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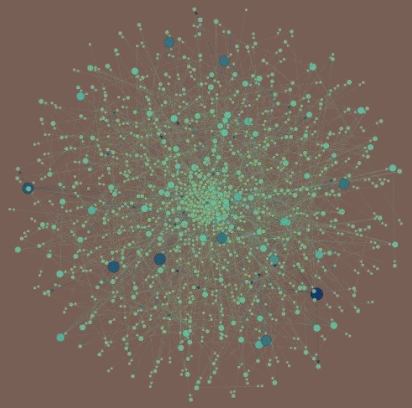

PROJECTS AS COMPLEX SYSTEMS: A NETWORK PERSPECTIVE

Systemic Consult Ltd

By Christos Ellinas

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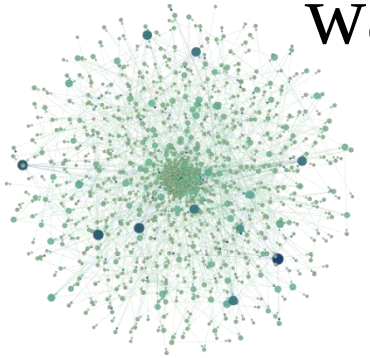
Take-away message

"Projects are at the core of economic prosperity. Yet their increasing complexity challenges our ability to successfully control them. Complex Networks can provide a quantitative framework to tackle practical challenges in an objective way using readily-available data"



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What it's all about

- Projects as Complex Systems
  - Complex Systems
  - Projects as Complex Systems
- Evaluating Project Complexity
  - Aspects of Project Complexity
  - Structural Complexity Evaluation
- Failure Cascades across Projects
  - Failure Cascade Sizes
  - Local Mitigation
  - Contractor activity

Projects as Complex Systems

"I am convinced that the nations and people who ***master the new sciences of complexity*** *will become the* ***economic, cultural, and political superpowers*** *of the next century"* —Heinz Pagels

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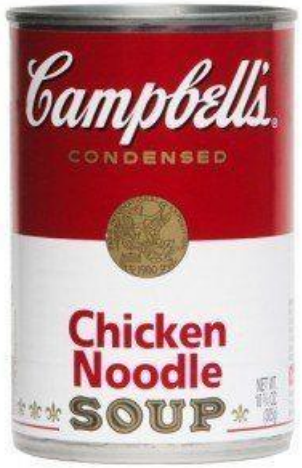
Complexity? Sounds complex …

Complex ≠ Complicated

Whole is bigger than the sum of its parts



- **Complexity**: both contain the same components, yet distinctly different.
- Its all about the **connections** ..
- Importantly, it is not about the extent of connectedness but rather on the **way it manifests**
- **Complex networks** form an ideal framework for exploring the implications of this complexity

Analogy courtesy of Dr. Thilo Gross

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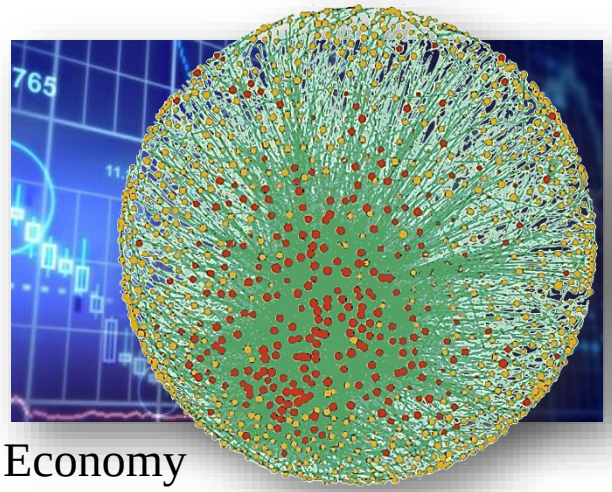
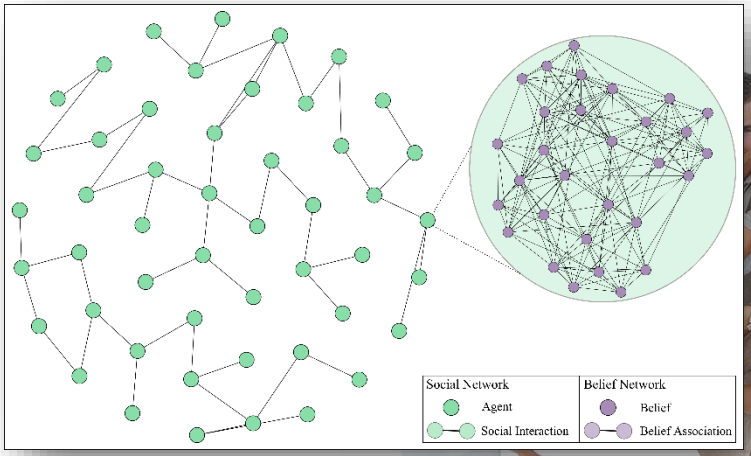
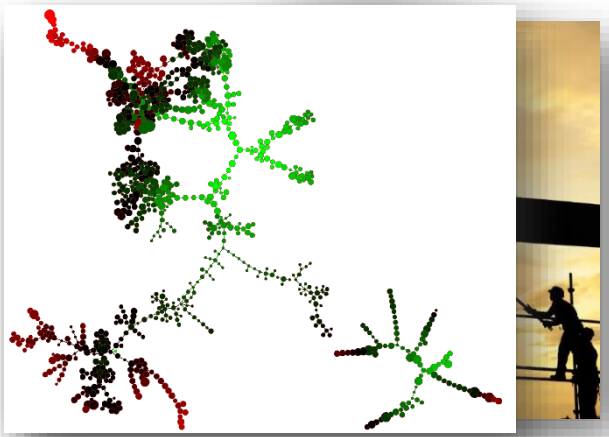
Real-World Complex Systems



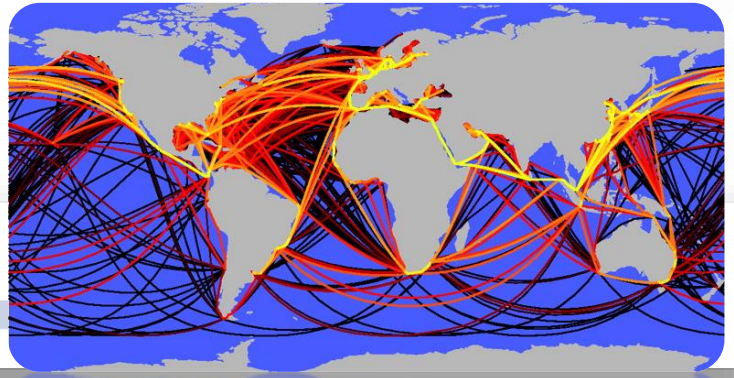
Economy



Organisational Culture



Projects



Supply Chains

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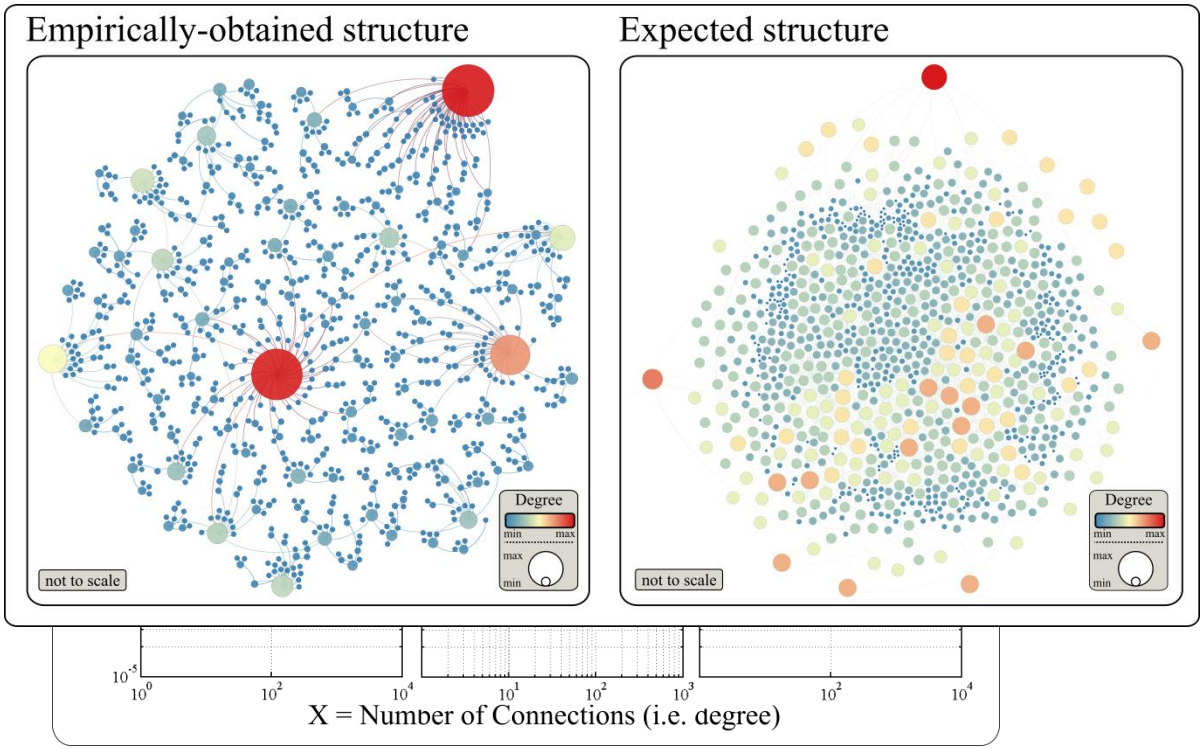
An example: The Internet (AS level)

- Complex Network can shed light into the **regularity of a system**.
- Consider the connectivity distribution of the Internet.
- No one would expect a node with 2390 connections (mean = is 4.21) yet there it is.



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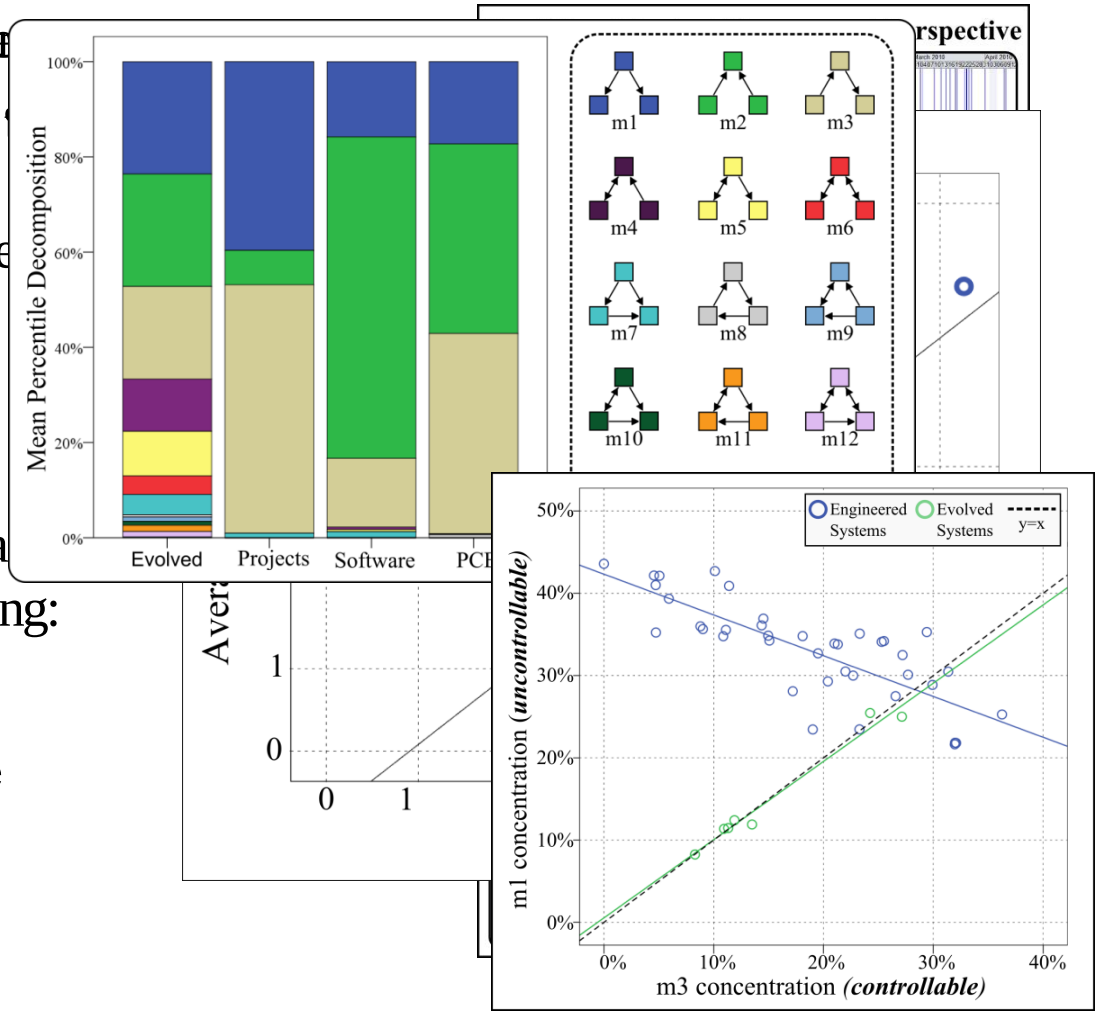
Projects: A process or a system?

- Consider a comparison between a **Process** optimised under a **prescribed** process)
  - **Engineered** Systems (i.e. result of a **centralised**, **top-down** process)
  - **Evolved** Systems (i.e. the result of a **decentralised**, **evolutionary** process)
- Projects show similar patterns as other complex systems, including:
  - PCBs
  - Software
  - Evolved (!!)

- Delving to a finer level of aggregation, consider the **composition of these systems** in **terms of subgraphs** (i.e. small patterns of interconnectivity)
- Clear distinction between evolved and engineered systems;
- **important implications on controllability capacity.**
- Whatever happened to the core assumption of PM - **"projects are unique endeavours"** ?!



Ellinas C., Allan N., Johansson A., "Structural Patterns in Complex Systems: A network perspective." (2014).
Ellinas C., Allan N., Johansson A., "Exploring Structural Patterns across Evolved and Designed Systems", Under Review

Evaluating Project Complexity

"*Complexity can be daunting, and practitioners are looking for guidance ... Having tools to analyse [...] complexity provides greater understanding and gives a start as to how to manage the complexity*"— Geraldi et al, 2011

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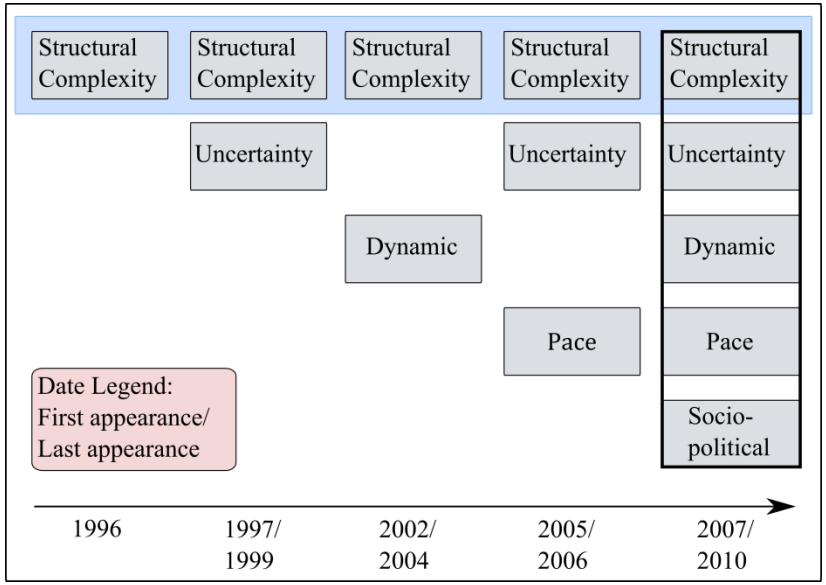
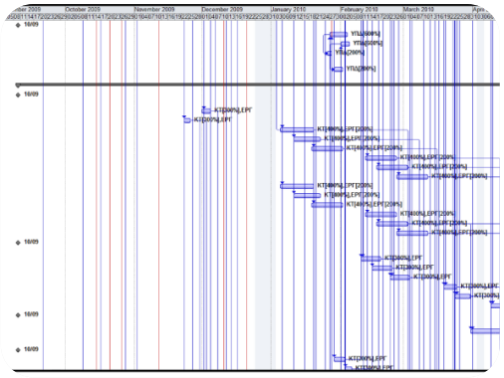
Aspects of Project Complexity

- Project Complexity stretches across five core aspects
- Focus on **structural complexity**; defined as "interactions between the activities of a project"
- **Project schedules** effectively capture these interactions, hence suitable data. Added bonus: **widely-captured** and **readily-available**.





Ellinas C., Allan N., Johansson A., "Towards Project Complexity Evaluation: A Structural Perspective" (In Press).

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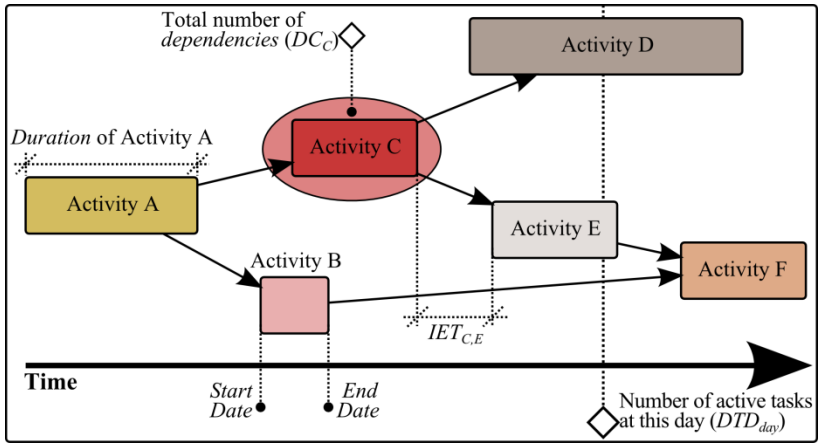
What can we measure?

- Typical project schedule contains information around:
  - Task Dependencies
  - Task Duration
  - Time Between Tasks
- Suitable **indicators** are constructed to measure these aspects
- Some indicators capture structural complexity **directly**; other **indirectly**



Measurement of Indicator Structural Complexity	
Direct	Degree Centrality (DC)
Direct	Betweenness Centrality (BC)
Indirect	Daily Task Density (DTD)
Indirect	Inter-Event Time (IET)

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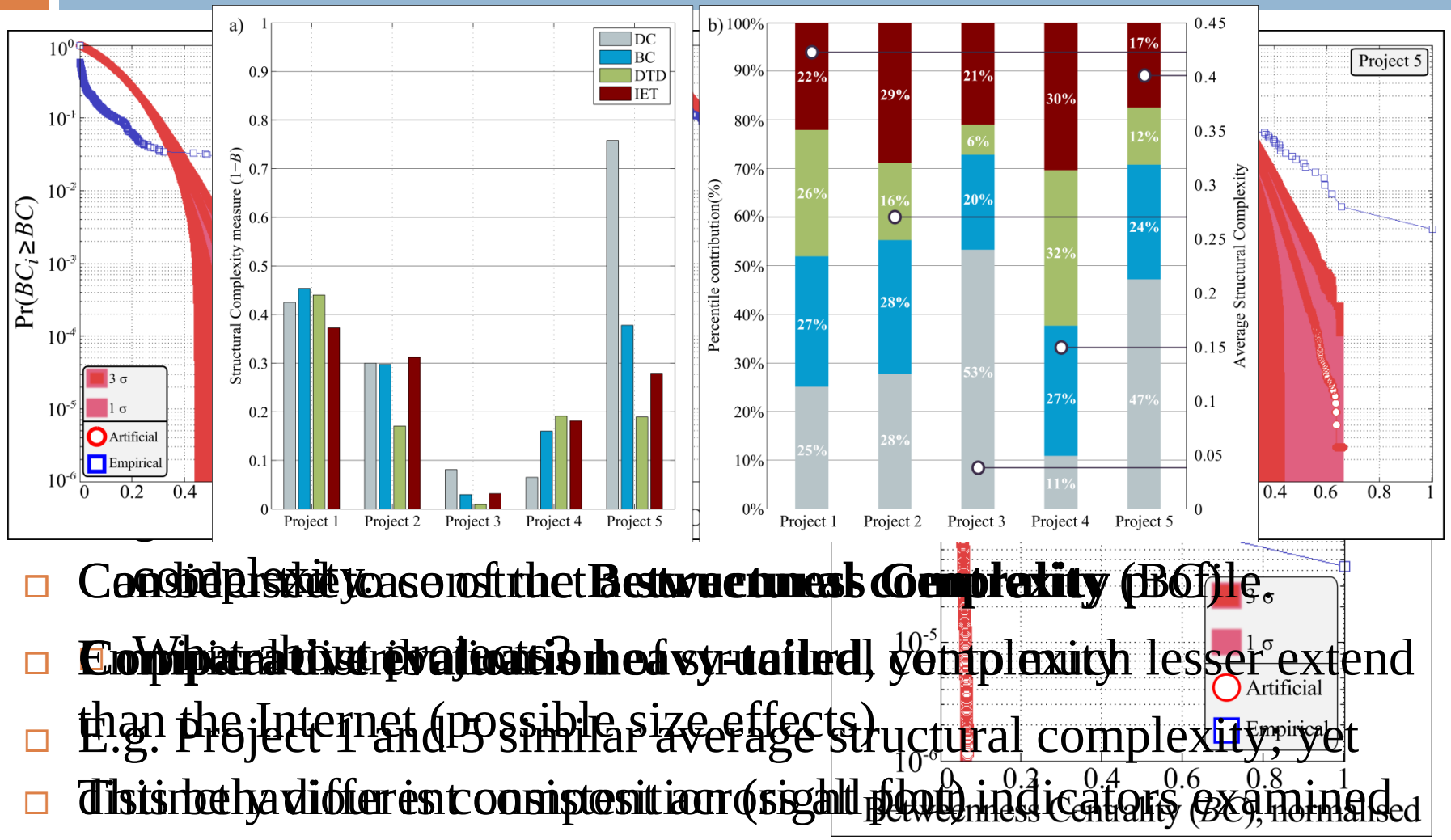
An Example



- Consider the case of the **Betweenness Complexity** (BC) profile.
- **Computational evaluation** of the **Structural Complexity** (BC) profile.
- What about projects?
- Distinctly different consistent profile.
- Is the **Internet** a very-tailed complexity with lesser extend than the Internet (possible size effects).
- E.g. Project 1 and 5 similar average structural complexity, yet distinctly different consistent profile.
- This behavior is consistent across all the indicators examined.

Ellinas C., Allan N., Johansson A., "Towards Project Complexity Evaluation: A Structural Perspective" (In Press).

Failure Cascades across Projects

*"**Failure cascades** […] are the result of a cascading process and can substantially impact the performance of the entire system – the manifestation of such **interlinked failures** is the core definition of **systemic risk**" – Elllinas et al (Submitted)*

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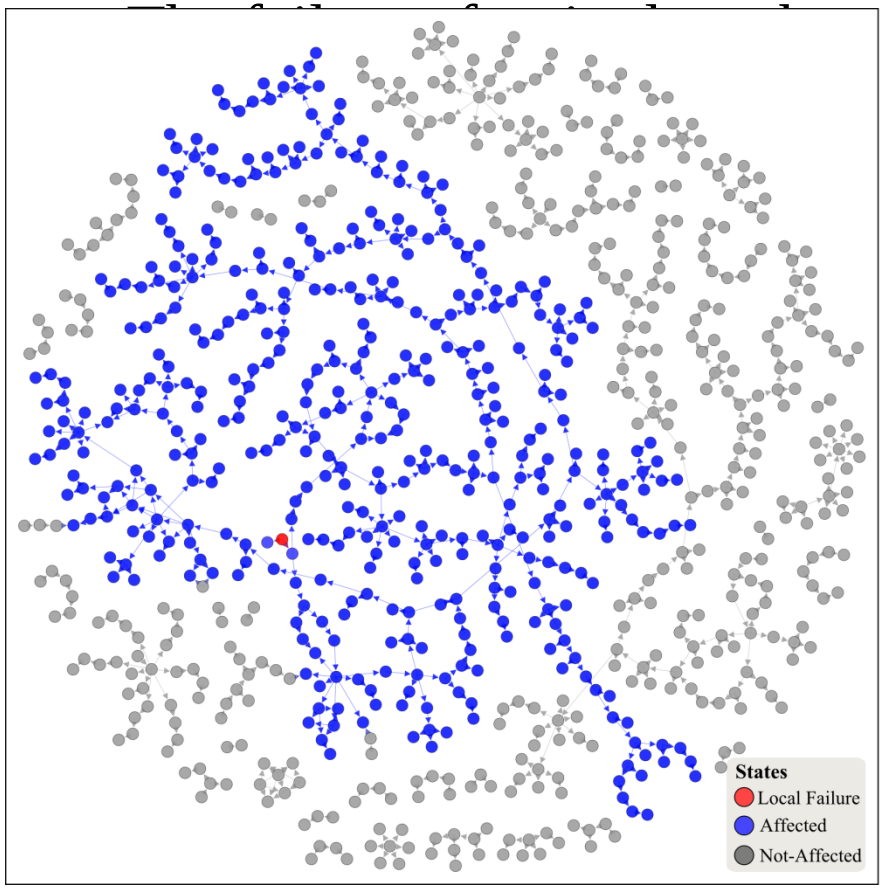
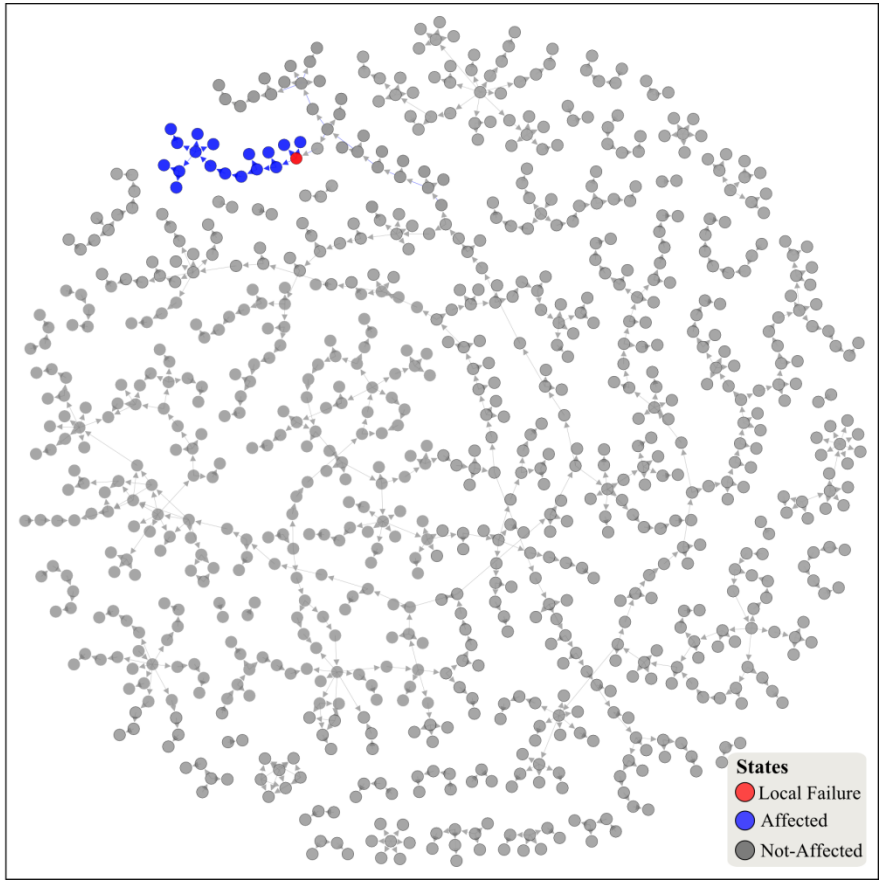
Project Systemic Risk





Ellinas C, Allan N, Durugbo C, Johansson A, “How Robust Is Your Project? From Local Failures to Global Catastrophes: A Complex Networks Approach to Project Systemic Risk”, (2015)

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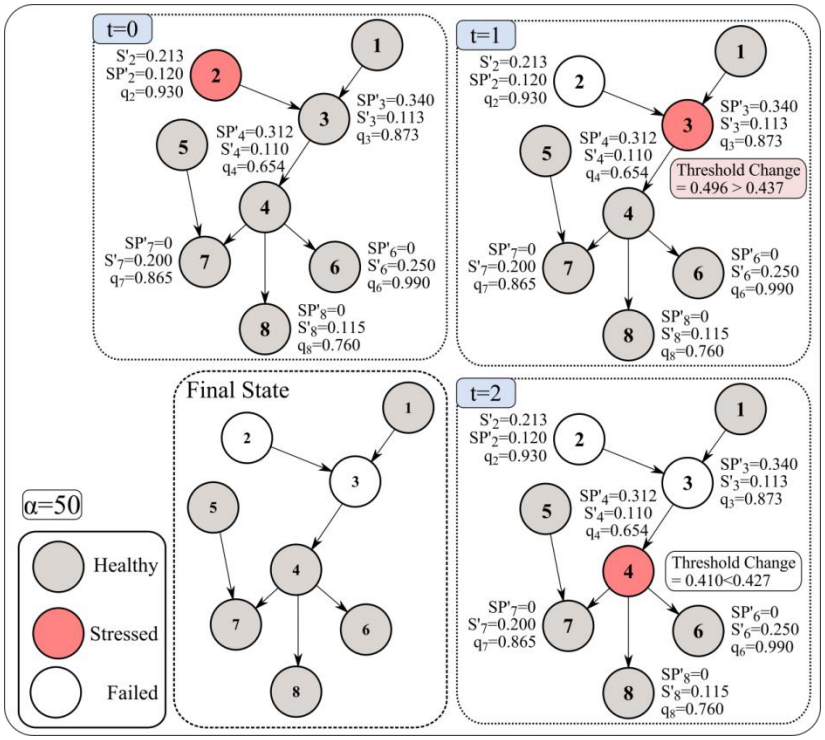
Modelling Failure Cascades

- Model belongs to the large class of "**threshold** models"
- A number of tweaks:
  - **Relative** rather than absolute **threshold**; accounts for large task variance
  - Link between **quality of task completion**, and **likelihood of failure**; introduces context into model dynamics



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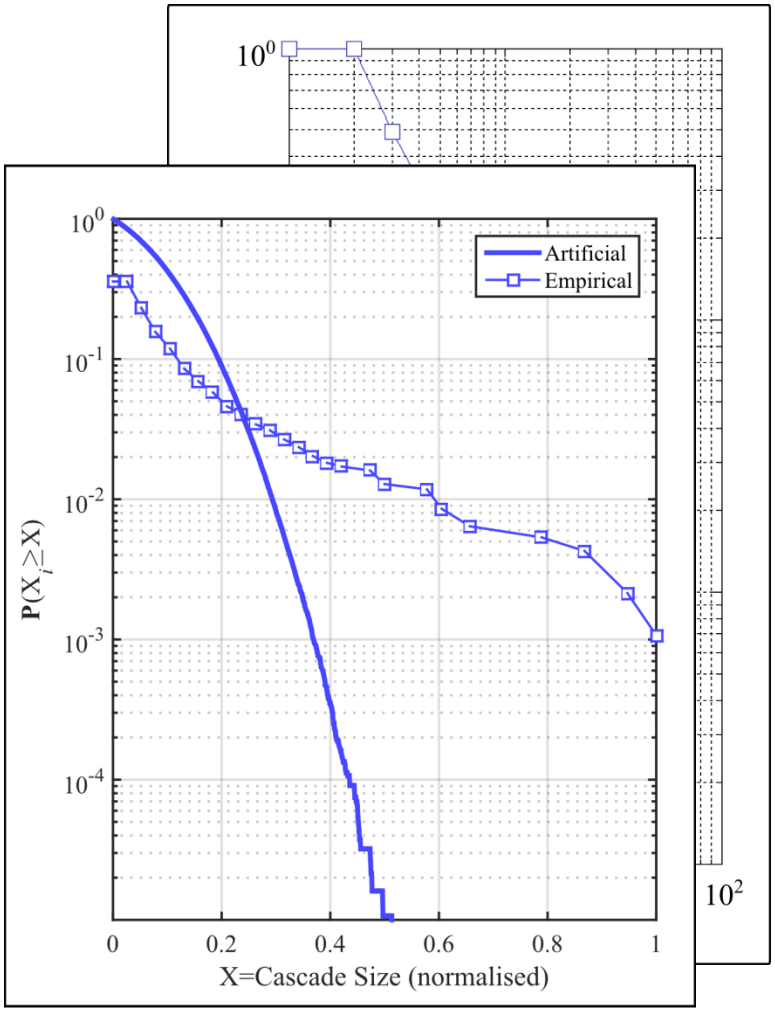
Failure Cascade Sizes

- Failure Cascade Sizes are **highly heterogeneous** (resemble power-law; similar to other complex systems).
- Larger and more frequent compared to what one would normally expect.
- Large failures materialise for the **exact same reason** as small ones do.
- Challenges the frequent use of **narrative-based explanations** for project failure (or success) (also see Bak and Paczuski, 1995)



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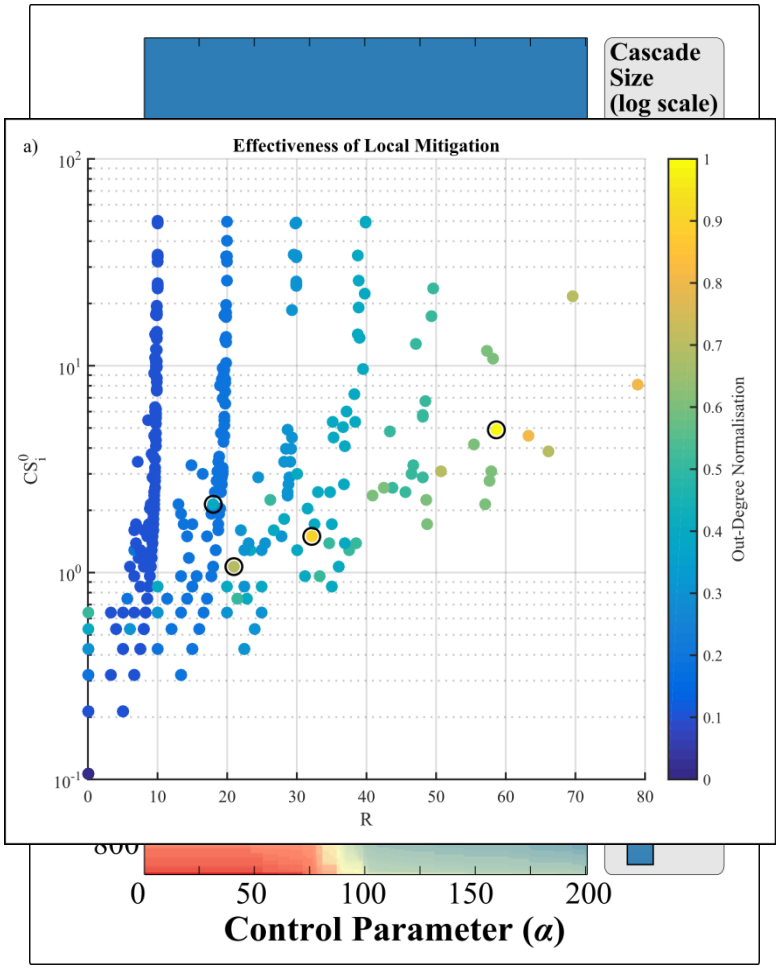
Local Mitigation

- **Local mitigation is** modelled by varying the **efficiency** by which tasks **utilise their assigned resource** (α).
- Failure cascade sizes are sensitivity to local mitigation.
- However, local mitigation is **unable to bring cascades into a complete stop.**
- Efficiency at which local mitigation is utilised is asymmetric (R) i.e. tasks that benefit the most are ones that trigger smaller cascades.



Ellinas C, Allan N, Durugbo C, Johansson A, "How Robust Is Your Project? From Local Failures to Global Catastrophes: A Complex Networks Approach to Project Systemic Risk", (2015)
Ellinas C, Allan N, Johansson A, "The domino effect: An empirical exposition of systemic risk across project activity networks ", (Under Review)

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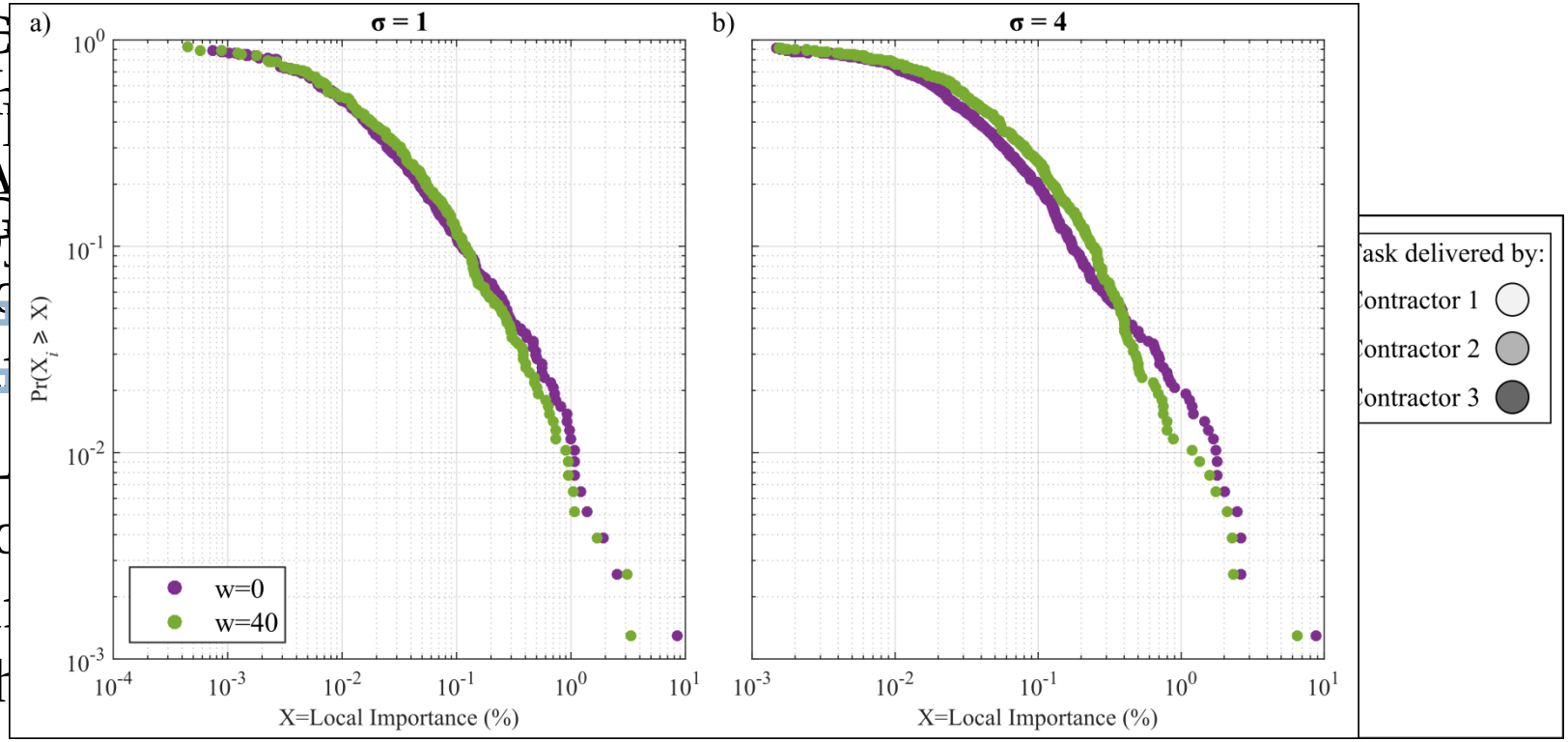
Influence of Contractor Activity



- Increasingly clustered activity (w>>) affects task local task importance **only** under increased number of contractors (σ>>)
- Such insight can be used to support the development of procurement strategies

Ellinas C, Allan N, Durugbo C, Johansson A, "Project Systemic Risk: Application Examples of a Network Model", (Under Review)

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Take-away message

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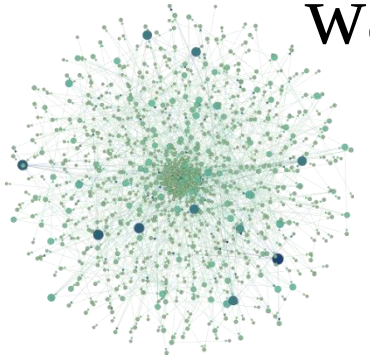

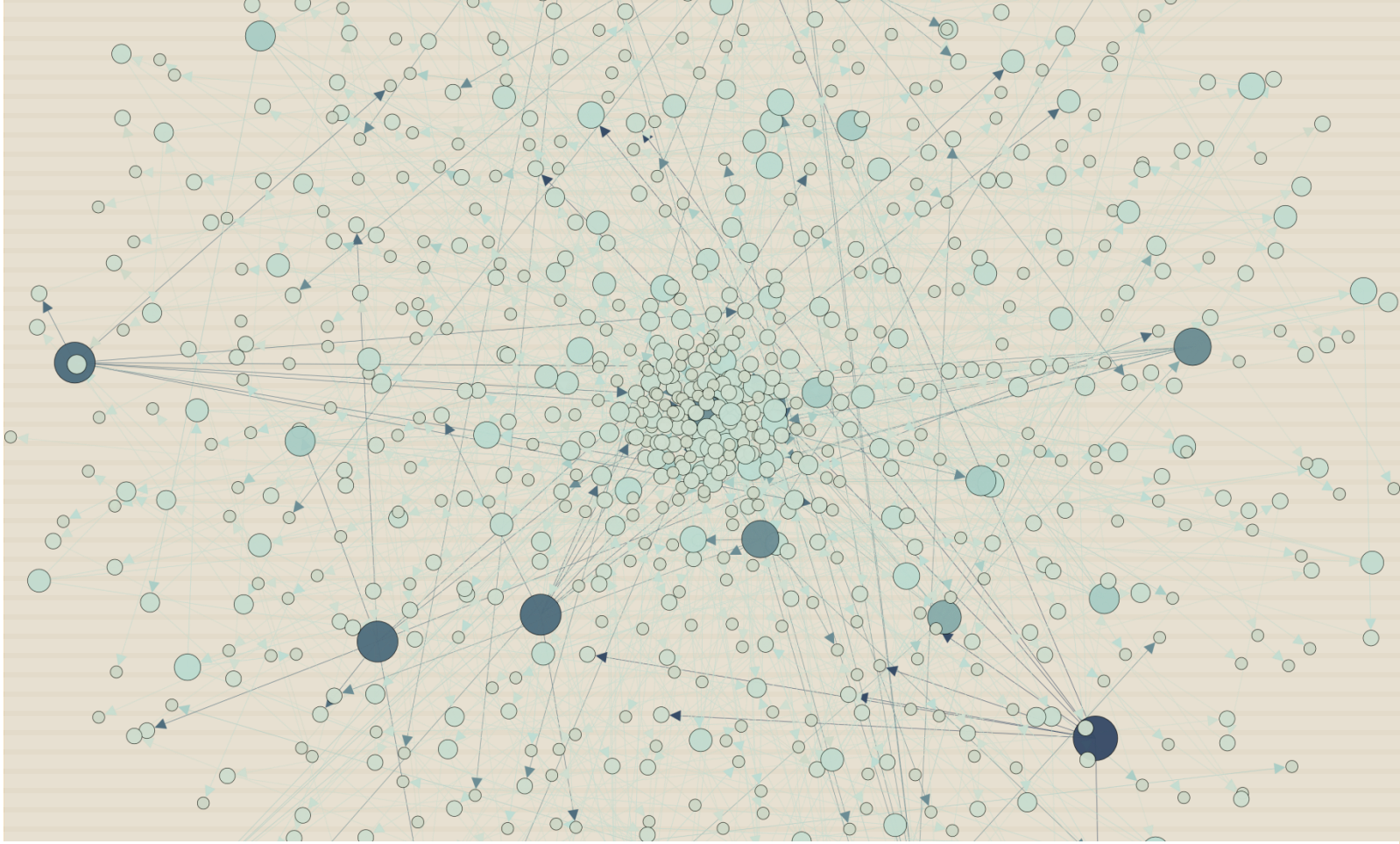

Thank you!

Questions? Collaborations? Papers? Data? – let me know at **ce12183@bristol.ac.uk**

Constructing heuristics

- In this case, critical tasks take place during the second half of the project