MODELLING DEADLOCK IN OPEN RESTRICTED QUEUEING NETWORKS

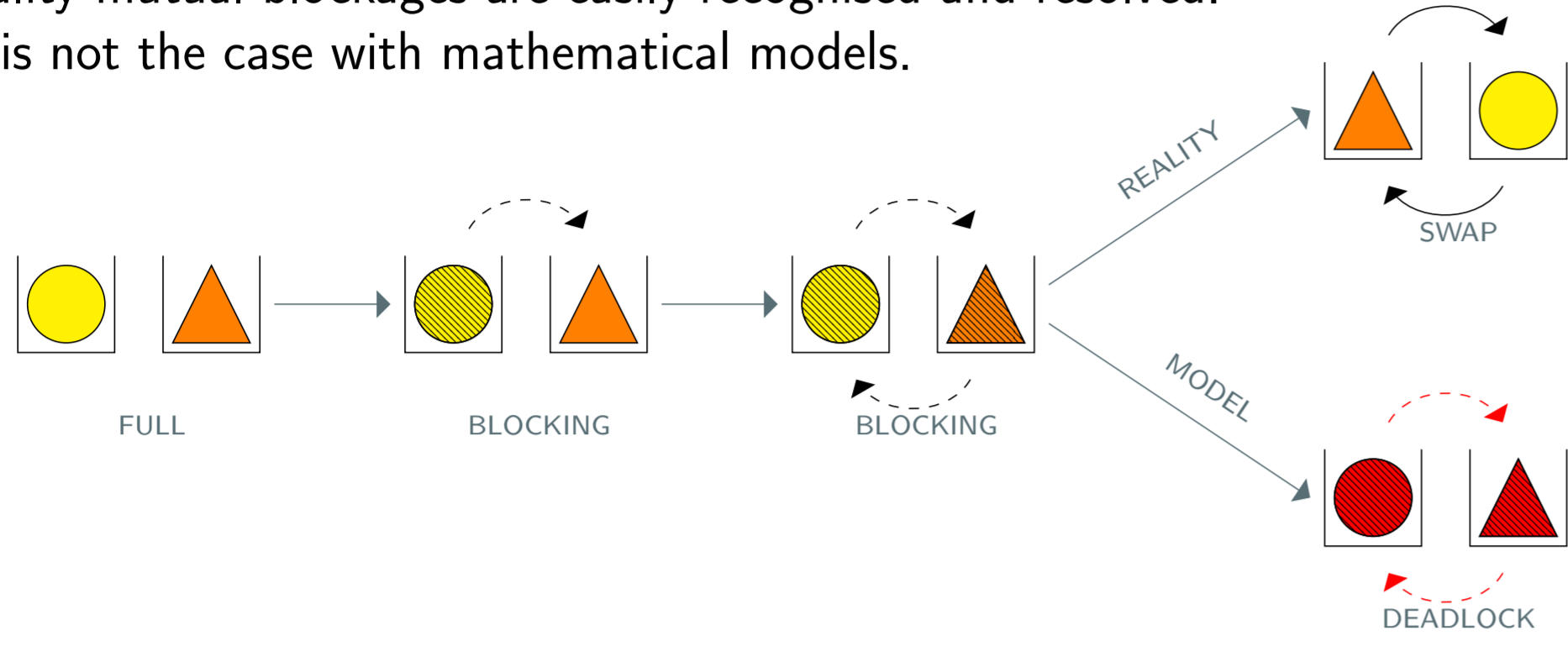## G.I. Palmer, P.R. Harper, and V.A. Knight

MODELLING QUEUEING NETWORKS

In reality mutual blockages are easily recognised and resolved.
This is not the case with mathematical models.

SIMULATION

Development of open-source research software: https://github.com/CiwPython/Ciw

```
>>> import ciw
>>> N = ciw.create_network(
...     Arrival_distributions=[['Exponential', 5.0], ['Exponential', 4.0]],
...     Service_distributions=[['Exponential', 3.0], ['Exponential', 4.0]],
...     Transition_matrices=[[0.1, 0.3], [0.2, 0.2]],
...     Number_of_servers=[3, 1],
...     Queue_capacities=[5, 10]
... )

>>> ciw.seed(0)
>>> Q = ciw.Simulation(N, deadlock_detector='StateDigraph')
>>> Q.simulate_until_deadlock()
>>> Q.times_to_deadlock[((0, 0), (0, 0))]
2.946008...
```
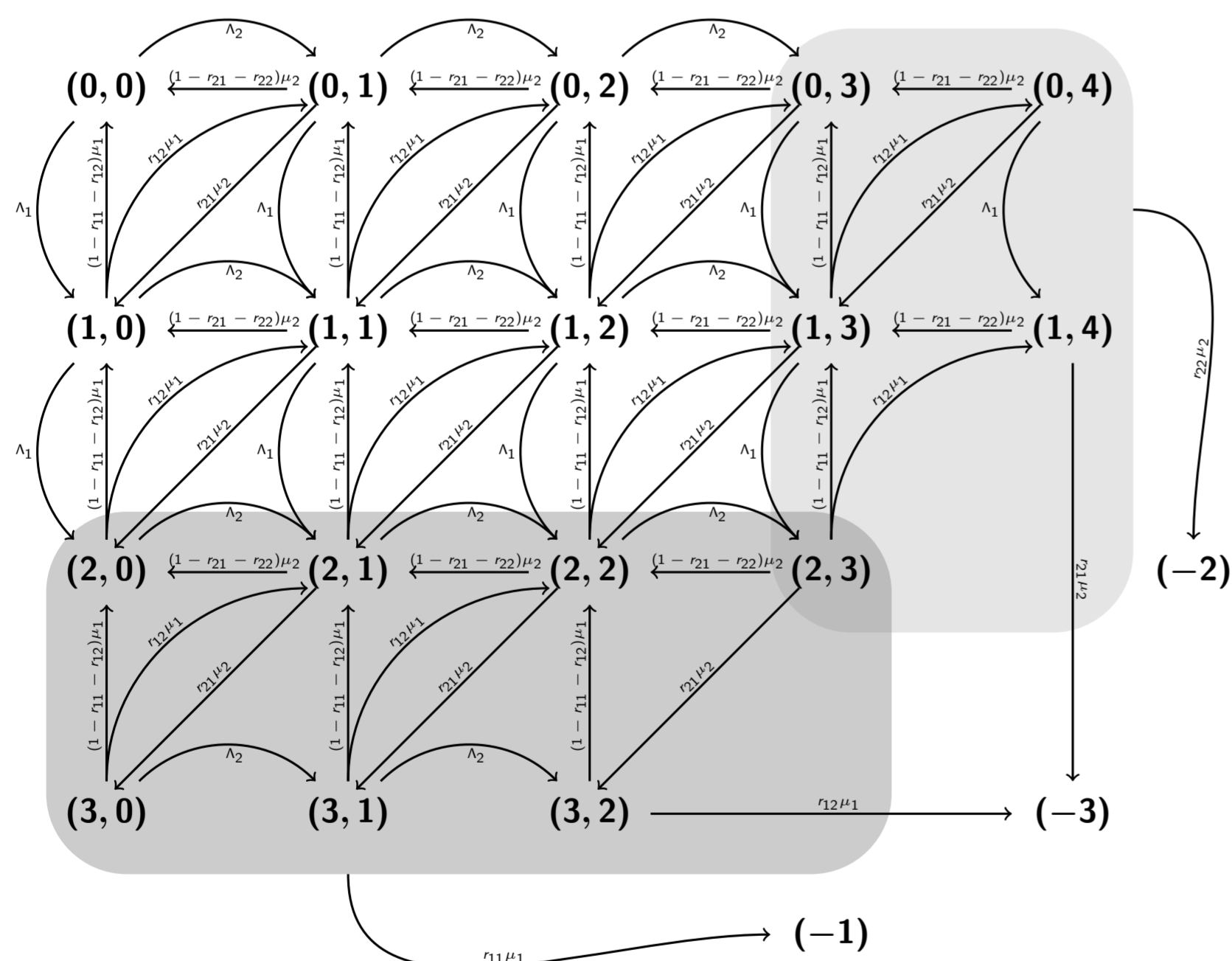
2018: **Ciw: An open source discrete event simulation library** Palmer GI, Knight VA, Harper PR, Hawa, AL. *Under review at Journal of Simulation*

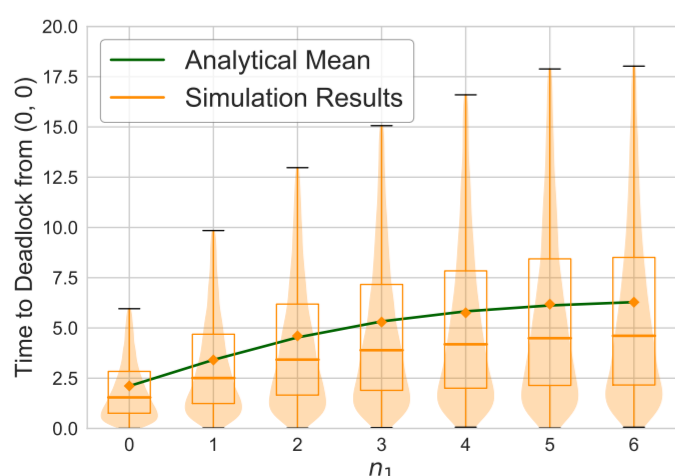## MARKOV MODELLING TIME TO DEADLOCK
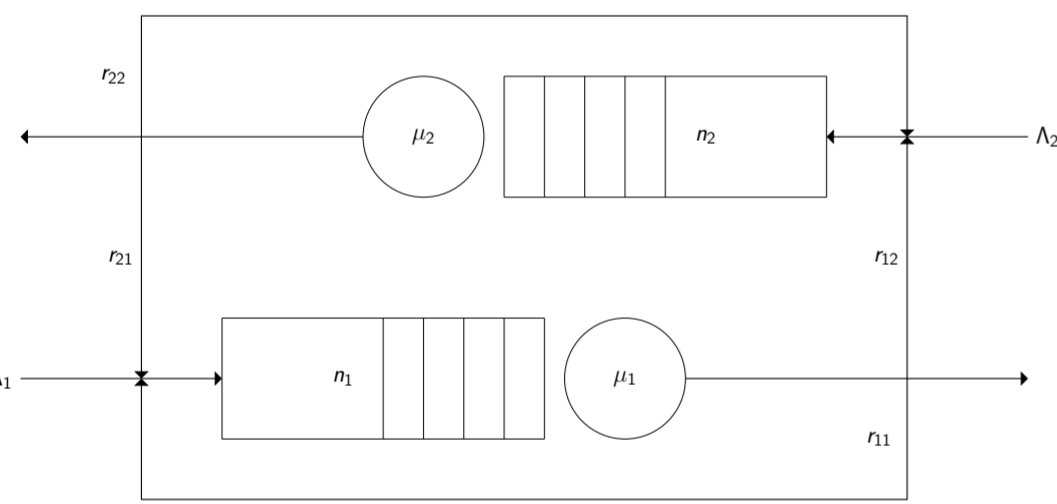
- Absorbing Markov chain with two-dimensional state space.
- Parameters' effect of time to deadlock.
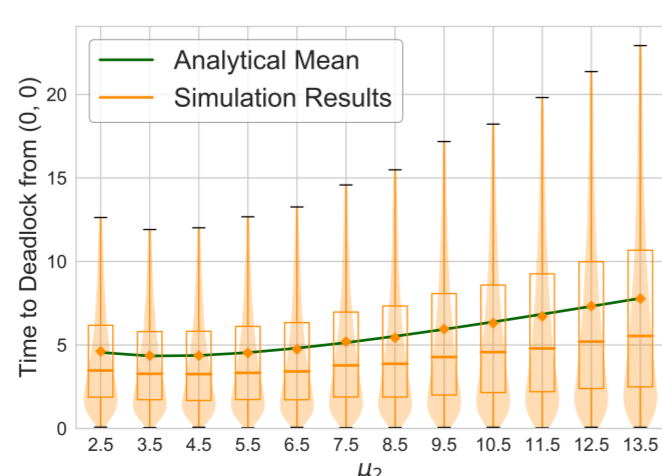- Analytical results which validate the theorem.

NUMERICAL RESULTS

EFFECT OF CAPACITY

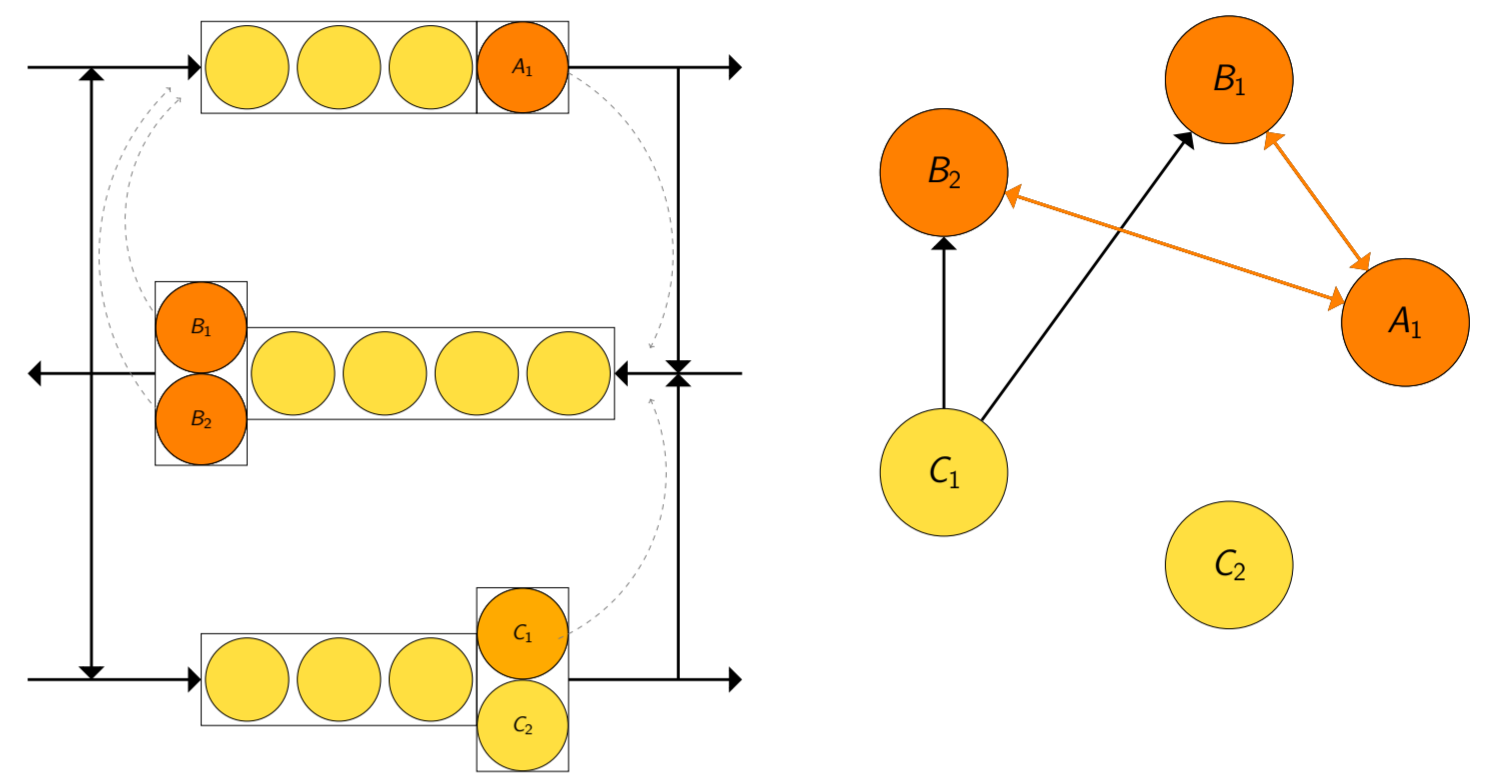#### EFFECT OF SERVICE RATE

2018: **Modelling Deadlock in Open Restricted Queueing Networks** Palmer GI, Harper PR, Knight VA. *European Journal of Operational Research.*

DETECTING DEADLOCK

Definition
When there is a subset of blocked customers who are blocked directly or indirectly by customers in that subset only, then the system is said to be in deadlock.
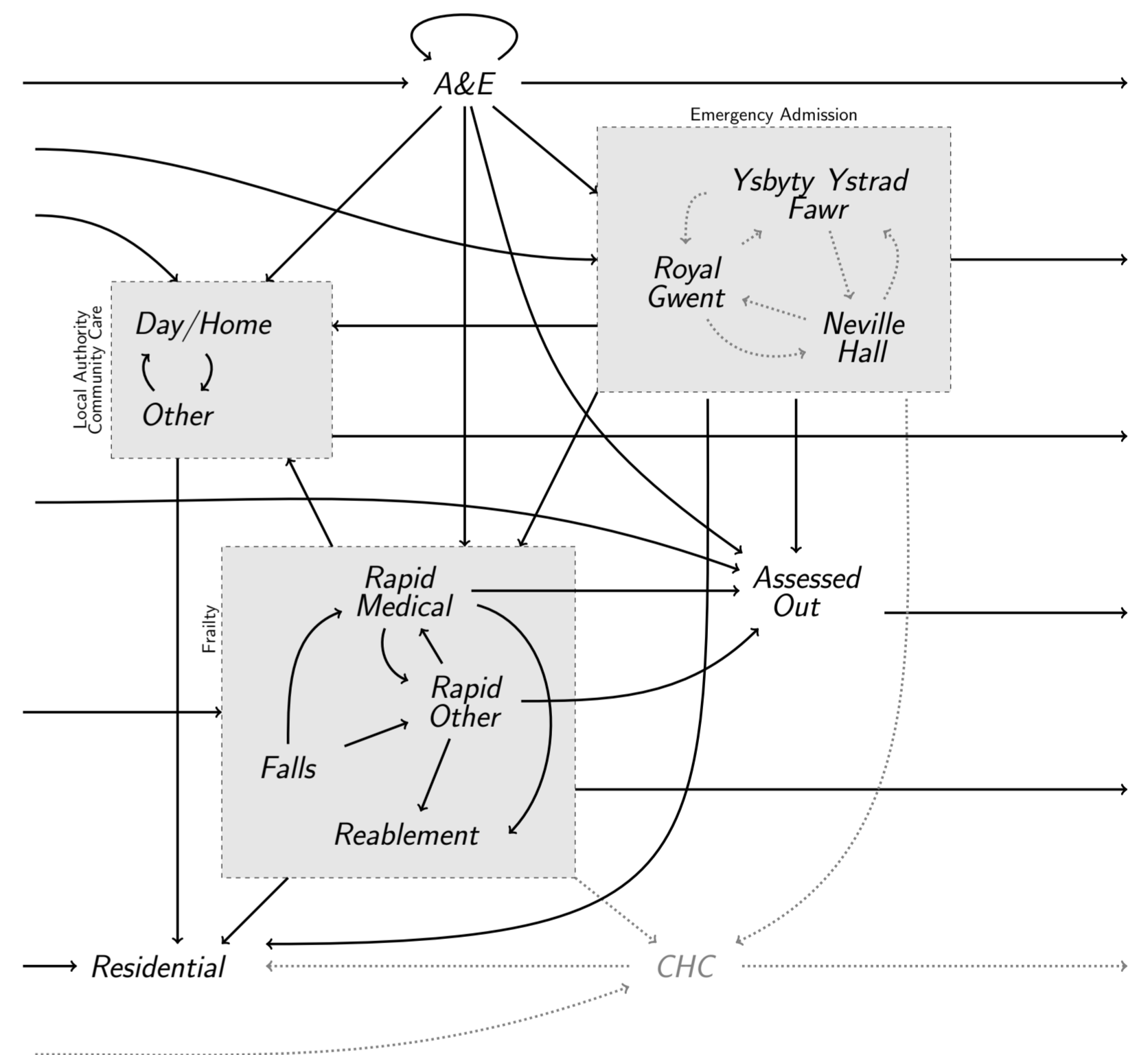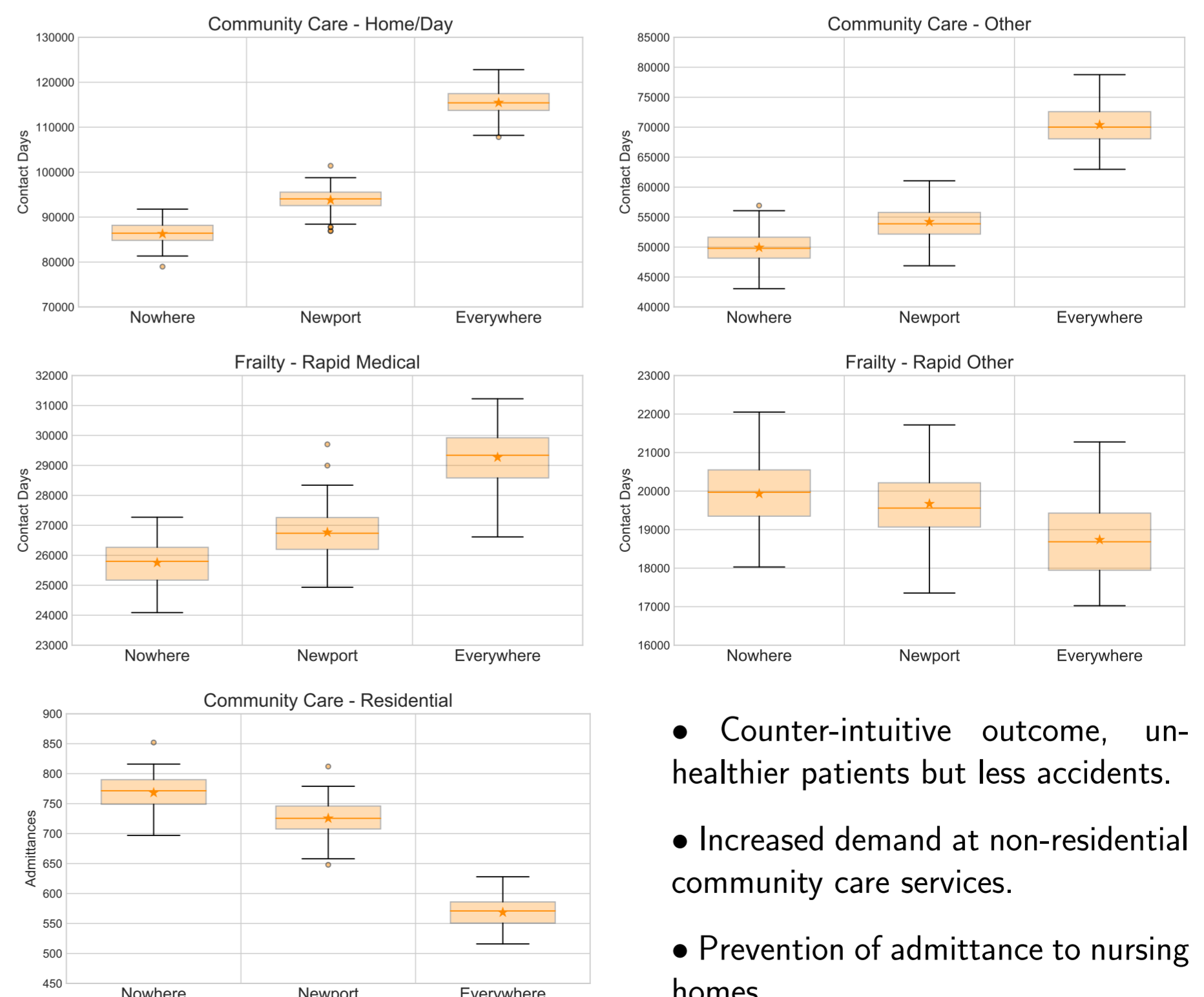

Theorem
A deadlocked state arises at time t if and only if $D(t) = (V, E(t))$ contains a knot.

GWENT STAY WELL PLANS

- Stay Well Plans in Gwent: extra home care and advice.
- How do these effect demand on healthcare system?

SIMULATION RESULTS

- Counter-intuitive outcome, unhealthier patients but less accidents.
- Increased demand at non-residential community care services.
- Prevention of admittance to nursing homes.

- Developed a novel method of detecting deadlock in models
- Validated results with analytical models

- Packaged methodology in an internationally used piece of software
- Software used in a healthcare application