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System Dynamics Structures for Modeling Lawmaking Processes

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Outline

- Introduction and Background
- Structures
  - Elements
  - Generic Flows
  - Infrastructures
- Example Lawmaking Process Structures
- Demonstration
- Conclusions and Future Work
- References

Introduction and Background

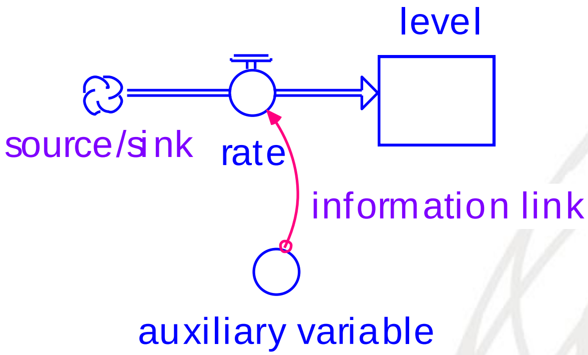
- Modeling and simulation can help improve the efficiency of lawmaking processes, and the effectiveness of laws created.
- System dynamics is a simulation methodology for modeling continuous systems that provides a rich and integrative framework for investigating lawmaking process phenomena and inter-relationships from a holistic perspective.
- This work applies simulation concepts to create model structures that can be used to
  - Evaluate the lawmaking process, i.e. the steps taken to create laws including their order
  - Assess laws before implementation on how well they will meet their goals and compare options. This includes all intended and unintended consequences of law implementation.
- It organizes system dynamics model structures and behaviors for lawmaking processes starting with elemental components, incorporating them into basic flow structures and building up to larger infrastructures.
  - The recurring structures are model "building blocks" that can be reused.

System Dynamics Principles

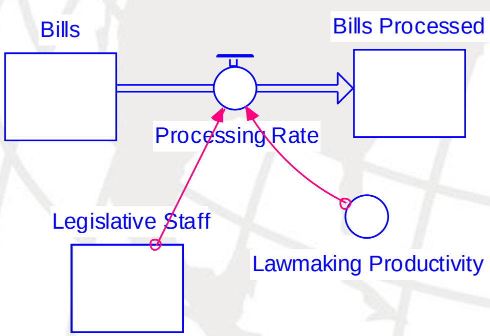
- Major concepts
  - Defining problems dynamically, in terms of graphs over time
  - Striving for an endogenous, behavioral view of the significant dynamics of a system
  - Thinking of all real systems concepts as continuous quantities interconnected in information feedback loops and circular causality
  - Identifying independent levels in the system and their inflow and outflow rates
  - Formulating a model capable of reproducing the dynamic problem of concern by itself
  - Deriving understandings and applicable policy insights from the resulting model
  - Implementing changes resulting from model-based understandings and insights.
- Dynamic behavior is a consequence of system structure
- The continuous view
  - Individual events are not tracked
  - Entities are treated as aggregate quantities that flow through a system, and can be described through differential equations
  - Discrete approaches usually lack feedback, internal dynamics

System Dynamics Notation

- *System represented by x'(t)= f(x,p).*
  - *x: vector of levels (state variables), p: set of parameters*
- *Legend:*



- *Example system:*



Terminology

- ***Elements*** are the smallest individual pieces in a system dynamics model: levels, rates, sources/sinks, auxiliaries and feedback connections.
- ***Generic flow processes*** are small microstructures and their variations comprised of a few elements, and are sometimes called *modeling molecules*. They are the building blocks, or substructures from which larger structures are created and usually contain approximately 2-5 elements.
- ***Infrastructures*** refer to larger structures that are composed of several microstructures, typically producing more complex behaviors.
- ***Flow chains*** are infrastructures consisting of a sequence of levels and rates (stocks and flows) that often form a backbone of a model portion. They house the process entities that flow and accumulate over time, and have information connections to other model components through the rates.

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Elements

- **Levels** are the state variables representing system accumulations. Their counts can be measured in a real system at a snapshot of time (e.g. the number of current laws on the books). Typical state variables are laws or rights, violations, lawsuits, or the numbers of people involved in legal systems.
- **Sources and sinks** represent levels or accumulations outside the boundary of the modeled system. Sources are infinite supplies of entities and sinks are repositories for entities leaving the model boundary. Typical examples for lawmaking sources could be needs for new regulations originating in society or business at-large, or the generation of court filings to be handled. Sinks could represent final judgments of cases leaving court dockets or legal personnel attrition repositories for retirees.

Elements (Continued)

- **Rates** in the lawmaking process are necessarily tied to the levels. Levels don't change without flow rates associated with them. Some examples include law-writing rates, law change rates, case turnover rates, infraction rates, personnel hiring and retiring rates.
- **Auxiliaries** often represent "score-keeping" variables. Example for tracking purposes include the percent of infractions per population level, percent of injuries or deaths per population, case progress measures, percent of cases in legal states, other ratios or percentages used as independent variables in dynamic relationships.

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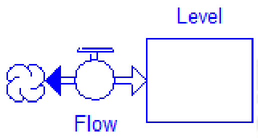
Major Level Types for Lawmaking

- **Laws or Rights** – These may include laws (e.g. statutes, ordinances, regulations, common laws); copyrights or intellectual property rights for any jurisdiction, etc. Laws can be represented at any stage in the lawmaking process from proposed bills to amended or repealed laws, and for any level of jurisdiction. Rights levels can be in different process stages from initial filing to infringement.
- **Violations** – Law violations cover crimes or infractions at any jurisdiction level (international, national, local) including copyright or intellectual property right infringements. These may lead to criminal cases potentially resulting in jail and/or fines levied, or civil lawsuits potentially resulting in damages to pay.
- **People** – People levels represent pools of individuals performing legal-related functions including their sub-divisions such as law creation by elected or appointed officials, legislative staff support, legal enforcement, and judicial personnel; people affected by laws such as overall population levels, victims, incarcerated prisoners, family dependents of incarcerated people, and others.

Generic Flows

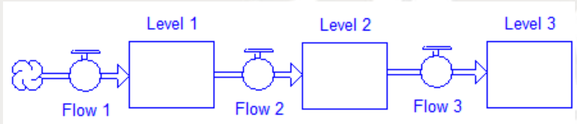
Rate and Level System

The simple rate and level system (also called stock and flow) is the primary structure from which all others are derived. This system has a single level and a bi-directional flow that can fill or drain the level. Subsequent structures each build on top of this basic structure with additional detail and characteristic behavior.



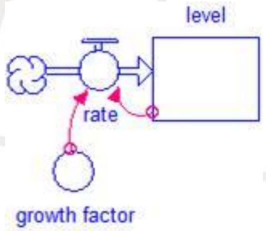
Flow Chain with Multiple Rates and Levels

The single rate and level system can be expanded into a flow chain incorporating multiple levels and rates. It can be used to model a process that accumulates at several points instead of one, and is also called a cascaded level system. A generic flow chain within itself does not produce characteristic behavior without other structure and relationships.



Compounding Process

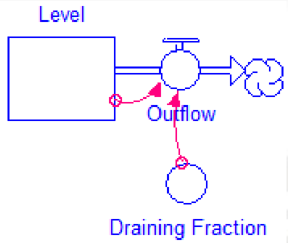
The compounding structure is a rate and level system with a feedback loop from the level to an input flow, and an auxiliary variable representing the fractional amount of growth per period. A compounding process produces positive feedback and exponential growth in the level. Modeling applications include the initial rapid escalation of paperwork due to a new ordinance, compounding of new laws to fix previous laws, legal or illicit market dynamics, social communication patterns (e.g. rumors, panic), etc.



Rate = Level * Growth Factor

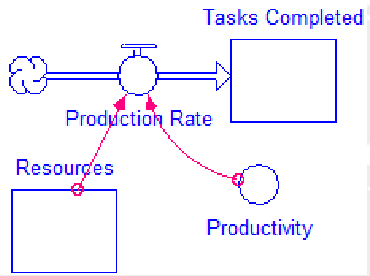
Generic Flows (continued)

Draining Process
Draining can be represented similarly as the compounding process, except the feedback from the level is to an outflow rate and the auxiliary variable indicates how much is drained in the level. Draining is a common process that underlies delays and exponential decays. Case promotions, fine payments, personnel retirement, skill loss and other trends can be modeled as draining processes.



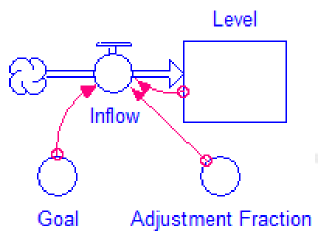
Outflow = Level * Draining Fraction

Production Process
A production process represents work accomplished at a rate equal to the number of applied resources multiplied by the resource productivity. It typically has an inflow to a level that represents production dependent on resource amounts, which may be a level in an external flow chain representing resources. E.g., the productivity of levying traffic tickets can be modeled this way as a function of police employed.



Production Rate = Resources * Productivity

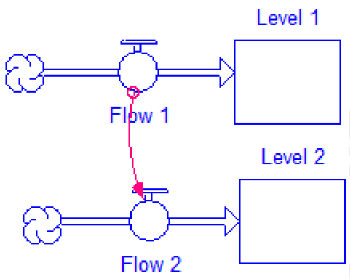
Adjustment Process
An adjustment process is an approach towards goals or equilibrium. The structure contains a goal variable, a rate, level, and adjusting parameter. The structure models the closing of a gap between the goal and level. The change is more rapid at first and slows down as the gap decreases. The inflow is adjusted to meet the target goal. This basic structure is at the heart of many policies and other behaviors.



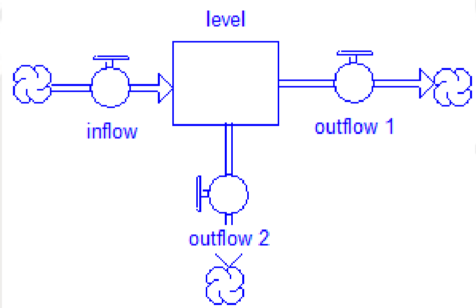
Inflow = (Goal – Level) * Adjustment Fraction

Generic Flows (continued)

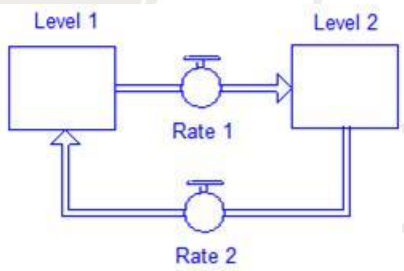
Co-Flow Process
Co-flows are a shortened name for coincident flows; flows that occur simultaneously through a type of slave relationship. The co-flow process has a flow rate synchronized with anot her host flow rate, and normally has a conversion parameter between them. This process can model the co-flows of laws and infractions, laws and associated paperwork, resource tracking such as effort expenditure, or tracking revenues as a function of traffic tickets levied.



Split Flow Process
The split flow process represents a flow being divided into multiple sub flows, or disaggregated streams. It contains an input level, more than one output flow, and typically has another variable to determine the split portions. Applications include litigation chains to differentiate prosecution case successes vs. failures, other court judgments won vs. lost, or personnel flows to model legal personnel resource allocation to different activities.



Cyclic Loop
A cyclic loop represents entities flowing back through a loop. The difference from non-closed chains is that a portion of flow goes back into an originating level. This structure is appropriate to represent law amendments, retried cases, habitual re-offenders, and other cycling phenomena.



Example Infrastructures

- Exponential Growth
- S-shaped Growth
- Delays
- Balancing Feedback
- Oscillation
- Smoothing
- Production
- Production Structure
- Learning Curve
- Attribute Tracking
- Attribute Averaging
- Effort Expenditure
- Decision Structures

* See paper for more detail and lawmaking process examples

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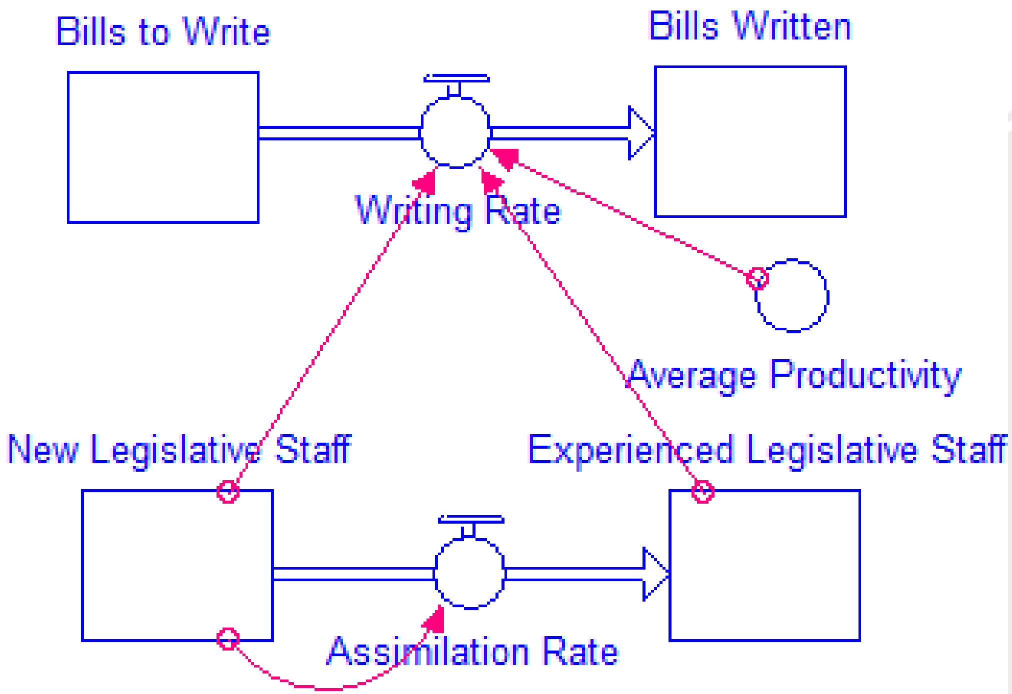
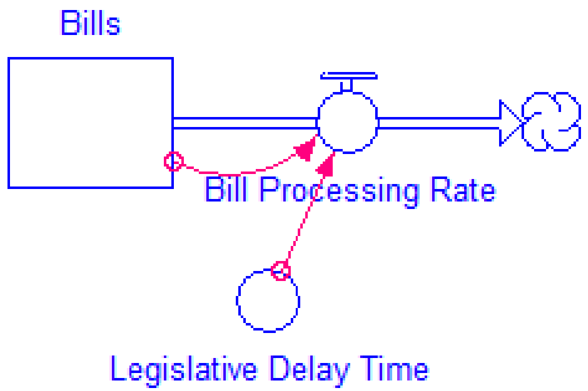
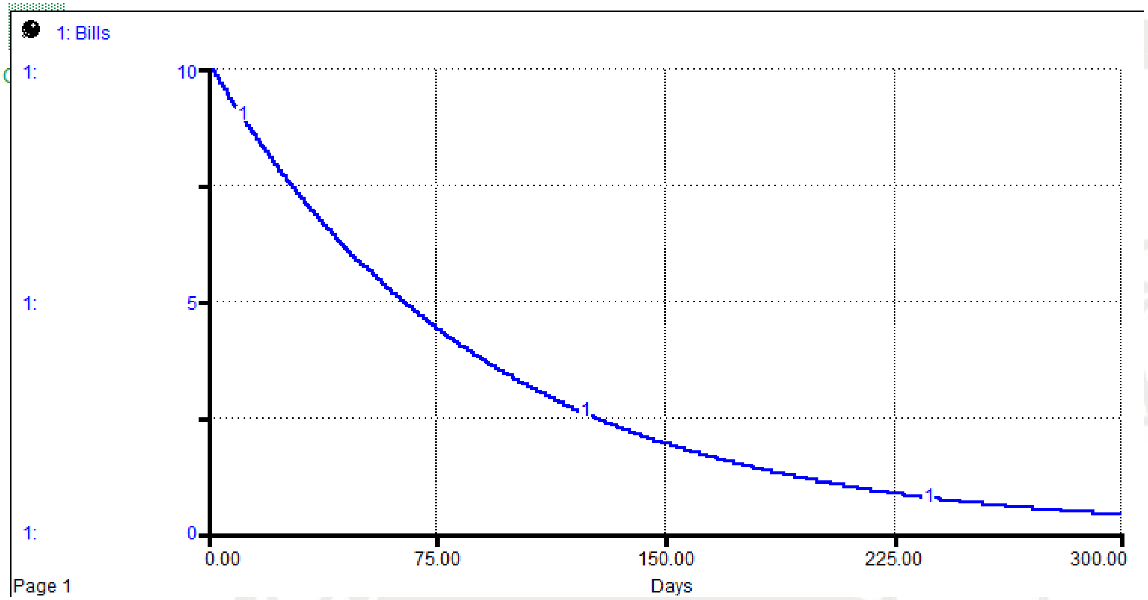
Example Production Structure



Writing rate productivity adjusted for experience levels

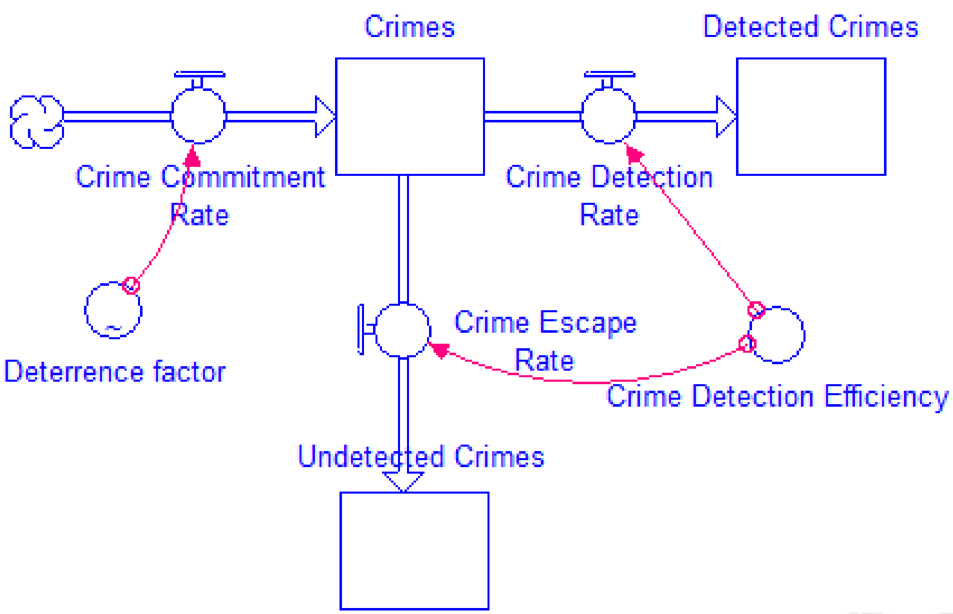
Example Delay Structure and Behavior





Bill Processing Rate = Bills / Legislative Delay Time

Example Crime Detection Structure

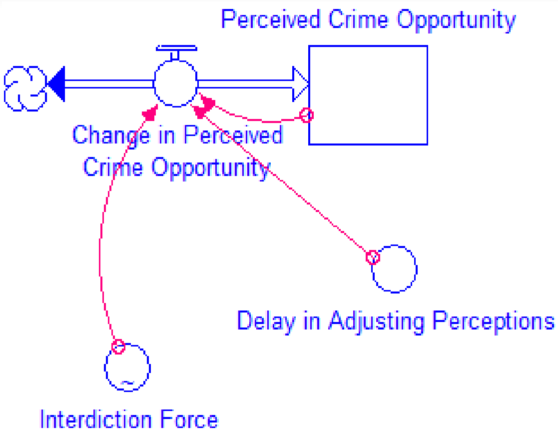


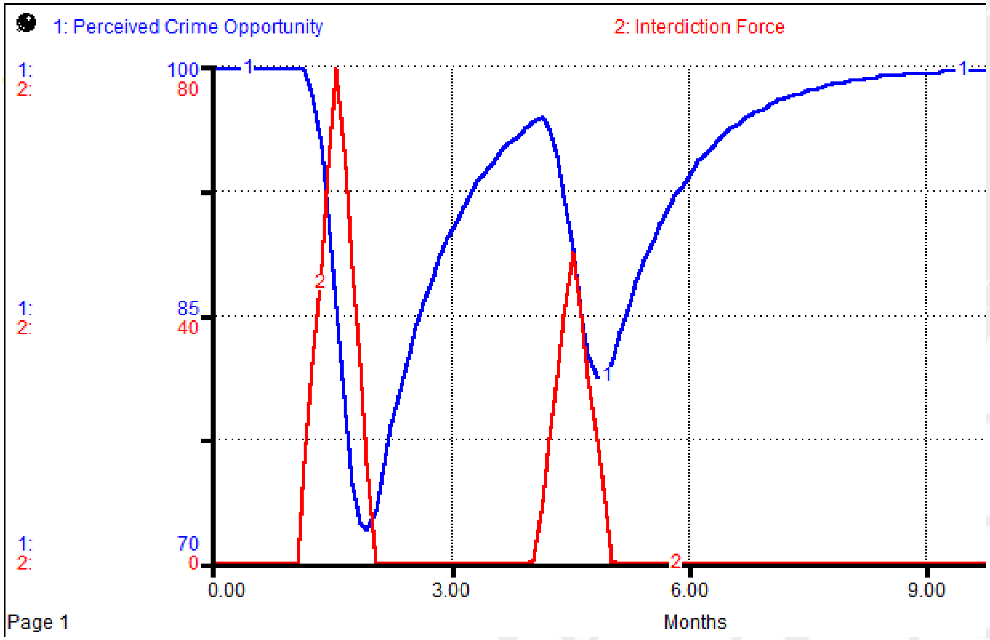
- Multiple level flow chain for crimes
- Split flow process

Crime Commitment Rate = Graph(Deterrence Factor)
Crime Detection Rate = Crime Detection Efficiency * Crime Commitment Rate
Crime Escape Rate = (1 - Crime Detection Efficiency) * Crime Commitment Rate

Example Information Smoothing Behavior

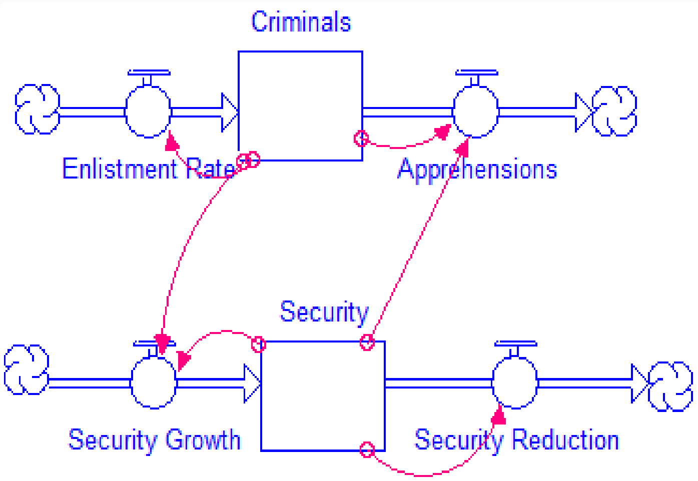
- Intermittent interdictions

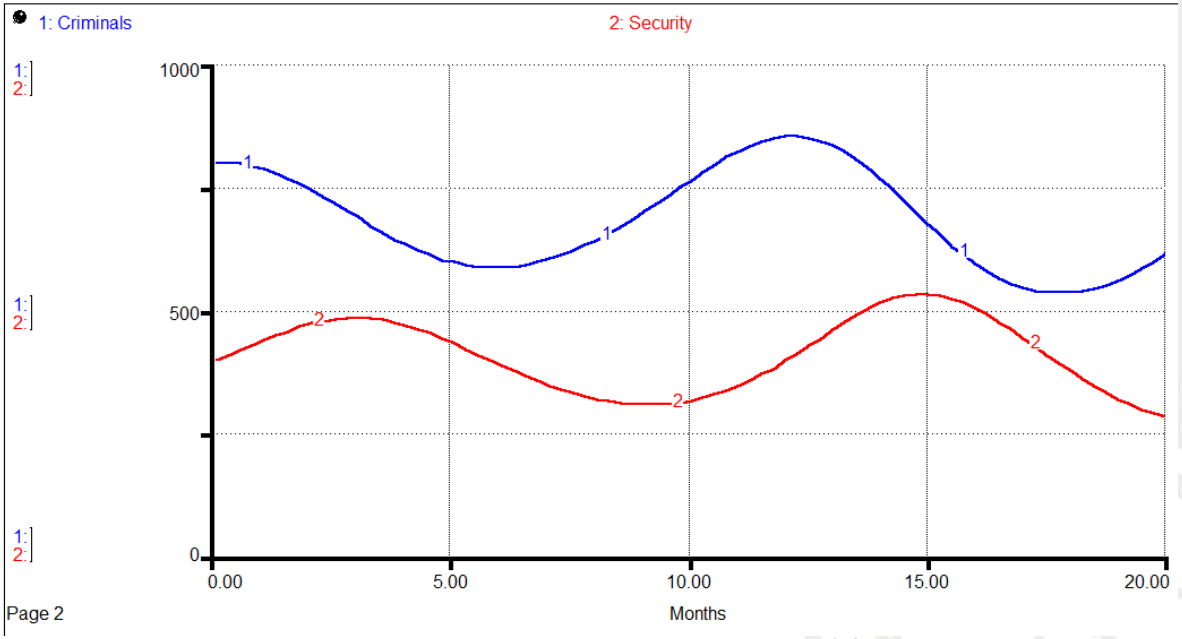




Example Oscillating Behavior

- Continuous forces in region as Predator-Prey model.





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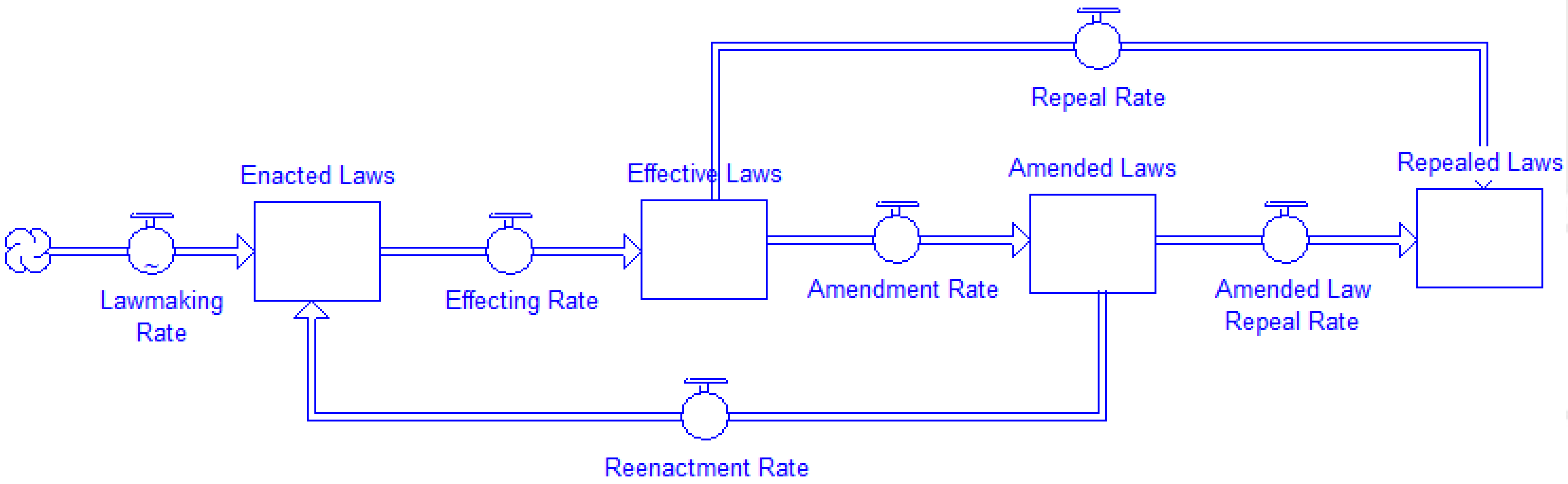
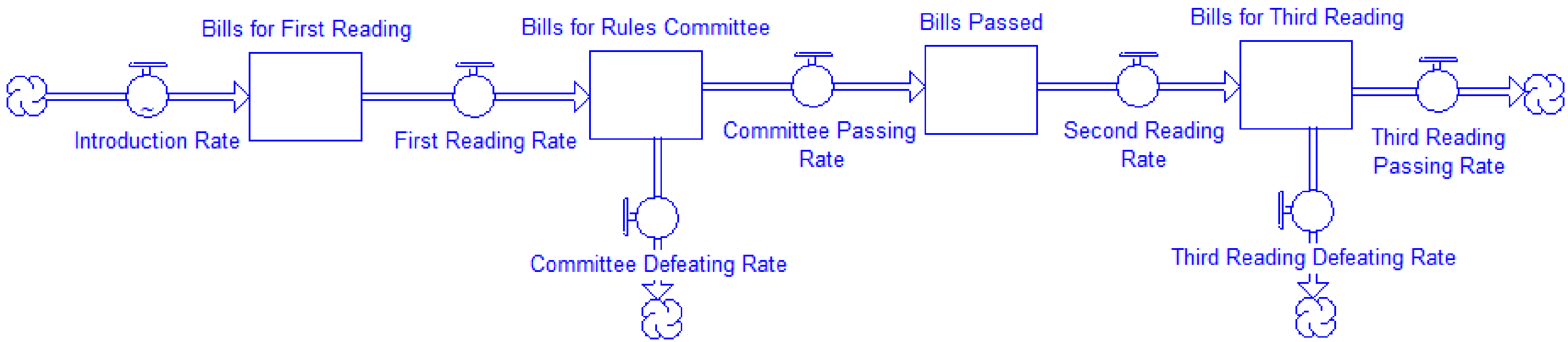
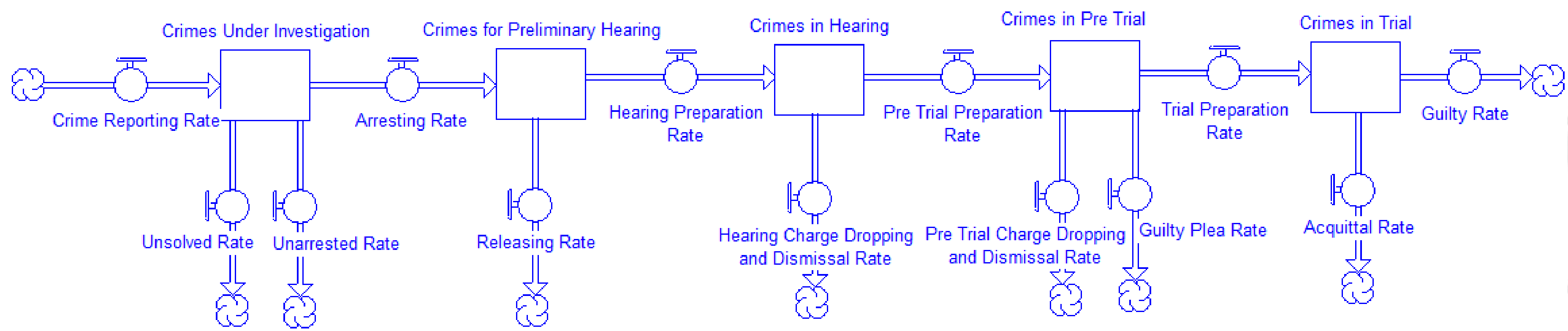
Lawmaking Flow Chain



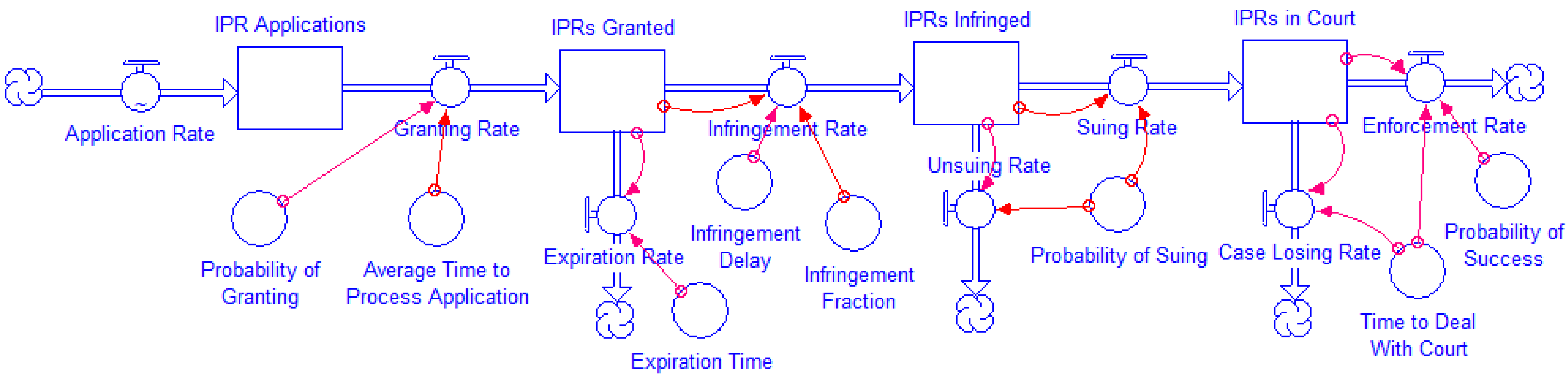
State Legislative Process Flow Chain



Criminal Justice Process Flow Chain

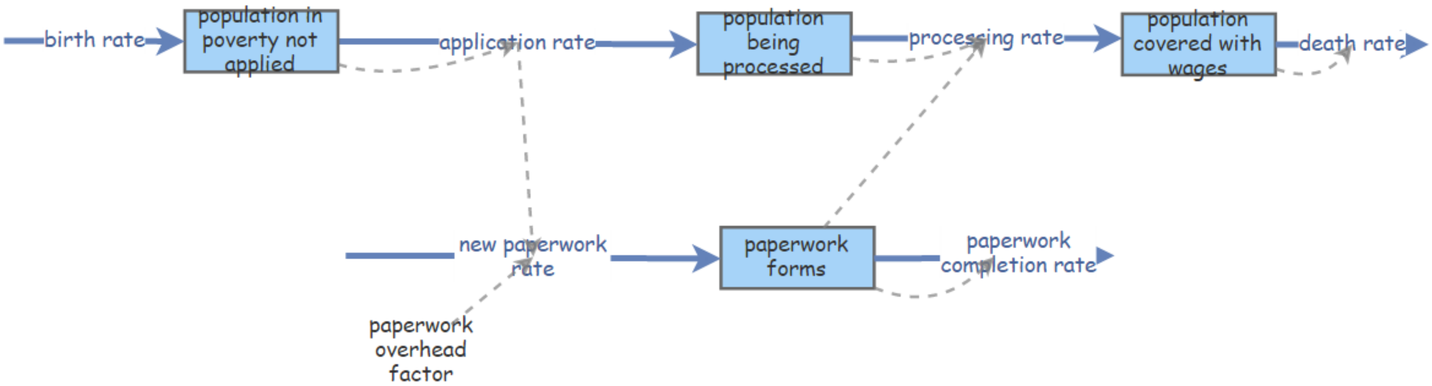


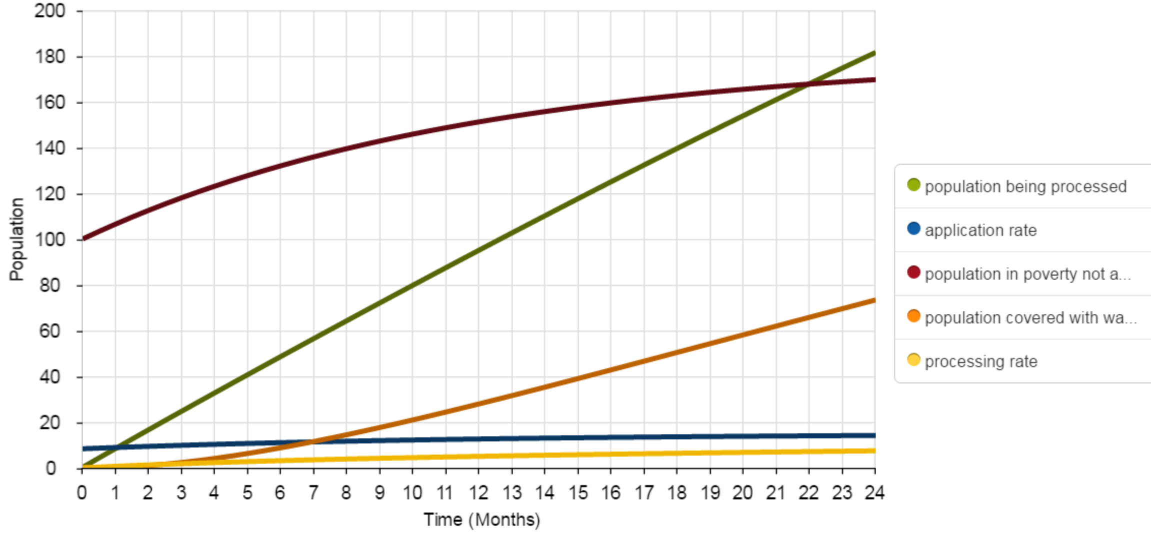
Intellectual Property Rights Flow Chain with Added Detail



Online Demonstration

- Anti-Poverty Law Unintended Consequences





- See http://scienceoflaws.org/models/ or http://sdsim.com/models/lawmaking/

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Conclusions and Future Work

- This work provides reusable model structures interpreted and tailored for the lawmaking process domain.
- The generic structures are starting templates that can be combined in different ways, and with detail added to create larger infrastructures and complex models.
  - Modelers can save time with reusable building blocks leveraging existing patterns.
- Will continue improving these modeling assets, developing fuller models for specific investigations and seeking actual data to support the modeling.
- Subsequent work will include small scale models demonstrating system archetypes in lawmaking and more elaborated, complete model applications.
- Web-based, executable versions will be accessible for public usage of the lawmaking applications.
  - See public models and resources at http://www.scienceoflaws.org/models or http:sdsim/com/models/lawmaking. We invite your feedback and suggestions.
- This paper is a beginning as there are numerous law topics to investigate aided by simulation.
- The models are for insight and impact, not just for play. The goal is to interject use of models and simulation into actual lawmaking practice.

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