Hybrid System Science Methods: Some Observations

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Using Modeling to Prepare for Changing Healthcare Needs
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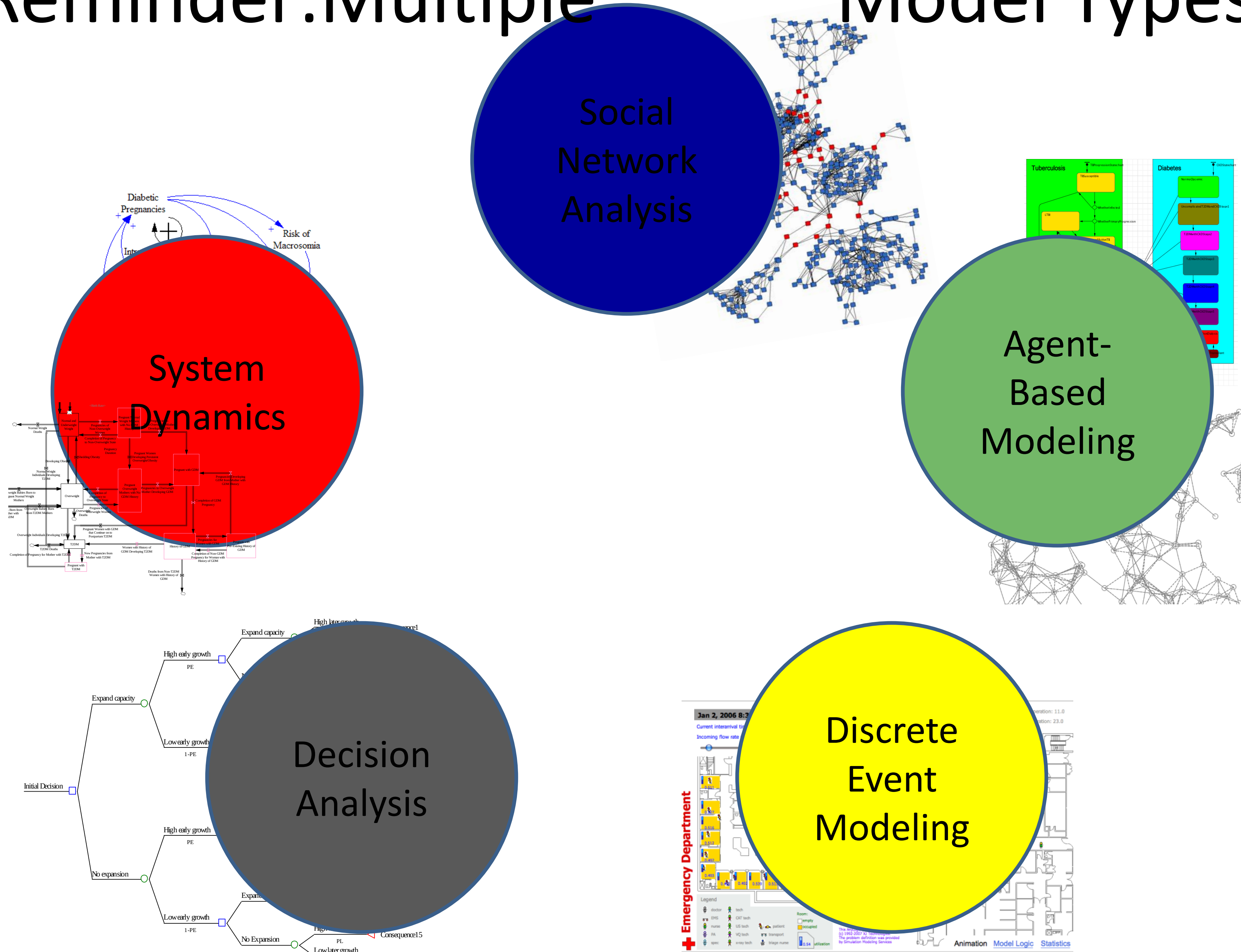
System Science Methodologies: Highly Complementary

- Different modeling methodologies seek to answer different types of questions
- No one system science methodology offers a replacement for the others
- Significant synergies can be secured by using combinations of methodologies to address the same problem
  - As cross-checks on understanding where two or more can be applied
  - Exploiting competitive advantages

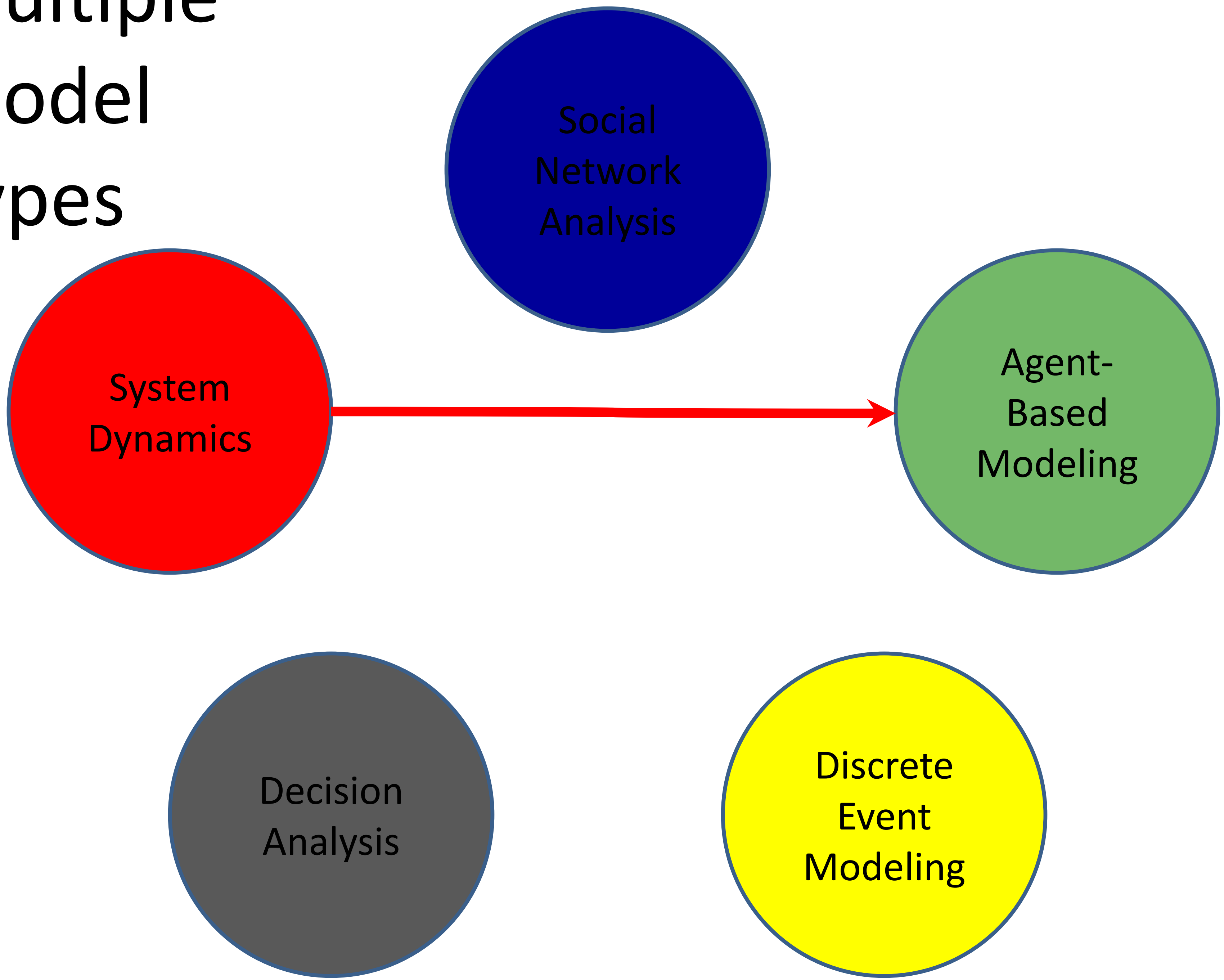
Multi-Framework Modeling

- We have found the use of multiple frameworks highly effective
  - Co-evolving multiple models for
    - Cross-validation
    - Asking different sorts of questions
    - Revealing new questions to answer
  - Within a single model
    - Dealing with questions at different scales
    - Improving robustness of models
    - Allowing for representation & changing of factors that are otherwise ignored

Reminder:Multiple Model Types



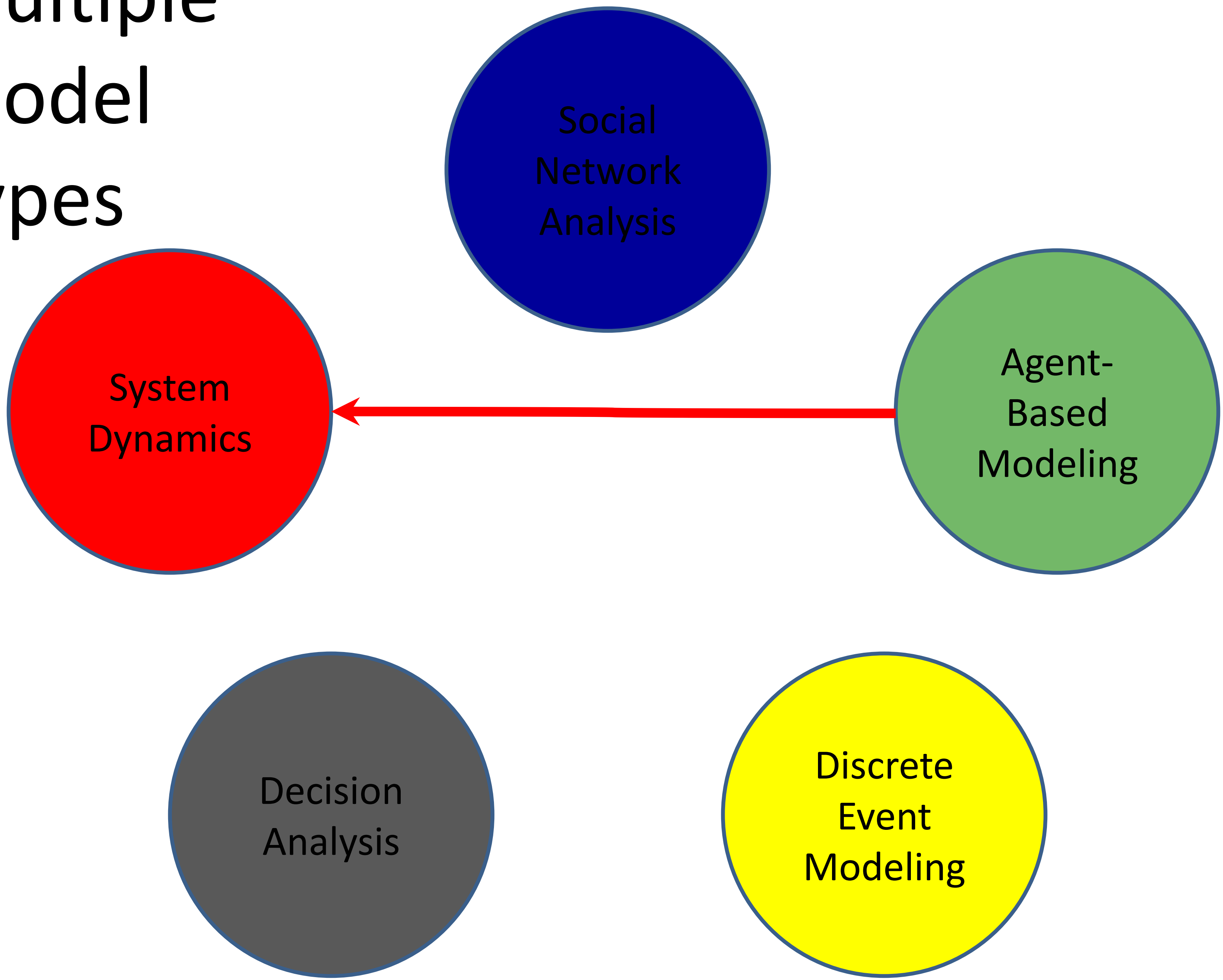
Multiple Model Types



System Dynamics Supporting ABM

- High level SD model drives global dynamics, which affects ABM dynamics
- Deriving calibrated parameter estimates for low-level model
- Focusing AB exploration
- SD within Agents: Stocks & flows drive continuous elements of agent evolution
- SD model is used to capture dynamics of lower interest population/infrastructure; ABM for the area of greatest interest
- Qualitative diagramming of
  - Interactions at a particular scale
  - Hypothesized drivers underlying emergent behaviour

Multiple Model Types



Agent-Based Modeling in Support of SD

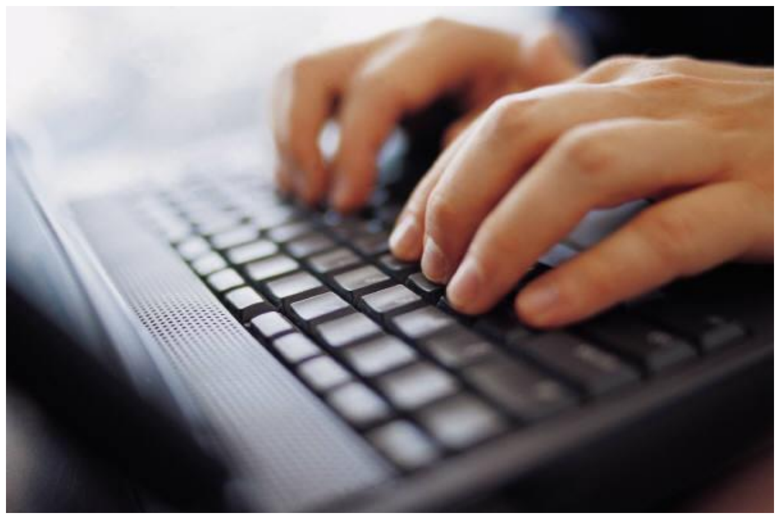
- Cross-validating SD aggregation: Evaluating importance of
  - Stratification by heterogeneities
  - Stochastics
  - Network dynamics
- Aggregated agent behavior drives some flows in higher-level SD model(s)
- Giving insight into feedbacks to depict
- Investigating specialized interventions
  - e.g. Interventions that depend on individual history, network position, etc.
- Use to determine parameters for SD model

Hands on Model Use Ahead

Load Provided Model:

CTL State Variable V4

Hands on Model Use Ahead



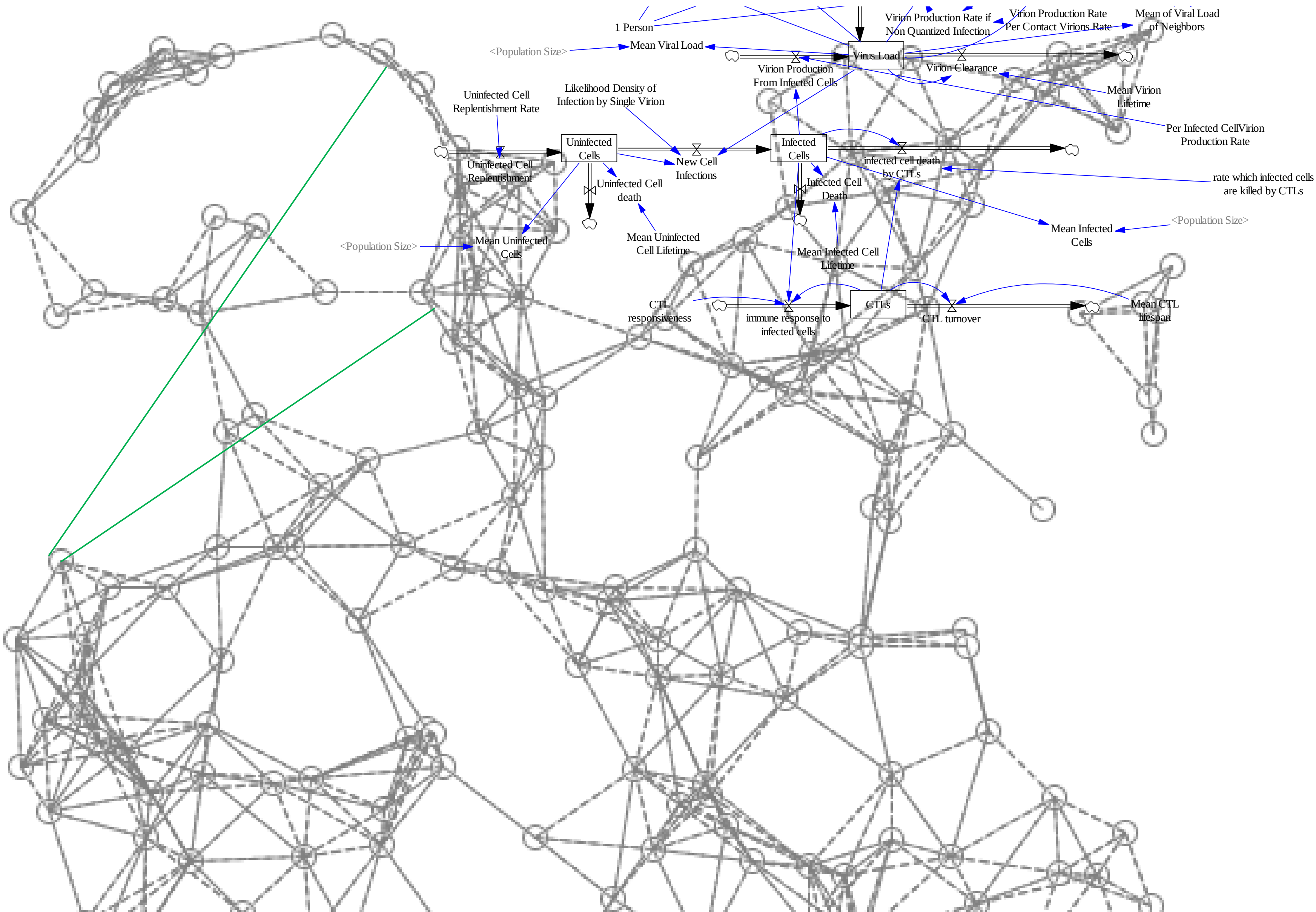
Load Provided Model:

GriddedSystemDynamics

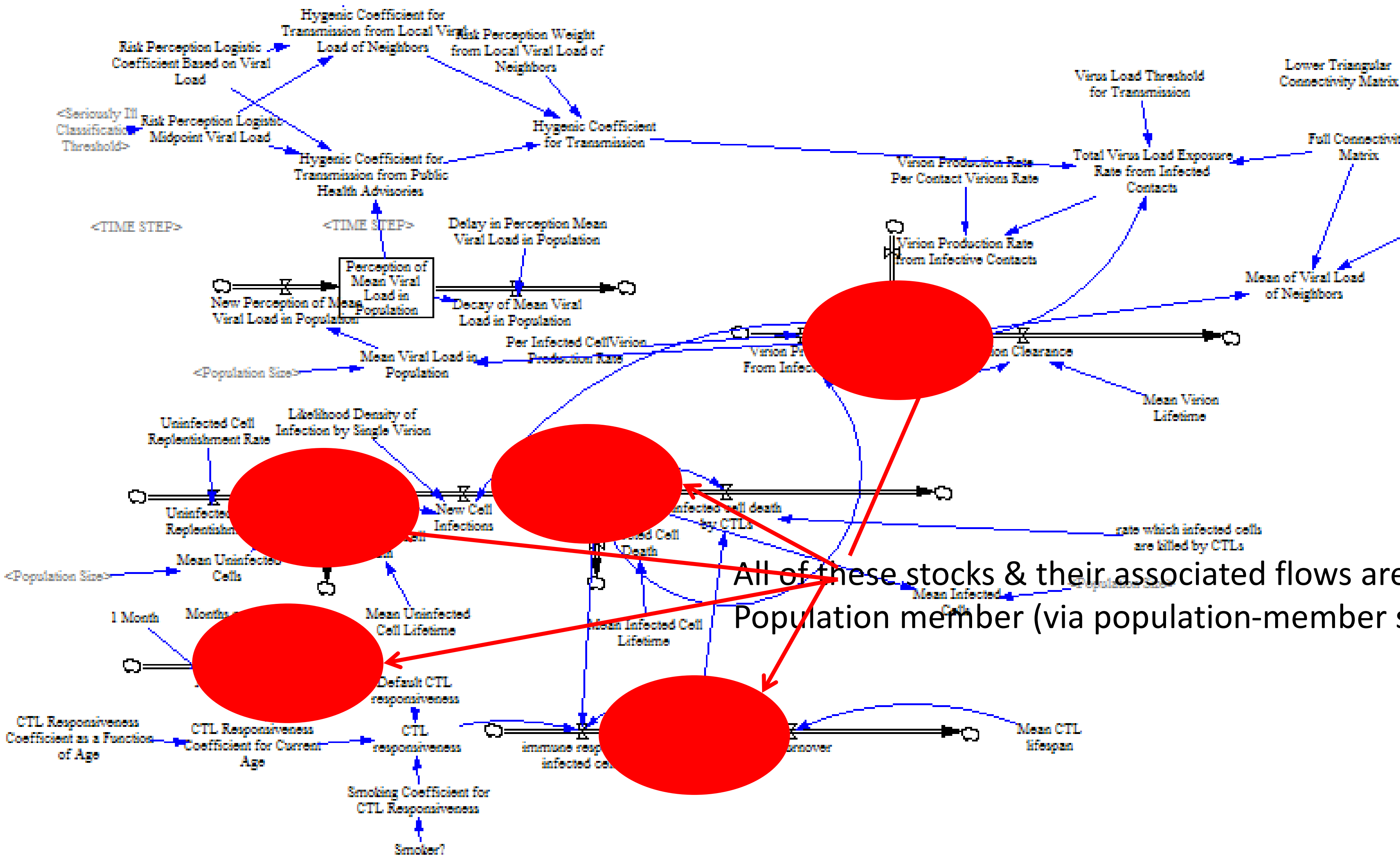
System Dynamics & Individual-Based Modeling

- Individual-based models can be created using
  - Traditional System Dynamics software
    - Small populations:
      - Separate stocks for each individual
      - Hand-drawn connections
    - Larger Populations
      - Subscripting stocks by population member
      - Binary network matrices
  - Stock & flows in other dynamic modeling software
    - e.g. in AnyLogic (e.g., embedded in agents)
  - System Dynamics methodology
    - Feedback-centric reasoning
    - Process-based work

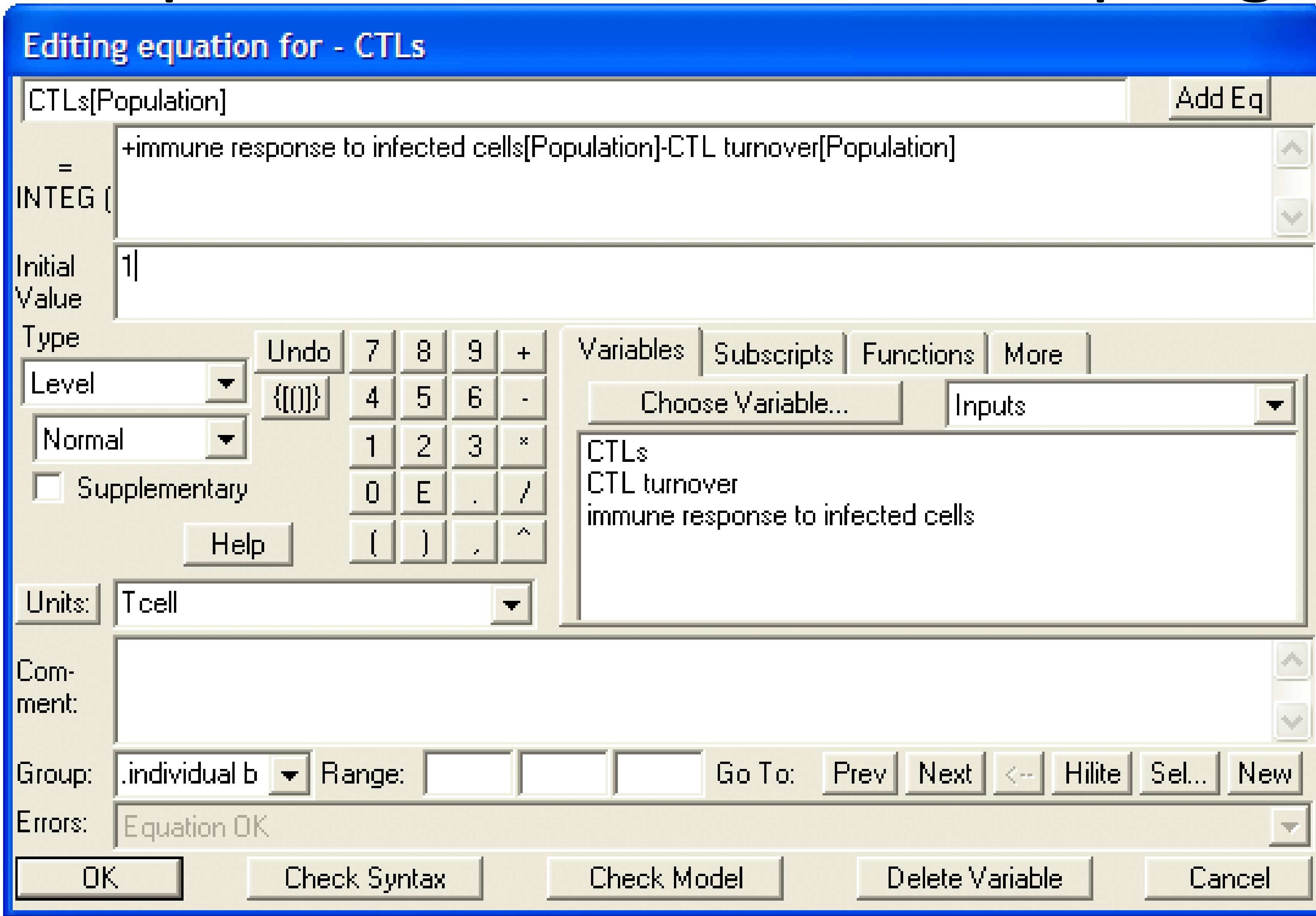
Network Embedded Individuals



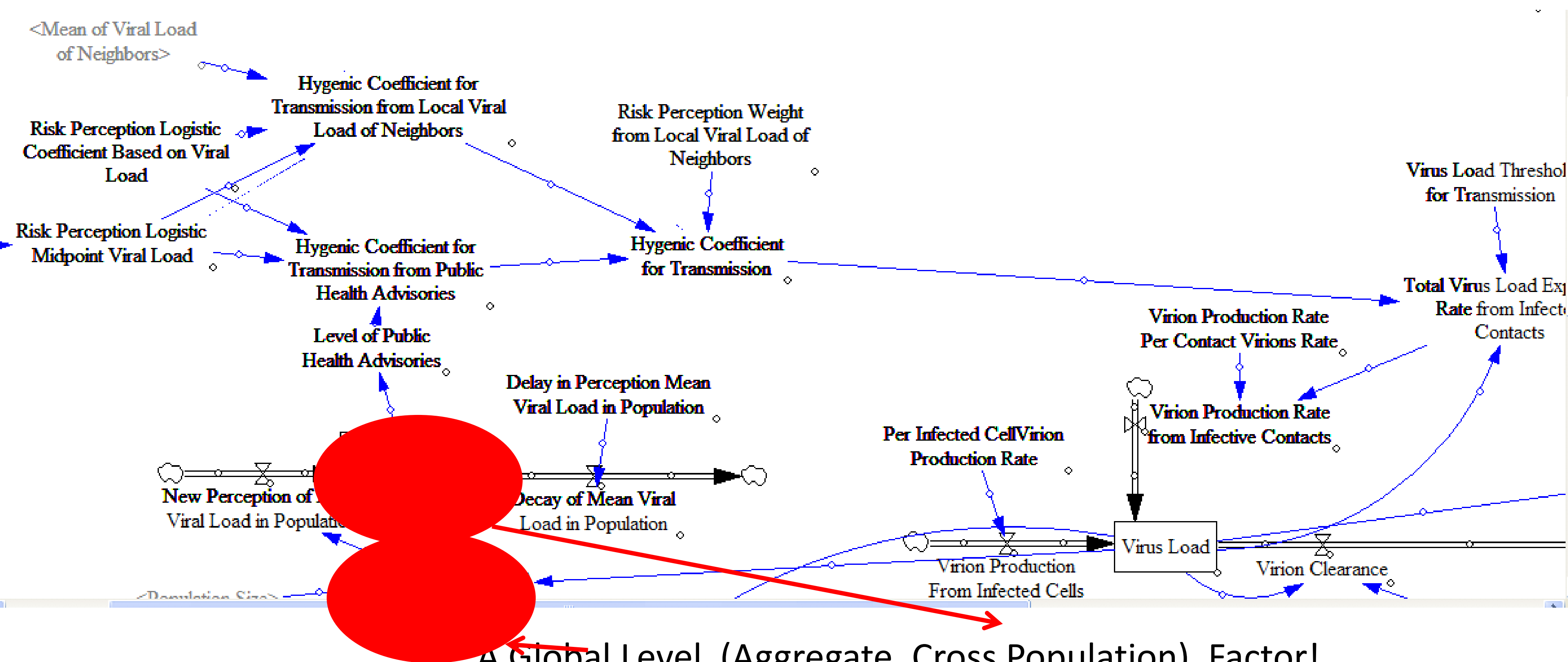
Individual-Based Model in Vensim



Population-Member Subscripting



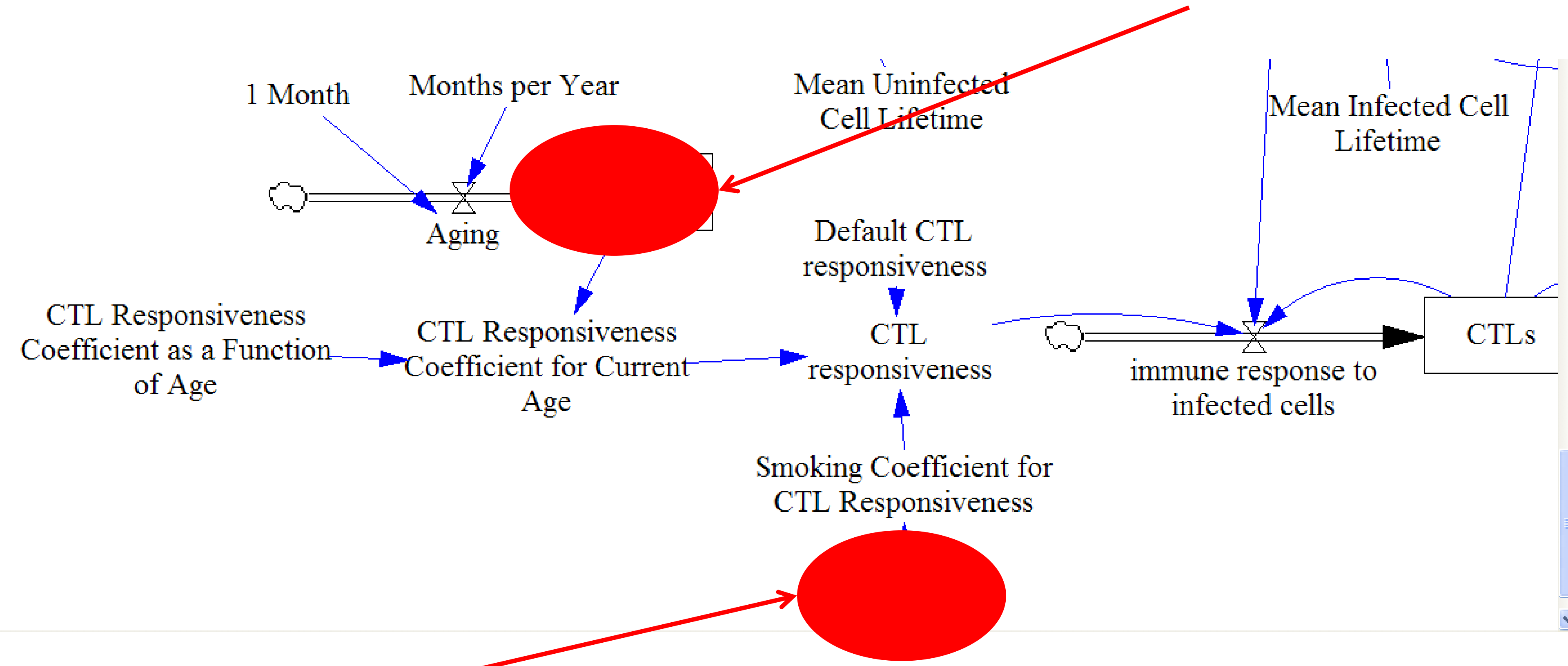
Example Interactions between Global & Local Levels



A Global Level (Aggregate, Cross Population) Factor!

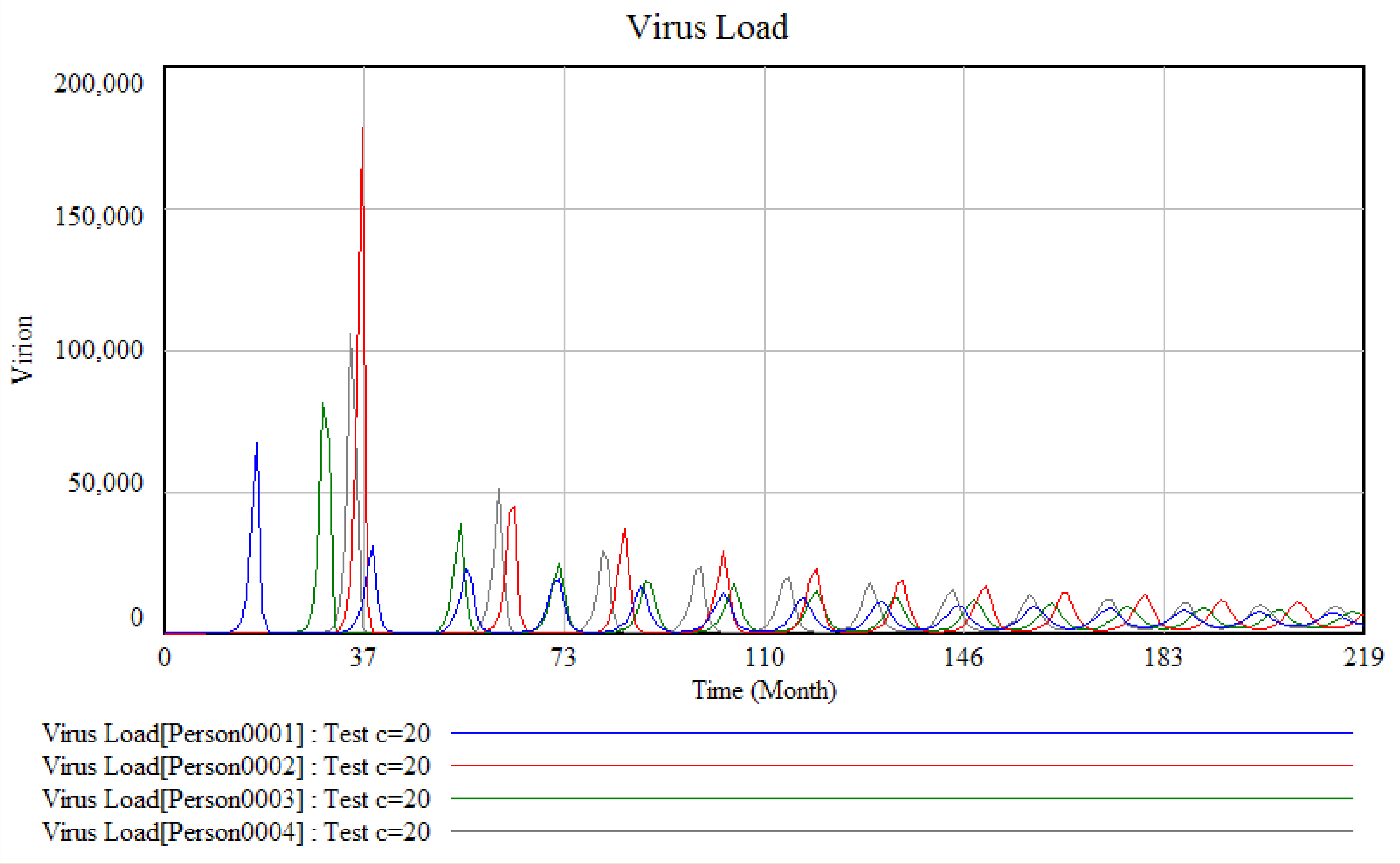
Example Individual-Level Risk Factors

An Individual-Level Risk Factor



er Individual-Level Risk Factor (here, represented categorically, but we could
sent it as a continuous variable – e.g. cumulative smoke exposure, some estimate of
lative physiologic damage from smoke, a moving average of smoke exposure, etc.)

Impact of Risk Factors on Individual Dynamics



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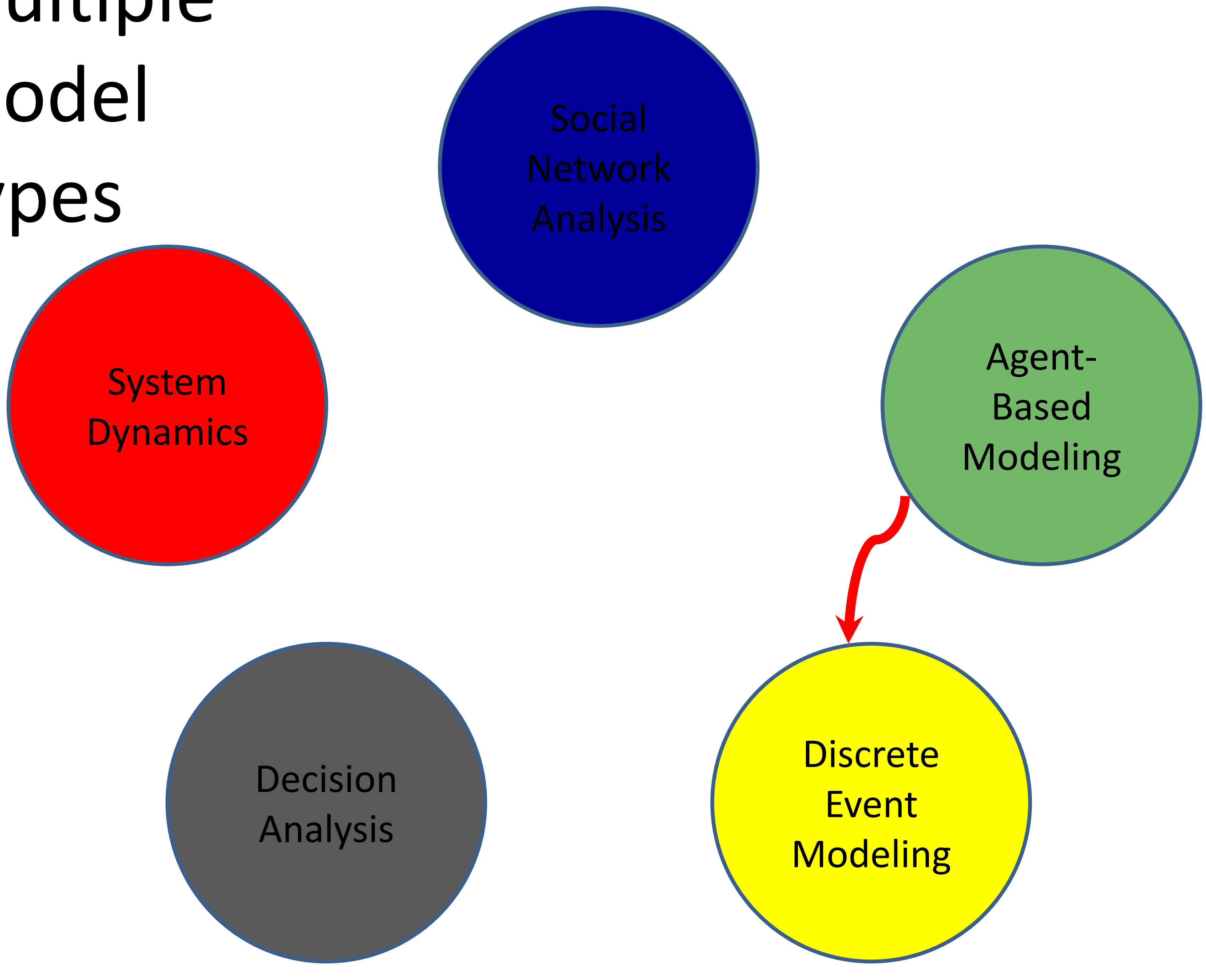
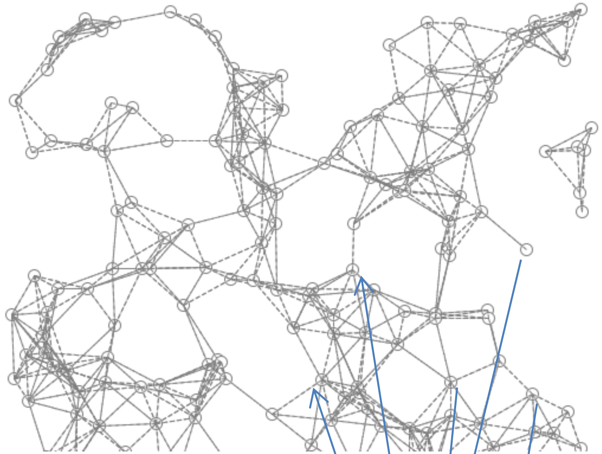
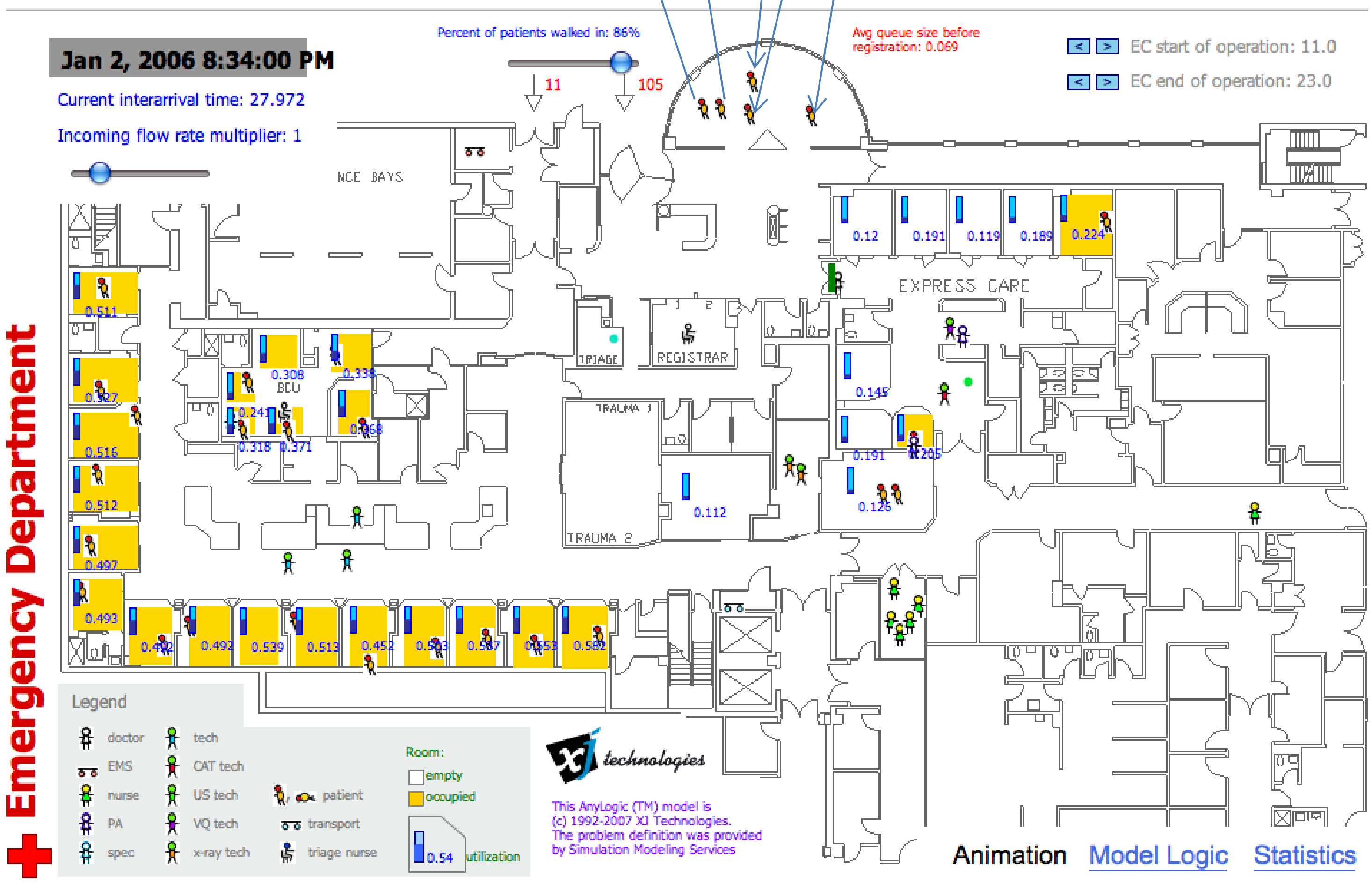


Agent-Based Modeling in Support of DES

- Representing network of individuals in population outside of flow process
  - Prior to entry (development of conditions)
  - Following exit (e..g trajectory dependent on quality of care)
  - Routing inflowing agents process based on agent’s history of care
  - e.g. representing “catchment basin” of care facility

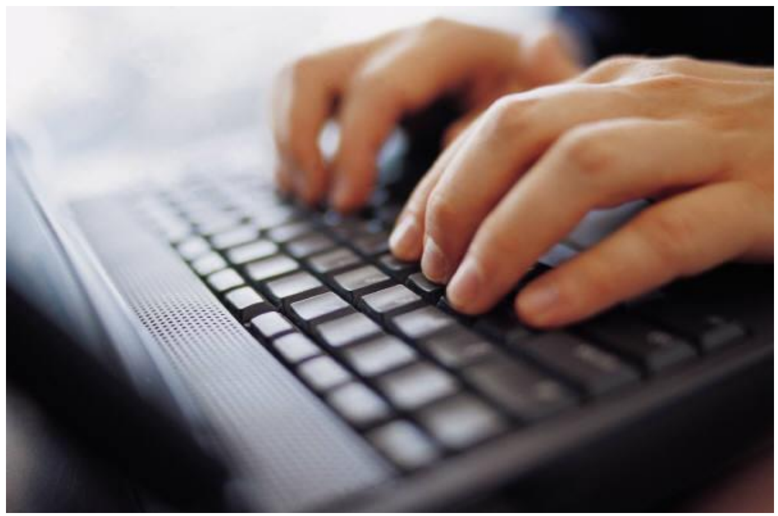
ABM & DES





Jan 2, 2006 8:34:00 PM
Current interarrival time: 27.972
Incoming flow rate multiplier: 1
Percent of patients walked in: 86%
11
105
Avg queue size before registration: 0.069
EC start of operation: 11.0
EC end of operation: 23.0
EXPRESS CARE
TRIAGE
REGISTRAR
TRAUMA 1
TRAUMA 2
BCU
Emergency Department
Legend
doctor
EMS
nurse
PA
spec
tech
CAT tech
US tech
VQ tech
x-ray tech
patient
transport
triage nurse
Room:
empty
occupied
utilization
xj technologies
This AnyLogic (TM) model is (c) 1992-2007 XJ Technologies. The problem definition was provided by Simulation Modeling Services
Animation
Model Logic
Statistics

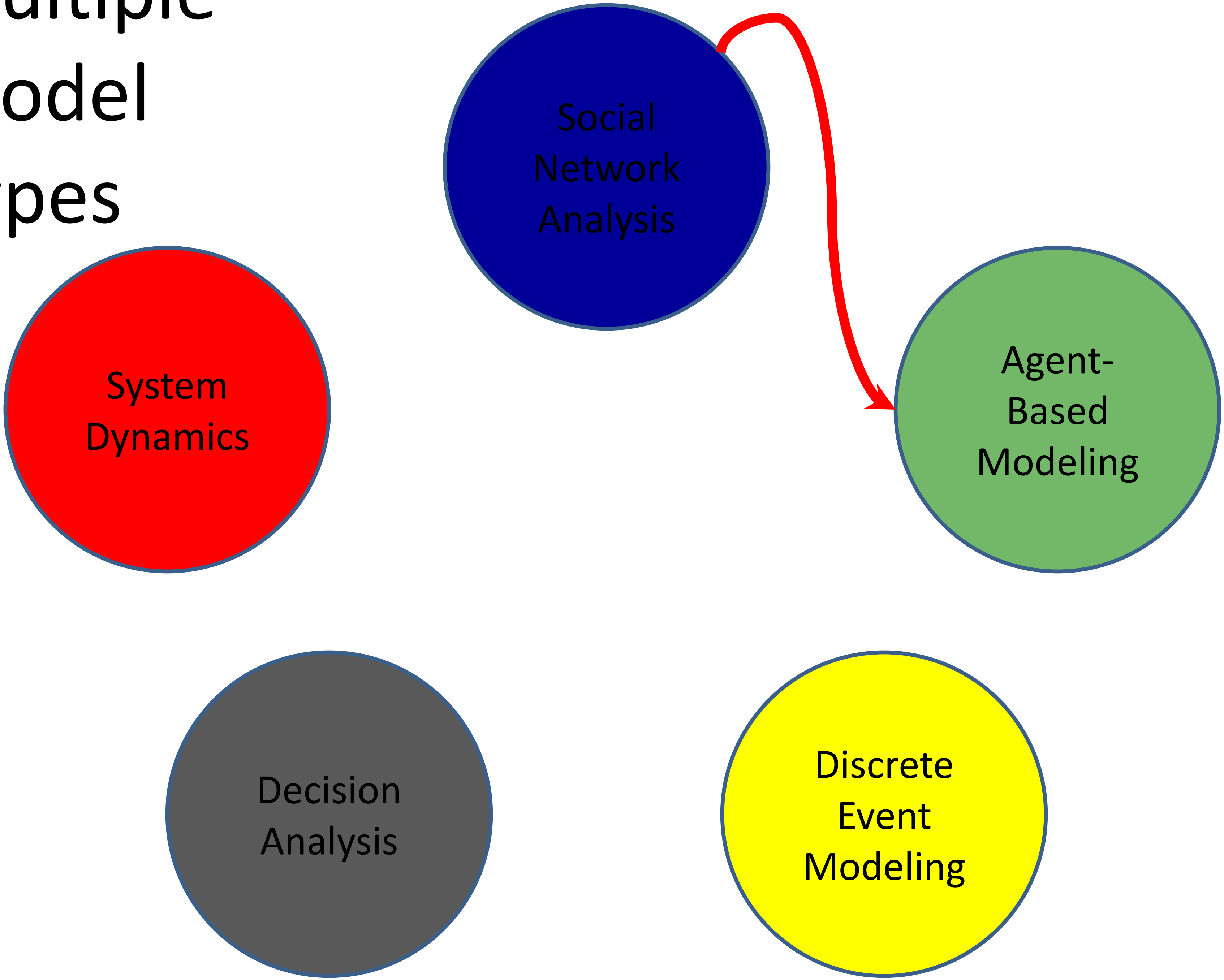
Hands on Model Use Ahead



Load Provided Model:

HybridABMNetworkModeling1

Multiple Model Types



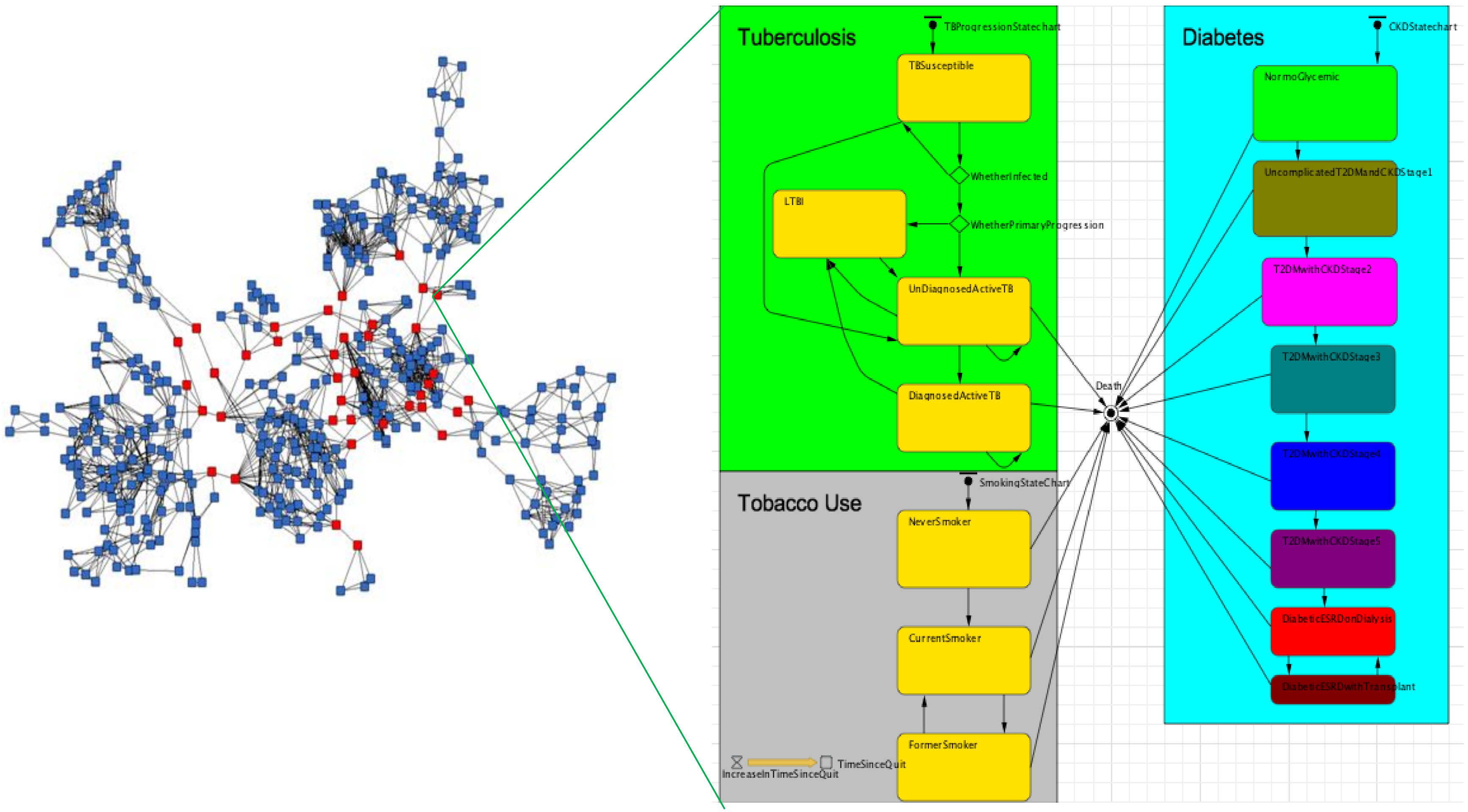
SNA Can Facilitate ABM

- Social network statistics that be used to formulate synthetic networks
- Identify patterns for calibration & investigation
- Cross-checks on ABM simulation findings
- Network visualization
- Highlighting diverse settings for contact

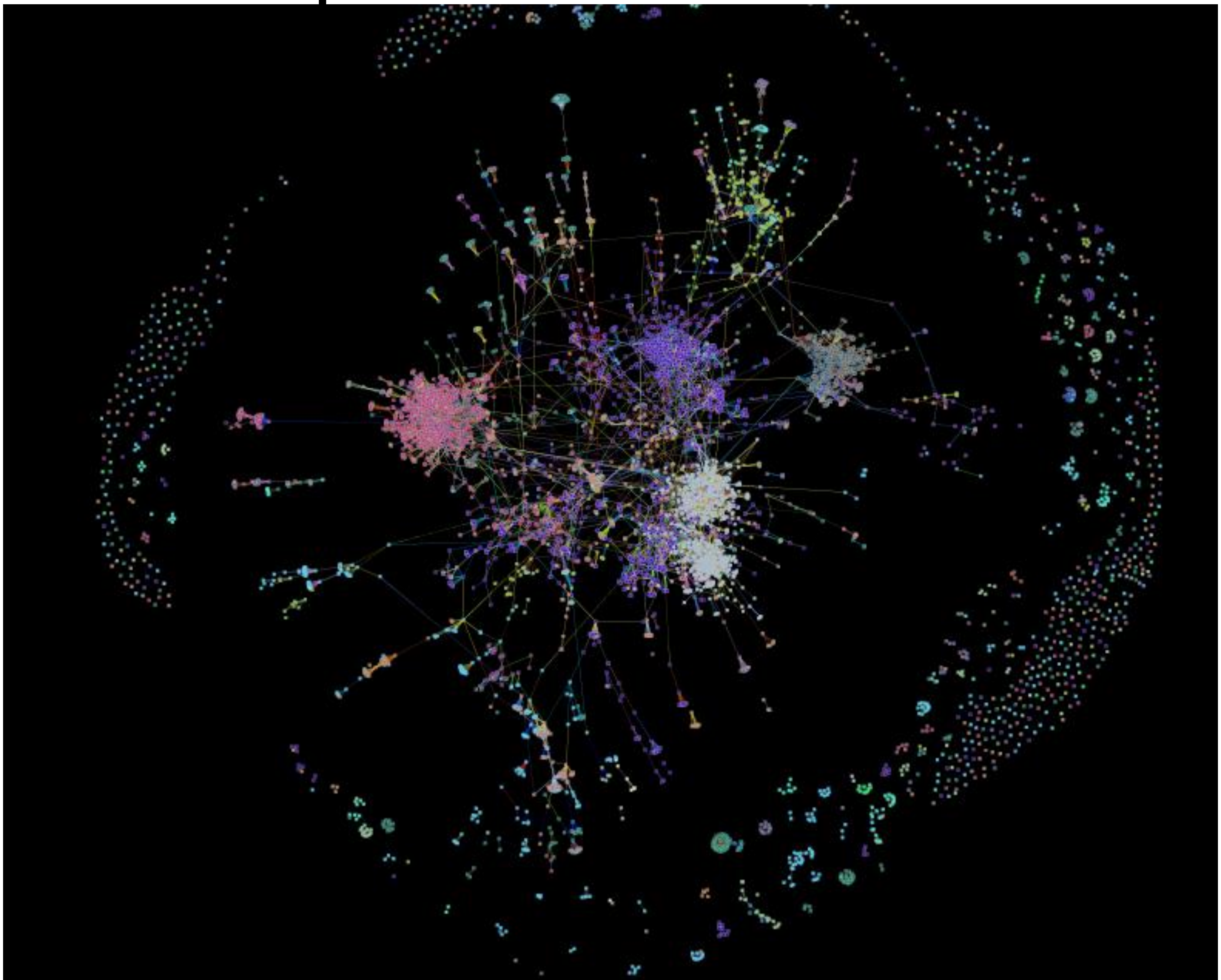
Challenges in Using Data from SNA in ABM

- SNA can provide an extremely valuable source of data to use for grounding ABM network structure
- It is relatively easy to get networks from software like Pajek into software like AnyLogic or Repast
- The bigger issue here is that we need to represent the hypothesized "true" spread of infection over the network
  - To do this, we need to represent the hypothesized underlying network that lies behind
  - Even the best of SNA data is highly incomplete (e.g. due to asymmetries in case-contact data, sampling in snowball sampling)

SNA Providing Context For ABM



Example Network Structure



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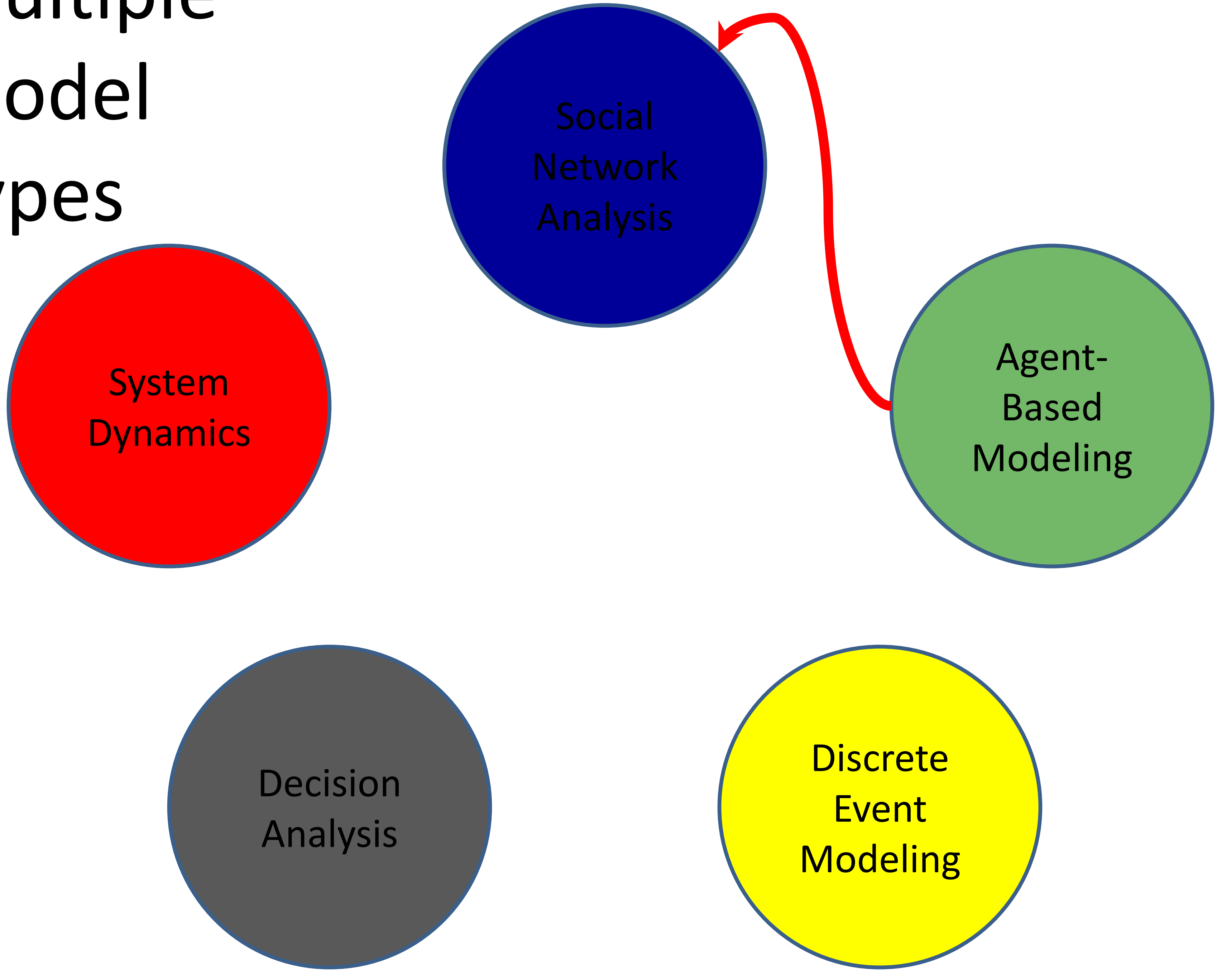


Agent-Based Modeling Facilitates SNA

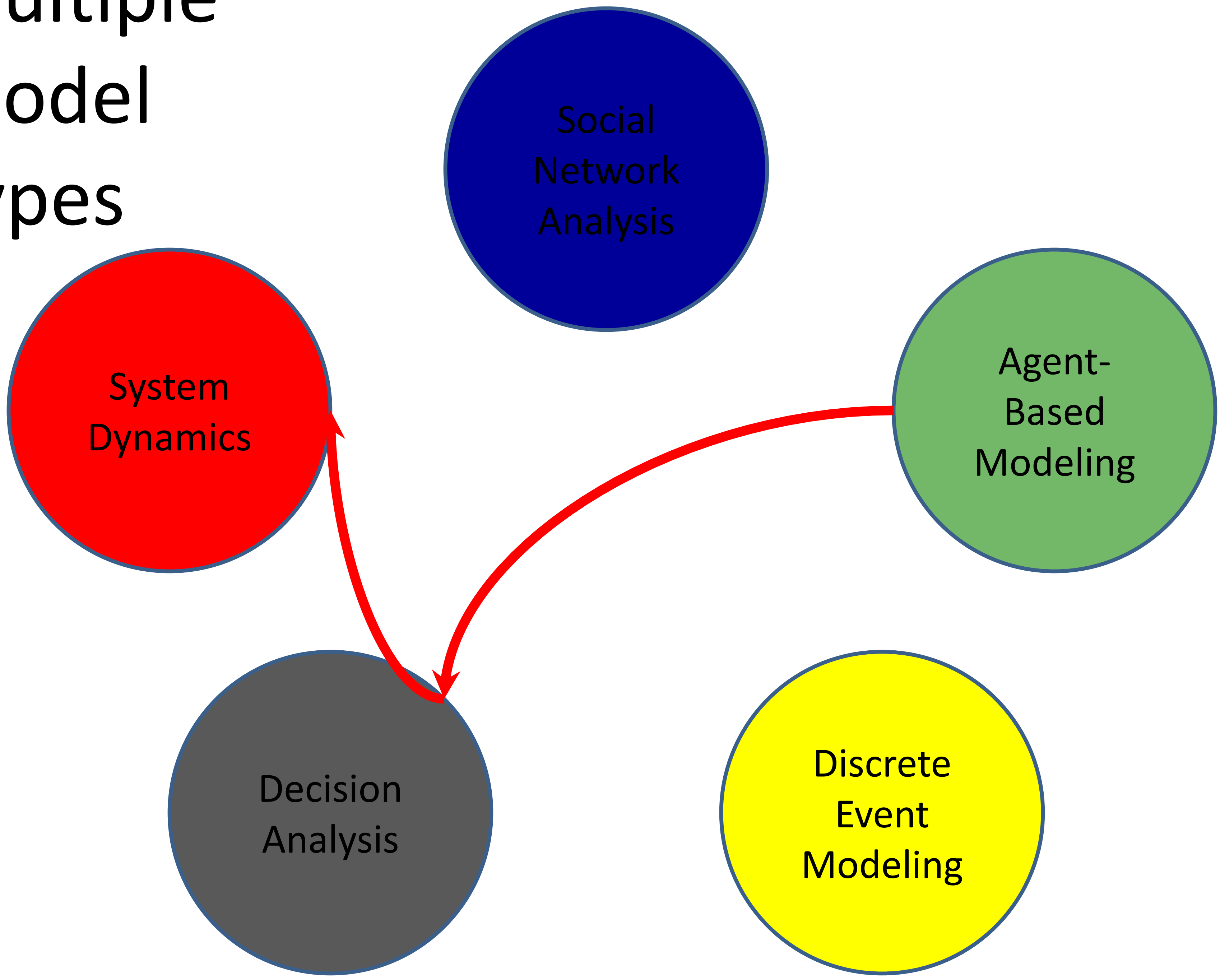
- Exploring dynamic hypotheses to explain SNA patterns
- Formulating ideas for SNA metrics that could be
- highly effective (discriminatory) for identifying at-risk individuals
- Understanding dynamic implications of given network structure
- Understanding implications of changing network structure
- Evaluating SNA-informed interventions (e.g. SNA-metric prioritized contact tracing)
- Examining impact of additional collection of SNA

ABM To Explain Emergent Patterns Uncovered via SNA

Network Degree	TB		Mantoux Positive		Mantoux Negative		Total
	(N)	(%)	(N)	(%)	(N)	(%)	
All	68	13.5	109	21.6	327	64.9	504
2	45	36.8	35	28.7	42	34.4	122
3	28	62.2	10	22.2	7	15.6	45
4	15	68.2	7	31.8	0	0	22
5	14	77.8	4	22.2	0	0	18
6	9	90	1	10	0	0	10
7	7	100	0	0	0	0	7
8	7	100	0	0	0	0	7

A.Al-Azem, Social Network Analysis in Tuberculosis
B.Control Among the Aboriginal Population of Manitoba2006

Multiple Model Types

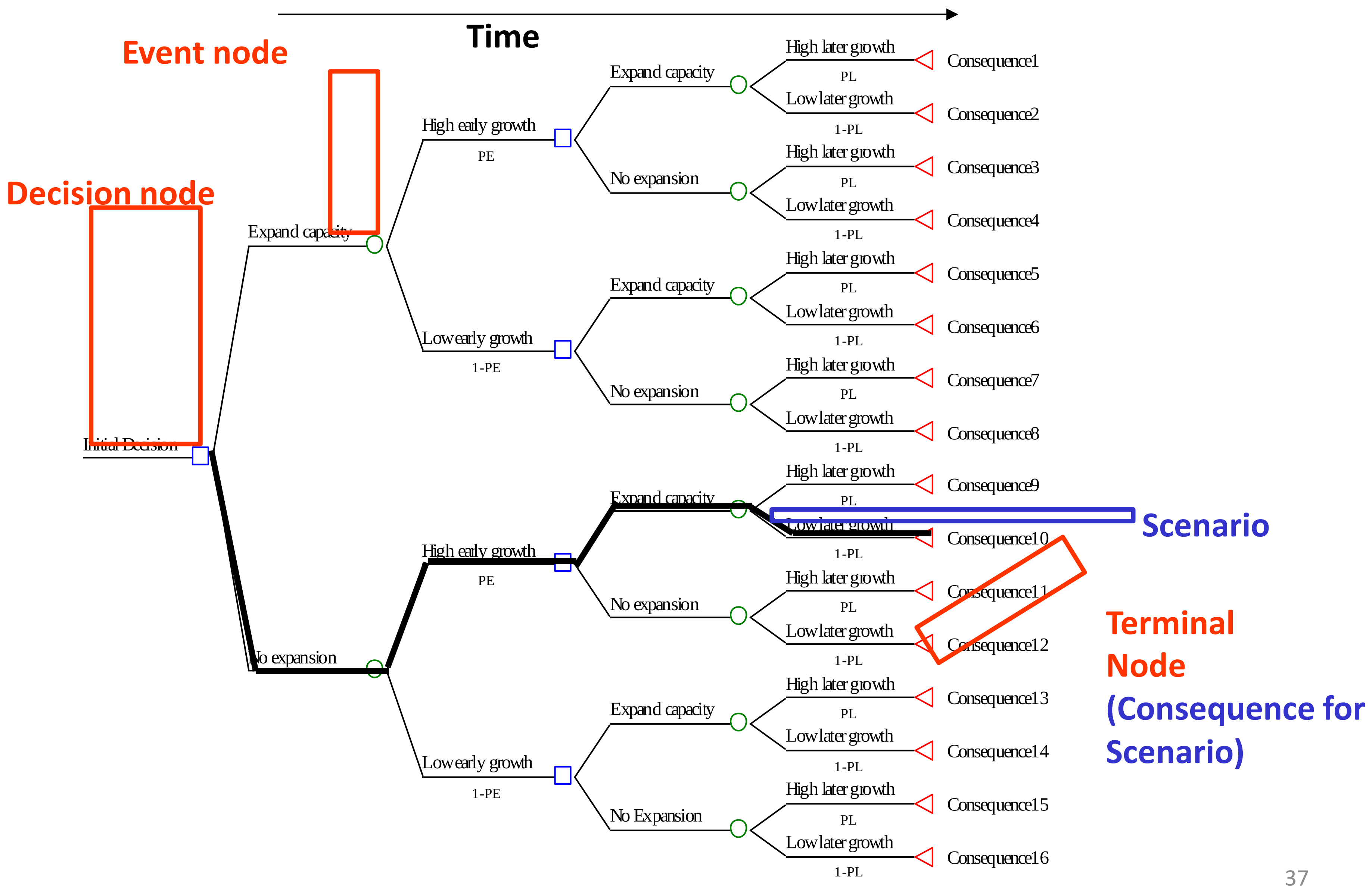


Two Relevant Methodologies

- Decision Analysis
  - Good for decision problems under uncertainty w/known scenario consequences
    - No endogenous means of determining consequences
  - Characterizes structured policy space
  - Sophisticated statistical tools & Sensitivity analyses typical
  - Identification of robust strategies via backwards induction
  - Discrete
    - Events/decisions
    - Time

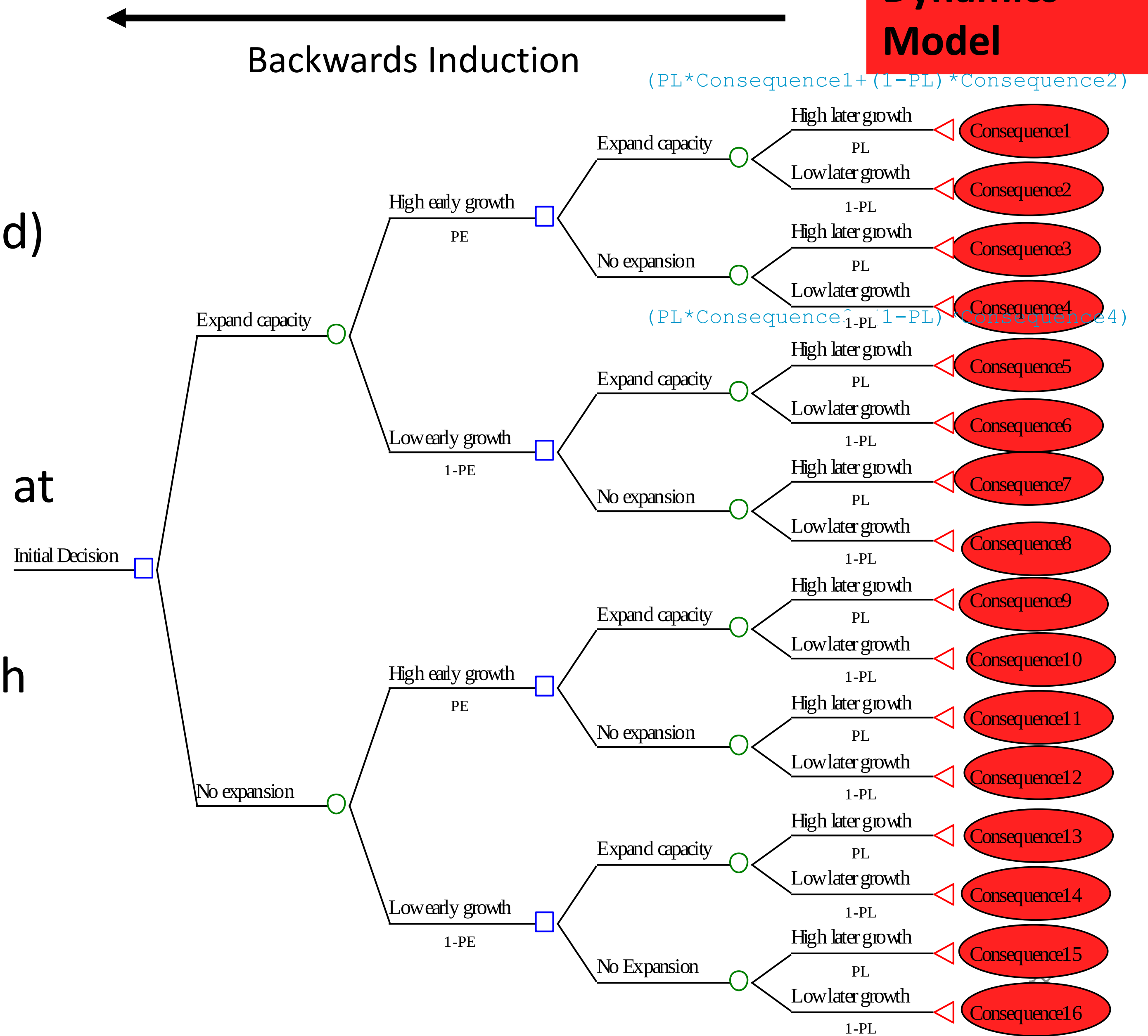
- Dynamic Modeling
  - Good for representing complex system response to scenario (events and actions)
  - Policy representation
    - Highly flexible
    - Less structured policy space
  - Basic statistical tools
  - Potentially continuous
    - Time
    - Events/decisions

Decision Tree To Structure Policy Space



Backwards Induction

- Run SD model to determine set of (preference-adjusted) outcomes for all terminal nodes
- Compute expected value & risk profiles at event nodes
- At decision nodes, choose decision with highest value
- **FAST**



itivity Analysis

- Offline sensitivity of likelihood impact on strategy selection

- Offline analysis (including Monte Carlo) of impact of likelihood change on risk profiles

Individual-Based Modeling in Vensim
Population Subscripting Tradeoffs

Advantages

- Conceptually simple
- Can SD tools
  - State trajectory file recording
  - Easy construction, structure visualization
    - No programming
  - Sensitivity analysis
  - Easy to aggregate

Disadvantages

- Difficult to visualize network structure & spread or spatial embedding
- Awkward to realize changing population size