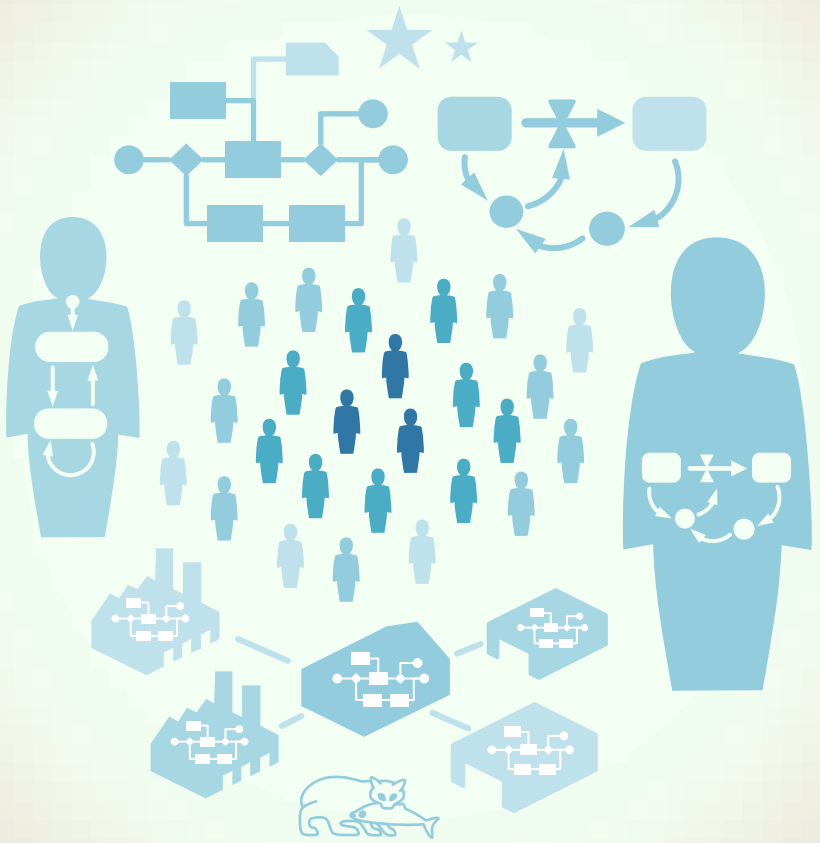


Combining System Dynamics with Discrete Event and Agent-Based Methods: Why and How

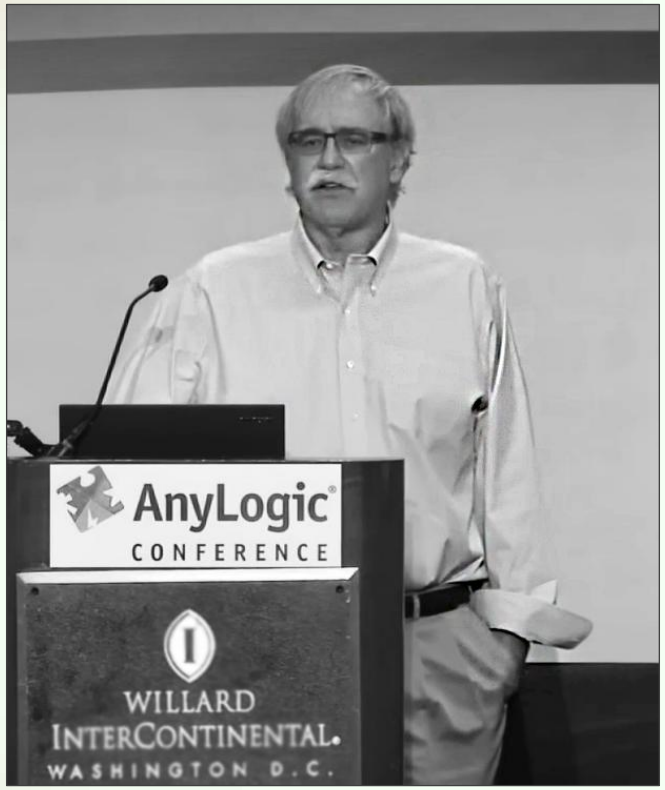
Dr. Andrei Borshchev
CEO The AnyLogic Company

November 3, 2026
Webinar
Special Interest Group of the System Dynamics Society

THE AnyLogic® COMPANY

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Before we begin: did you know that:



Mark Paich



Lyle Wallis

These two members of the System Dynamics Society played a major role in shaping AnyLogic during its early years. Coming from the SD world (and being simulation practitioners), they recognized the limitations of the paradigm and were looking for a tool that would allow them to combine SD with Agent Based modeling to capture more of the real world in a more natural way.

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Agenda

1. Modeling methods and modeling languages. What does "Discrete Event" actually mean?
2. Mapping System Dynamics Models to Agent-Based Models – and what you can do next [live demo]
3. Multi-Method Modeling. Combining System Dynamics with other methods [live demo]

The webinar is based on these publications (full texts available online):



A. Borshchev and A. Filippov
From System Dynamics and Discrete Event to Practical Agent Based Modeling: Reasons, Techniques, Tools.
ISDC 2004



A. Borshchev
Multi-Method Modeling.
WSC 2013



A. Borshchev and I. Grigoryev
The Big Book of Simulation Modeling: Multimethod Modeling with Anylogic 8.
Online edition.

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1.

Modeling methods and modeling languages. Terminology: What does “Discrete Event” actually mean?

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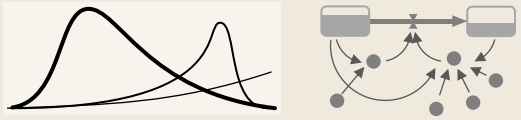
Continuous and Discrete approaches in “business” and physics models

High Abstraction
Minimum Details

System Dynamics

Accumulations, Flows, Feedback loops

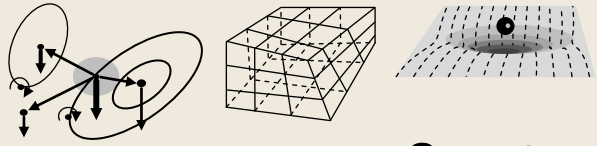
Ordinary Differential Equations (ODEs). No space



“Classical” Physics

Newton mechanics, Theory of relativity, Fluid and Aerodynamics, Solid body, Thermodynamics

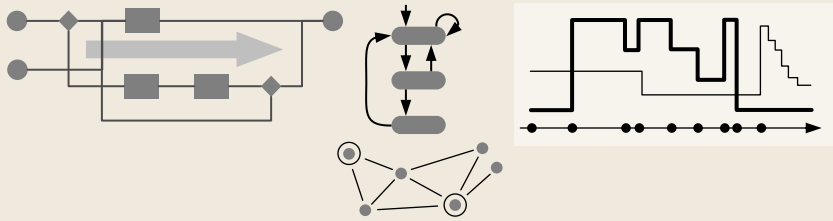
Continuous time & space, ODEs, PDEs, Finite Element Method, …



Discrete Event (process) Models & (most of) Agent Based Models

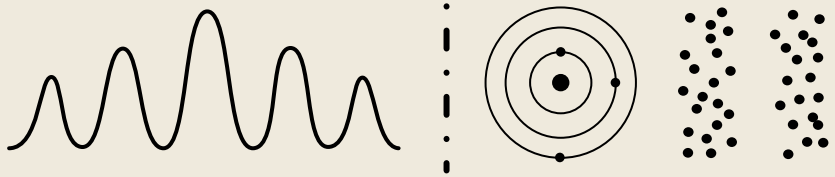
Individual objects, discrete time (important events only)

Event queues, states, mostly continuous space, network structures



Quantum Mechanics

Wave-particle duality, Fundamentally discrete states/space & stochastic view



Maximum Details
Low Abstraction

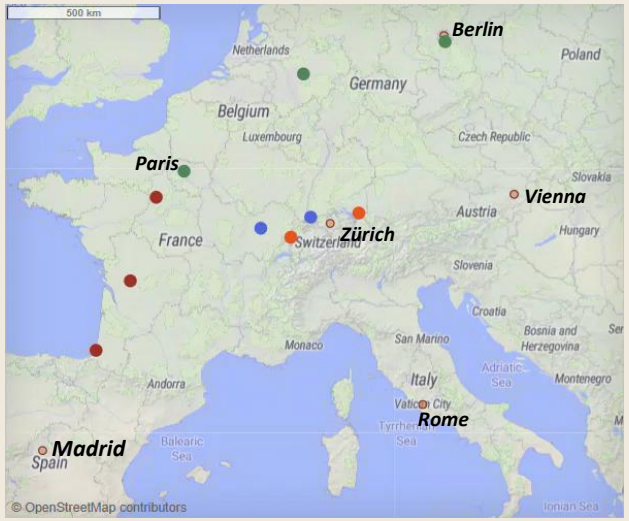
Continuous and Deterministic ⟷ **Discrete and Stochastic**

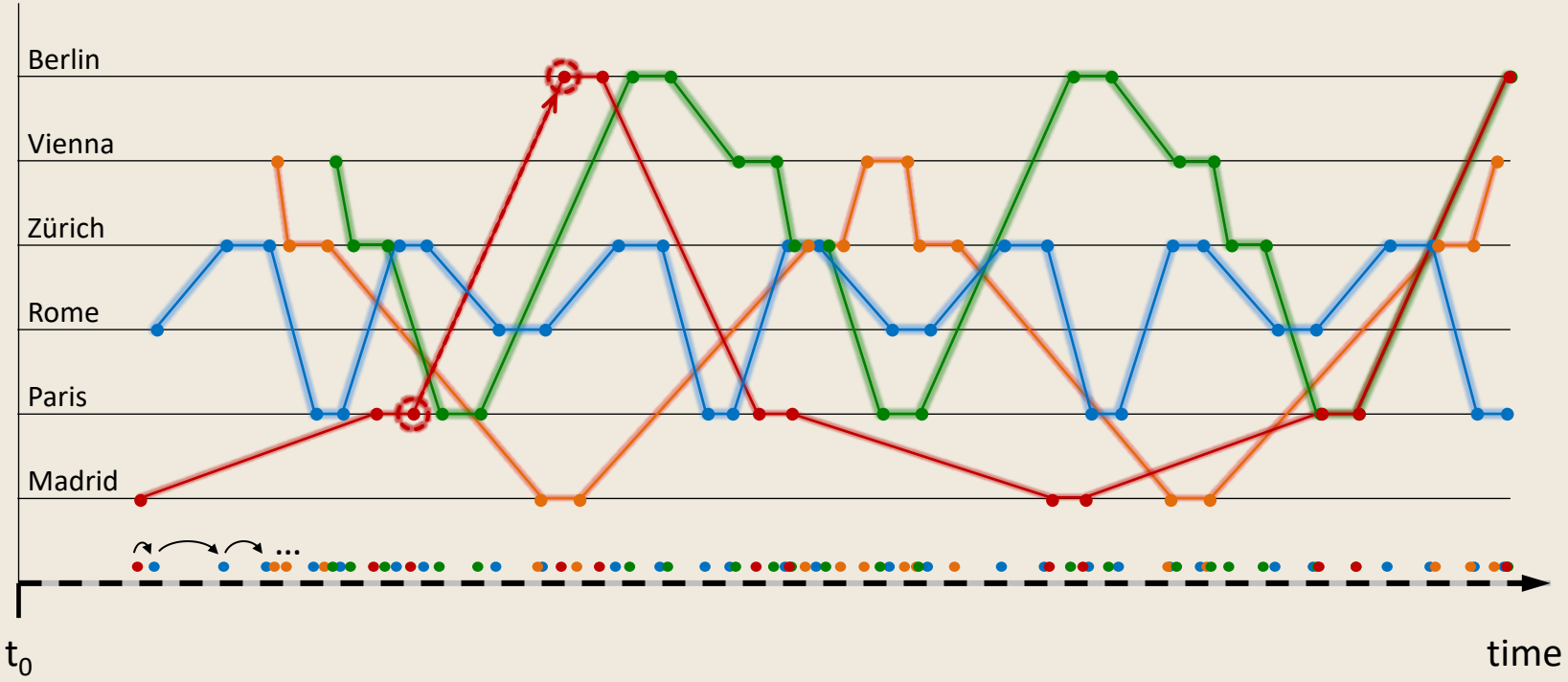


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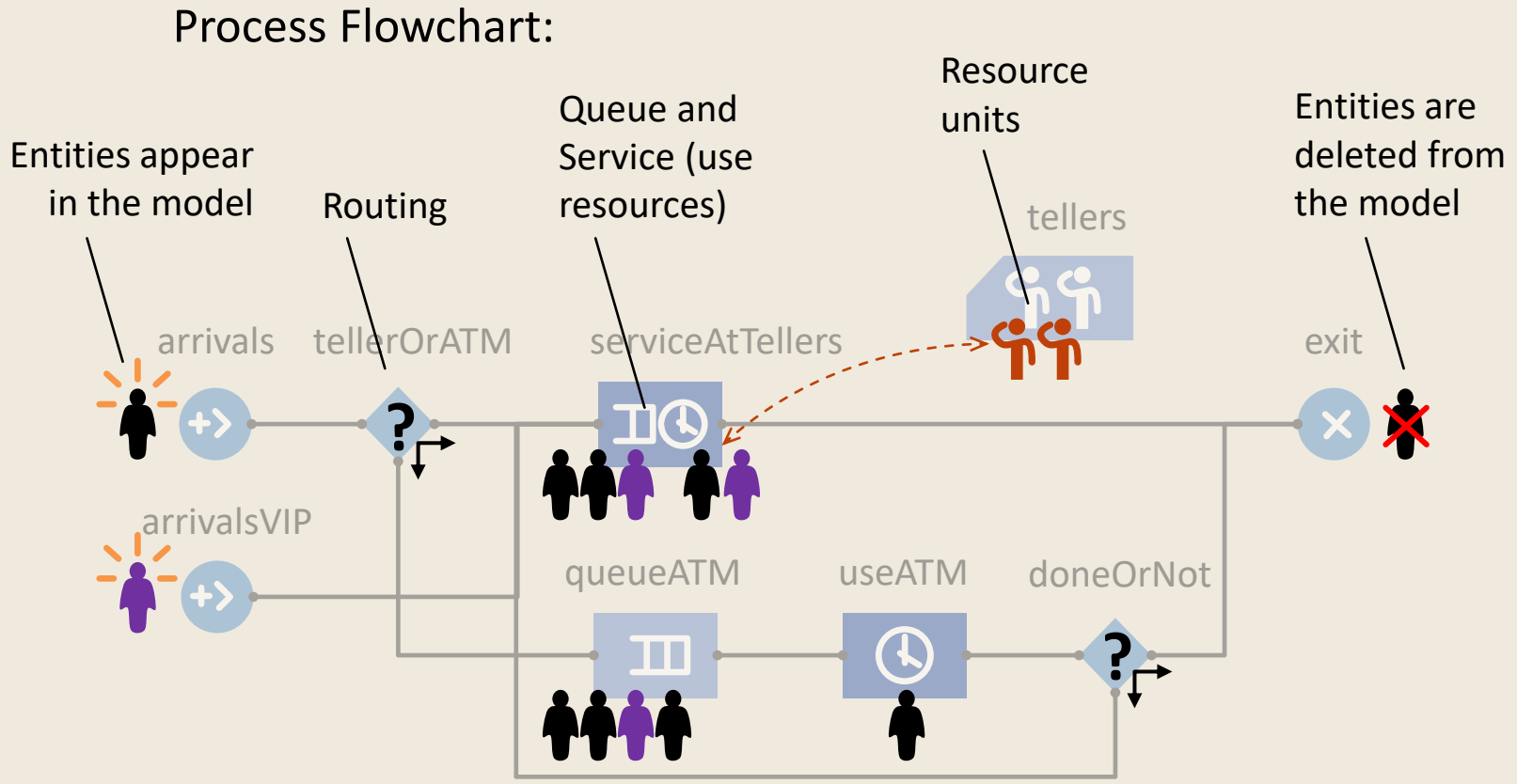
What is DES* (Discrete Event Simulation)?

- Only important events (such as arrivals and departures) matter – nothing happens or changes in between
  - Even though the smooth animation might make you think otherwise!
- Upon departure, we calculate the arrival time and schedule the arrival event – that's it.
  - The simulation engine maintains the event queue and jumps from the current event to the next scheduled event
- This is the abstraction level suggested by DES
  - (*Historically, people have used the terms "DES" and "Process Modeling" interchangeably – lots of confusion!)





What is Process Modeling?



- Process flowcharts are useful when the system being modeled is best described as a sequence of operations performed on entities (possibly sharing resources)
  - That's not always the case, but it covers a very large class of systems
  - Entities can have properties (such as priority, task list, complexity, etc.), and their progress through the flowchart may depend on these properties
- The underlying simulation engine is Discrete Event!

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What is Agent Based Modeling (ABM)?



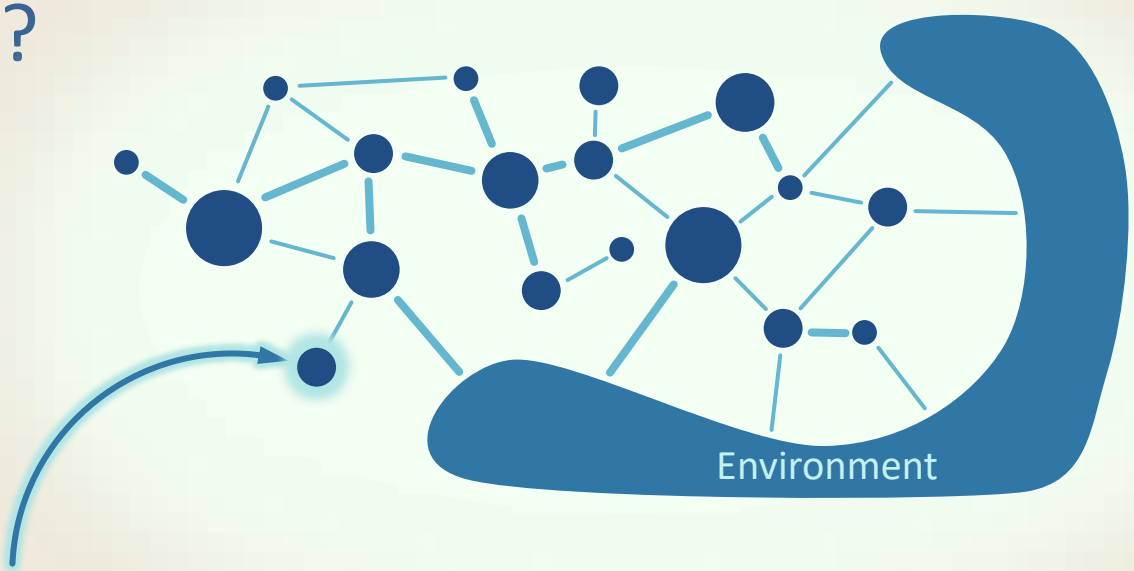
Beware of "academic" literature

- Agents are NOT cellular automata living in discrete space
  - In most applications, space is continuous (e.g., geographical space, a site map, a facility layout) or there may be no space
- ABM does NOT assume synchronous time (clock "ticks")
  - Most AB models are asynchronous with events occurring at arbitrary times. Continuous-time dynamics may also be part of agent or environment behavior
- Agents are NOT necessarily people
  - Anything can be an agent: a household, a project, a brand, an asset, an investment, an ideology…
- Agents are NOT necessarily "active" or "intelligent"
  - Consider e.g., a pipe segment in a water supply network, with its maintenance and replacement schedules, costs, breakdown events, etc.
- There can be many or very few agents in an AB model
  - E.g., consider an AB model of a consumer market vs. a model of a supply chain
- There are AB models where agents do not interact directly
  - Consider patients with chronic non-contagious diseases – they may only interact through sharing resources (i.e., through the environment)
- There are AB models with and without environment

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OK, so what IS Agent Based Modeling?

Agent Based Modeling is essentially a decentralized view of the world, focusing on individual behavior and interactions among objects and with the environment.



You may not know how the system as a whole behaves, what its key variables are, or how they depend on one another. You may not see a feedback loop structure or a process flow.

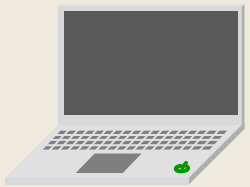
But you may have some idea of how individual objects in the system behave. You can then start building the model bottom-up by identifying those objects (agents) and defining their behaviors*.

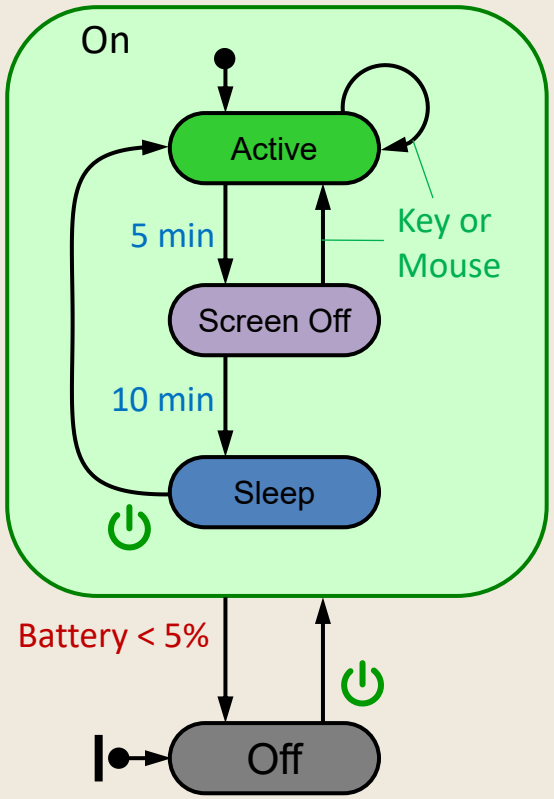
The global behavior of the system then emerges from the interactions of concurrent individual behaviors.

*ABM does not suggest any specific modeling language. Statecharts are useful for state/event-driven behavior. However, both process flowcharts and SD are used inside and outside agents as well.

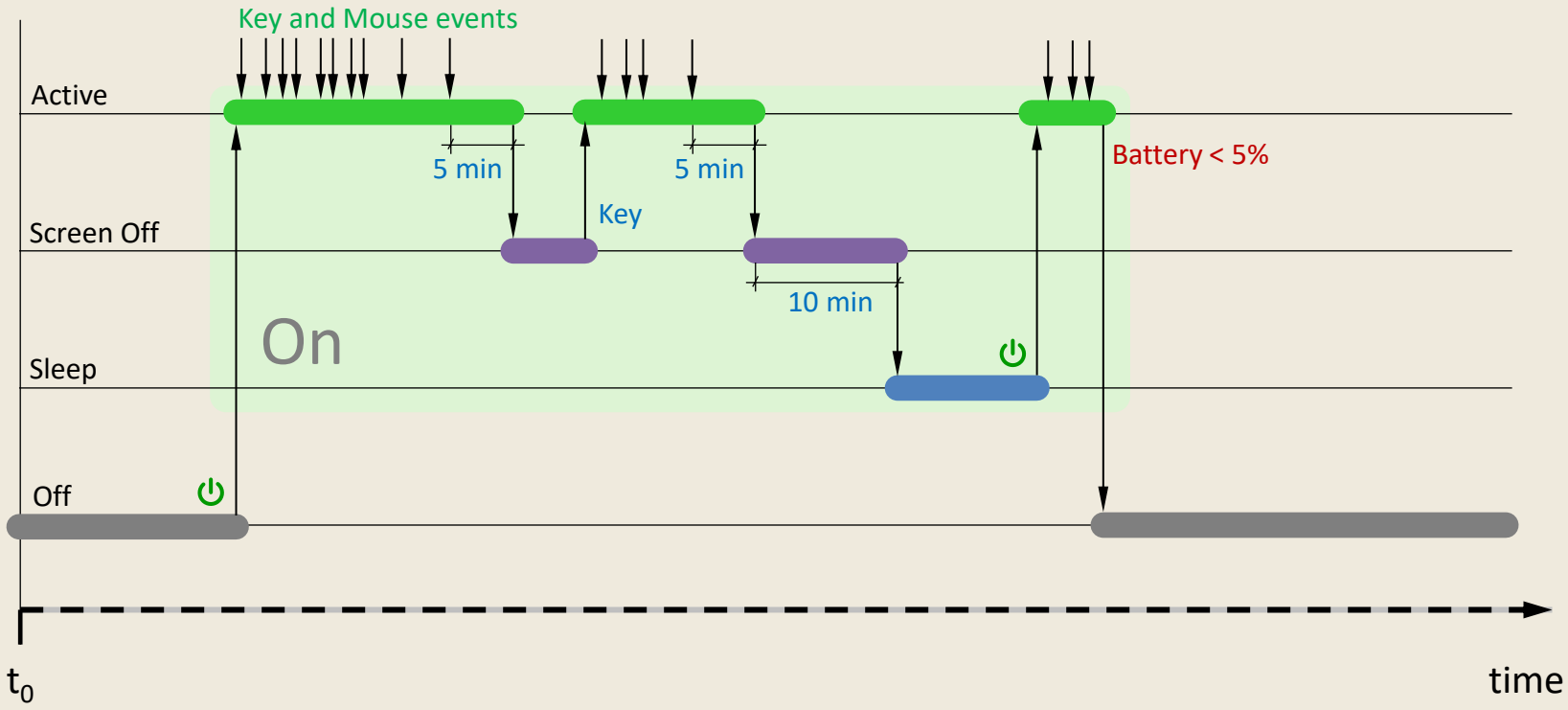
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Statecharts (enhanced state machines) – frequently used in AB models





- Statecharts describe behavior of objects with mutually exclusive* states.
  - (*Of course, simple states are mutually exclusive, composite states group simple states)
- Transitions are instantaneous and are triggered by events: messages, timeouts, conditions, etc.).
  - No continuous changes in this system!

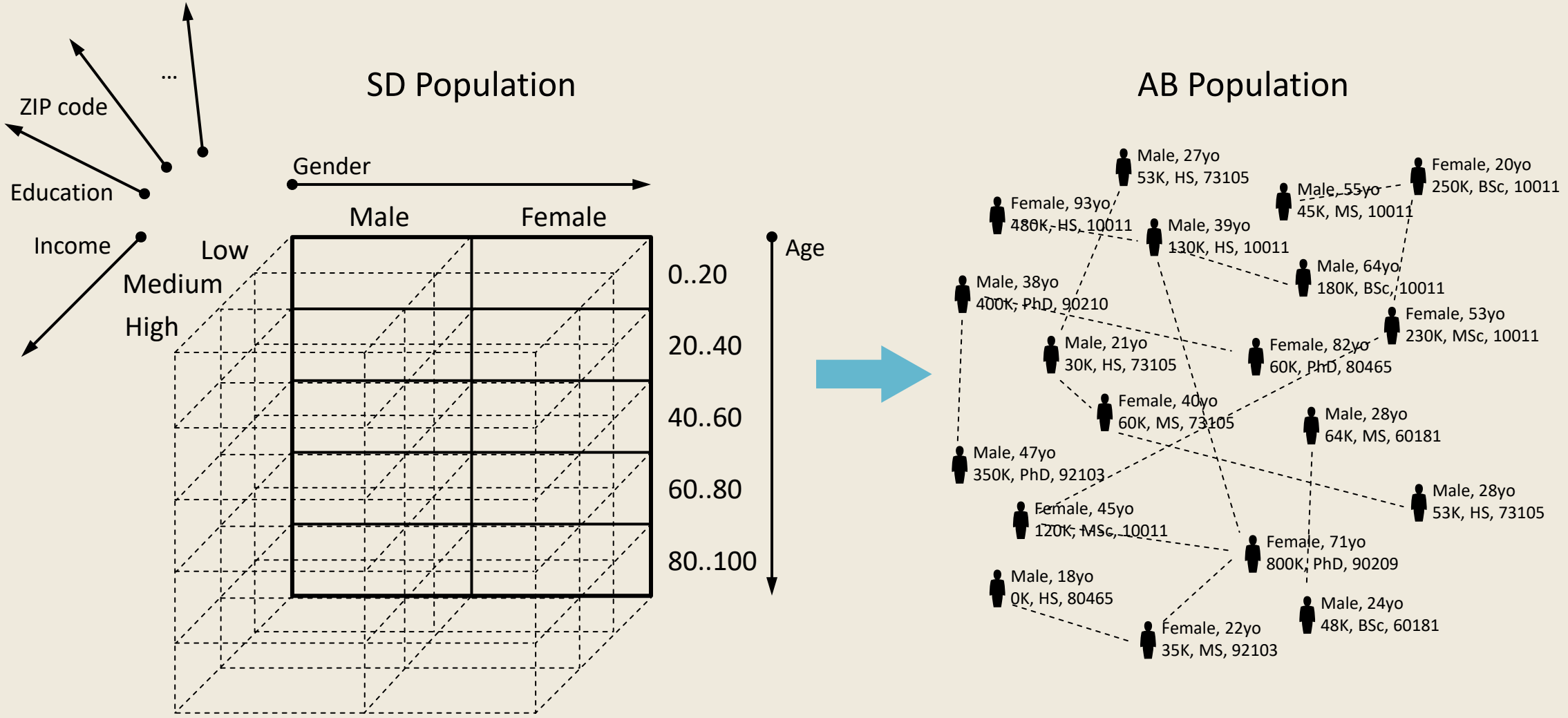


2.

Mapping System Dynamics Models to Agent-Based Models – and what you can do next

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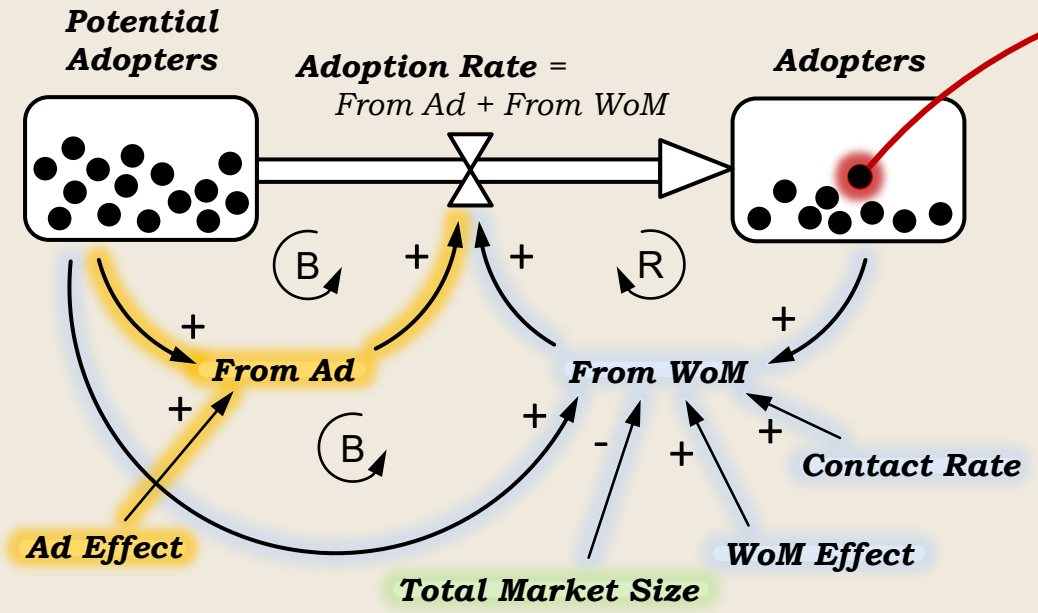
System Dynamics Hyper Arrays to Agent populations



From Stock & Flow diagrams to Agent behavior: Bass Diffusion Model

Wave <----------> Particle

SD Stock & Flow Diagram

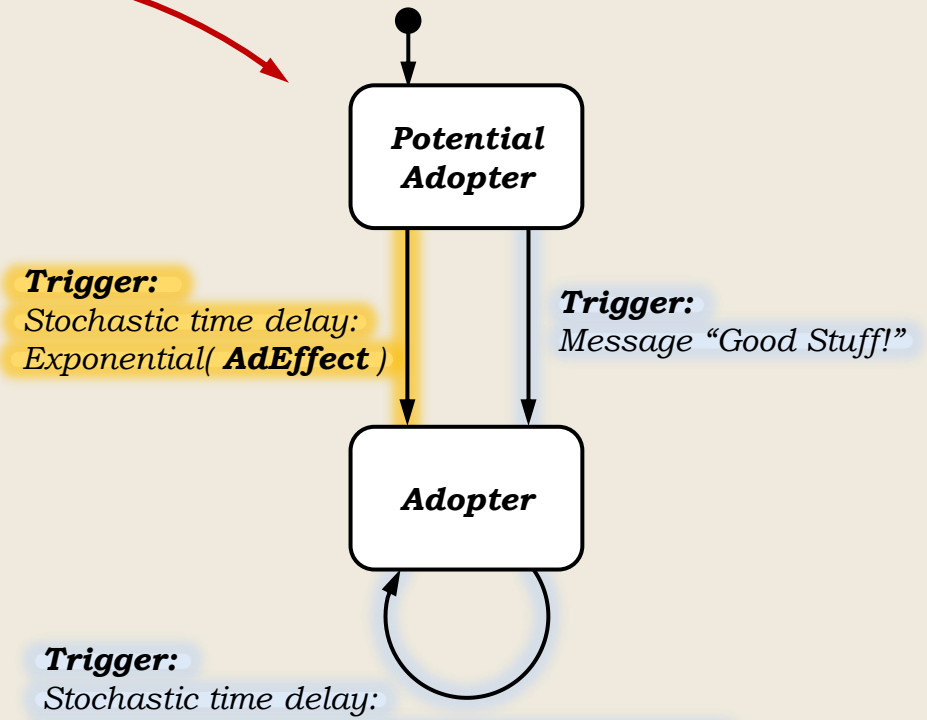


From Ad =
*Potential Adopters * Ad Effect*

From WoM =
*Adopters * Potential Adopters * Contact Rate * WoM Effect / Total Market Size*

Agent Behavior (Statechart)

Number of Agents: ***Total Market Size***



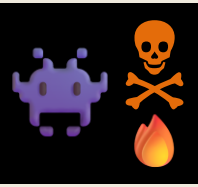
*By multiplying by WoM Effect here we model only successful contacts

Demo time!

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Is there a price you pay when you go from SD to AB?

- Well, first of all, you commit heresy and betray the faith. 

- You need to learn other modeling languages – and some coding as well
- You may spend more time putting together the model structure and collecting statistics
- You have a lot more degrees of freedom – and it's easier to make mistakes / bugs
- CPU and memory – for large volumes of agents

- Also: it's not always possible or worth it – and it is NOT our goal. So, what IS our goal? - - - - - - - >

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Our goal is to keep our models clean, minimalistic (free from unnecessary details), and elegant (free from workarounds).

- If we are to capture business, economic, and social systems in their interaction, staying within one single paradigm may become a serious limitation.
- Depending on the project goals, the data available, and the nature of the system being modeled, different components may call for different methods and different languages.

Therefore:

3. ★ Multi-Method Modeling ★

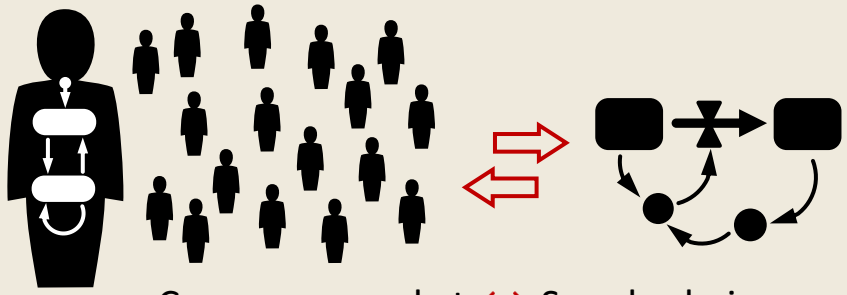
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Let's see a working model first!

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Some examples of Multi-Method model architectures that include SD



Consumer market ↔ Supply chain

Inpatients ↔ Clinical decision making

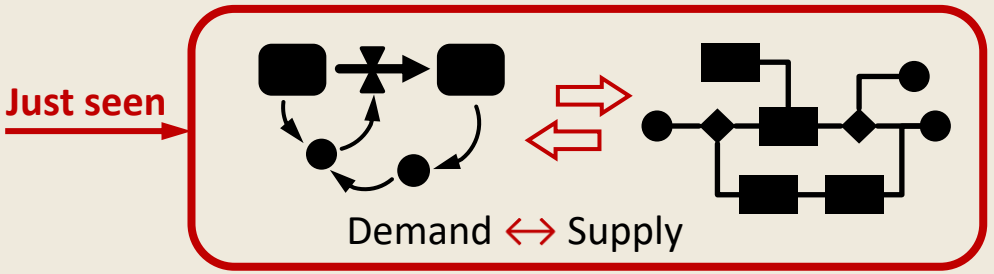
Gov supporters / dissidents ↔ Government policies

Population ↔ Housing / Infrastructure

Animal population ↔ Habitat

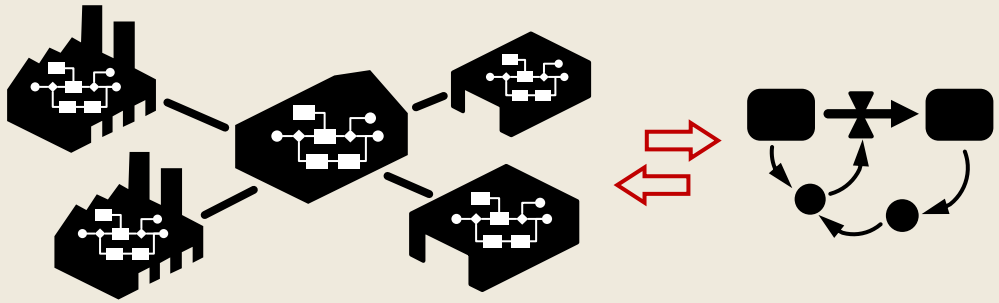
Patients with diabetes ↔ Health economics

Projects & Products ↔ Capital

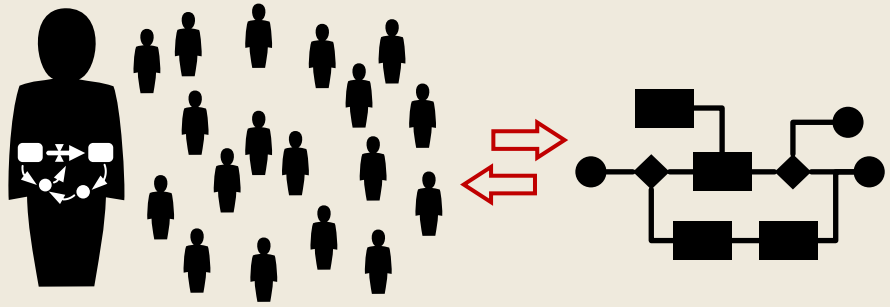


Demand ↔ Supply

Epidemic ↔ Hospital facilities



Supply chain ↔ Demand



Patients with chronic diseases ↔ Regional healthcare

Credit applicants' decision making ↔ Credit approval process

Client satisfaction ↔ Service

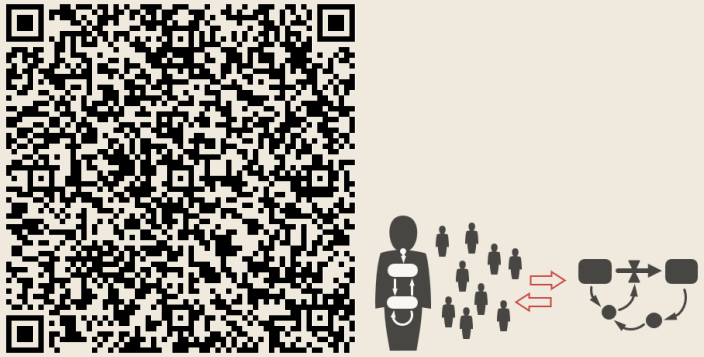
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More multi-method models online (you can view source and edit):



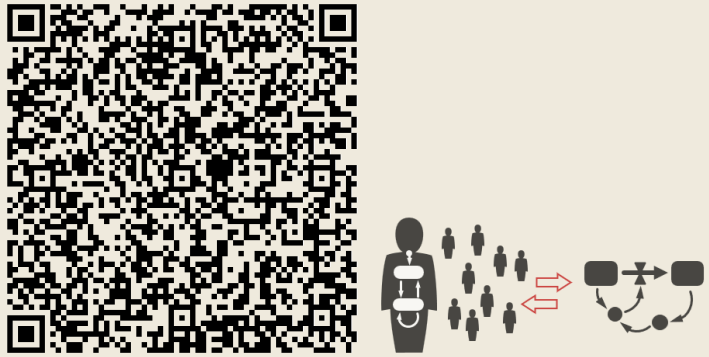
Insurgency Dynamics

AB model of population (Government Supporters, Dissidents, Insurgents) + SD model of political and economic environment



Agent Population and SD Housing

A model of city housing where families (agents) are moving between neighborhoods trying to optimize their comfort / costs. SD is used to model housing availability & rent prices.



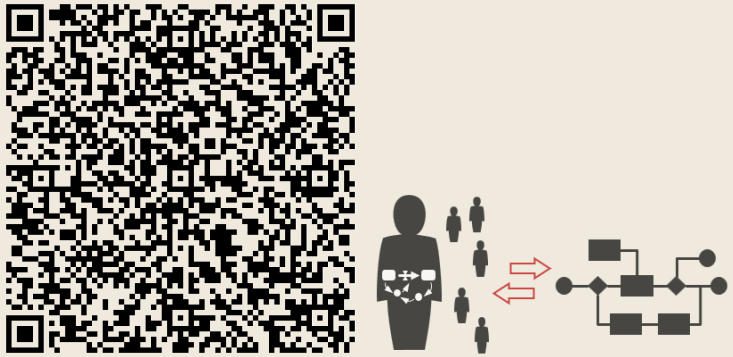
Product Portfolio and Investment Policy

A consumer products company finance and investment policy is modeled using SD while the R&D projects and in-market products are agents. Statecharts model lifecycles.



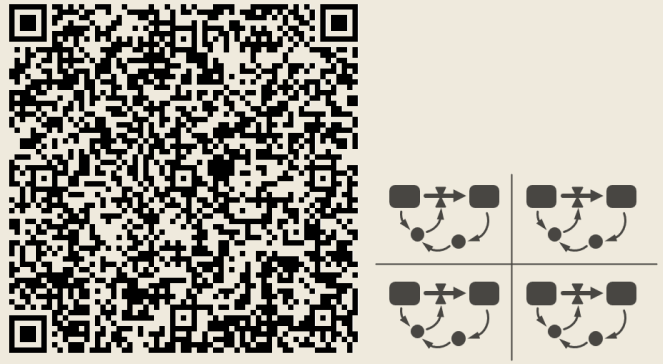
Basic Health Economics

Agents are patients with diabetes progressing into ESRD. SD is used to model quality adjusted life years and associated healthcare and intervention costs.



User Satisfaction

SD is used inside agents – SaaS users – to model user satisfaction and loyalty. Outside agents, a DE process model captures customer support services.

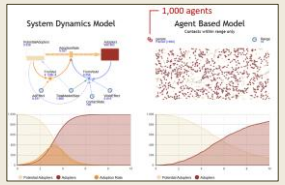


Gridded System Dynamics Population

A model of a sea animal population dynamics in a small area. The area is divided into a 2D grid of patches. Each patch is an SD model capturing maturation and migration.

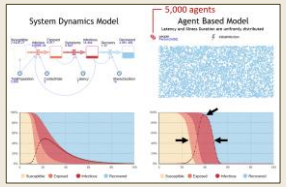
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Models used in this webinar and other useful resources:



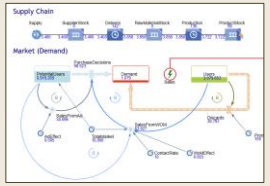
[Diffusion - Comparing SD and AB]

Bass Diffusion SD model compared with the basic equivalent AB model and its enhanced versions.



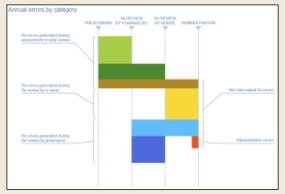
[Infectious Disease - Comparing SD and AB]

SEIR SD model compared with the basic equivalent AB model and its enhanced versions



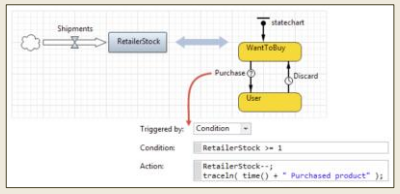
[Supply Chain and Market]

DE model of a supply chain + SD model of demand



[Ward Medication Management]

SD: hospital drug formulary uses, infrastructure, incident reporting, staff retention, etc. AB: daily generation and interception of errors during the medication management.



[AnyLogic help: combining modeling methods]

Technical side of SD <-> AB, SD <-> DE, DE <-> AB integration: examples and instructions.



[Nathaniel Osgood YouTube Channel]

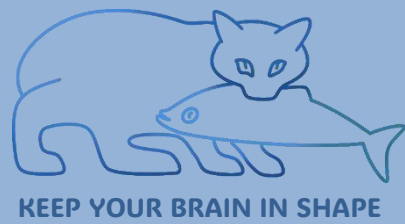
Nate Osgood is a Professor at University of Saskatchewan, an expert in AnyLogic and in AB and SD simulation modeling in the areas of epidemiology, health policy, and health economics.

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