Dynamic Cohorts

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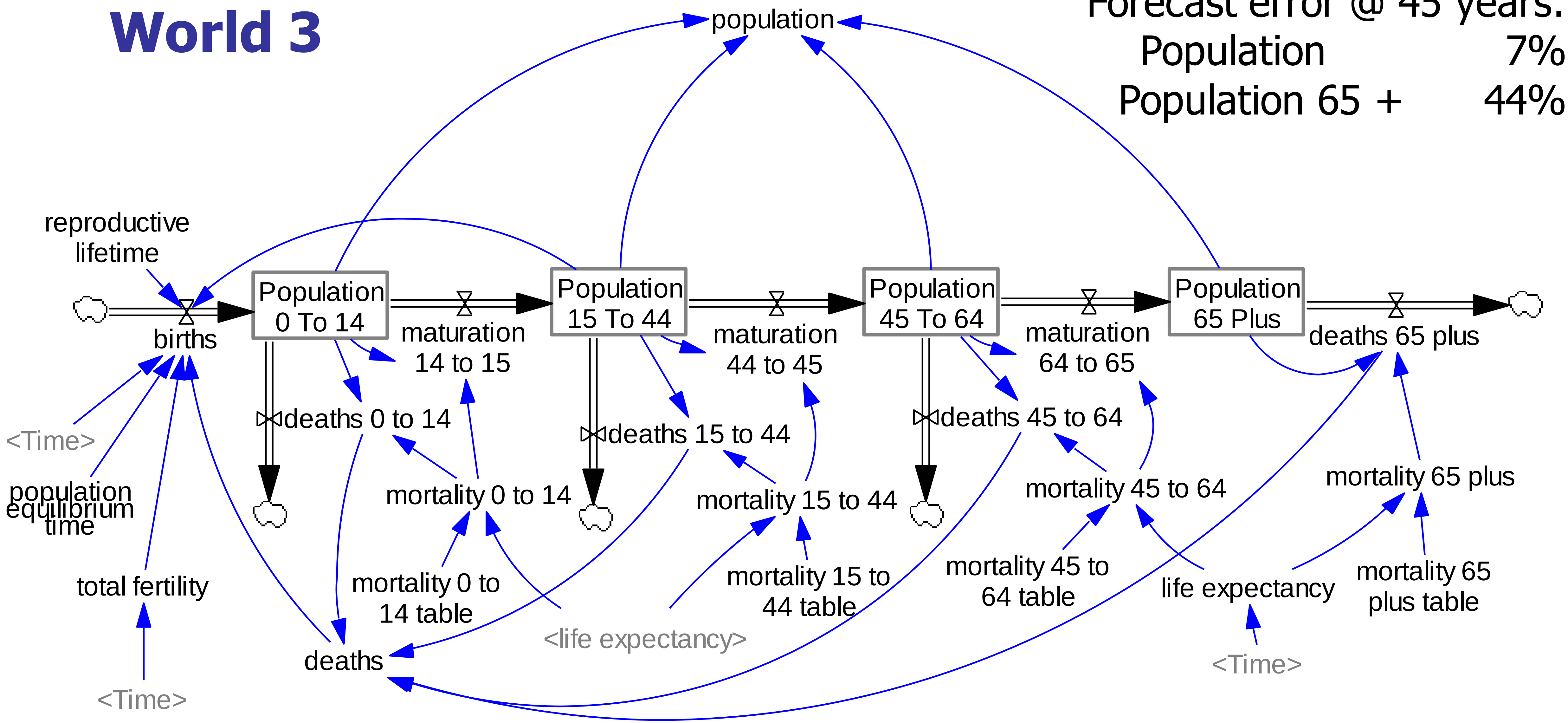
ISDC, 2017

Contents

World 3

Forecast error @ 45 years:

Population	7%
Population 65 +	44%



What are we looking for?

- **Maximize quality**
  - Accuracy
  - Operational correspondence with policies
  - Speed
  - Transparency

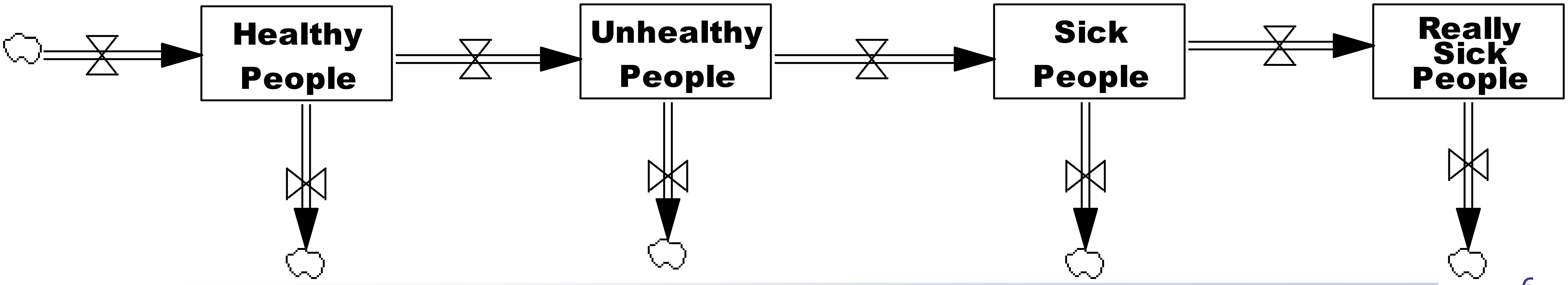
- **Minimize effort**
  - Construction
  - Initialization
  - Calibration
  - Reuse

Why disaggregate?

- **Components of interest have different dynamics**
- **A priori aggregation is hard**
- **Correspondence with measurements**
- **Representation of policies**

State vs. Categorical Representation

Vs.



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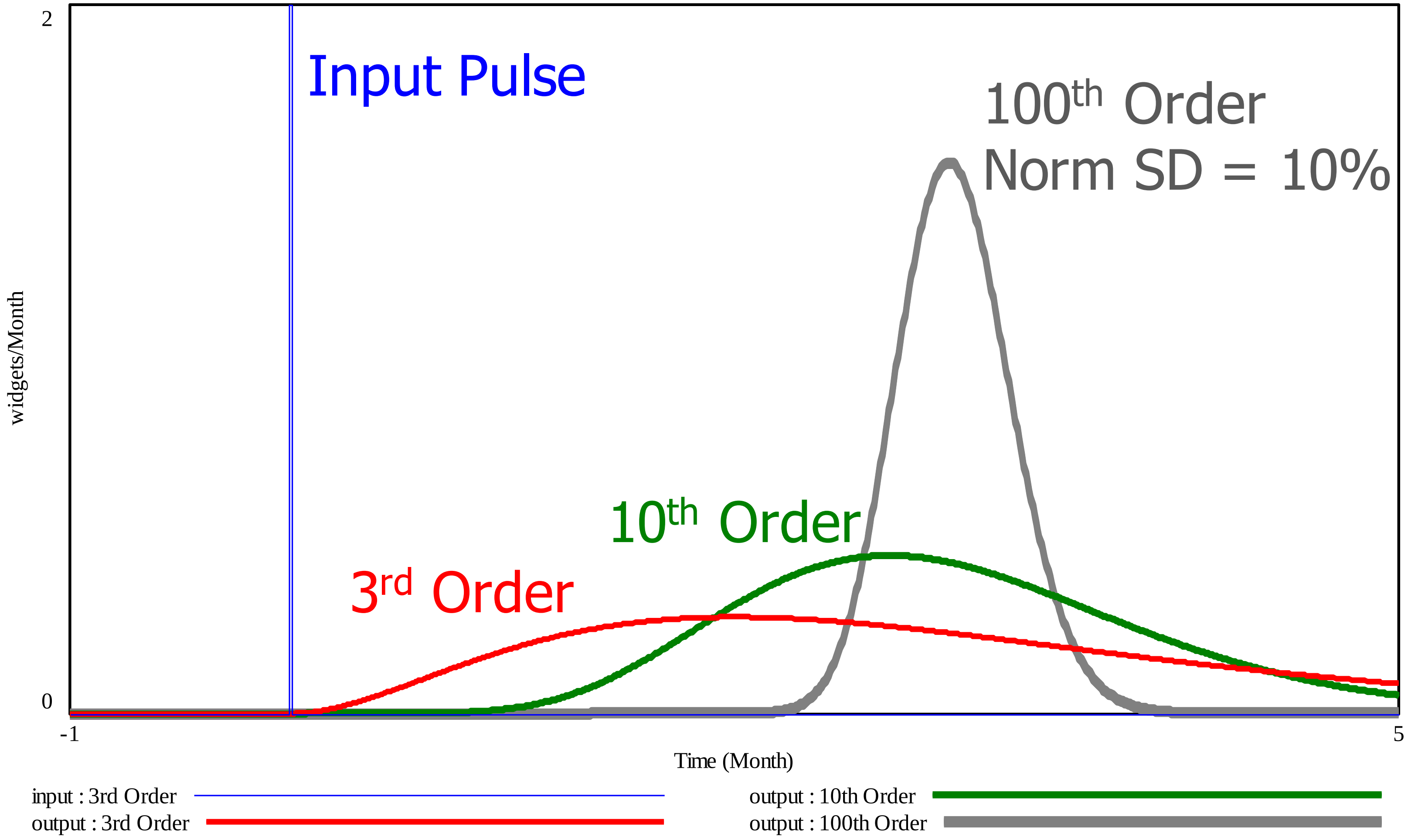
Aging Chains

- **Advantages**
  - The obvious approach in a "flat" language (no arrays)
  - Visible
  - Works when you don't need explicit age interpretation
- **Limitations**
  - Dispersion
  - Abrupt dynamics
  - Transition time ≠ age difference
  - Lots of work, especially for coflows

Dispersion



2
0
-1
5
widgets/Month
Time (Month)
Input Pulse
100th Order
Norm SD = 10%
10th Order
3rd Order
input : 3rd Order
output : 3rd Order
output : 10th Order
output : 100th Order

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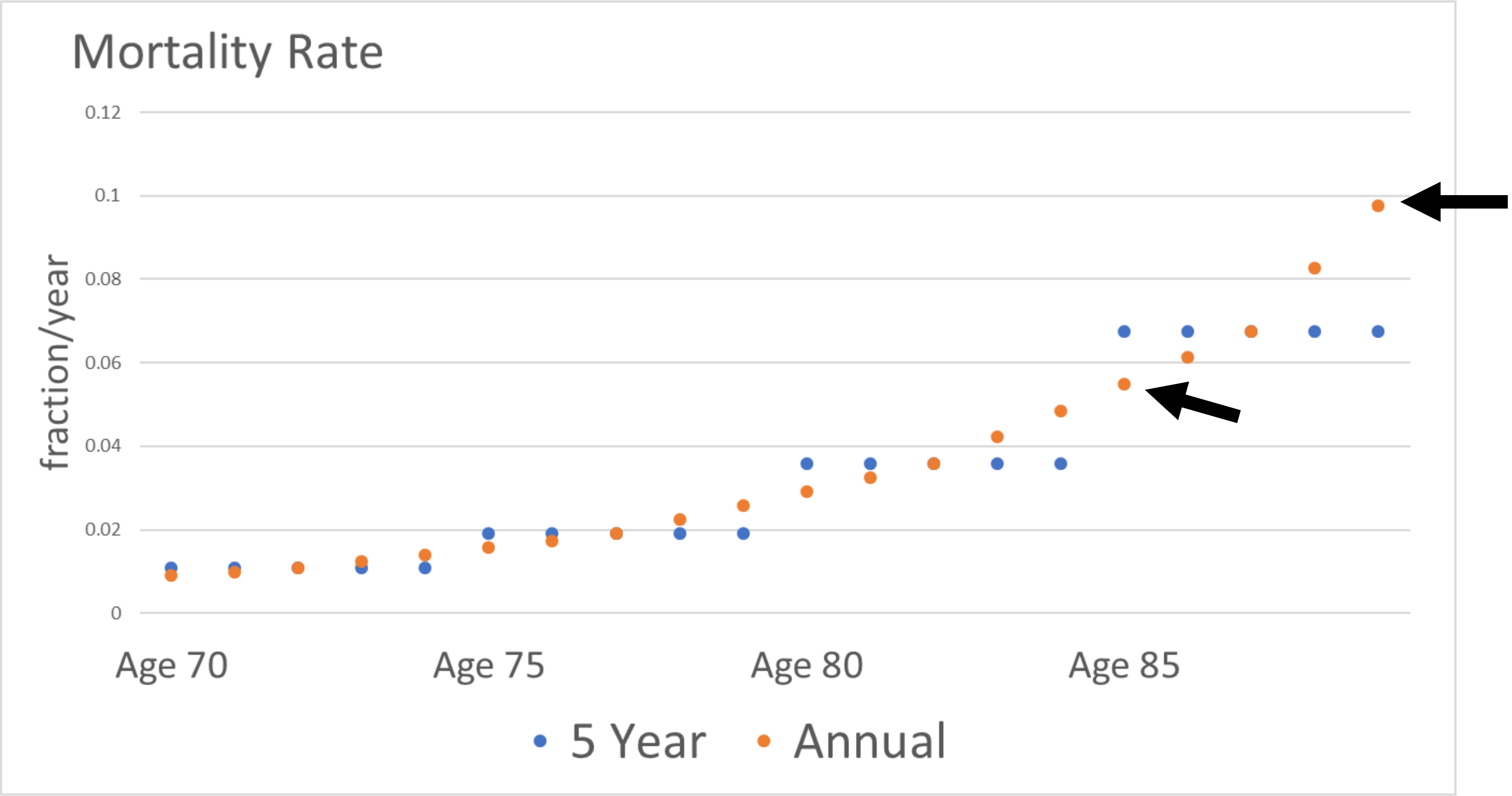
Abrupt Age Shifts in Dynamics



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Discrete Time

- **Set time step (DT) = cohort duration**

+ **No dispersion**

—**No flexibility to represent fast dynamics**

—**No ability to test for stability**

Shifting

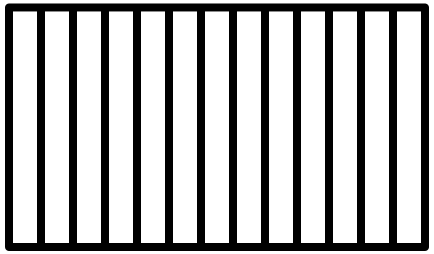
- **Instead of moving people continuously, move them at discrete times**

+ **No dispersion**
+ **Flexible time step**

—**Sawtooth behavior**

Continuous Cohorting

- **Use hidden internal states, one per time step (DT)**

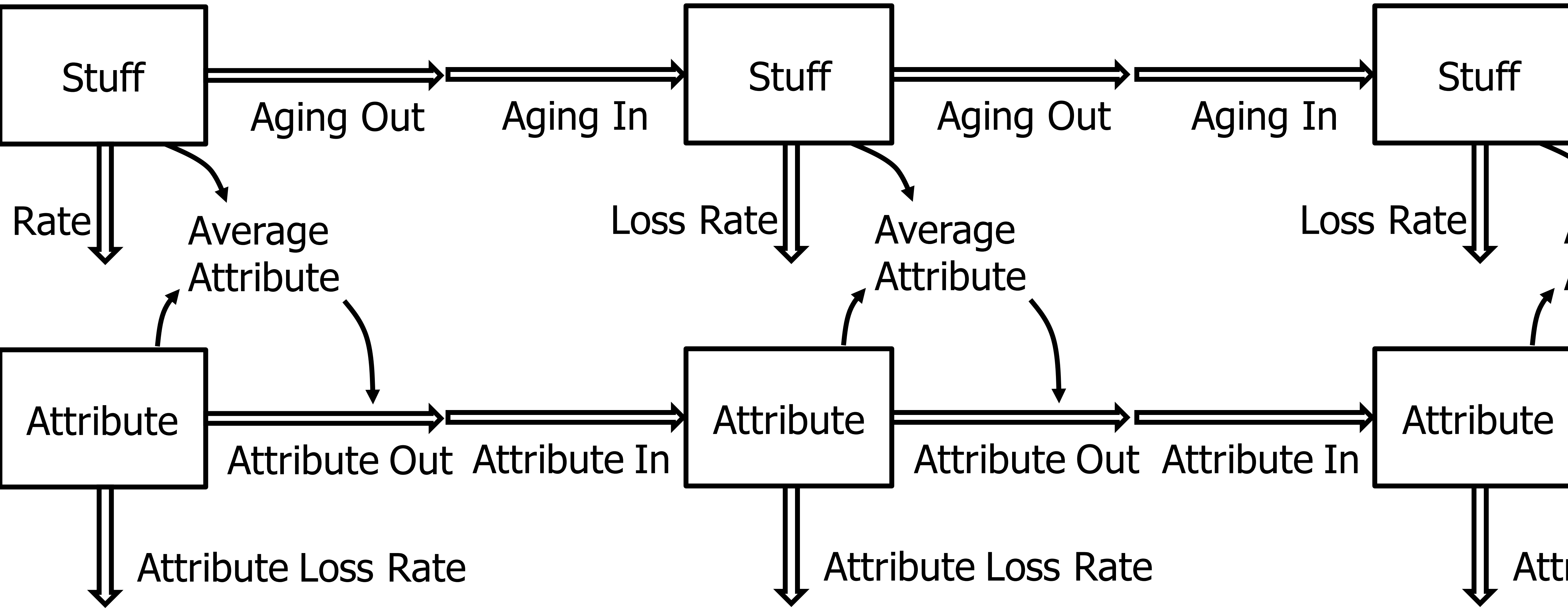


\+ **No dispersion**

— **Potentially heavy computational burden**

Robert L. Eberlein and James P. Thompson, 2013. Precise modeling of aging populations. *Syst. Dyn. Rev.* 29, 87–101.

Diagramming Aging Chains



Agents

- **Model individuals**
- **Age is a state of the person, not a stock of people**

\+ **No dispersion**
\+ **Any nonlinear behavior can be represented**
? **Discrete, stochastic behavior**
— **Big computational and cognitive burdens**

I have a map of the United States … actual size.
It says, "Scale: 1 mile = 1 mile." I spent last summer folding it.
– Steven Wright

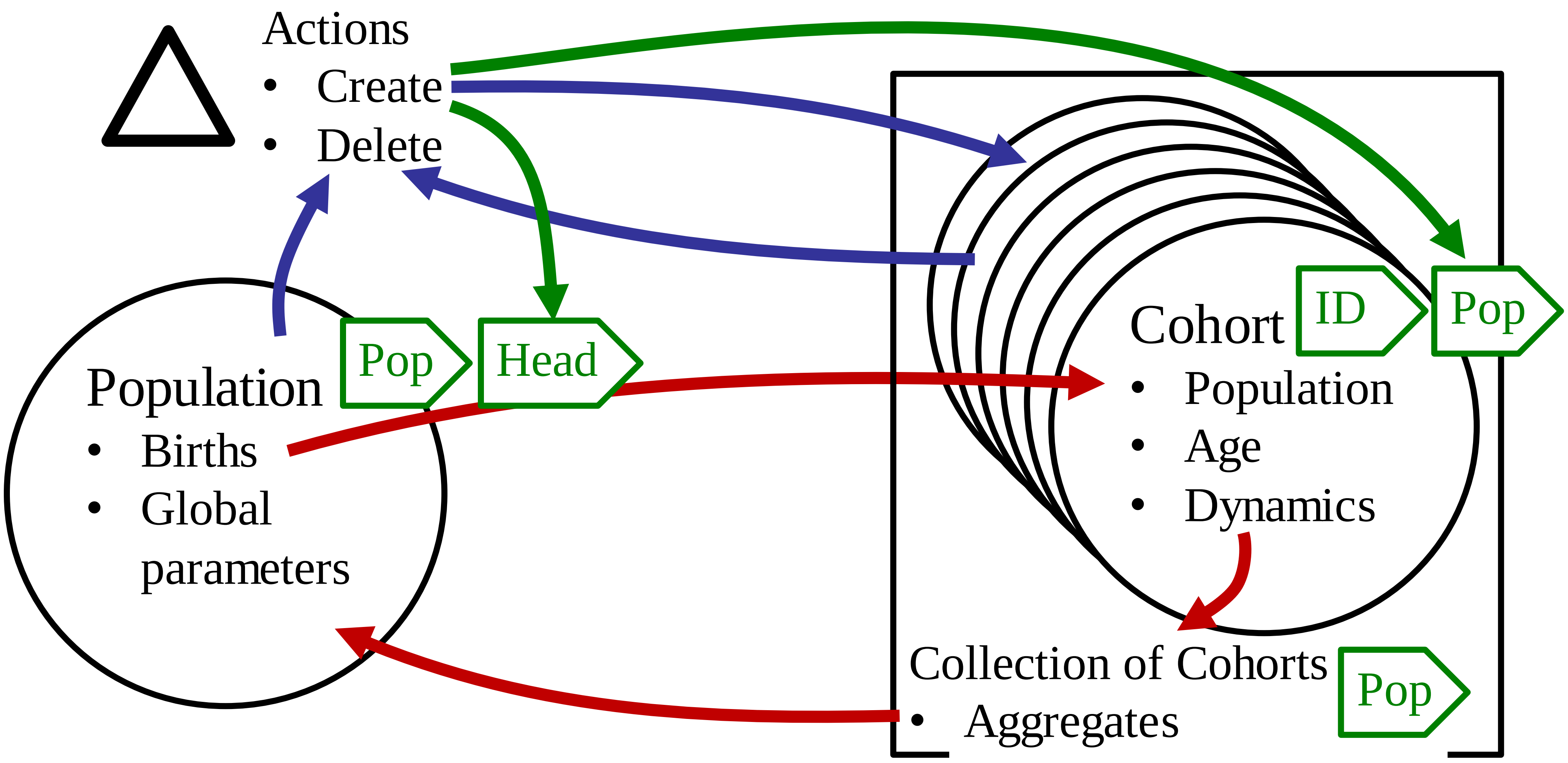
Dynamic Cohorts

- **Moving things through age categories is hard work and causes dispersion.**
- **So, don't move them!**
- **Instead, maintain a dynamic list of cohorts, with age as a state.**

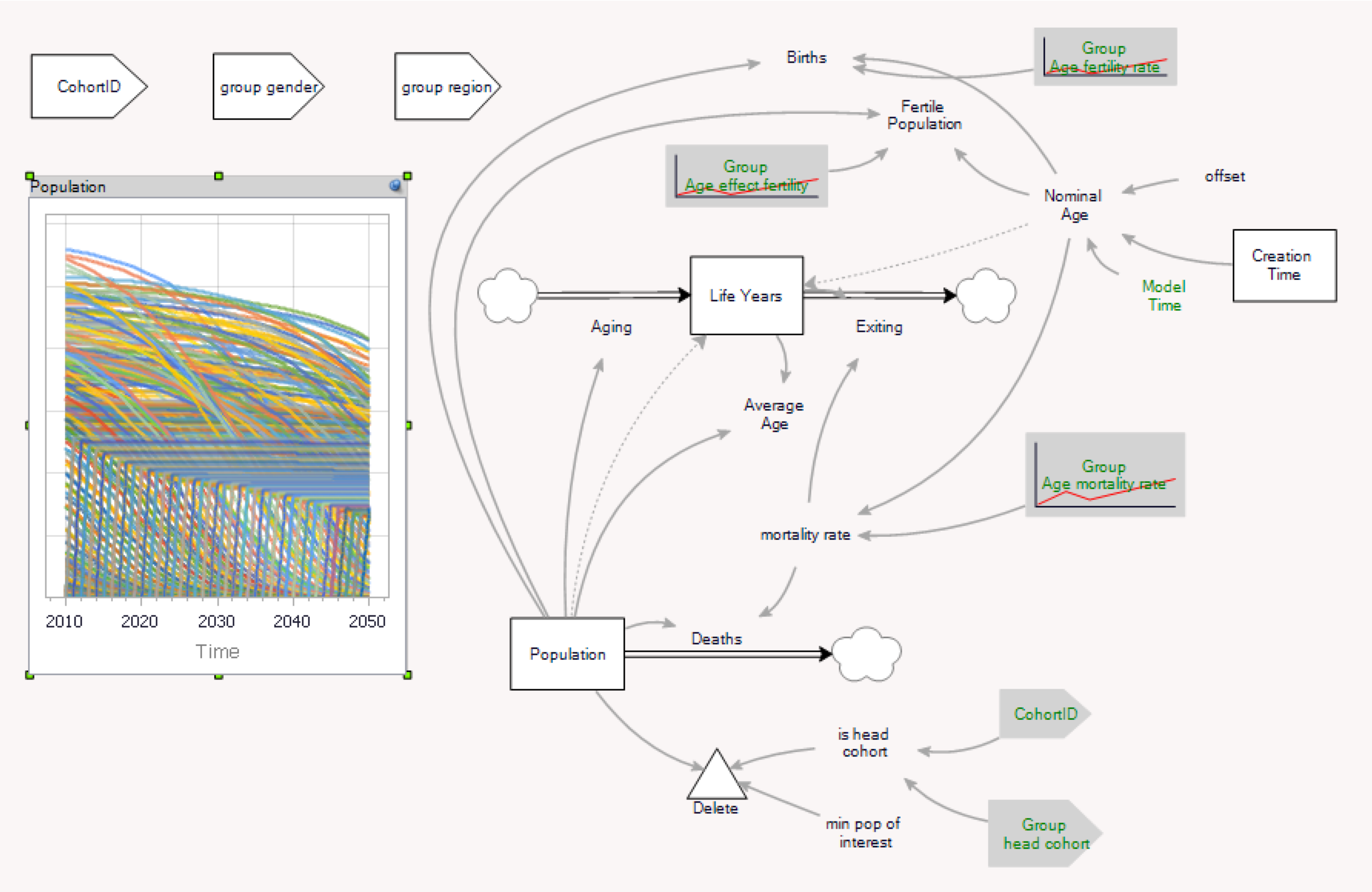
Ingredients

- **Create cohorts "born" within an interval**
  - Rationale: people born at the same time have similar attributes and experiences
  - Not conceptually different from disaggregation by gender, region, vehicle type
- **Accumulate age (or calculate it from the birth date)**
- **Represent internal dynamics of the group**
- **Track until you lose interest**
  - Too few members
  - Age > maximum age of interest
- **Calculate aggregates for feedback to the rest of the model**

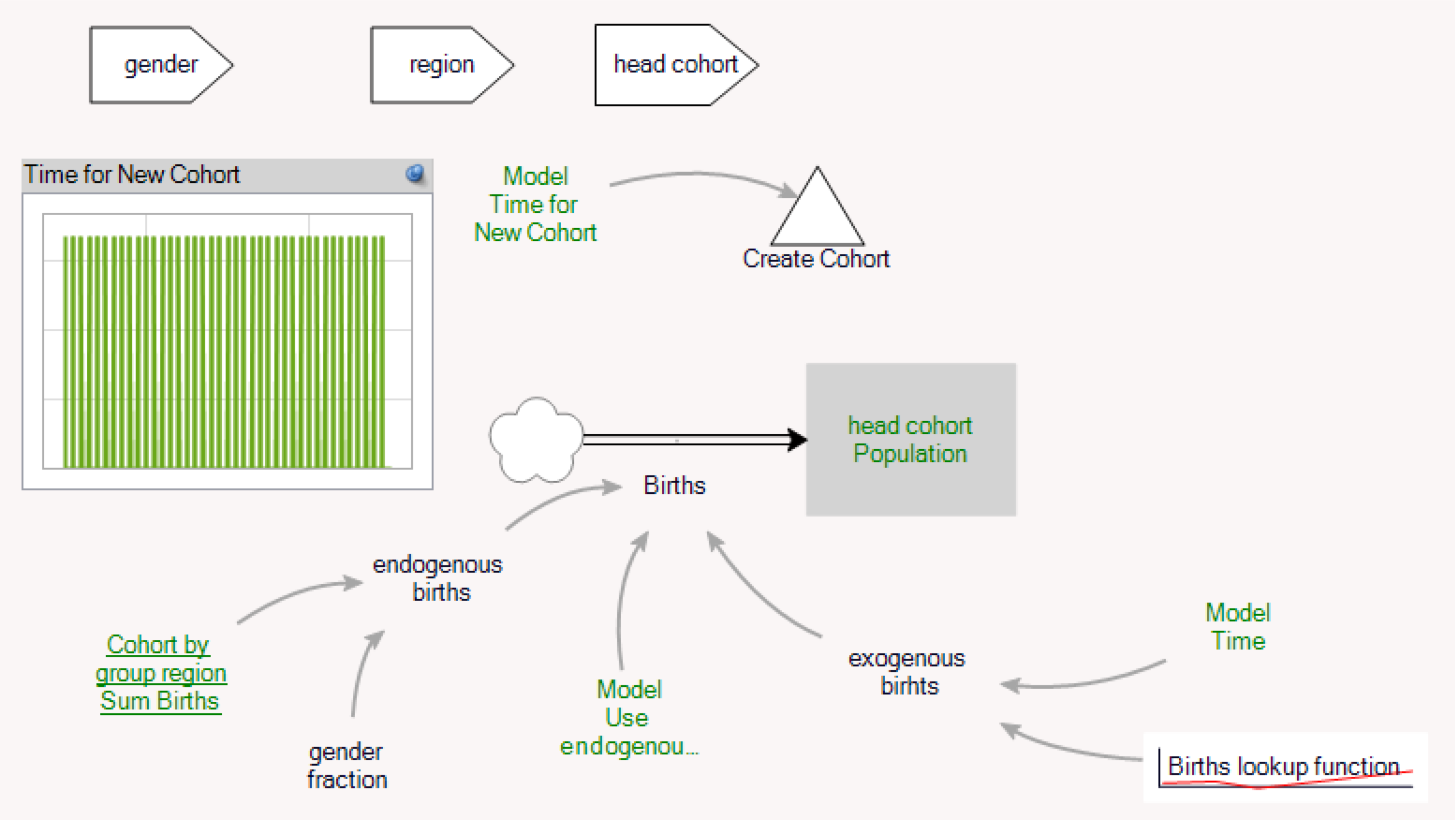
Implementation in Ventity



Cohort Entity

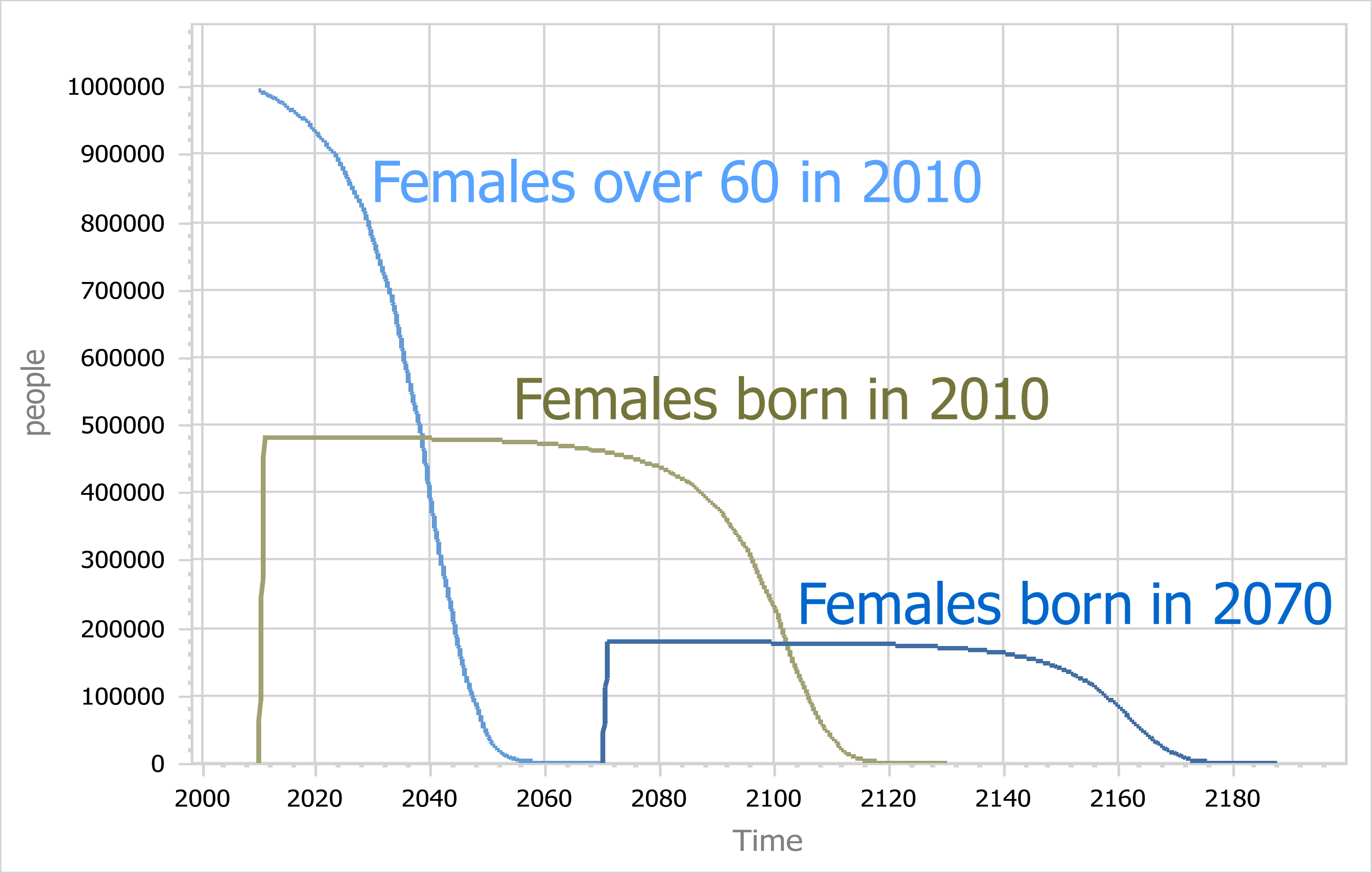


Population Entity



Cohort Life Cycles

Population



Parameters corresponding with Japan in Eberlein & Thompson

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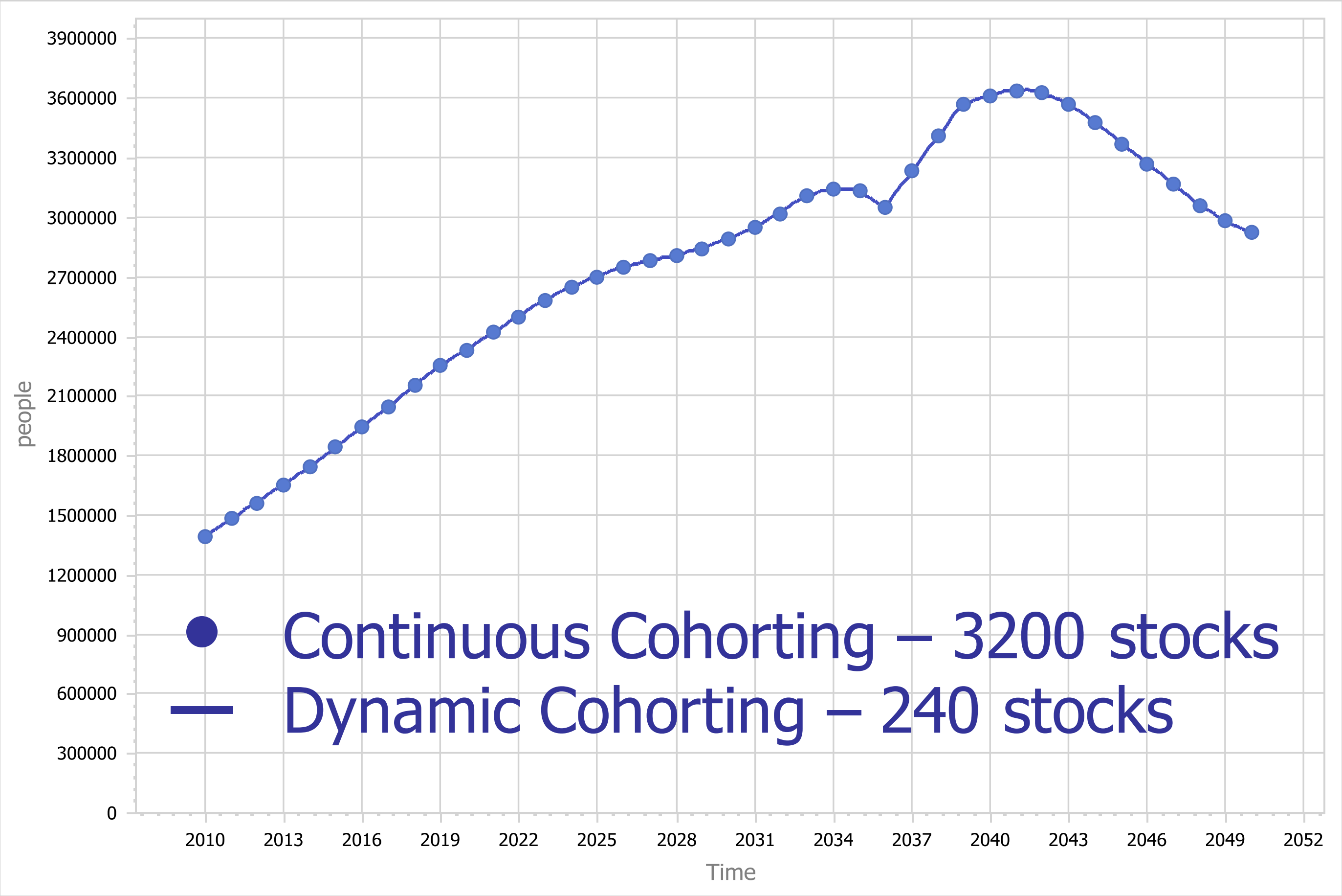
Initialization

Table 1 Cohort Initialization Data

Enabled	Time	CohortID	group gender	group region	Creation Time	Life Years	Population
TRUE		F A0	F	Japan 1yr	2009		501613
TRUE		F A1	F	Japan 1yr	2008		512203
TRUE		F A2	F	Japan 1yr	2007		522909
TRUE		F A3	F	Japan 1yr	2006		530882
TRUE		F A4	F	Japan 1yr	2005		536693
...							

Precision

Population over 90, Japan

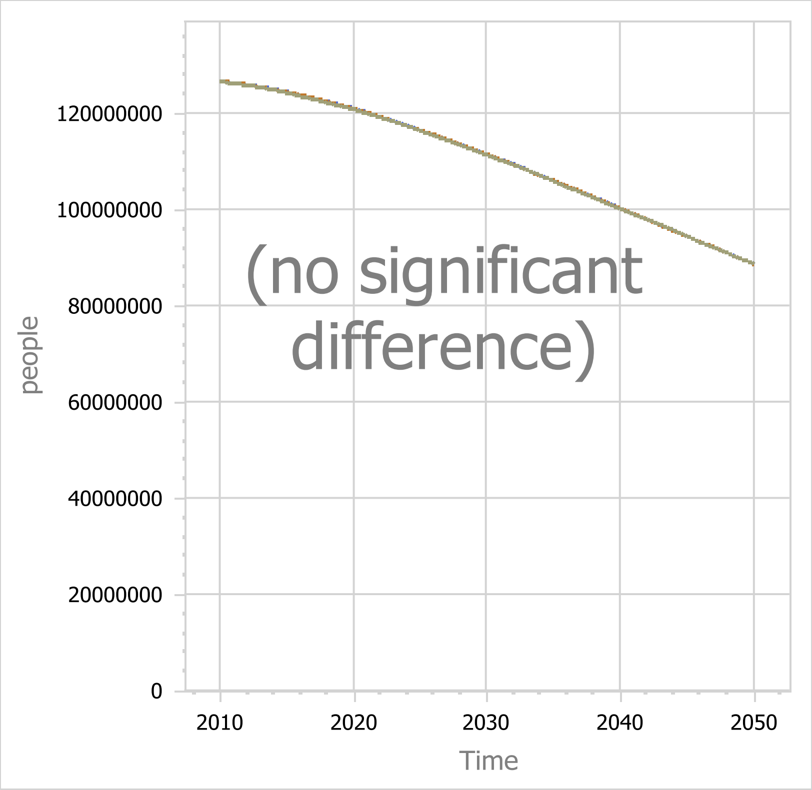


Dynamic Cohorting in Comparison

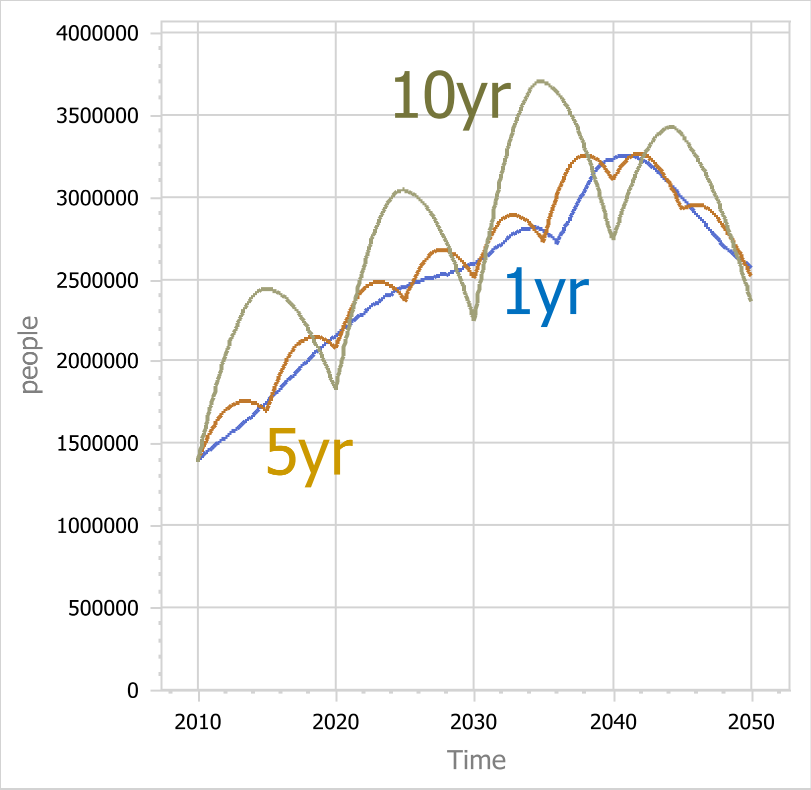
- **Advantages**
  - Low computational burden
  - Clear mapping of agent to group
  - Simple internal dynamics
  - Easy debugging
- **Differences**
  - Data-model matching
  - Initialization in equilibrium
- **Limitations**
  - Nonlinearity in group dynamics
  - Heterogeneity in group members

Projections at Different Resolutions 1, 5, 10 year cohorts

Population



Population over 90



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Two Ways to Fail

- **Insufficient detail**
  - Cohorts too wide
  - Neglected heterogeneity
- **Omitted dynamics**
  - Age-Period-Cohort effects
  - Time-varying rates
  - Internal dynamics of groups

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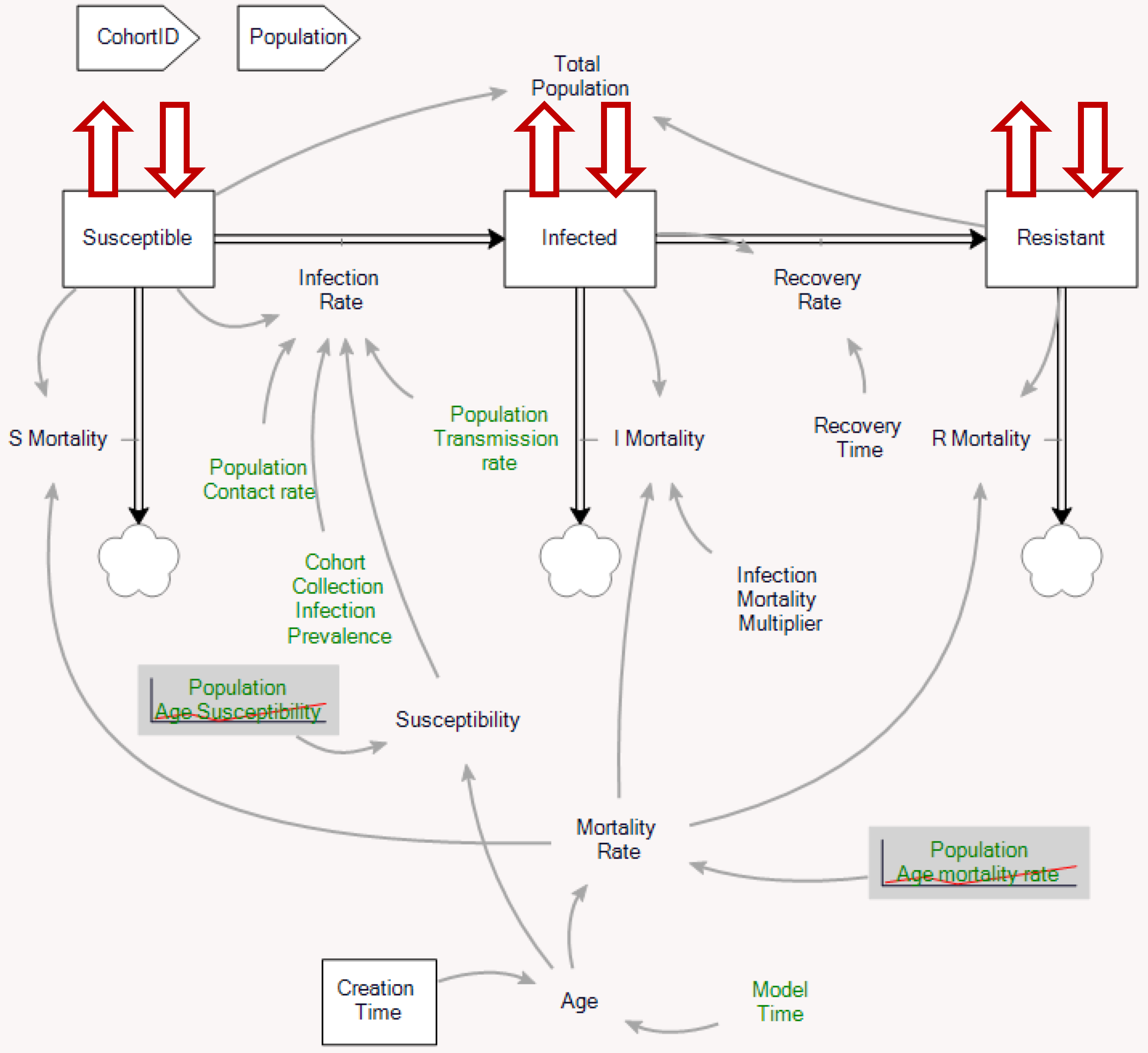
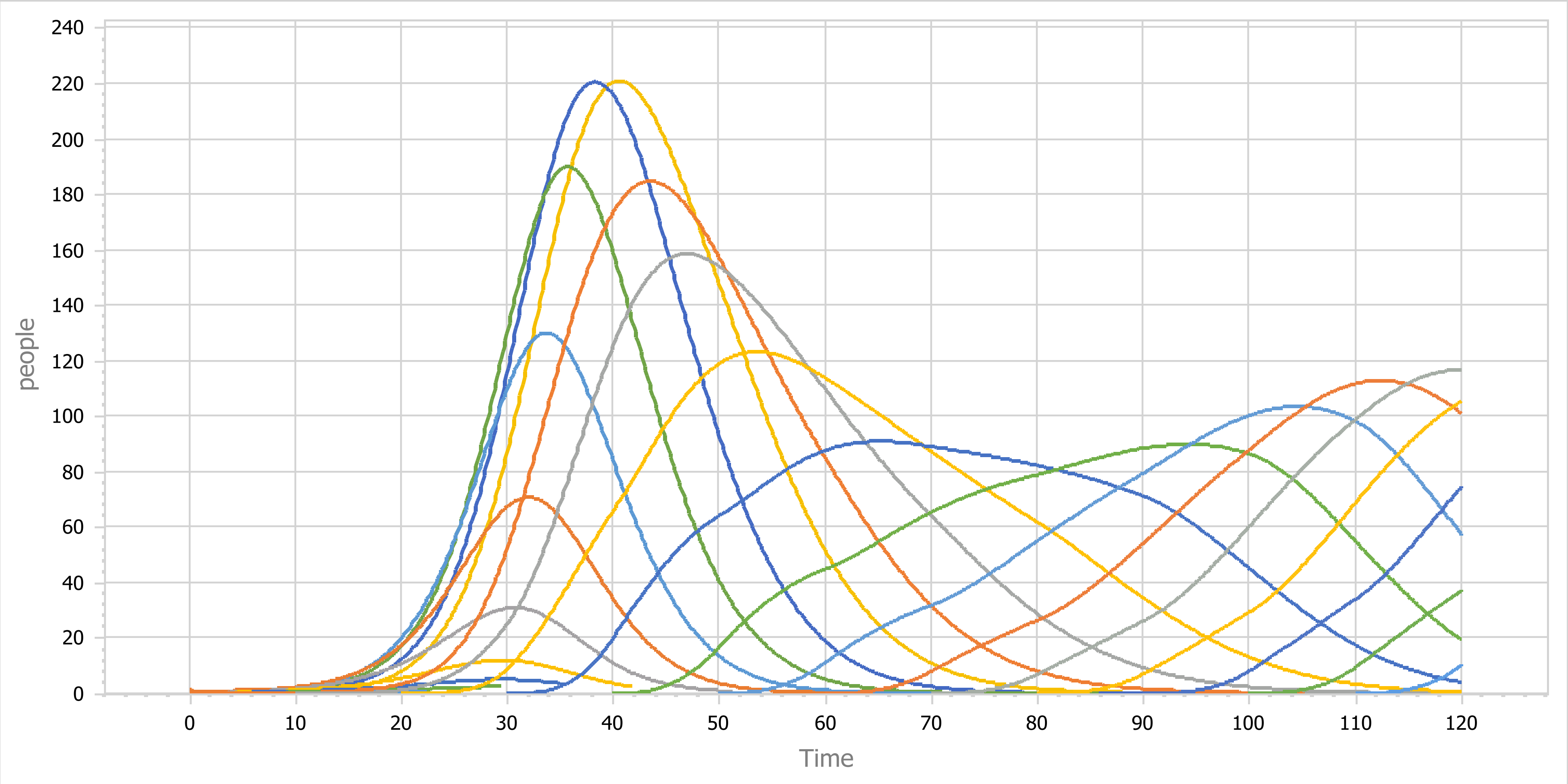
Example: Infection Model x Cohort

Introduce a disease into an age-disaggregated population, with

- **Infection onset proportional to age, and**
- **Infection-induced mortality**



Infected Population



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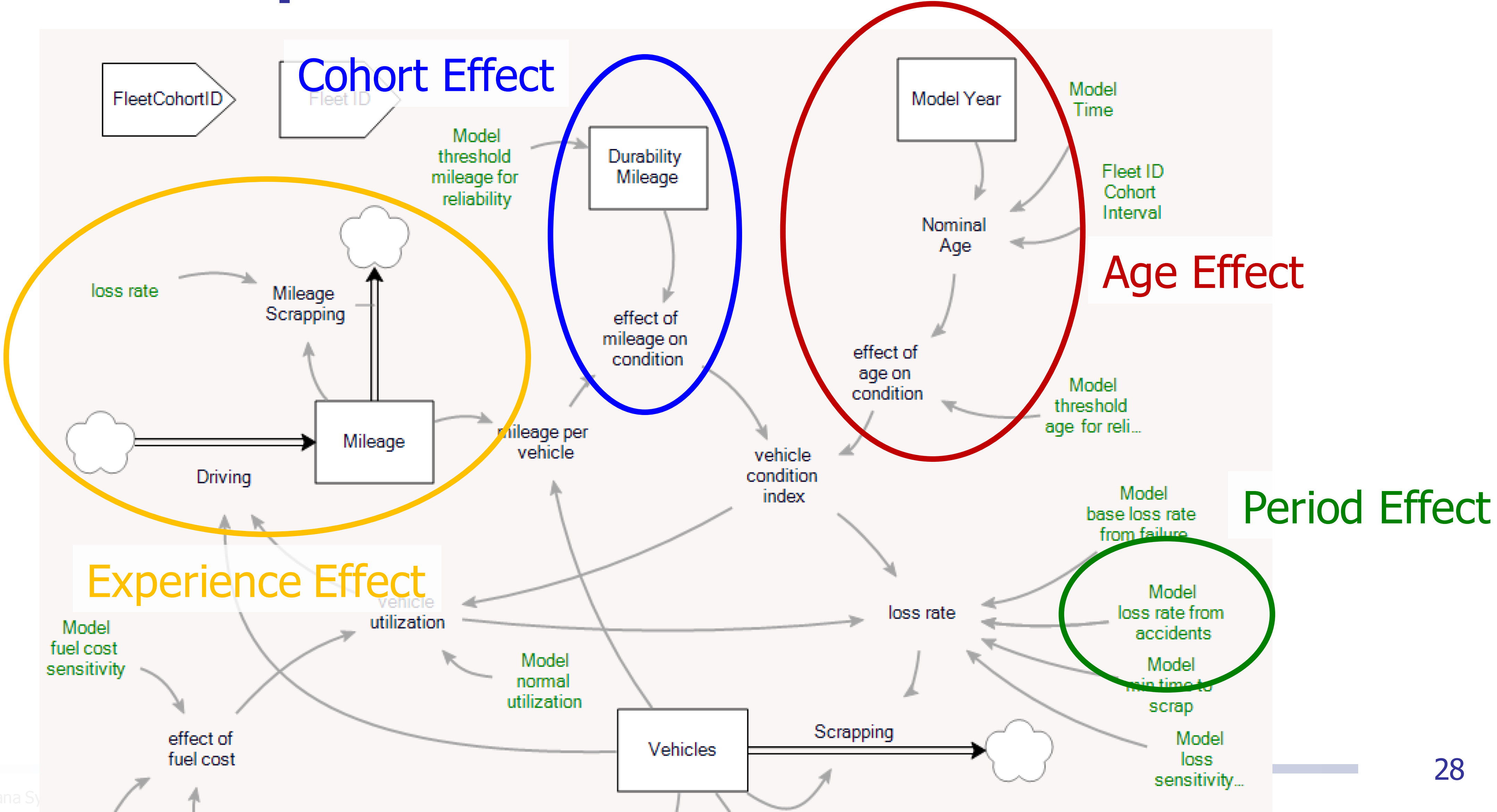
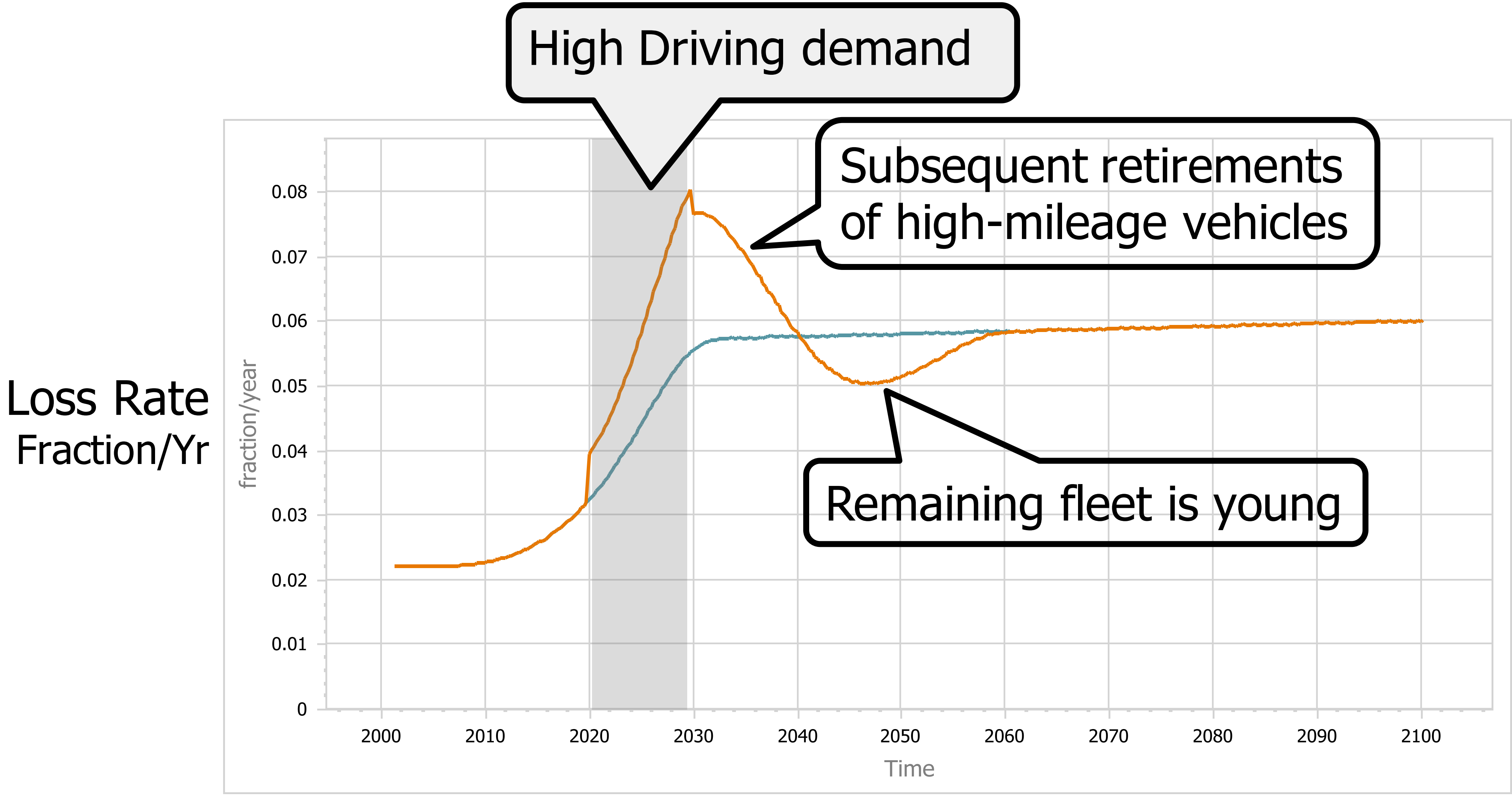
Example: Vehicle Fleet x Model Year



Vehicle Utilization Effect on Scrap Rate



Applications

- **Living things**
  - People – health, education
  - Fish
- **Perishables**
  - Pharmaceuticals
  - Food
- **Capital**
  - Vehicles
  - Buildings
- **Services**
  - Loans
  - Bonds
  - Contracts

Bottom Line 1

- Cohorts are everywhere
- Cohorts are just a special case of aggregation questions we face every time we model
- We need tools that make it easy to quickly build and test alternative specifications

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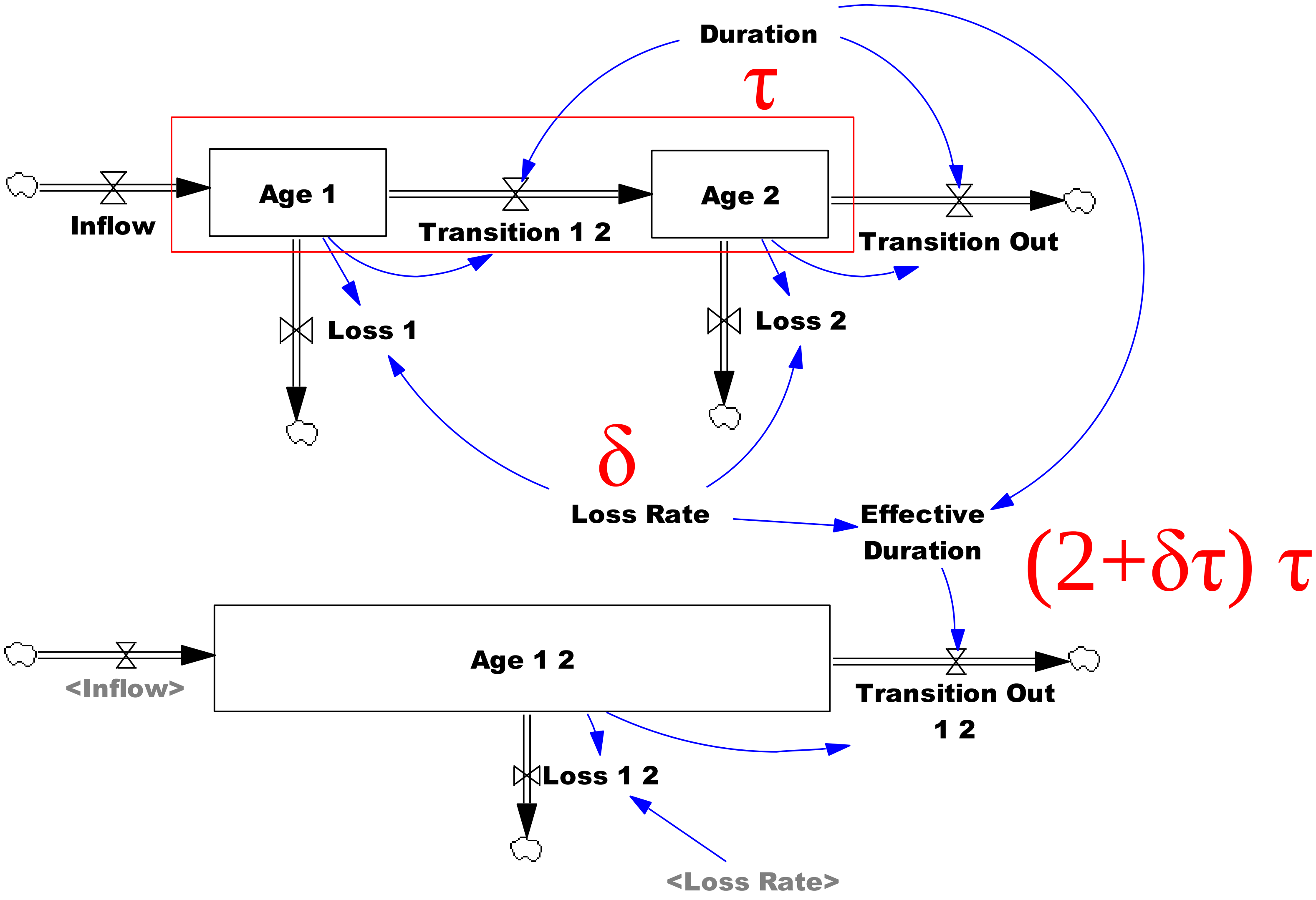
Bottom Line 2

- **Managers have always had an appetite for tactical detail**
- **Big data availability is growing**
- **We need ways to fill the appetite and exploit the data *without losing the essential insights of feedback and accumulation.***

THANK YOU

Cohort Duration Aggregation



Age-Period-Cohort Effects

- **Vital Rate = F(Age, Period, Cohort)**
- **E.g., Mortality Rate = F(Age, Current Time, Birth Year)**
  - Age: aging process effect on mortality
  - Current time: medical technology and risk
  - Birth year: cohort has common experience

- **Statistical challenge: Age = Current Time – Birth Year**

- **Dynamic challenge: Cohorts have common dynamics and experience**
- **Vital Rate = F(Age, Period, Cohort, Experience)**