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Modeling Psychological and Sociological Dynamics Methods and Applications

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- Part 1 – Preliminaries
- Part 2 – Modeling Approach
- Part 3 – Construct to Variable
- Part 4 – Model Building Mechanics
- Part 5 – Validating Models
- Resources

“Let us step into the night and pursue that
flighty temptress, adventure.”

J.K. Rowling, Harry Potter and the Half-Blood Prince



Modeling Psychological and Sociological Dynamics

PART 1 – PRELIMINARIES

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Be careful of the meaning of terms

Construct

- Theoretical
- Often Qualitative

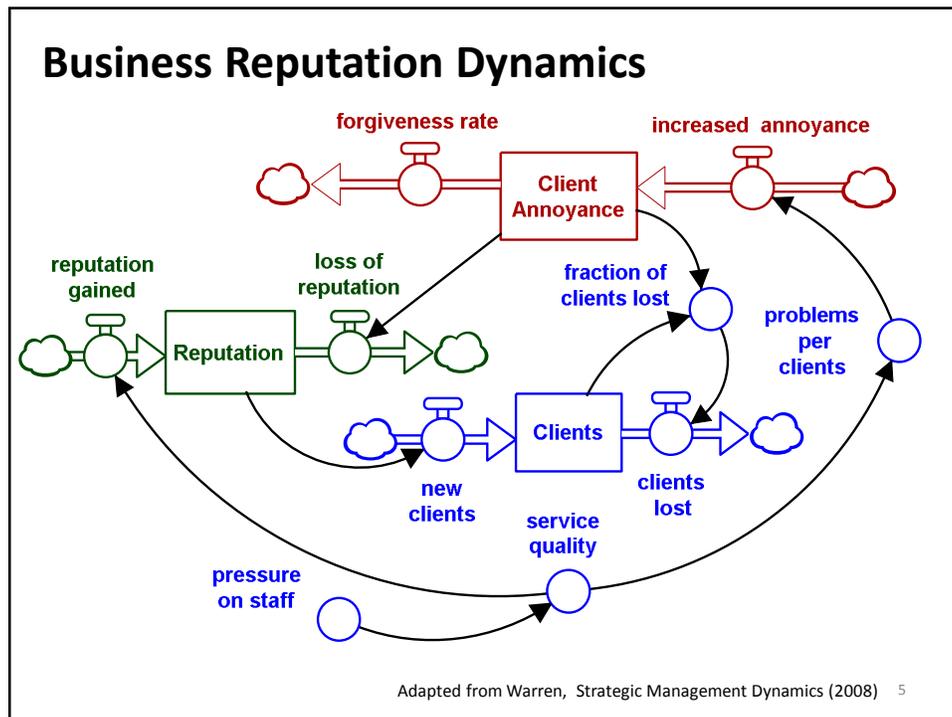
Variable

- Quantifiable
- Measurable

service quality **enthusiasm** **fear** morale **motivation** reputation **burnout** experience **distress**
motivation to avenge attitude **happiness** schedule pressure media interest **anger**

**Soft Variables – “soft” principally because they are
connected with social sciences, not because they are
intrinsically unmeasurable**

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Experience and Expectations

- What disciplines are represented here today?
- Who has used soft variables, intangibles, psychological or sociological variables in models?
- Were they useful?
- What do you expect from this workshop?

Expressed Concerns



Soft variables should not be used because they are intangible and thus can't be measured

Their representations in typical SD models are not routinely validated

They are not "material", so how can they be used in "stock and flow" diagrams?

It is not good practice to have more than one soft variable in a model

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Impact



"It is widely accepted that intangible or soft factors have a substantial impact on an organization's performance - a damaged reputation can destroy a business, strong staff motivation can drive powerful growth..."

Warren, Strategic Management Dynamics (2008)

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Benefit



“Often the greatest benefit of a modeling project is to help the client see the importance of and begin to measure and account for soft variables and concepts previously ignored.”

Sterman, “All Models are Wrong: Reflections on Becoming a Systems Scientist” SDR, 2002

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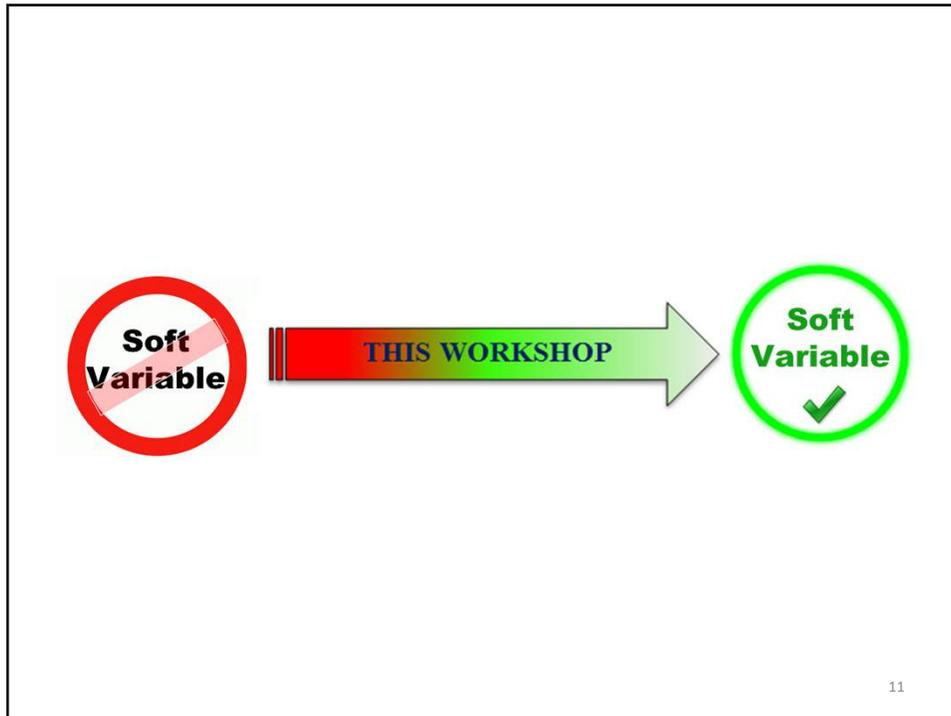
Need



“[The] understanding ... that a mathematical model cannot be undertaken until every constant and functional relationship is known to high accuracy. .. often leads to the omission of admittedly highly significant factors ...because these are unmeasured or unmeasurable. **To omit such variables is equivalent to saying that they have zero effect – probably the only value that is known to be wrong.**”

Forrester, Industrial Dynamics, 1961 (our emphasis)

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“We have to remember that what we observe is not nature herself, but nature exposed to our method of questioning.”

Werner Heisenberg

Modeling Psychological and Sociological Dynamics

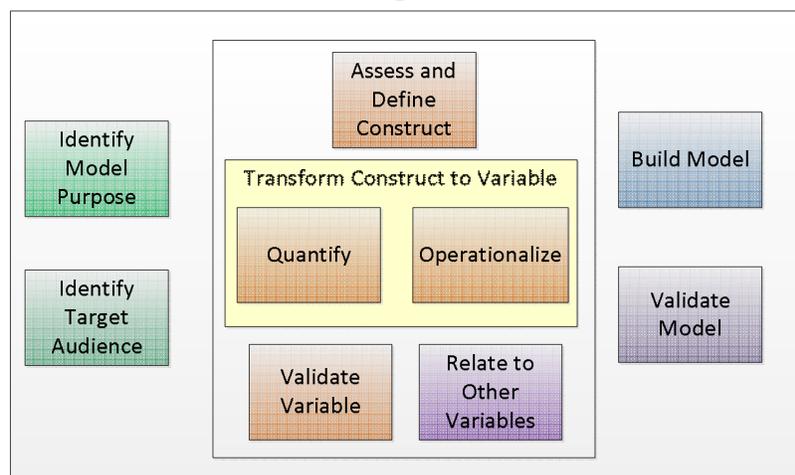
 **PART 2 – MODELING APPROACH**

“The ultimate success of a system dynamics investigation depends on a clear initial **identification of an important purpose and objective.** ... If a model is to have impact, it must couple to the concerns of **a target audience.**”

Jay Forrester, Lessons from System Dynamics Modeling, 1986 (our emphasis)

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Modeling Activities



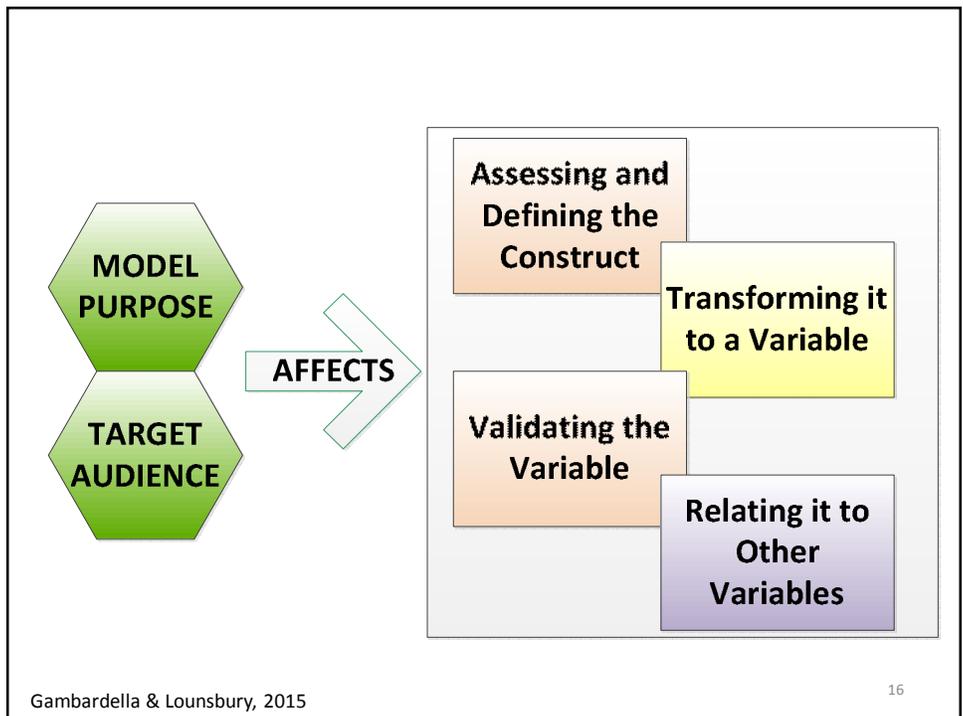
- **Construct** refers to a psychological or sociological concept
- **Operationalize** = transforming “construct” to “measurable variable”

Gambardella & Lounsbury, 2015 14

Purpose of a Model

<p>Purpose (Examples)</p> <ul style="list-style-type: none"> • Modeling psychological and sociological theories • Modeling a problem • Teaching • Coaching 	<p>Attributes</p> <ul style="list-style-type: none"> • Explore • Gain insight • Enforce precision in thinking • Predict (patterns) • Make decisions • Clarify thinking • Gain understanding • Promote common group understanding • Be surprised!
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Purpose and attributes are for intended target audience(s)



Examples of Models by Purpose

- Modeling Psychological and Sociological Theories
 - Family Crisis/Equity Theory (Levine)
 - Stanford Prison Experiment (Doyle, Saeed, Skorinko)
 - Milgram Experiment (Doyle, Saeed, Skorinko)
- Modeling Problems
 - Dynamics of HIV Prevention and Care (Lounsbury, Levine)
 - Riots (Hayward, Jeffs, Howells, Evans)
 - Burnout (e.g., isee systems; Levine, Homer)
 - Physician Burnout (Gambardella)
 - Labor Experience co-flow with learning curve (Thompson)
- Teaching Shakespeare
 - Hamlet (isee systems, Patricia Hopkins)

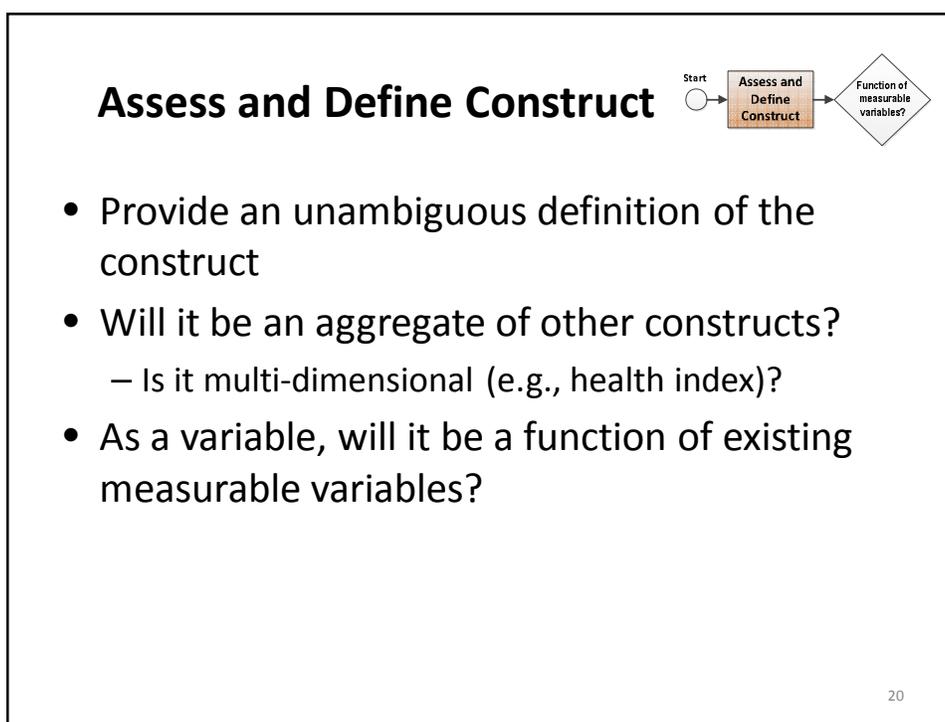
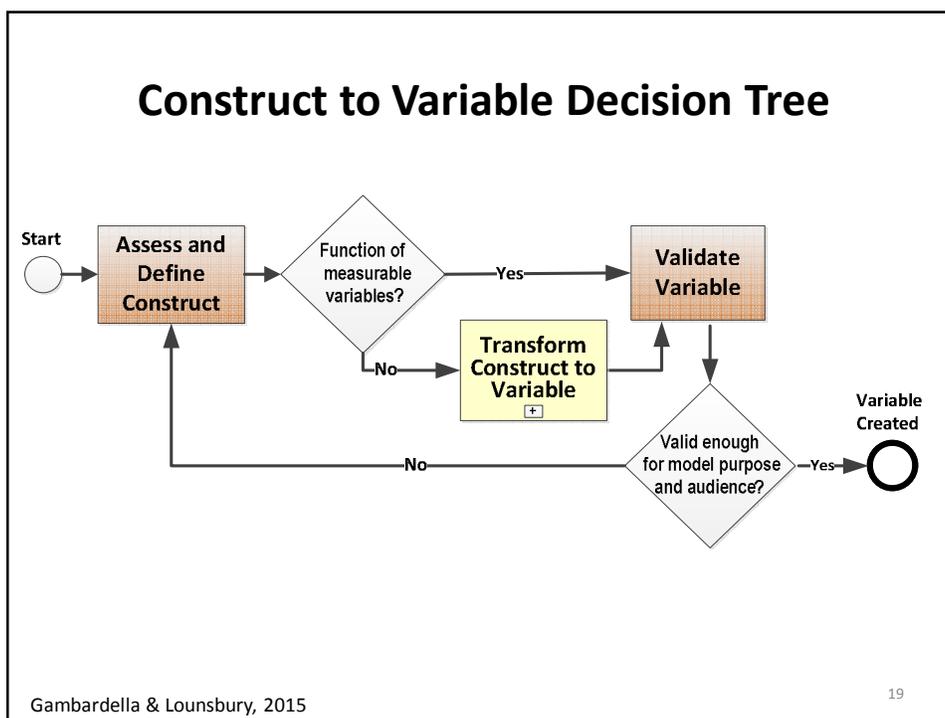
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Modeling Psychological and Sociological Dynamics

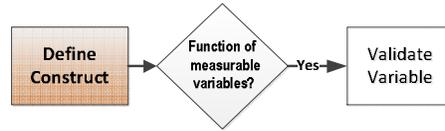


PART 3 – CONSTRUCT TO VARIABLE

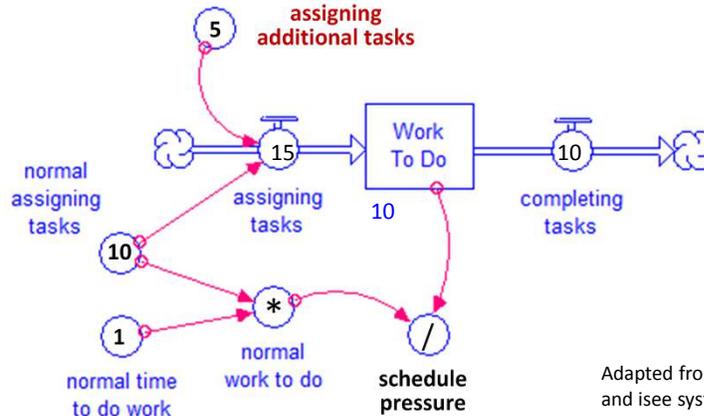
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Proxy Example of a “Measurable” Variable



- Schedule pressure = Work_To_Do/normal_work_to_do
- This computed ratio is a proxy for schedule pressure since, for example, it misses extreme situations

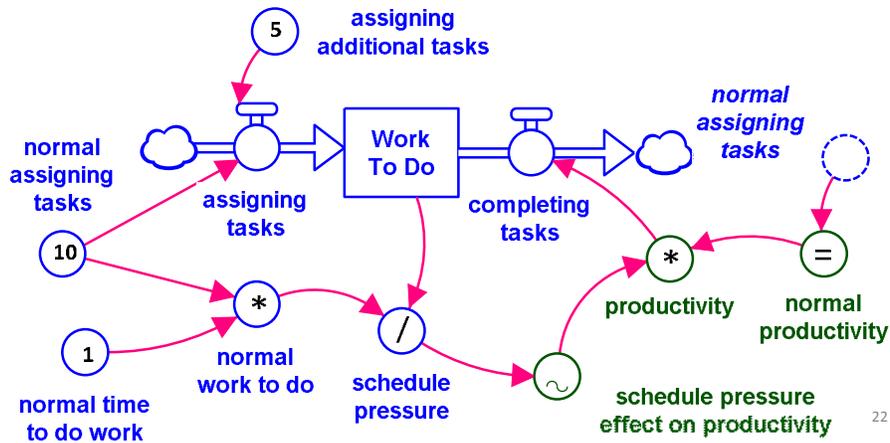


Adapted from Richmond (2001) and isee systems 21

EXERCISE 1: Relating “Schedule Pressure” to other Variables

Relate to Other Variables

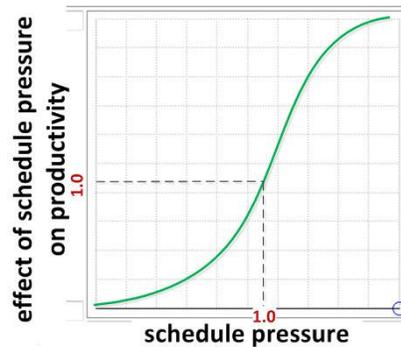
Draw the **schedule pressure effect on productivity** graphical function and justify your answer. Set proper boundary conditions (e.g., no effect when =1).



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Exercise 1: Additional Questions

1. Does it make sense for schedule pressure be less than 1
2. Can it be zero?



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Validity Checklist for Variable

Validate Variable

- **Validity Definition**
 - **Face.** Subjectively measure what it is supposed to measure? Correspond to something in the real world?
 - **Content.** Tap into the full range of meanings of the underlying concept? Other dimensions?
 - **Construct.** Correlate appropriately with other theoretical constructs (related and unrelated)?
 - **Concurrent.** Correlate with alternate measures of same phenomena at the same time?
 - **Predictive.** Does it predict future behaviors or conditions
- **Validity Check: **Schedule Pressure****
 - **Face.** Yes. The additional work can create pressure
 - **Content.** Yes. Other possible dimensions may be at play (e.g., external product deadlines). You might need to extend the model.
 - **Construct.** Yes. Correlates with burnout and morale, and not sunspots
 - **Concurrent.** What else influences productivity similar to schedule pressure, e.g., number of available co-workers
 - **Predictive.** Does it predict turnover?

$$\text{Schedule pressure} = \text{Work_To_Do} / \text{normal_work_to_do}$$

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Validity Checklist for Variable (2)

Validate
Variable

- **Reliability Definition**
 - **Inter-Observer Consistency.** Different observers assign the same values to the same phenomena?
 - **Psychometric Consistency.** Statistical analyses of multi-item scales (e.g., Cronbach's Alpha)
- **Reliability Check: *Schedule Pressure***
 - **Inter-Observer Consistency.** Yes, however what counts as a task may be abstract
 - **Psychometric Consistency.** Check for published literature for quantitative of measures (scales) of *schedule pressure*

Schedule pressure = Work_To_Do/normal_work_to_do

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Key Lesson

Looking at the validity of your variable helps you critique the validity of your model

Exercise 2

Validate Variable

Select a psychological or sociological variable in a model and go through our suggested validity checklist:

- Face Validity
- Content Validity
- Construct Validity
- Concurrent Validity
- Predictive Validity

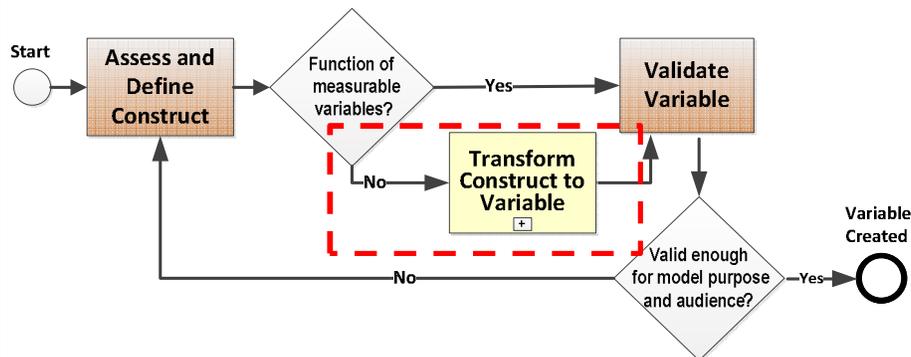
“brand” resilience service quality

enthusiasm fear morale motivation reputation burnout experience distress
 motivation to avenge attitude happiness schedule pressure media interest anger

Gambardella & Lounsbury, 2015

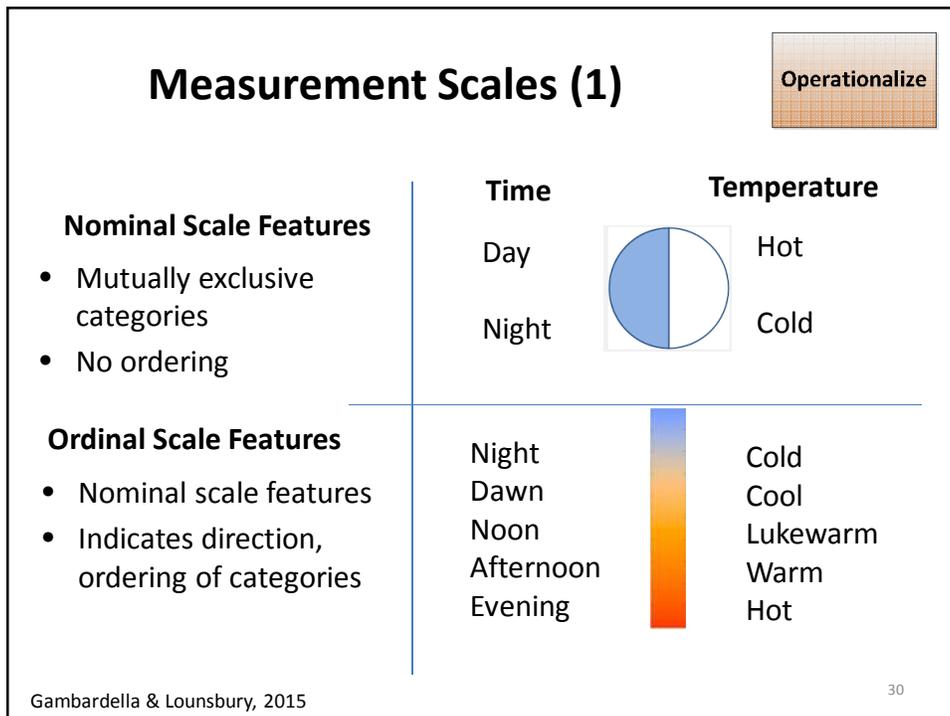
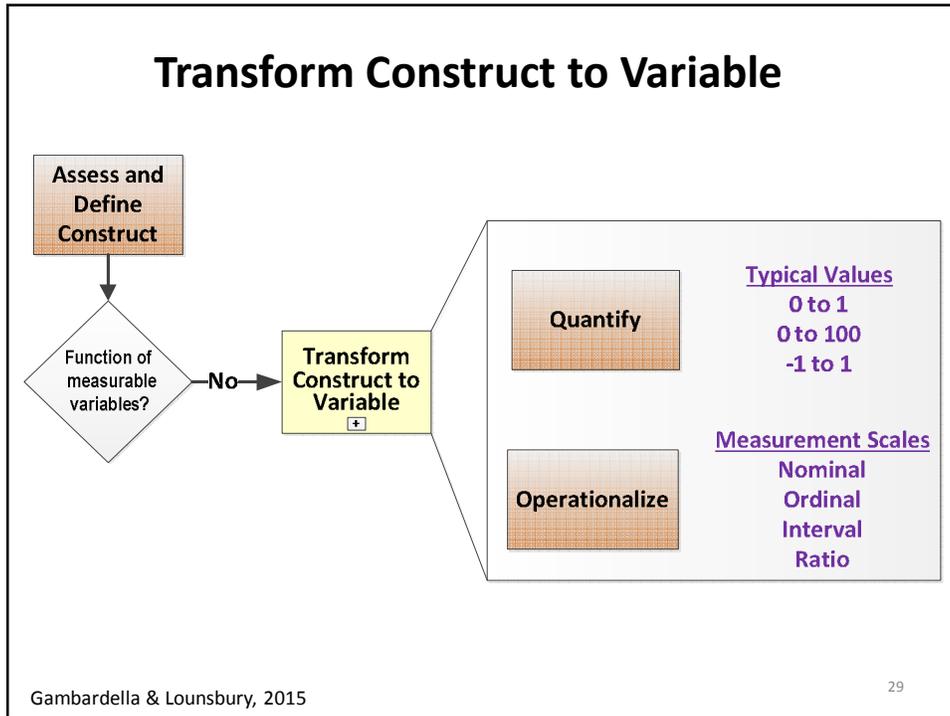
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Construct to Variable Decision Tree



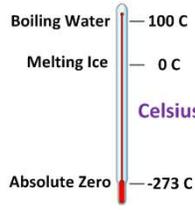
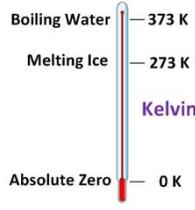
Gambardella & Lounsbury, 2015

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Operationalize

Measurement Scales (2)

<p>Interval Scale Features</p> <ul style="list-style-type: none"> • Previous scale features • Differences between scaled units meaningful and constant <p>Ratio Scale Features</p> <ul style="list-style-type: none"> • Previous scale features • Meaningful origin • Ratio comparisons meaningful (e.g., twice the temp in K) 	<p>Time</p> 	<p>Temperature</p>  <p style="text-align: center; color: purple;">Celsius</p>
		 <p style="text-align: center; color: purple;">Kelvin</p>

Gambardella & Lounsbury, 2015 31

Marital Satisfaction

Scale	Question	Response Categories or Assessment
Nominal	Are you satisfied with your marriage?	YES or NO
Ordinal	How satisfied are you with your marriage?	‘Hot’ ‘Warm’ ‘Luke warm’ ‘Cold’
Interval	How satisfied are you with your marriage?	5=Very satisfied, 4=Somewhat satisfied, 3=Unsure, 2=Somewhat unsatisfied, 1=Very unsatisfied
Ratio	What is the quality of couple interactions?	Ratio of positive to negative interactions observed over a specified time period (Gottman Ratio)

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Quantification Guidance

A rectangular button with a light brown background and a grid pattern, containing the word "Quantify" in black text.

- Most often we want variables on a ratio scale
 - We want a meaningful origin
 - Differential equations require ratio scales
 - If a variable is on a ratio scale the range of the scale does not matter (e.g., 0 to 1, 0 to 100, 0 to 6)
- If values need to be compared with empirical data then they need to be
 - Calibrated to fit that data
 - Meaningful and realistic
 - For example, university reputation index

Gambardella & Lounsbury, 2015

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Quantification Guidance (2)

A rectangular button with a light brown background and a grid pattern, containing the word "Quantify" in black text.

- Try to quantify variables as fractions (0 to 1) because they have a finite range and are meaningful, e.g.,
 - Fractions
 - Percentages
 - Probabilities
- However, other ranges okay (e.g., 0 to 100)
- Consider need for multiplicative vs addition effects (or a combination)

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Example - Motivation as a Variable

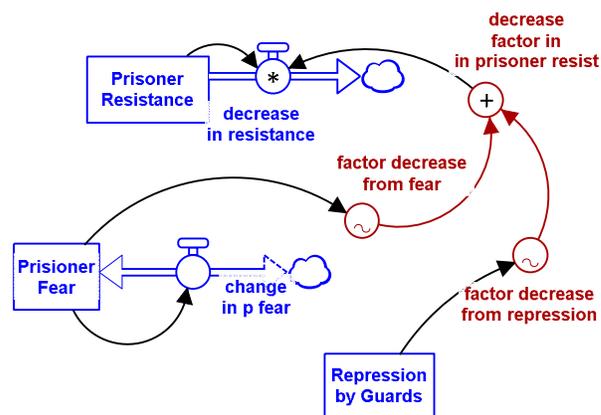
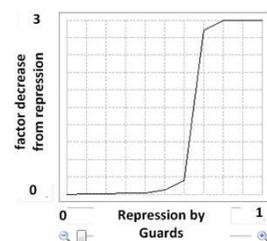
- Create a meaningful origin, e.g., no motivation
 - 0 to 1: 0 = no motivation, 1 = highest motivation
 - 1 to 1: -1 being highest negative motivation
 - 1 = motivated toward eating well
 - 1 = motivated away from eating well (or eating poorly)
- When possible define the influence of a variable as a ratio
 - Motivation factor = current motivation/maximum motivation
- The variable itself could be a product:
 - Motivation = (effect of winning awards)*(normal motivation)

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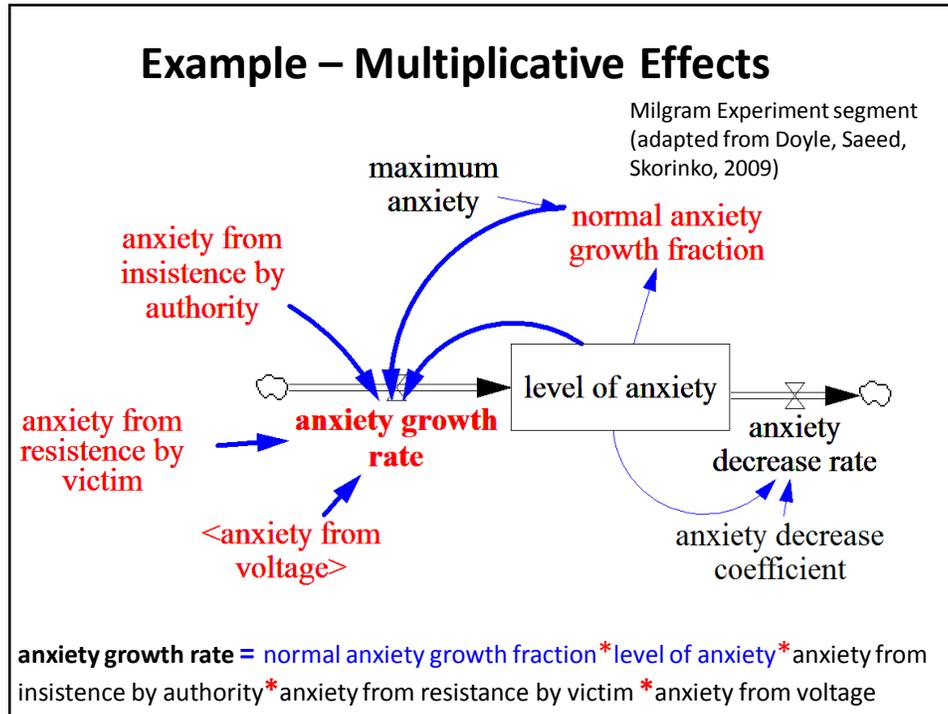
Example - Additive Effects

Decrease factor in prisoner resistance =
 $\text{factor_decrease_from_fear} + \text{factor_decrease_from_repression}$



Stanford Prisoner Model segment (adapted from Doyle, Saeed, Skorinko, 2009)

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Guidance on Combining Variables

- Need a meaningful origin, e.g., 1 means no effect
- In a product of multiple effects use zero for a variable only if its absence cancels the total effect
- Be careful of the ranges of variables
- Recall that multiplying two variables less than 1 yields a smaller result
- Use intermediate graphical functions if needed when relating one variable to another

Exercise 3: Reasoning from Construct to Variable

- Pick a model with at least one psychological or sociological construct
- Define the purpose and audience of the model
- Transform the construct to variable
- Do as homework!

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Advanced Topic - Cognitive Algebra

Understand the Effect Needed

$0 \leq X \leq 1$ $0 \leq Y \leq 1$	$0 \leq f(X,Y) \leq 1$	If $X = 0$ (X turned off)	If $X = 1$ (X set to max)	COMMENTS	EXAMPLES
Logical AND	$X*Y$	0	Y	One variable restricts the effect of the other	$f(X,Y) = X*Y =$ productivity X = normal productivity Y = schedule pressure effect on productivity
Arithmetic Average	$\frac{X + Y}{2}$	$\frac{Y}{2}$	$\frac{1 + Y}{2}$	An average	$f(X,Y) = (X+Y)/2 =$ average worker experience X = experience worker 1 Y = experience worker 2
Logical OR	$X + Y - XY$	Y	1	Only one variable at its maximum is enough for a maximum effect	$f(X,Y) = X + Y - X*Y =$ combined effect of media interest and enthusiasm on riot recruitment X = effect media interest on riot recruitment Y = effect of enthusiasm on riot recruitment Either media interest (which increases sympathy to riot) or enthusiasm (to riot) is sufficient for recruitment Hayward, J., et al. (2014). Model Building with Soft Variables: A Case Study on Riots.

“A model is a lie that helps you see the truth.”

Howard Skipper

“All models are wrong but some are useful.”

George Box

Modeling Psychological and Sociological Dynamics



PART 4 – MODEL BUILDING MECHANICS



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Decisions for Modelers

Build Model

- Choose variable type for the psychological or sociological variable:
 - Auxiliary variable (conveyer), state (level, stock)
 - Is a rate (flow) a candidate for this type of variable?
- How do we represent the state, stock? (generic structure)
 - Biflow (net change), two or more uniflows, or coflow?
 - How do you control a state's range?
- What influences how a state will change?
 - “A decision, an external condition, or another stock [state]” (Kim Warren)

Gambardella & Lounsbury, 2015

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Decisions for Modelers

Build Model

- How will the variable relate to other variables?
 - Algebraic relationship?
 - Graphical function?
 - Some combination?

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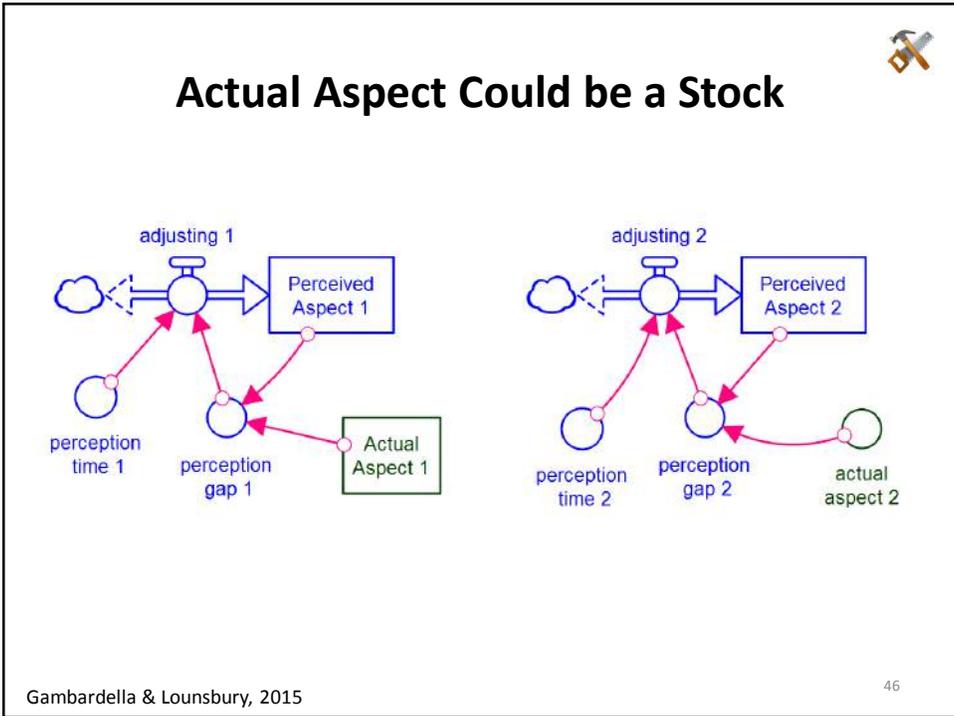
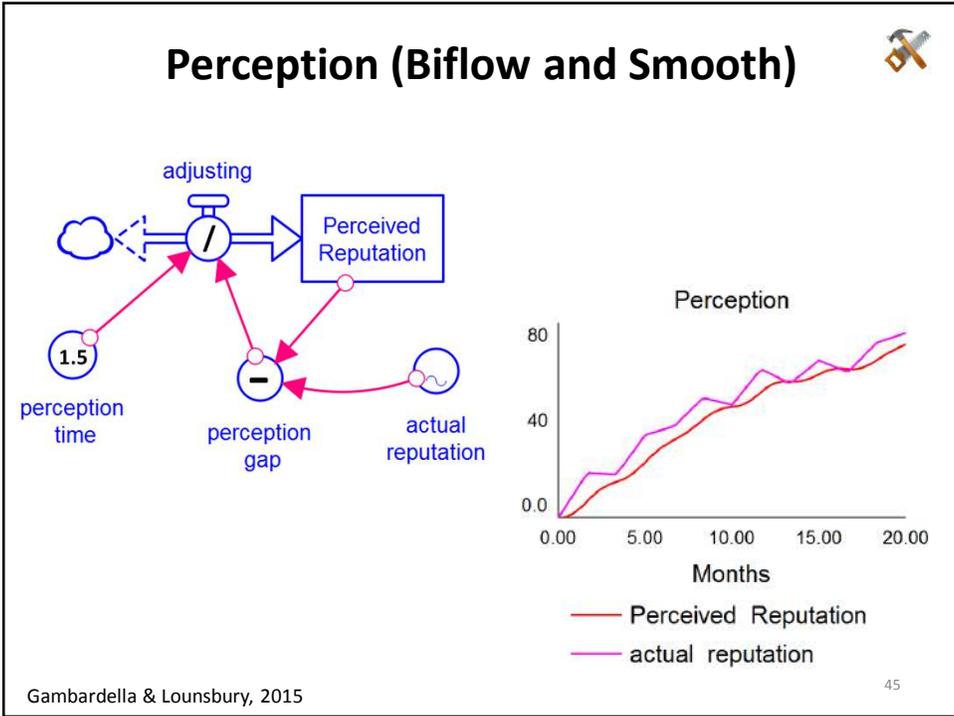
Auxiliary Variable (conveyer, parameter) or State (level, stock)

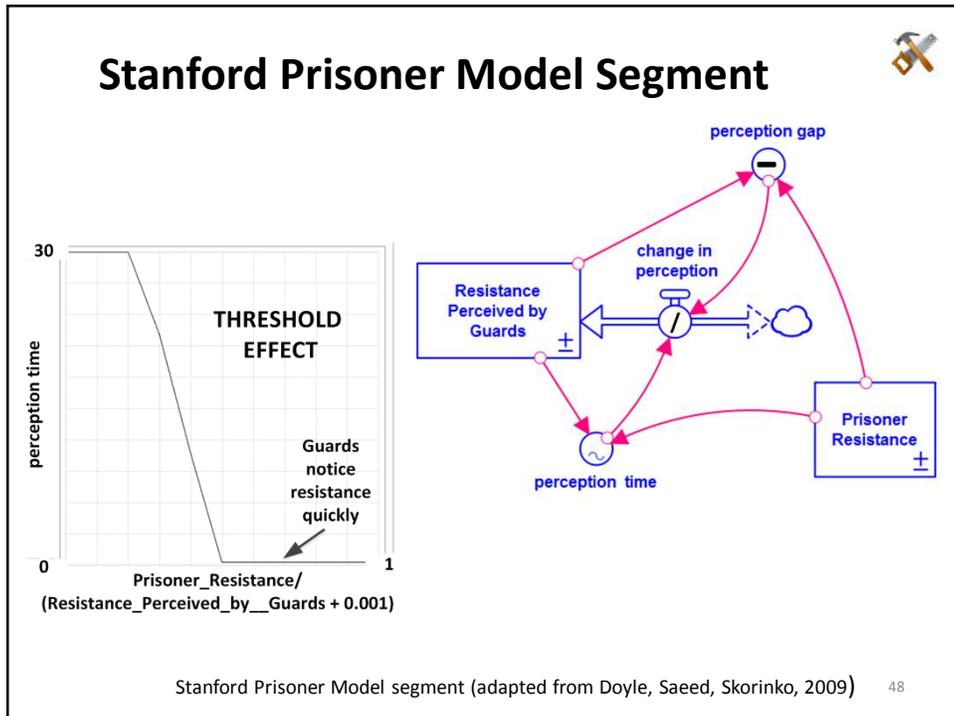
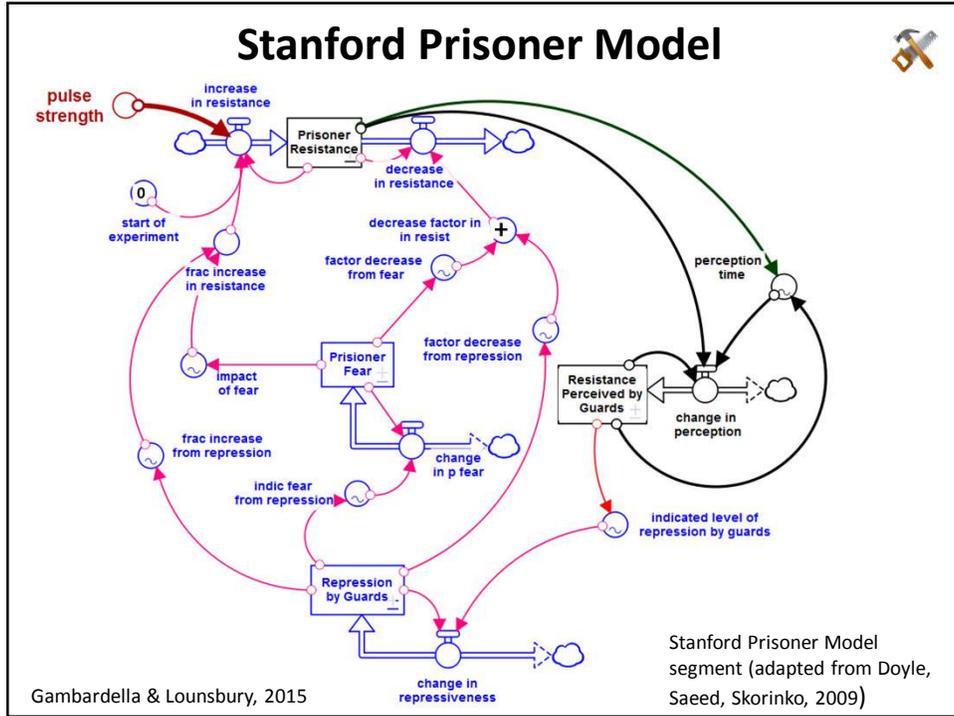
- **Within the boundaries of the model** is it possible for the psychological or sociological variable to accumulate?
 - If so, then it is a state (stock, level) (e.g., **anger**)
 - If not then it is an auxiliary variable (e.g., **schedule pressure**)
- Anger is a state (level, stock) if it **accumulates over time**

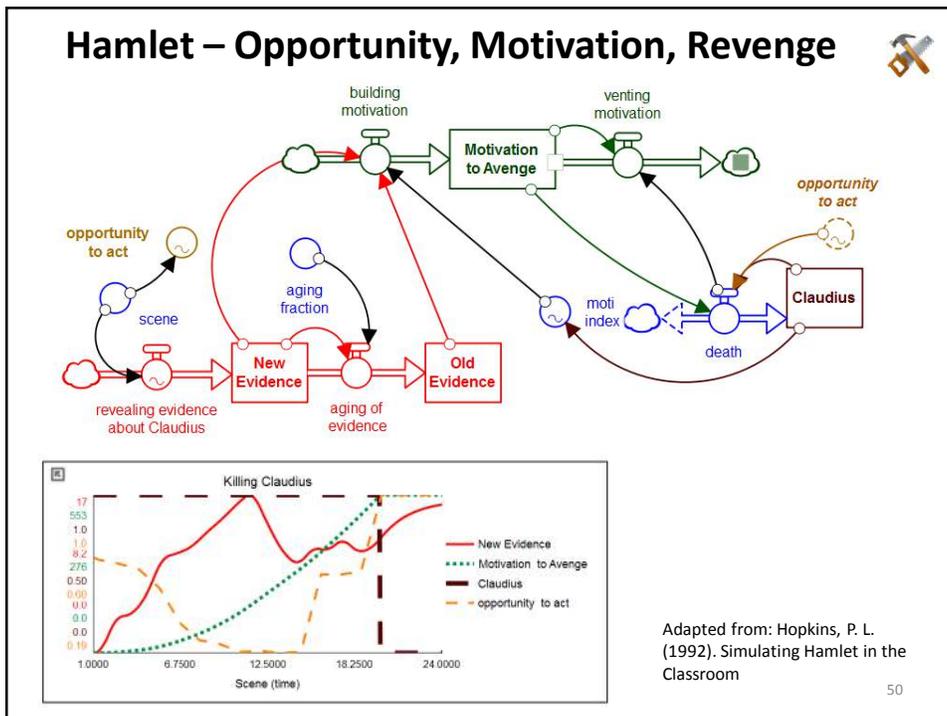
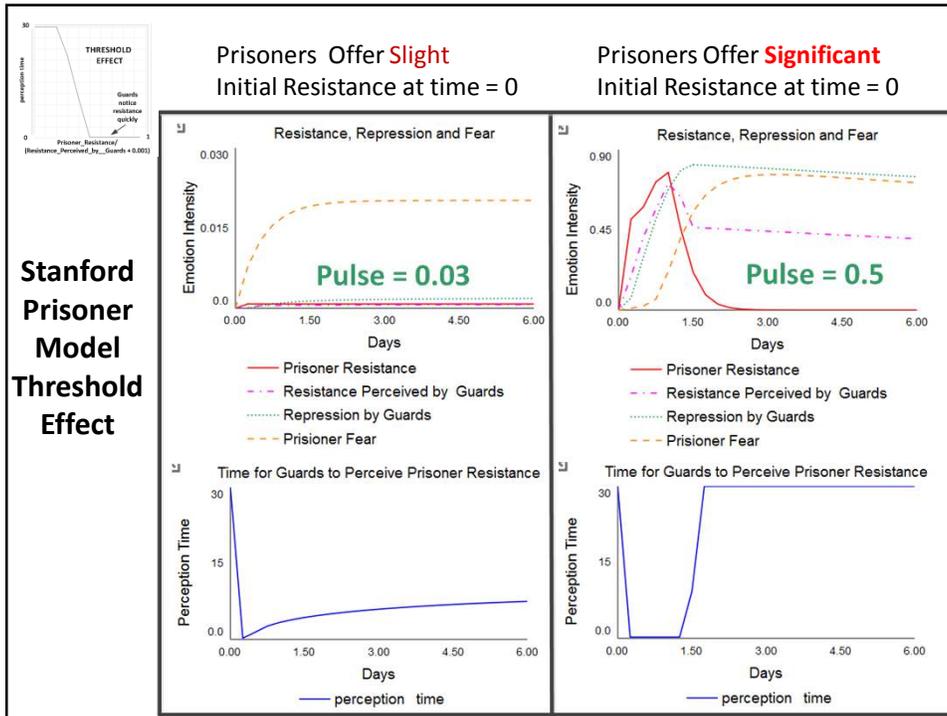


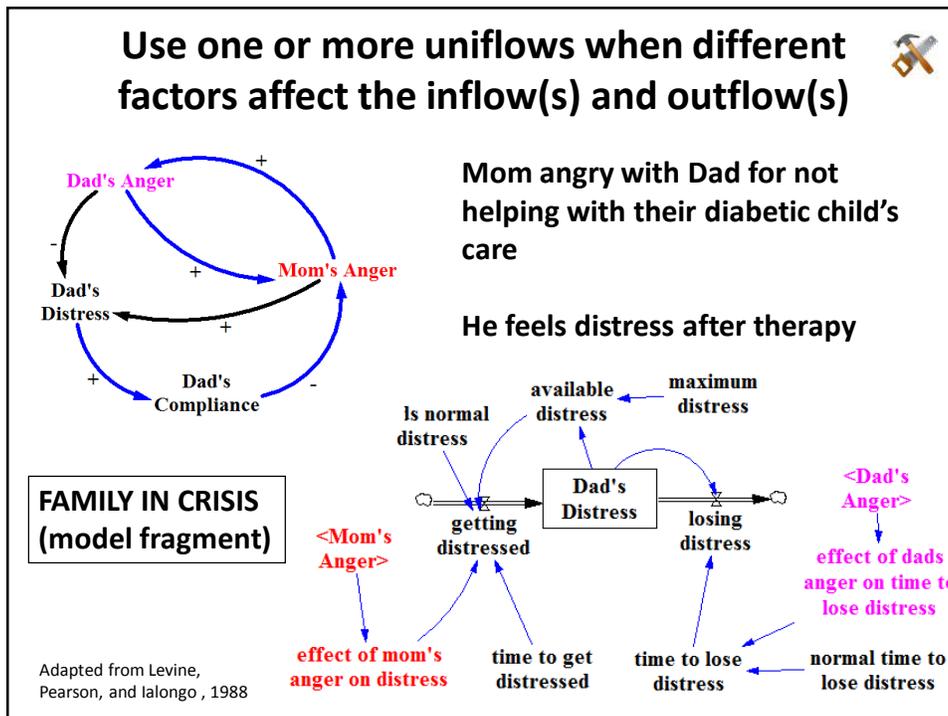
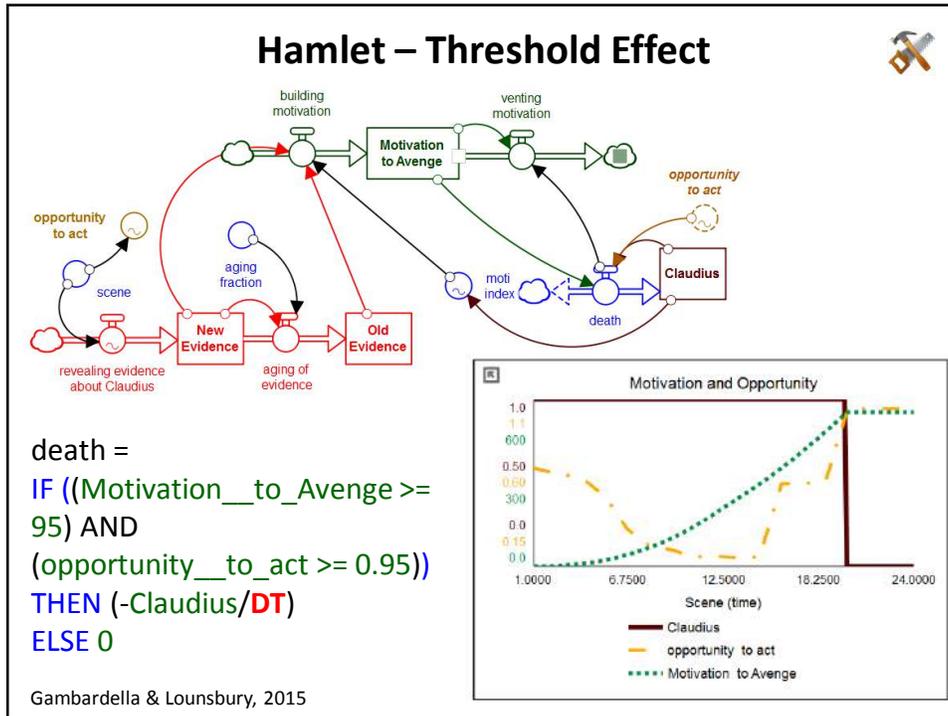
Gambardella & Lounsbury, 2015

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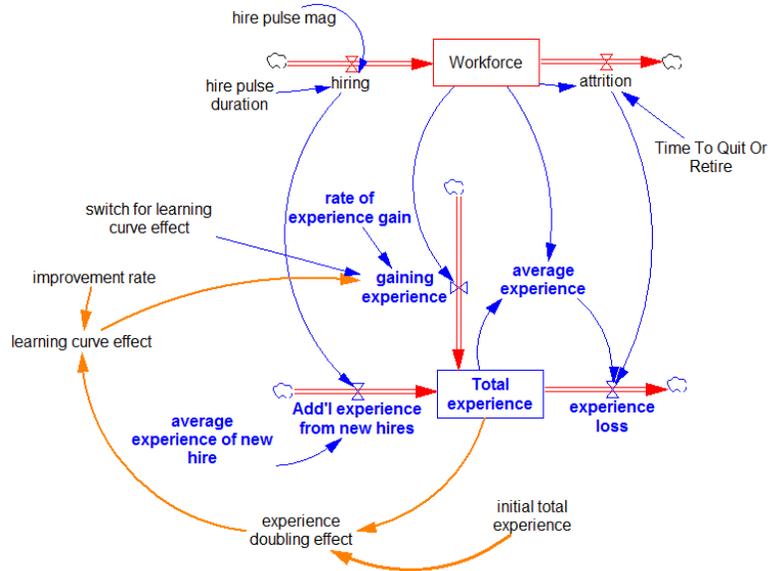








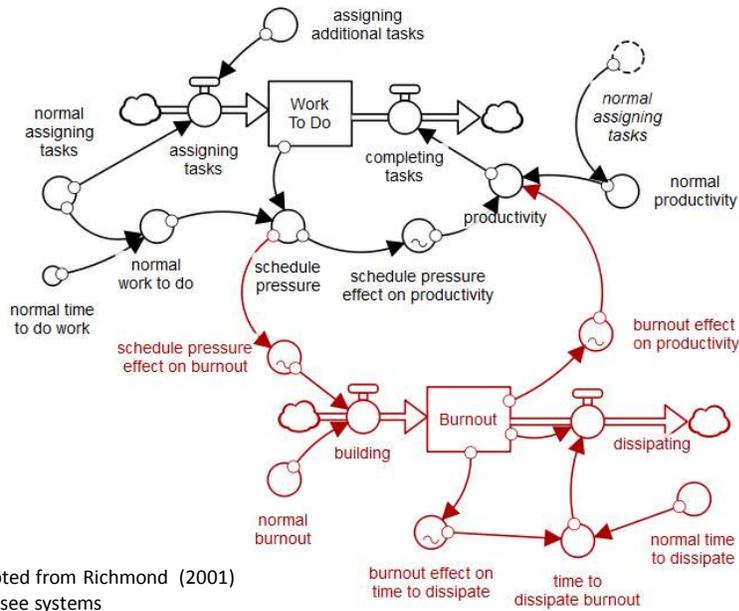
Coflow – Total Experience with Learning



Adapted from Jim Thompson, WPI

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Coflow – Burnout



Adapted from Richmond (2001) and isee systems

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Controlling the Maximum Range of the State

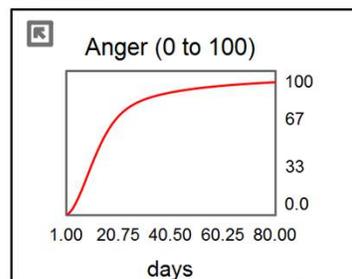
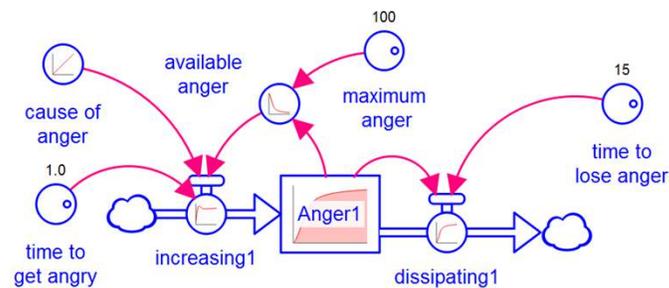


- Alternatives
 - Just stay in range (weak alternative)
 - Algebraic function
 - Graphical function
 - Combination of algebraic & graphical functions
- Do not use the “if-then-else” function since it can interfere with integration

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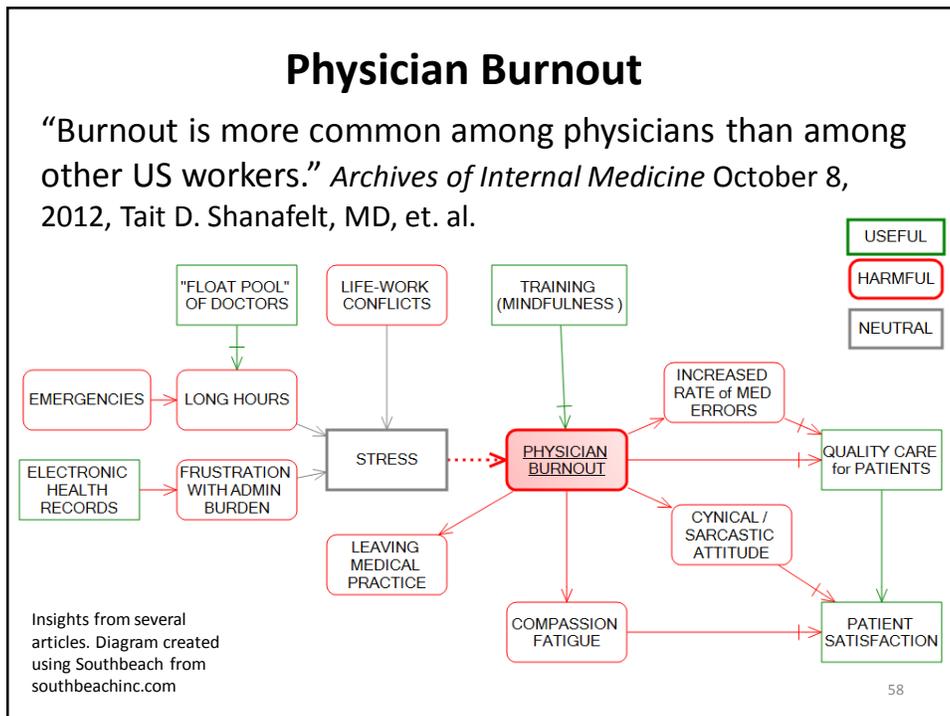
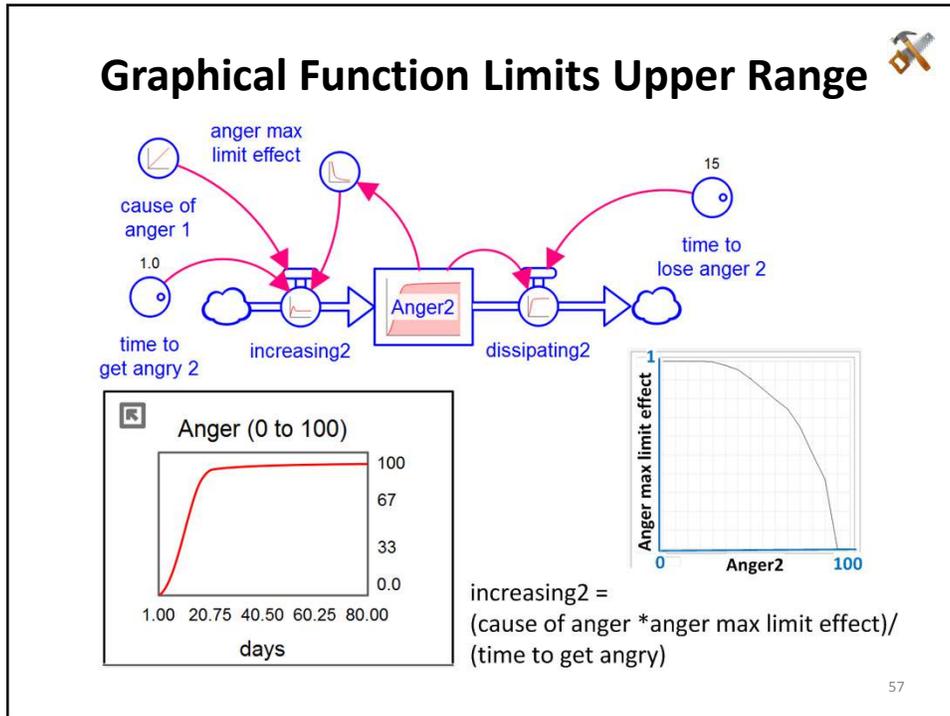
Algebraic Function Limits Upper Range

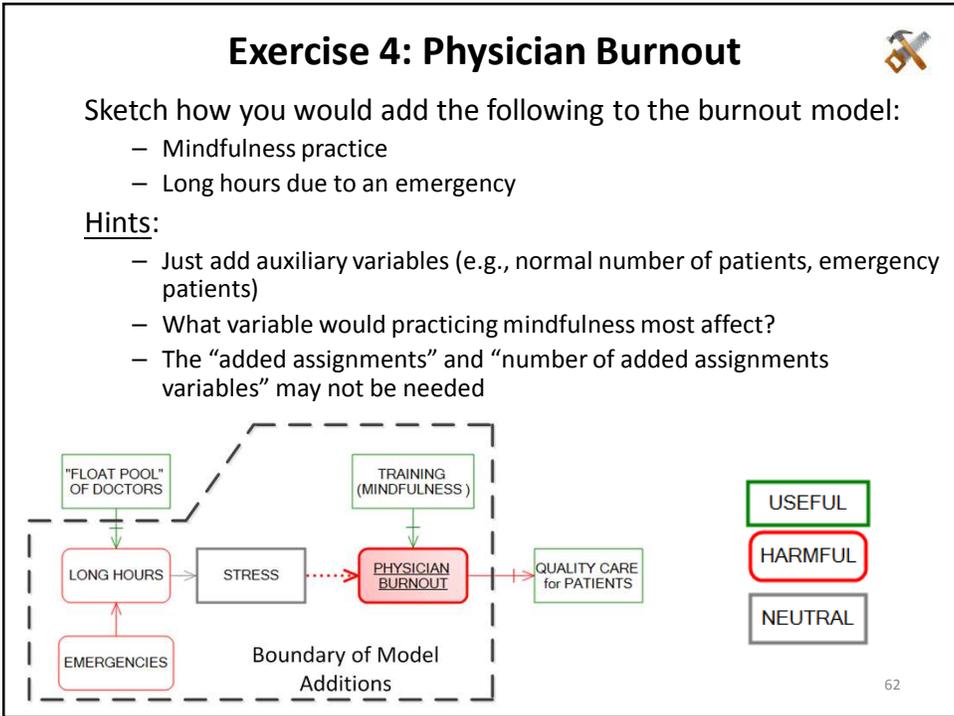
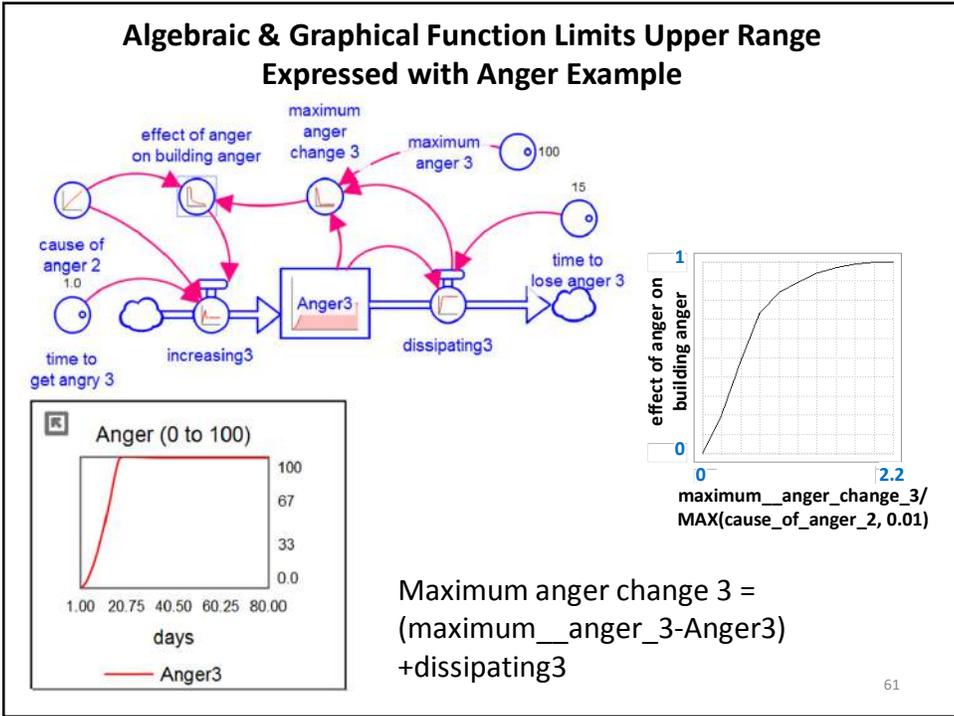


increasing1 =
 $(\text{cause of anger} * \text{available anger}) /$
 $(\text{time to get angry})$

available anger =
 $(\text{maximum anger} - \text{Anger1}) /$
 (maximum anger)

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Modeling Psychological and Sociological Dynamics



PART 5 – VALIDATING MODELS

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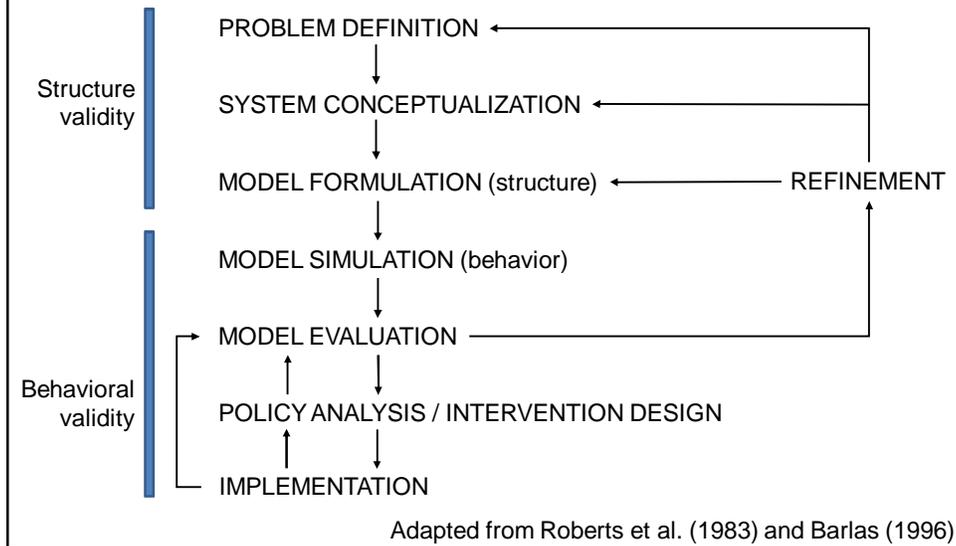
Model Validation

- A process of comparing the model and variables with
 - Extant published literature
 - Available data sources
 - Expert opinion

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The Iterative Nature of SD Model Development and Validation



Validating Models with Psychological and Sociological Variables

Validating models is a topic of many papers. Here are very general categories. Each have many different types of tests:

- Structural
- Behavioral
- Construct
- Data

Structural Validity

- Does the structure of the model correspond to what it is intended to represent in the real world?
- Does the structure in the model adequately support its purpose?
- (Verification) Does the model adequately represents the developers' conceptual description of the model?

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Behavioral Validity Supports the Model's Credibility

- Does the simulated behavior have sufficient accuracy for the model's intended purpose?
 - How well does it replicate any existing historical behavior or data (e.g., events)? Multiple datasets?
 - How well does it predict behavior patterns? (e.g., trends, period, frequencies, delays, amplitudes)
- How does the simulated data compare with the actual data if psychological or sociological variables are not included?

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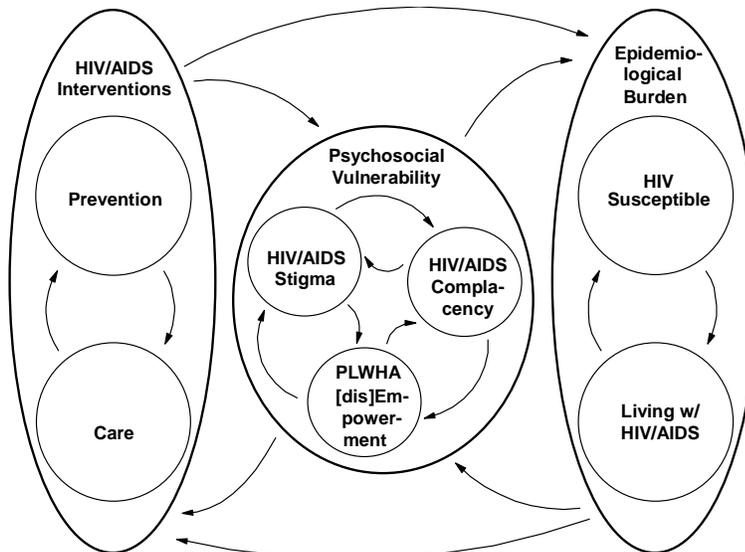
SD Model Validity by Tests of *Suitability, Consistency and Utility*

(Forrester & Senge, 1980; Barlas 1996; Martis, 2006)

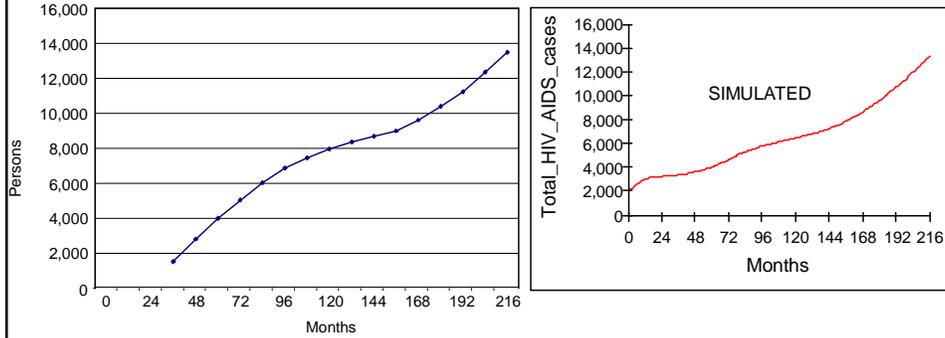
Validity Type	Tests of suitability	Tests of consistency	Tests of utility
Structural	<ul style="list-style-type: none"> • Structure-Verification • Dimensional-Consistency • Extreme-Conditions • Boundary-Adequacy 	<ul style="list-style-type: none"> • Face Validity • Parameter-Verification 	<ul style="list-style-type: none"> • Appropriateness for Audience
Behavioral	<ul style="list-style-type: none"> • Parameter Sensitivity • Structural Sensitivity • Policy Sensitivity and Robustness 	<ul style="list-style-type: none"> • Behavior-Reproduction • Behavior-Prediction • Behavior-Anomaly • Family Member • Surprising Behavior • Extreme-Policy • Boundary Adequacy • Behavior-Sensitivity • Statistical • Changed Behavior Prediction 	<ul style="list-style-type: none"> • Counter Intuitive Behavior • Implementable Policy

Conceptual framework for the HIV Empowerment Study

Lounsbury &
Levine 2002

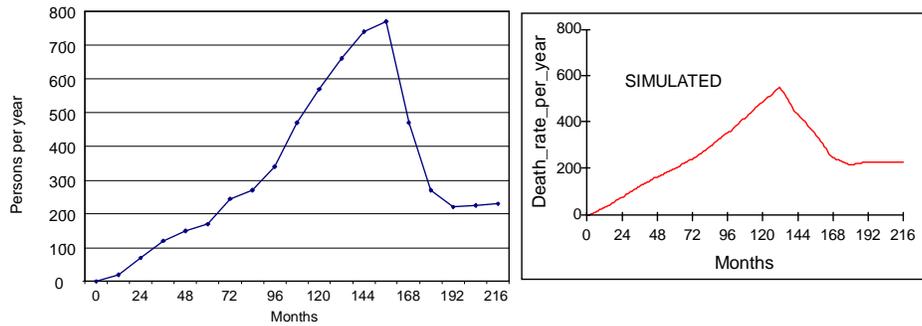


Actual and simulated reference mode for HIV/AIDS prevalence in Michigan, 1983 - 2001



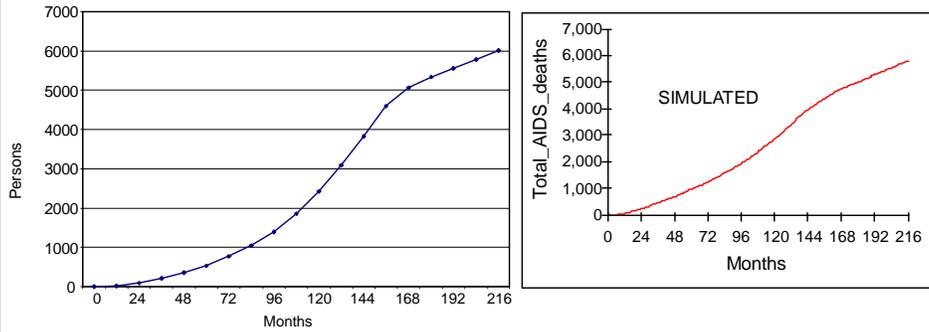
Lounsbury & Levine 2002

Actual and simulated reference mode for HIV/AIDS mortality rate per year in Michigan, 1983 - 2001



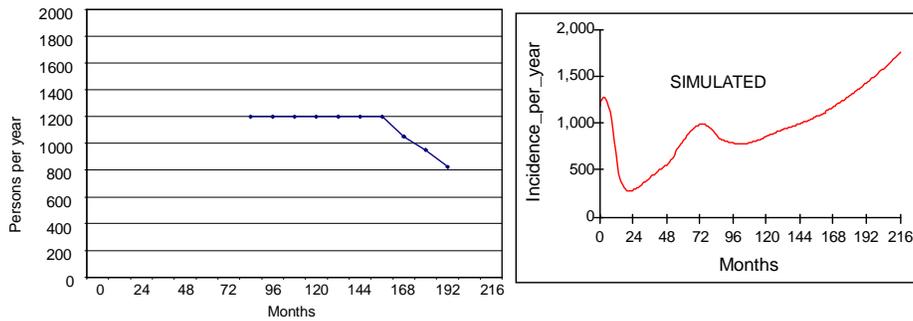
Lounsbury & Levine 2002

Actual and simulated reference mode for HIV/AIDS cumulative mortality in Michigan,1983 - 2001



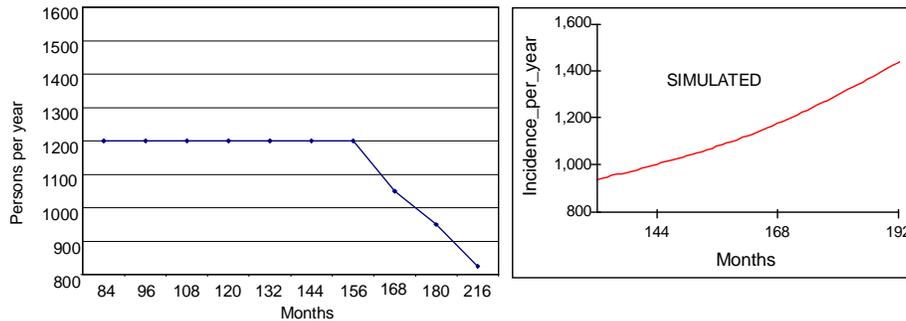
Lounsbury & Levine 2002

Actual and simulated reference mode for HIV/AIDS incidence per year in Michigan,1983 - 2001



Lounsbury & Levine 2002

Actual and simulated reference mode for HIV/AIDS incidence per year in Michigan, 1990 - 1999



Lounsbury & Levine 2002

Construct Validity

- Are the theories and assumptions underlying the model's subject correct and reasonable for the purpose of the model?
- Is the model (which is a theory) aligned with relevant external theories?
- Discussed as part of "psychological or sociological variable validation" earlier

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Data (and/or special knowledge, tacit expertise) Validation

- Is the data necessary for building (e.g., calibration) evaluating, and applying (virtual experiments, policy analyses) the model adequate and reliable for the intended purpose of the model?

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 **RESOURCES**

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Supplementary Material

- Annotated Bibliography of Psychological and Sociological Modeling
 - Key References (citations)
 - 1. Psychological and Sociological Variables
 - 2. Validating and Calibrating Psychological and Sociological Variables in Models
 - 3. Validating and Calibrating Models in General
 - 4. Psychological and Sociological Variable Examples
 - 5. Modeling in the Social Sciences
 - 6. Psychological and Sociological Dynamics
- Example Models

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