Imperial College London

What if? Incorporating uncertainty and contingency in social network models

Ray Rivers (Physics, ICL)

Collaboration with

Tim Evans (Physics, ICL):

Historical Network Research Conference, Ghent 2014

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Les Nouvelles de
l'archéologie
135, 21-28, 2014

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(Pre-)Historic Exchange networks

- Nodes/vertices = Major Population or Resource Sites
- Links/edges = ‘Exchange’ between sites

  - physical trade of goods
  - soft power and hard power/social cohesion
  - transmission of culture

- Exchange controlled by physical limitations of travel

Goal: Why do some sites become ‘important’ and others not?

Theory modelling: Networks are ‘roughly’ optimal

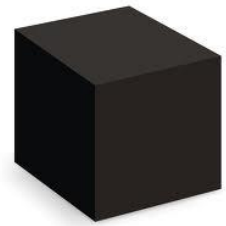
Models adapted from

- Financial modelling

  - cost-benefit analysis

- Transport modelling

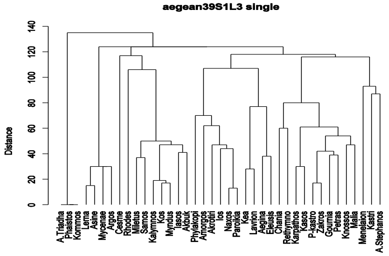
  - generalised gravity



Equally appropriate for qualitative data

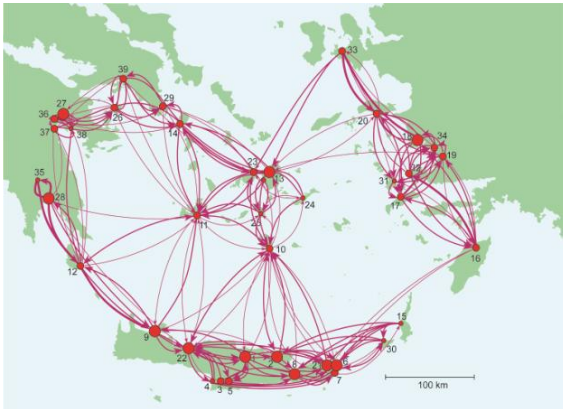
Model:

Inputs:



Model/Simulator

Output:

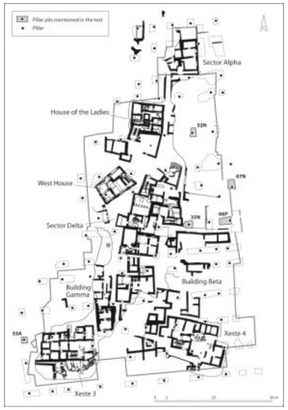


Output:

- Links: ‘Exchange’ T_{ij}

Flattening of ‘exchange’ into a single measure

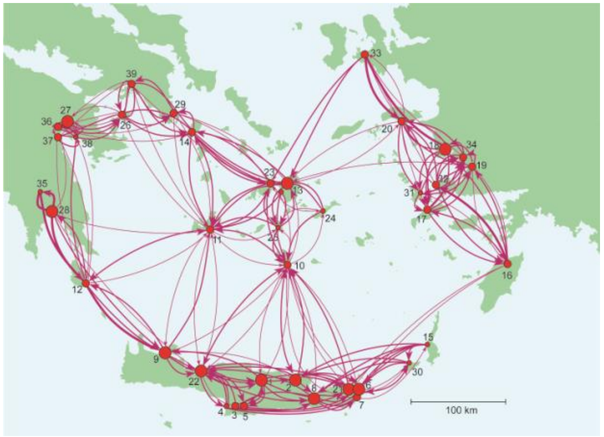
- Nodes: ‘Population’ P_i



Derived attributes:

- Rank
- Centrality
- ‘Betweenness’:

‘Importance’



Uncertainty and Contingency:

No laws: guaranteed ambiguity!

Wish to discriminate between

I. Uncertainty quantification: largely a question of inputs!

- Incompleteness of data
- Uncertainty about model morphology - model inadequacy
- ...

II. Contingency: largely a question of outputs!

Q. How susceptible are outcomes to ‘equally good’ choices? What if ...?

e.g. Nixon’s speeches for moon landing.

- Not black swan events!

Issues are general, but applications have to be specific!

This Talk: One data set/two questions/two models

Data set: **Greece in 9th and 8th C BCE - Emergence of the polis**

Questions:

I. Uncertainty induced by choice of ‘ease-of-exchange/deterrence’ function

Wilson ‘retail’ (constrained gravity) model

II. Contingency realised through ‘social landscapes’

Cost-benefit *‘ariadne’* model (Evans/Rivers)

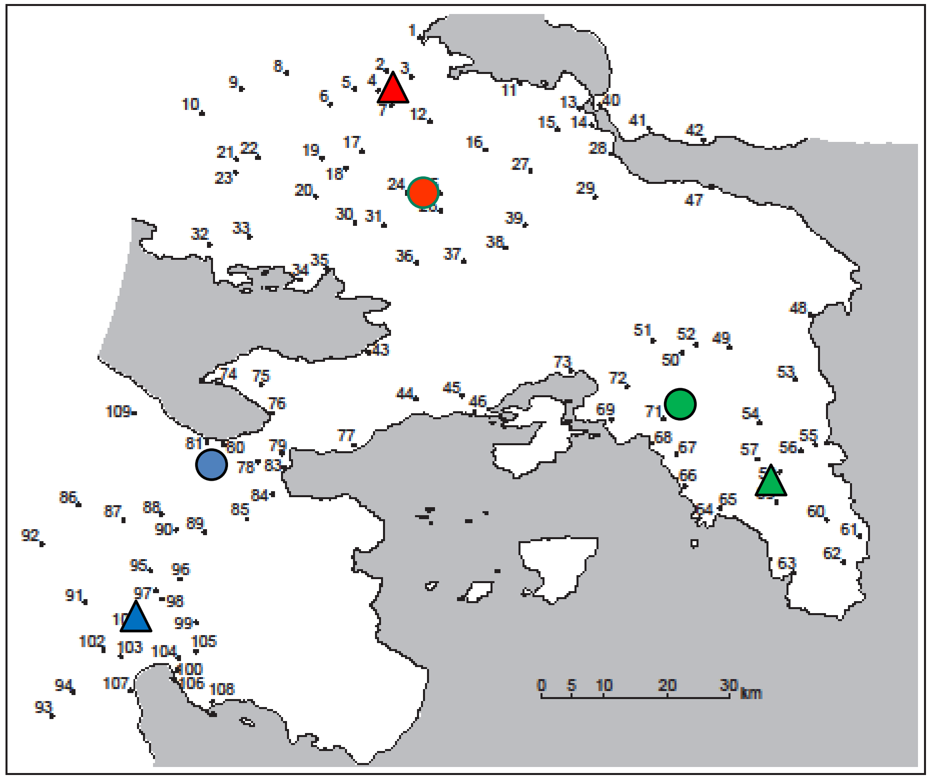
Greece in 9th and 8th C BCE

Emergence of the polis:

Rihll and Wilson (1979, 1991)!

- Urbanisation – emergence of dominant settlements

- Synoikism – surrendering of local sovereignty to a larger community



In particular:

- Thebes
- Corinth
- Athens
- ......
- Argos
- Akraiphnion
- Kalyvia
- .....

Greece in 9th and 8th C BCE

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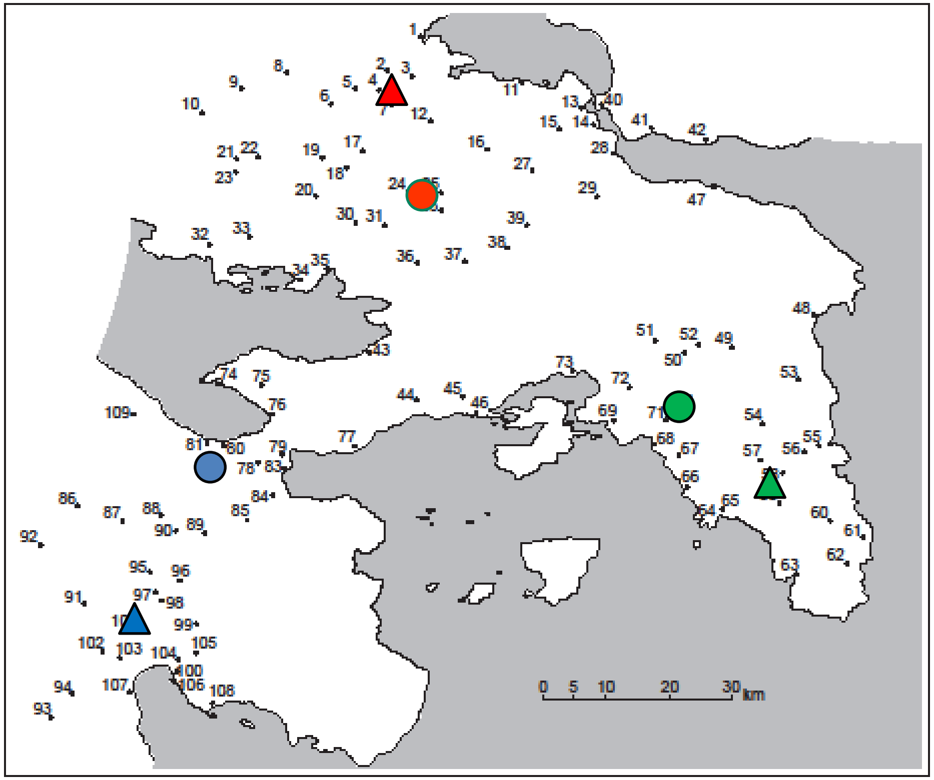


In particular:

- Thebes
- Corinth
- Athens
- ……
- Argos
- Akraiphnion
- Kalyvia
- …..

Distance scales:

- average distance ***d*** to n. neighbour ≈ 5km
- **Journée (foot/mule) ≤ 30km;** **distance scale *D* ≈ 10 – 15 km > *d***

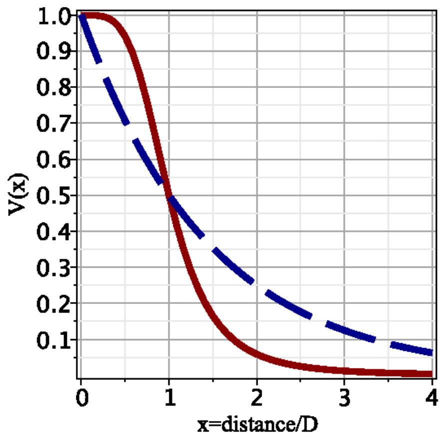
I. Uncertainty in the 'ease of exchange' function:

'Exchange' determined by 'ease of exchange/deterrence' function

$$V(x) = V(d_{ij}/D)$$

for travelling 'distance' d_{ij} with distance scale D set by 'technology'

- 2 feet or 4!



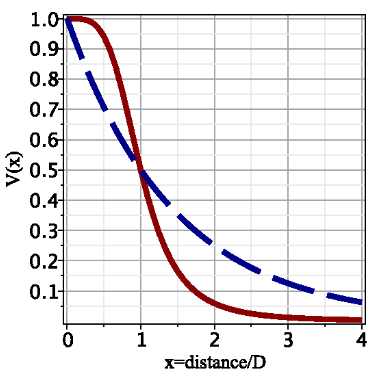
Question: How do we choose between

a) canonical 'equal cost for equal distance' i.e. exponential fall-off (R&W)

b) 'so far and no further' ? i.e. power behaviour fall-off with a shoulder (E&R)

The Wilson 'Retail' model

'Deterrence' function V(x):



Generalised gravity model

Designed to describe the dominance of supermarkets and shopping centres and the collapse of High Street shops!

- latter day Synoikism

$$T_{ij} = A_i\, O_i\, (I_j)^{\Upsilon}\, V(d_{ij}/D)$$

Two 'physical parameters:

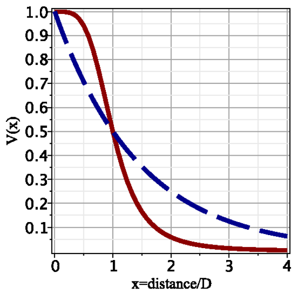
- distance scale D
- 'attractiveness' ϒ

- benefit of concentrated resources

Thebes as the 'Walmart' of geometric/archaic Greece!

Standard technique most recently used to describe Bronze Age Khabur triangle! (Davies et al., JAS 2014)

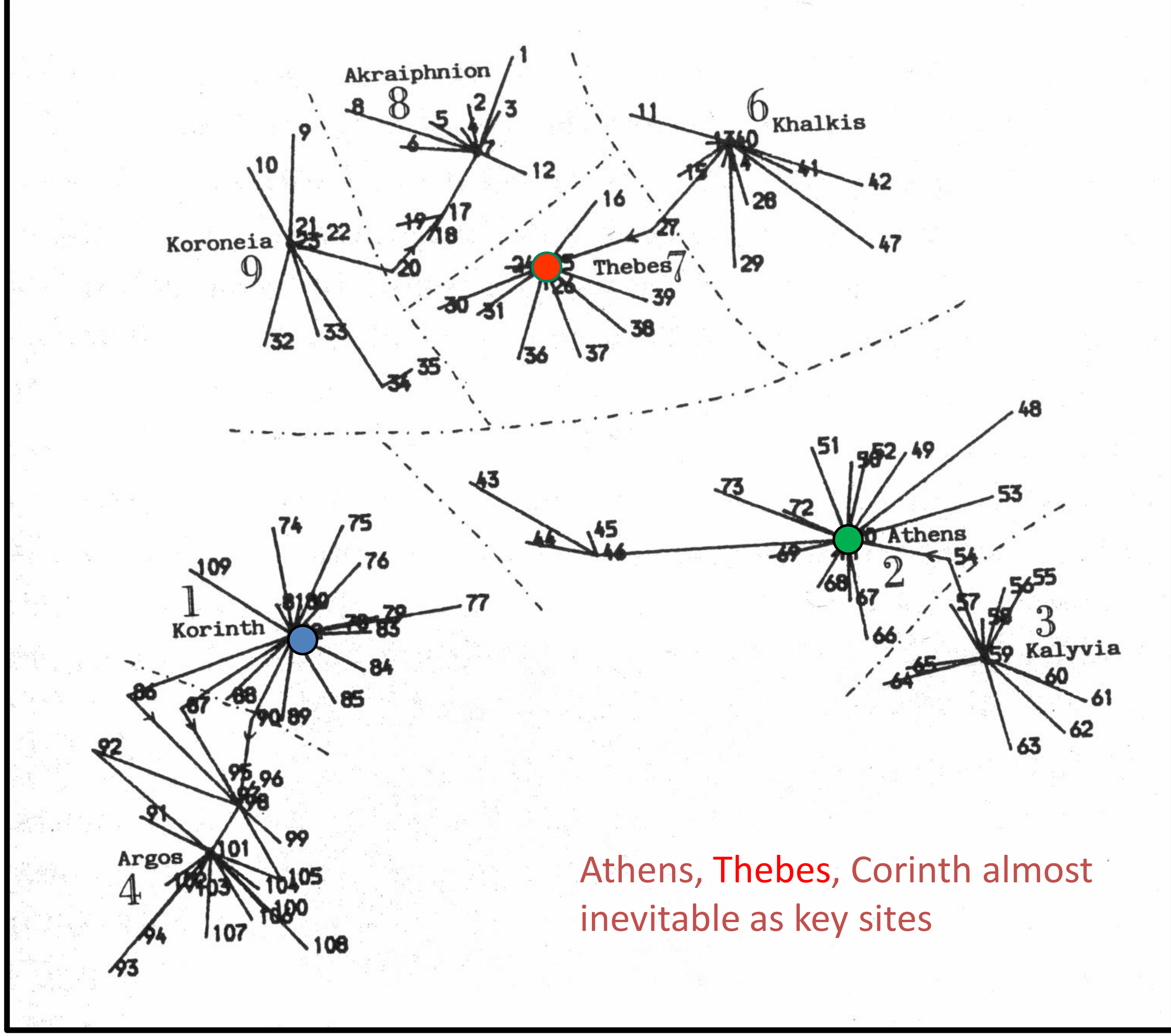
Exponential deterrence function (blue) !



- A few important sites grow at the expense of small sites
- identifiable 'regional structure'

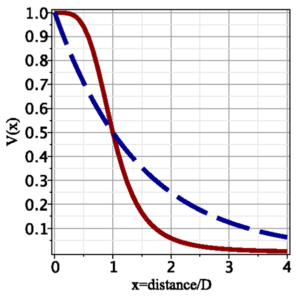
Rhill & Wilson, Histoire & Mesure , 1979

- Key sites are 'in accord' with historical record!



Athens, Thebes, Corinth almost inevitable as key sites

Power behaved deterrence function (red) !



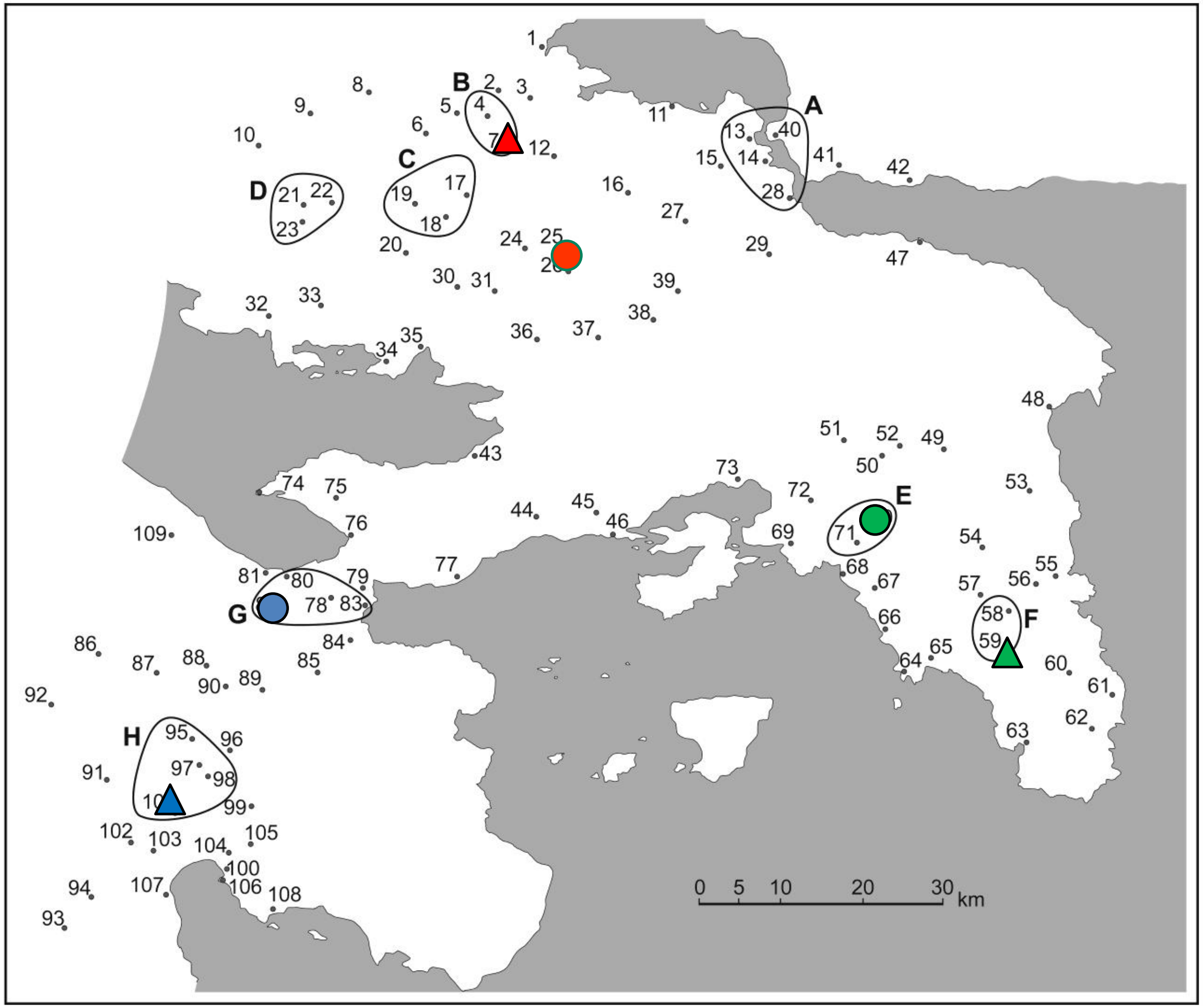
- A few important sites grow at the expense of small sites

- identifiable ‘regional structure’

Rivers & Evans, Nouvelles de l’archéologie, 2014

- Key sites in neighbourhoods A,B,C, ... G, NOT in accord with historical record!

- Thebes NO LONGER a significant site!



Other key sites ‘roughly right’ in the sense that a key site can always be found in relevant neighbourhood!

Q. Can we use data to determine deterrence function?

- good Bayesian question

Yes!

- Thebes is crucial in that period – take exponential falloff!

No!

- Models designed to help our understanding of how the ‘real world’ works rather than demonstrate what happens in detailed reality.

  - two parameter fit for 109 sites, albeit with poor data!

  - R & W model ‘accidentally too good to be true’

- take lack of Thebes as statistically unimportant although historically disastrous!

- consider this ‘error’ to be due to factors beyond naive ‘retail’ effects e.g. naive geography

II. Contingency and the 'Social Landscape'

Cost-benefit models are generally not deterministic

- allow for non-optimal behaviour!

Contingency understood as reflecting the more or less equally good, but different, choices that can be made.

- 'Satisficing' strategy/bounded rationality
  - Look for the 'best' – be satisfied with the 'good'

- Not talking about 'chaos'!

Q. What if? How easy is it to make one choice rather than another?

The ‘social landscape’:

Cost-benefit optimisation ≡ Minimising altitude in ‘social landscape’

Each point on ‘landscape’ corresponds to a network: look for ‘lowest’ point

Not the geographical landscape!

Q. What penalties are incurred by making different choices!

- ‘Swiss valley’ landscape of networks

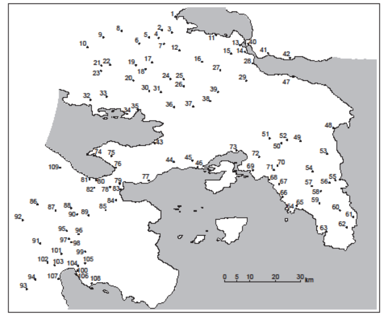
  - high penalties in crossing from one ‘valley’ to the next
  - low contingency

- ‘American mid-west’ landscape of networks

  - low penalties in roaming landscape
  - high contingency

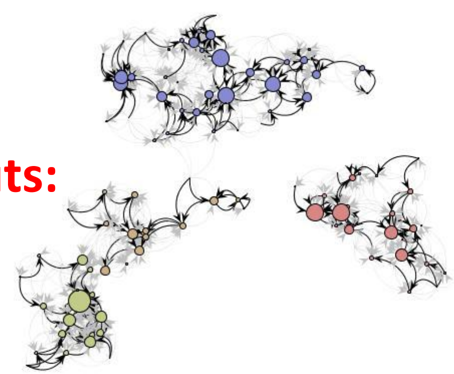
Contingency:

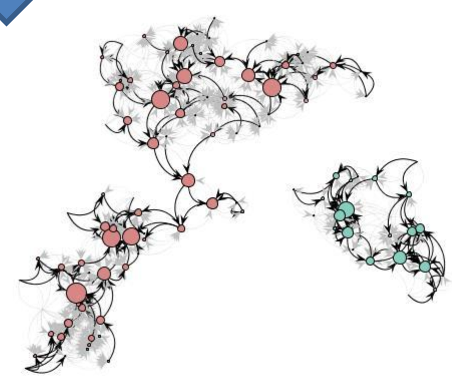
***'ariadne'* cost-benefit model**



Flat social landscape!

Identical inputs:





-Very high contingency

For all V(x)!

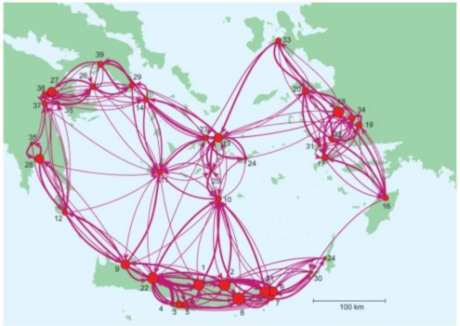
Reason: D » d

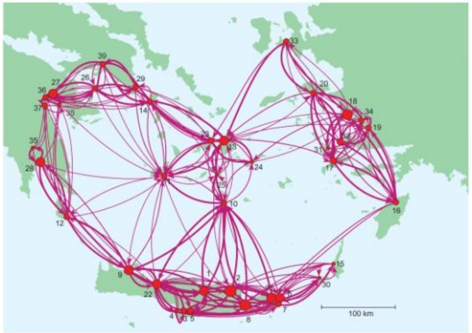
- too many ‘equally good’ destinations in a single journée

cf. MBA Aegean: Rivers, Evans & Knappett, 2013

d ≈ D ≈ 100km for rigged sail matches distance scale
for geographical connectivity!

Low contingency!





Conclusions: Theory modelling

Great ambiguity in how we choose and construct models!

No rules!

- Models designed to help our understanding of how the 'real world' works rather than demonstrate what happens in detailed reality.

- Very few parameters – need to coarse-grain data

  'Acceptable' uncertainty commensurate with coarse-graining

- Potentially high levels of contingency if easy to roam social network 'landscape'

  Happens if D » d - easy to make different choices with no penalty

- Need more sophisticated modelling e.g. 'brand loyalty'

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Thank you!