An exposure to system dynamics modeling

A System Dynamics Society

seminar series presentation

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Mindseye Computing

20 October 2021
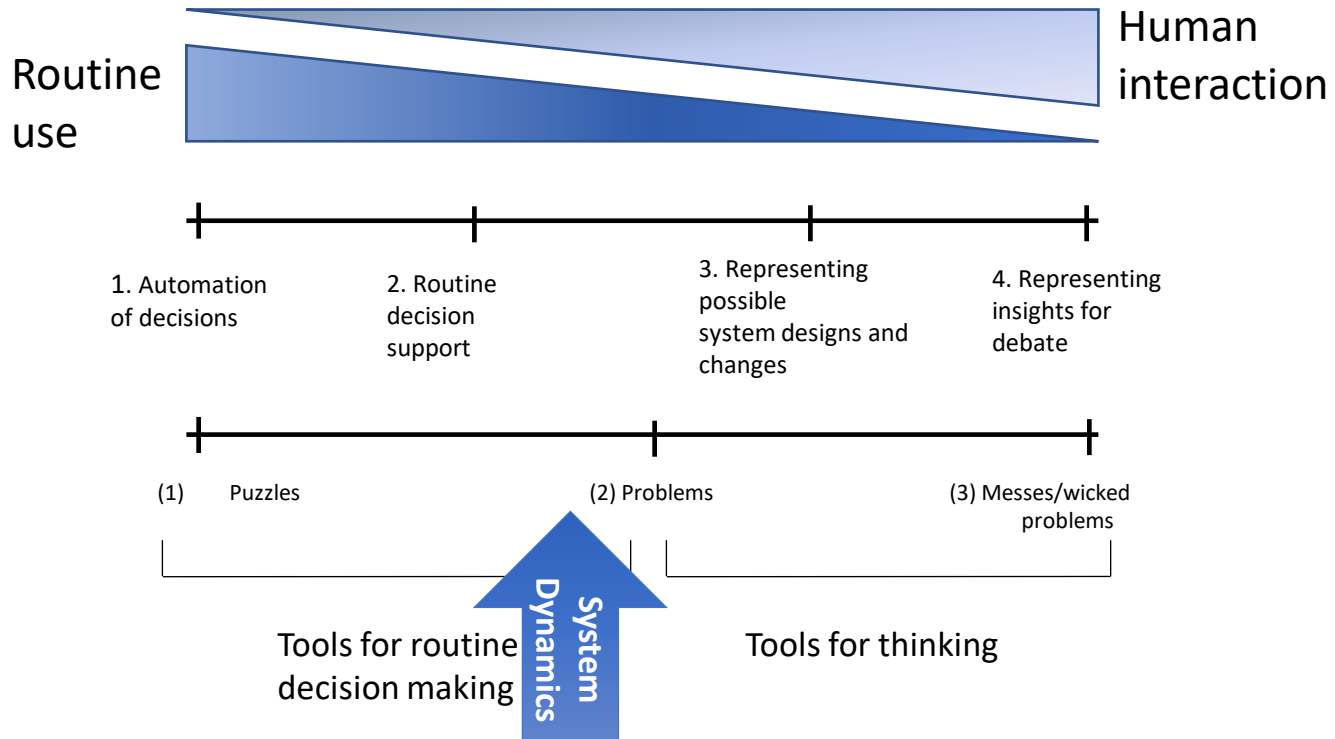
MindsEye Computing, LLC
Visualizing the Future

Powersim
SOFTWARE

Will I learn the system dynamics method in this session?

- NO!
  - Learning will require practicing the method
  - We all learn differently
- Good news
  - There are many places to learn – Google search of "system dynamics" About 424,000,000 results (run on October 8, 2021)
  - Links will be provided later in this presentation

A spectrum of systems modeling uses

Routine use

Human interaction

1. Automation of decisions

2. Routine decision support

3. Representing possible system designs and changes

4. Representing insights for debate

(1)   Puzzles

(2) Problems

(3) Messes/wicked problems

Tools for routine decision making

System Dynamics

Tools for thinking

Adapted from: Systems Modeling: Theory and Practice, Michael Pidd, ed., Complementarity in systems modeling, pp. 2 and 8

The beginning: Industrial Dynamics

In **Industrial Dynamics**[1], Jay Forrester (1961) presents a type of model structure. He indicated that a model should have the following characteristics:

- Be able to describe any statement of cause-effect relationships that we may wish to include.
- Be simple in mathematical nature.
- Be closely synonymous in nomenclature to industrial, economic and social terminology.
- Be extendable to large numbers of variables (thousands) without exceeding the practical limits of digital computers.
- Be able to handle "continuous" interactions in the sense that any artificial discontinuities introduced by solution-time intervals will not affect the results. It should, however, be able to generate discontinuous changes in decisions when these are needed.

[1] Now commonly termed System Dynamics.
The original article was in the Harvard Business Review, July-August 1958, "Industrial Dynamics a major breakthrough for decision makers"

Operationalizing the methodology as

- **"an alternating structure of reservoirs or levels interconnected by controlled flows."**
  - **Forrester's proposal has often been described metaphorically as "bathtub dynamics."**
  - **Objects:**
    - **Stocks are the bathtubs themselves,**
    - **Controlled flows are the automated or humanly controlled decision functions on the flows to and from bathtubs,**
    - **and the interconnections serve as pipes between objects**
  - **Feedback is an important feature of these systems**
  - **Delay is an important feature of these systems**

When do we want a system dynamics simulation model?

A change has created a challenge, we want to

- **Increase our understanding of a problem**

- **Improve existing systems**

- **Improve behaviors**

- **Reduce complexity**

- **Avoid black-box decision making**

**Basically: Get qualified answers – Reduce cost – Save time**

John Sterman at MIT - https://www.youtube.com/watch?v=AnTwZVviXyY

Systems-thinking: A Little Film About a Big Idea
- https://www.youtube.com/watch?v=-sfiReUu3o0

The System Dynamics Method, Powersim Studio, and the Problem Domain

Your challenge today:
- **You have little or no conceptual knowledge of the method**
- **You have little or no syntactic knowledge of Studio**

- **Hopefully, you are familiar with (or are eager to learn about) the problem domain**

Powersim Studio capability

System Dynamics method
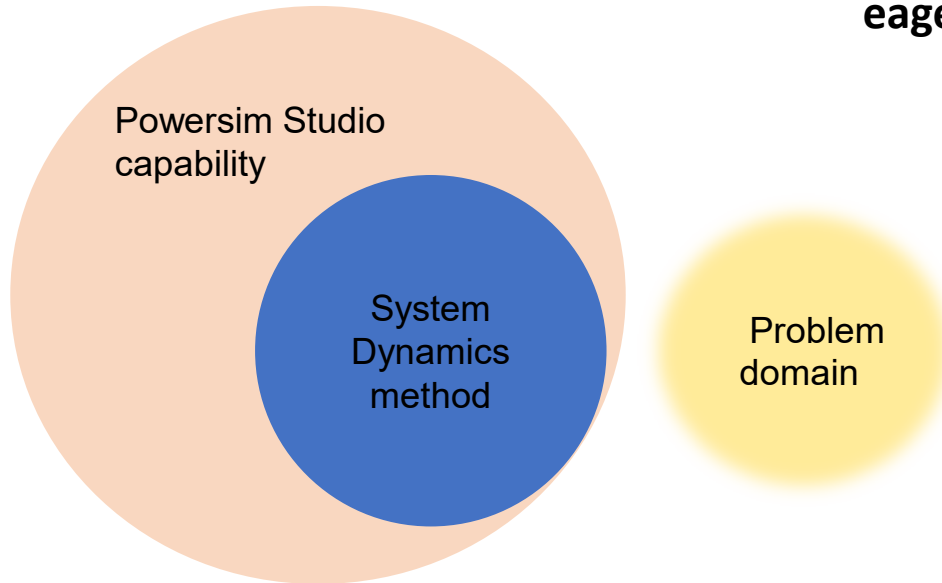
Problem domain

The approach today:
- **Acquire some knowledge of the method**
- **Learn basic tool syntax that supports the method**
- **Learn extra-method syntax that supports the problem domain**

PREPARING FOR SYSTEM DYNAMICS SIMULATION

Problem definition: Formulating a problem from a dynamic perspective

Key variables: Recognising central factors and key variables

Behaviour over time: Recognising and estimating the behaviour of key variables over time
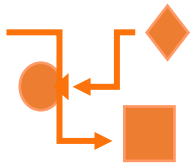
Feedback diagrams: Identifying cause and effect, drawing feedback diagrams

Thank you to Dr. Nici Zimmerman of University College London England for this and the next slide. Some changes applied

THE PROCESS OF SYSTEM DYNAMICS SIMULATION

Stock and flow diagrams:
Identification of stocks and flows in the system

Model equations:
For stocks: integrations, for flows: identification of policies

Simulation:
Generating model behaviour over time

Analysis and implementation:
Compare real and simulated behaviour, test structure, identify and test policy alternatives, implement changes in the real system

Tool to be used today: Powersim Studio **10** Express
Express gives you the ability to build and run simulations with basic modeling features

The free Express edition will give you the ability to:

•Build simulation models and run scenarios

•Translate your models into multiple languages to share around the world

•Use automatic unit control

•Connect to Spreadsheet Datasets

•Access a function library of more than 200 functions

NOTE: It is not possible to receive free Technical Support for this product, and a Service Agreement is not offered for this product.

HOWEVER: You can go to the Studio User Group at: https://groups.io/g/powersimtools for Q&A, models, tips, etc.

•Express has a few limitations*

*These limitations are:
- A model can have a maximum of 50 variables (useful for instructors)
- An array variable can have a maximum of 1000 elements
- The maximum amount of memory allowed for variable values is 80 KB
- The maximum size of dynamic ranges is 20
- Only one CPU core utilized in multi-core processing during simulations
- Only available in 32-bit version
- The license will last for 6 months, indefinitely renewable

- More information at: www.powersim.com including an academic version

Building the simple model: an outside -> in approach

What could be identified from the text and a spreadsheet approach?

1. CONSTANTS
   NORMAL VACANCIES
   INITIAL ACTUAL VACANCIES
   DEMAND FACTOR
   INITIAL APARTMENTS RENTED
   TIMING OF STEP INCREASE IN APARTMENT RENTAL
   STEP INCREASE IN APARTMENT RENTAL
   APARTMENT COMPLETION DELAY
2. Stocks
   Actual Vacancies
3. rates
   apartments rented
   apartments completed
4. auxiliaries
   apartments started
   net apartments added

Go to MS Excel

Yikes! This is simple? No worries, we are all unique and have different ways of learning.

Mapping to and from MS Excel

- 1. CONSTANTS
  - NORMAL VACANCIES
  - INITIAL ACTUAL VACANCIES **?**
  - DEMAND FACTOR **?**
  - INITIAL APARTMENTS RENTED **?**
  - TIMING OF STEP INCREASE IN APARTMENT RENTAL **?**
  - STEP INCREASE IN APARTMENT RENTAL **?**
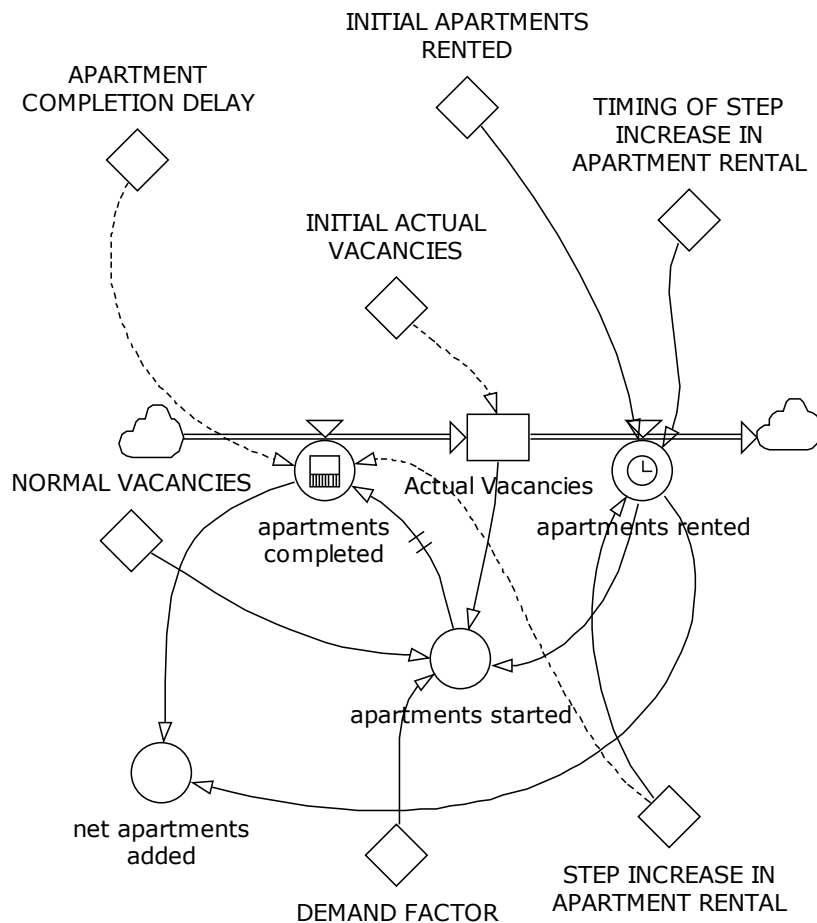 - APARTMENT COMPLETION DELAY **?**
- 2. Stocks
- Actual Vacancies
- 3. rates
  - apartments rented
  - apartments completed
- 4. auxiliaries
- apartments started
- net apartments added

	A	B	C	D	E	F
1		Pp. 10 Problems in Industrial Dynamics				
2	Year	Normal Vacancies	Actual Vacancies	Apartments Started	Apartments Completed	Apartments Rented
3	1	1000	1000	2000	2000	2000
4	2	1000	1000	2000	2000	2000
5	3	1000	800	2300	2000	2200
6	4	1000	600	2400	2000	2200

# Building the simple model: an outside -> in approach

STEPS in constructing the model
1. CONSTANTS name, units (with inline definition)
    NORMAL VACANCIES (create apartment unit)
    INITIAL ACTUAL VACANCIES (inline)
    DEMAND FACTOR (create dimensionless)
    INITIAL APARTMENTS RENTED
    TIMING OF STEP INCREASE IN APARTMENT RENTAL
    STEP INCREASE IN APARTMENT RENTAL
    APARTMENT COMPLETION DELAY
2. Stock
    Actual Vacancies (show unit inheritance)
3. Rate
    apartments rented
4. Auxiliary
    apartments started
5. Rate
    apartments completed
6. Auxiliary
    net apartments added

Let's open Studio

Outside -> in approach: the advantages when using Studio

1. Adding constants first helps to
   1. distinguish the exogenous from the endogenous variables,
   2. indicate potential opportunities to grow model scope,
   3. highlight potential policy variables, and
   4. determine model units
2. Adding stocks next enables
   1. unit inheritance when setting initial values and
   2. model transparency
3. Iterating through auxiliaries and rates helps to
   1. manage model logic,
   2. reinforce unit inheritance, and
   3. enforce the system dynamics methodology
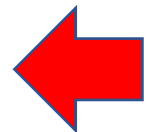
Wait a minute!

- Is this the *only approach* to the problem?
  - No, there may be other equally valid models
  - Ideally you would work with the appropriate stakeholders
- However
  - This approach is based upon the text (<u>Problems in Industrial Dynamics</u>) to have a common problem definition
  - The approach and results can be compared to the text
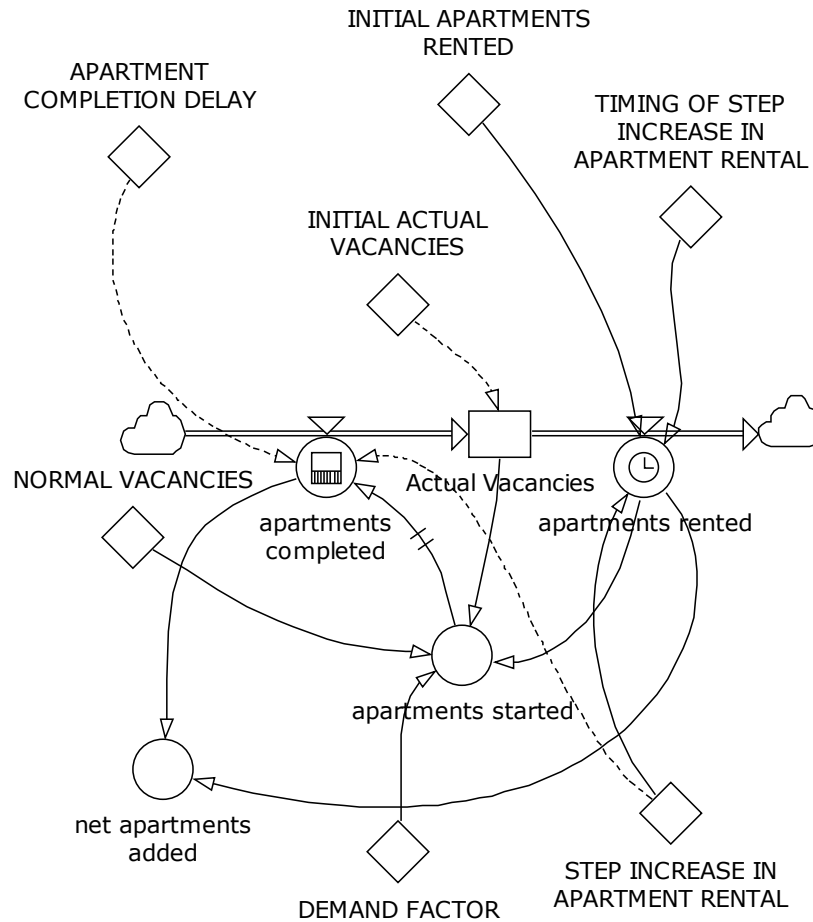 - This approach follows best practices in model construction *

* D-Memo (D-4851, 01/15/2001) System Dynamics Model Checklist
Best Practices for System Dynamics Model Design and Construction with Powersim Studio,
SANDIA REPORT, SAND2011-4108, Unlimited Release, June 2011

STUDIO hands-on

The model

The CONSTANTS

APARTMENT COMPLETION DELAY	**yr**	**3<<yr>>**
TIMING OF STEP INCREASE IN APARTMENT RENTAL	**@yr**	**STARTTIME + 3<<yr>>**
STEP INCREASE IN APARTMENT RENTAL	**apartment/yr**	**200<<apartment/yr>>**
INITIAL APARTMENTS RENTED	**apartment/yr**	**2000<<apartment/yr>>**
INITIAL ACTUAL VACANCIES	**apartment**	**1000<<apartment>>**
DEMAND FACTOR	**%/yr**	**50<<%/yr>>**
NORMAL VACANCIES	**apartment**	**1000<<apartment>>**

The Level

Actual Vacancies	**apartment**	**'INITIAL ACTUAL VACANCIES'**
Actual Vacancies.apartments rented.out		**'apartments rented'**
Actual Vacancies.apartments completed.in		**'apartments completed'**

The auxiliaries

net apartments added	apartment/yr	'apartments completed' - 'apartments rented'
apartments rented	apartment/yr	'INITIAL APARTMENTS RENTED' + STEP('STEP INCREASE IN APARTMENT RENTAL', 'TIMING OF STEP INCREASE IN APARTMENT RENTAL')

apartments completed	apartment/yr	//DELAYMTR('apartments started','APARTMENT COMPLETION DELAY',3)
		DELAYPPL('apartments started','APARTMENT COMPLETION DELAY','INITIAL APARTMENTS RENTED')

apartments started	apartment/yr	'apartments rented' + ('NORMAL VACANCIES' - 'Actual Vacancies') * 'DEMAND FACTOR'

NYT October 15, 2021

21587 days after the problem description article

- **Rising Rents Are Fueling Inflation, Posing Trouble for the Fed**

- Economic policymakers have said inflation will prove temporary, but rising rents may challenge that view and pressure Washington to react.

- https://www.nytimes.com/2021/10/15/business/economy/rent-inflation.html?campaign_id=9&emc=edit_nn_20211015&instance_id=42913&nl=the-morning&regi_id=144854885&segment_id=71712&te=1&user_id=a3257c2532ed6706a3777afa04be15ab

Some excerpts

- That dearth of properties has been exacerbated by work stoppages, supply shortages and labor constraints during the coronavirus era, all of which have kept developers from ramping up production to meet demand.

- Such an intervention would take time — homes are not built overnight. And in the meantime, rents will almost certainly continue moving in the inflation data, which reflect rising housing costs at a long delay. More up-to-date measures of rental pricing pressure produced by Apartment List and Zillow have shown costs climbing in recent months, though many measures of rent and new leases have calmed down somewhat after a red-hot summer.

- The national median rent has increased 16.4 percent since January, Apartment List said in its September rental report, with monthly growth slowing slightly from its July peak.