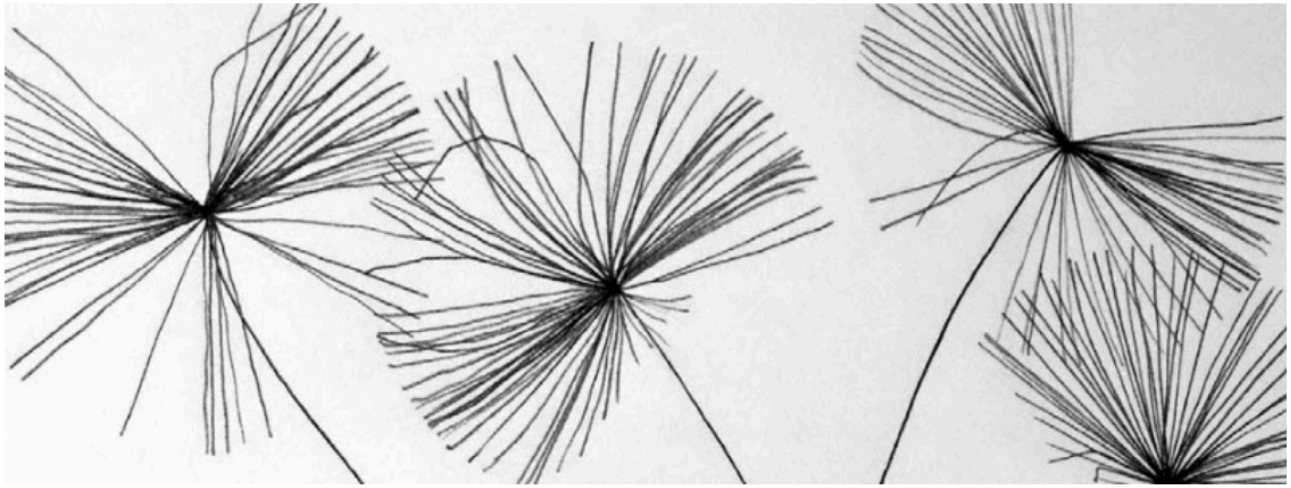

An Introduction to Influence Mapping in Evaluation: Methods, Practice and Use-Cases

Monday 13th July 2020, 13:00 - 16:00 (Part 1) &
Tuesday 14th July 2020, 09:30 - 13:00 (Part 2)

Live Online Training (via Zoom)

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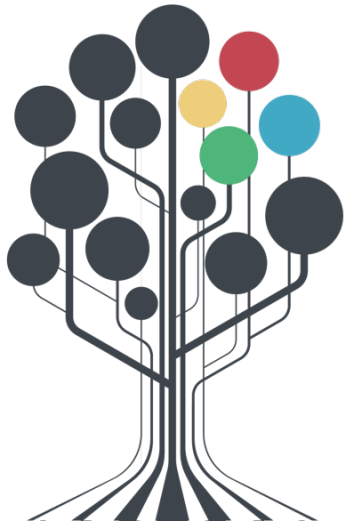
Simon Henderson
& Stuart Astill

But they put Bayesian belief propagation on the networks so I think have to make acyclic



Causal loop diagram, e.g for a life insurance company (wikipedia)

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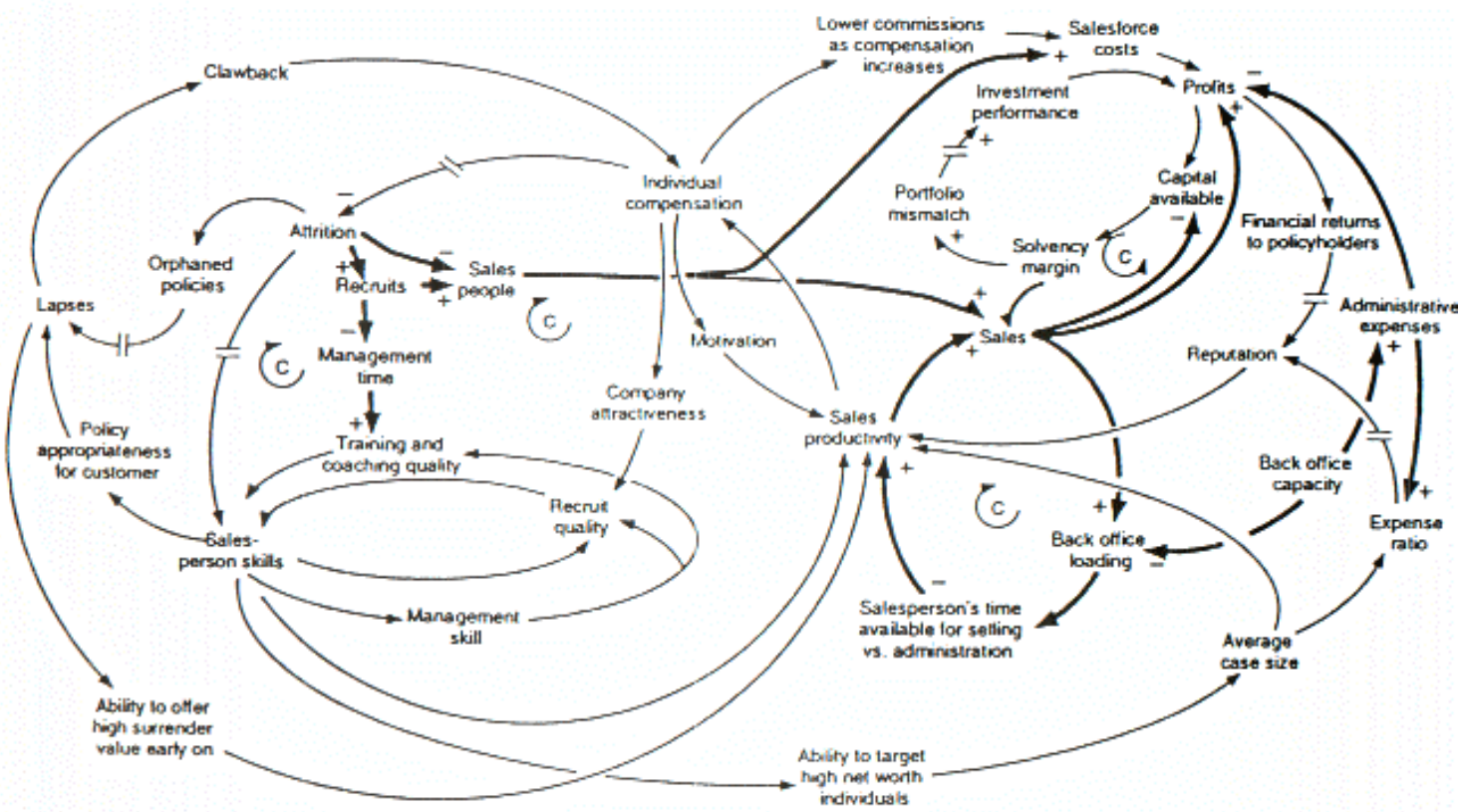

Outcome pathways for Theories of Change

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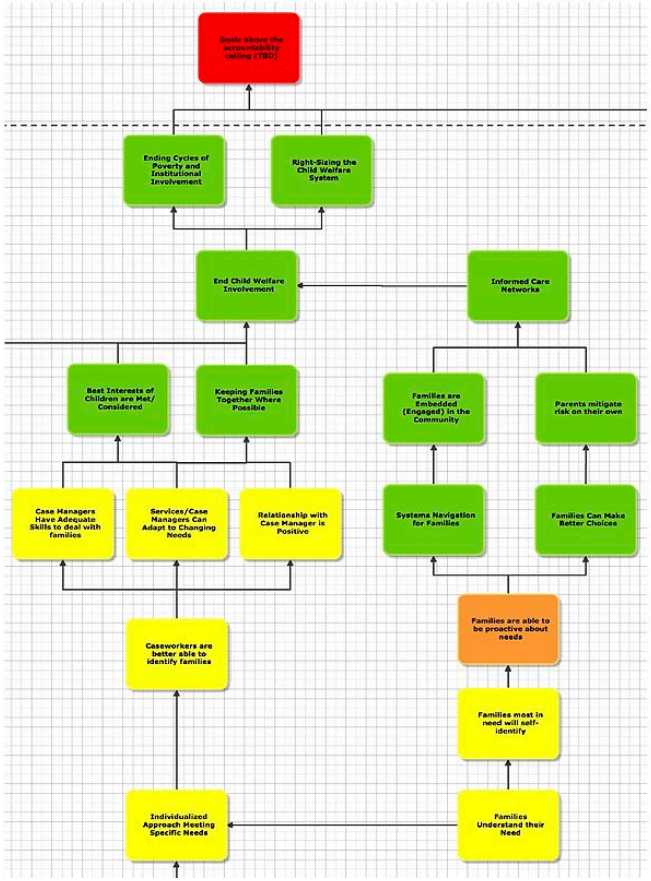
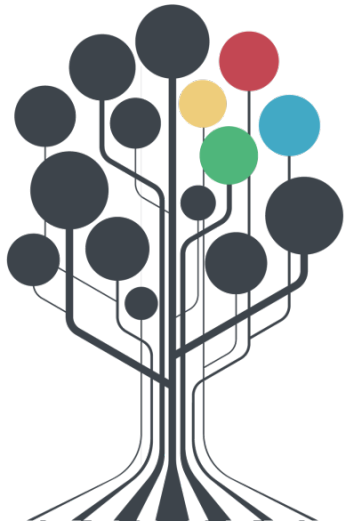


This example from wikipedia is for Child Welfare.
Often acyclic.
Also known as a Results Chain or Logic Chart.
This example is perfectly coherent.

A subsidiary theme is Contribution Analysis:
quantifying the influence of a decision on an outcome



A refinement: specify target level differences

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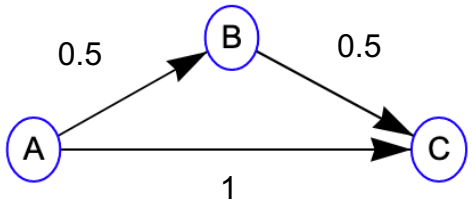
- e.g. for feedforward motif could put target level differences as shown and get perfect coherence.



- More generally, minimise $F(h) = \frac{\sum_{mn} w_{mn}(h_n - h_m - \tau_{mn})^2}{\sum_{mn} w_{mn}\tau_{mn}^2}$,

  over h; equivalent to solving L h = v, with $v_n = \sum_m (w_{mn}\tau_{mn} - w_{nm}\tau_{nm})$.

- Maybe one could allow target height differences to choose themselves, leaving incoherence to come only from cycles?

- As an extreme, we make a method to assign strengths to teams based on a set of pairwise comparisons that is not necessarily complete.

Example: Women's Super League

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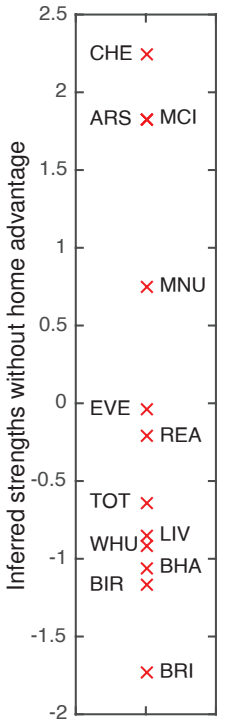
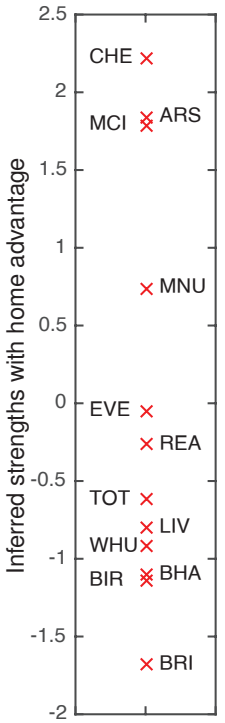
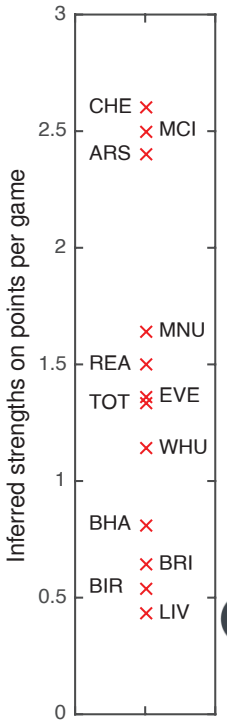
Home	Away											
	ARS	BIR	BHA	BRI	CHE	EVE	LIV	MCI	MUN	REA	TOT	WHU
Arsenal		2–0	4–0	11–1	1–4	–	1–0	1–0	–	–	–	2–1
Birmingham City	–		–	0–1	0–6	0–1	2–0	0–2	–	–	1–1	–
Brighton & Hove Albion	0–4	3–0		–	1–1	1–0	1–0	–	1–1	2–2	0–1	1–3
Bristol City	–	0–2	0–0		0–4	–	0–1	0–5	–	–	1–2	–
Chelsea	2–1	2–0	–	6–1		–	–	2–1	1–0	3–1	1–0	8–0
Everton	1–3	–	2–0	2–0	–		–	0–1	2–3	3–1	3–1	–
Liverpool	2–3	–	–	1–1	1–1	0–1		–	–	0–1	–	1–1
Manchester City	2–1	3–0	5–0	1–0	3–3	3–1	1–0		1–0	–	–	5–0
Manchester United	0–1	–	4–0	0–1	–	3–1	2–0	–		2–0	3–0	–
Reading	0–3	1–0	–	3–3	–	3–2	–	0–2	1–1		3–1	2–0
Tottenham Hotspur	0–2	–	1–0	–	–	2–2	1–0	1–4	0–3	–		2–1
West Ham United	–	1–0	2–1	–	1–3	–	4–2	–	3–2	2–3	0–2	







Can allow for a home advantage by minimising
$\Sigma\, w_{mn}(G_{mn}-S_m+S_n-b)^2$ over S and b,
where G_{mn} is goals for m minus goals for n in a match at m's home and w_{mn} is the number of such matches.

Could also compute the incoherence of the results.

b=0.38

What do we want systems maps (and their variants) to achieve?

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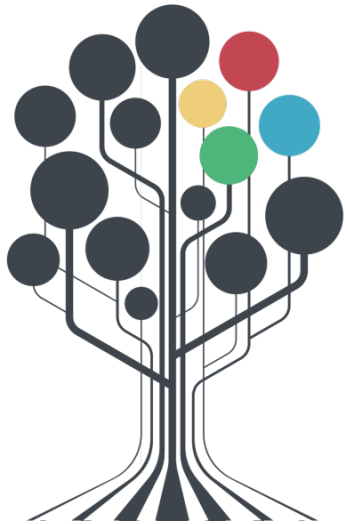
- One of the goals of participatory systems mapping is the engagement of stakeholders
- Another is to recognise the complexity of most policy environments, e.g. cycles
- Contribution analysis endeavours to attribute a quantification of cause to interventions, but usually based on an acyclic systems map
- Trophic analysis lays out a preferred horizontal coordinate, indicating how far along the flow of influence is a given factor
- It also quantifies the extent to which the network fails to be perfectly coherent, with factors arranged in layers and level differences = 1
- But the incoherence F_0 confounds cycles with feed-forward motifs and the method does not yet take signs of edges into account



References

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- RS MacKay, S Johnson, B Sansom, How directed is a directed network? RSOS 7 (2020) 201138 https://doi.org/10.1098/rsos.201138
- RS MacKay, Incomplete pairwise comparison, Mathematics Today (Aug 2020) 132–5