



# The Fallacy of Single-Point Forecasts

Introducing the BayesiaLab WebSimulator





Hello  
my name is

Stefan Conrady

# Today's Agenda

## Motivation & Challenge

- The Fallacy of Single-Point Forecasts

## Objective

- Explicit Communication of Distributions
- Independent Simulation and Evaluation by Stakeholders

## Case Study Topic

- Inventory/Capacity Planning Based on Forecasts



20 min.

# Today's Agenda

## Workflow

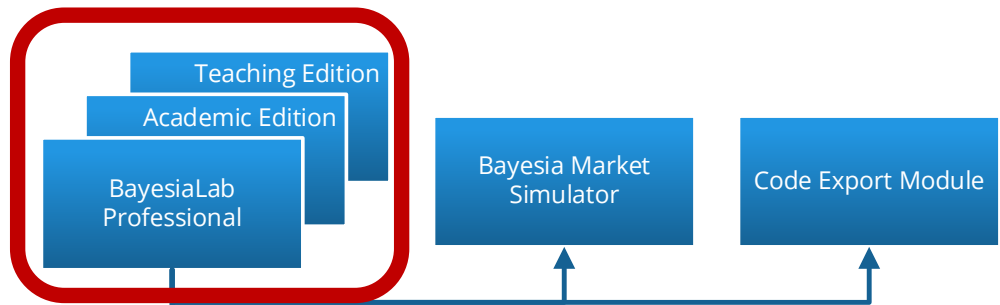
- In BayesiaLab
  - Create Bayesian Network Model
  - Search for Optimal Solution
  - Define WebSimulator Appearance
- In the WebSimulator
  - Upload Bayesian Network Model
  - Simulate Conditions
  - Import Predefined Scenarios



40 min.



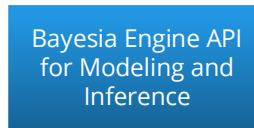
## Desktop Software



## Web Application



## API



# Today's Agenda

## Featured BayesiaLab Functions

- Decision Nodes



- Utility Nodes



- Equations

Normal(?Daily Demand?, ?Demand Forecast?, ?Demand Forecast Uncertainty (SD)?)

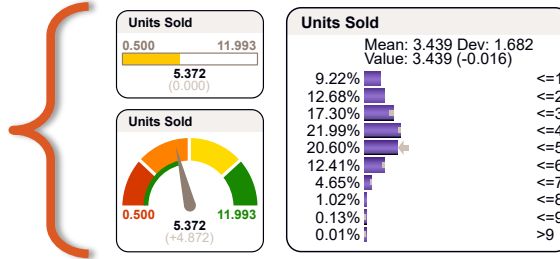
- Scenarios



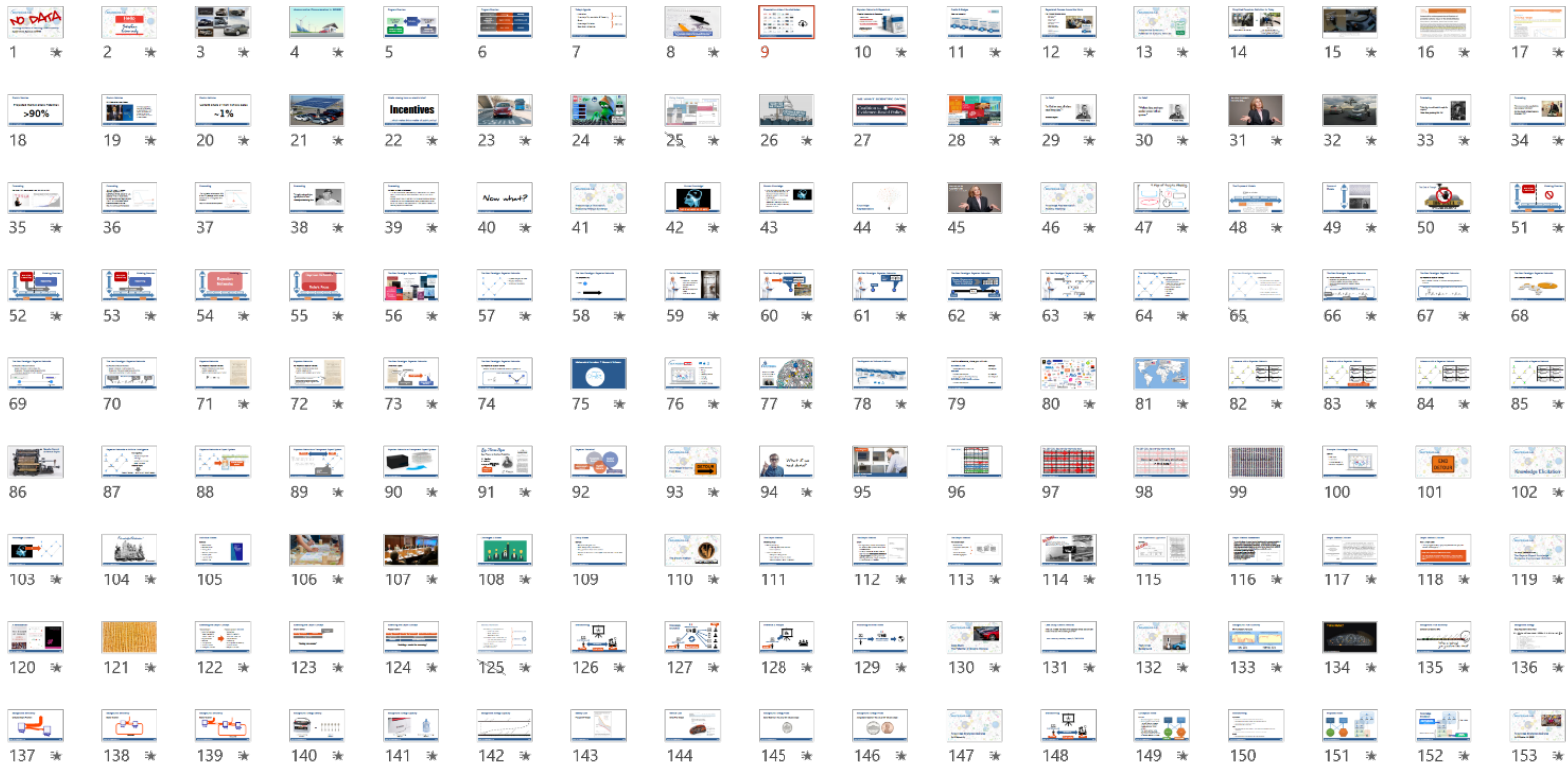
- Images on Nodes

- Node Appearance

- Policy Learning



# Slides, networks, and video will be available





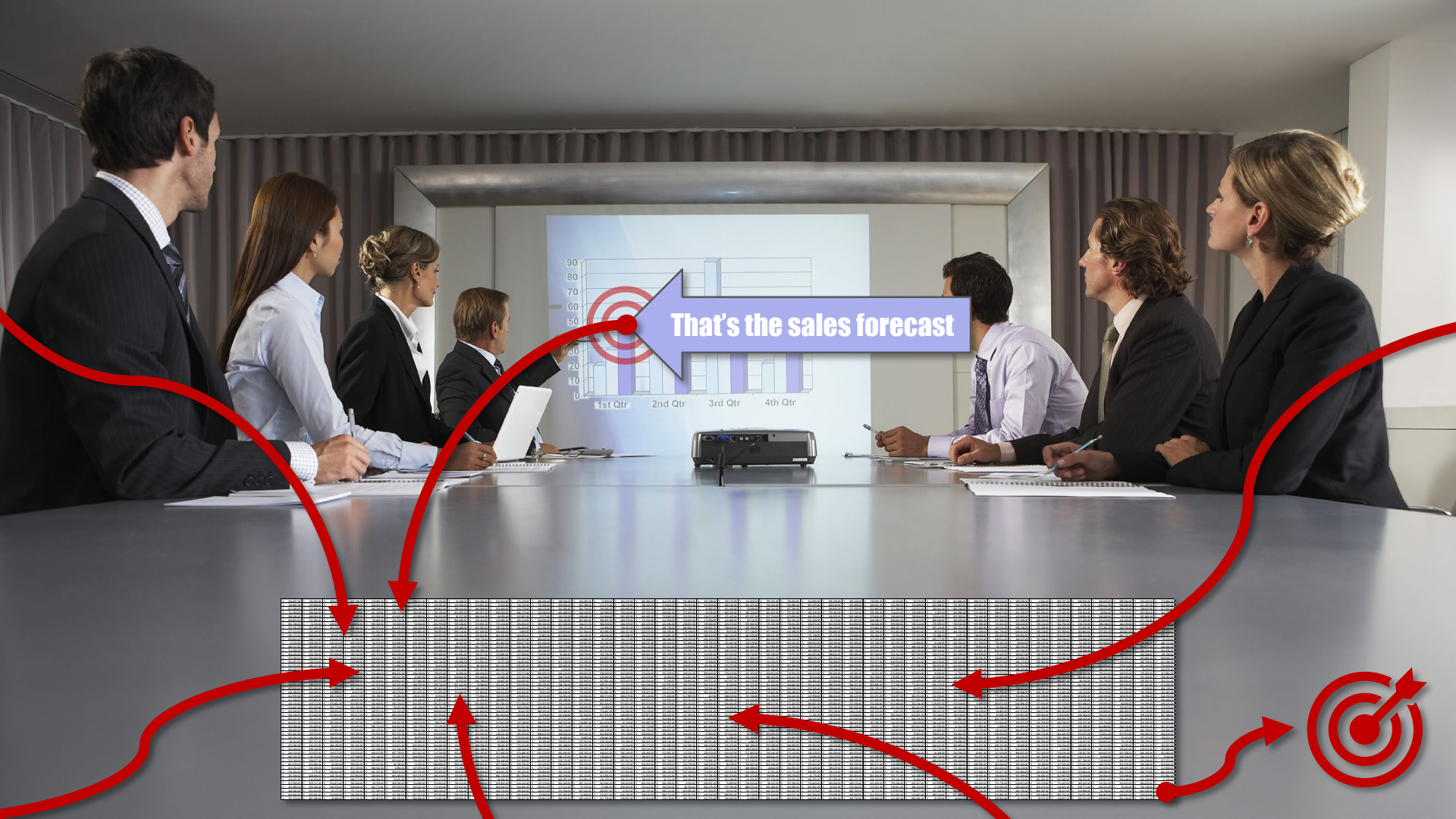
# Motivation

The Fallacy of Single-Point Forecasts



**What's the  
sales forecast?**





That's the sales forecast

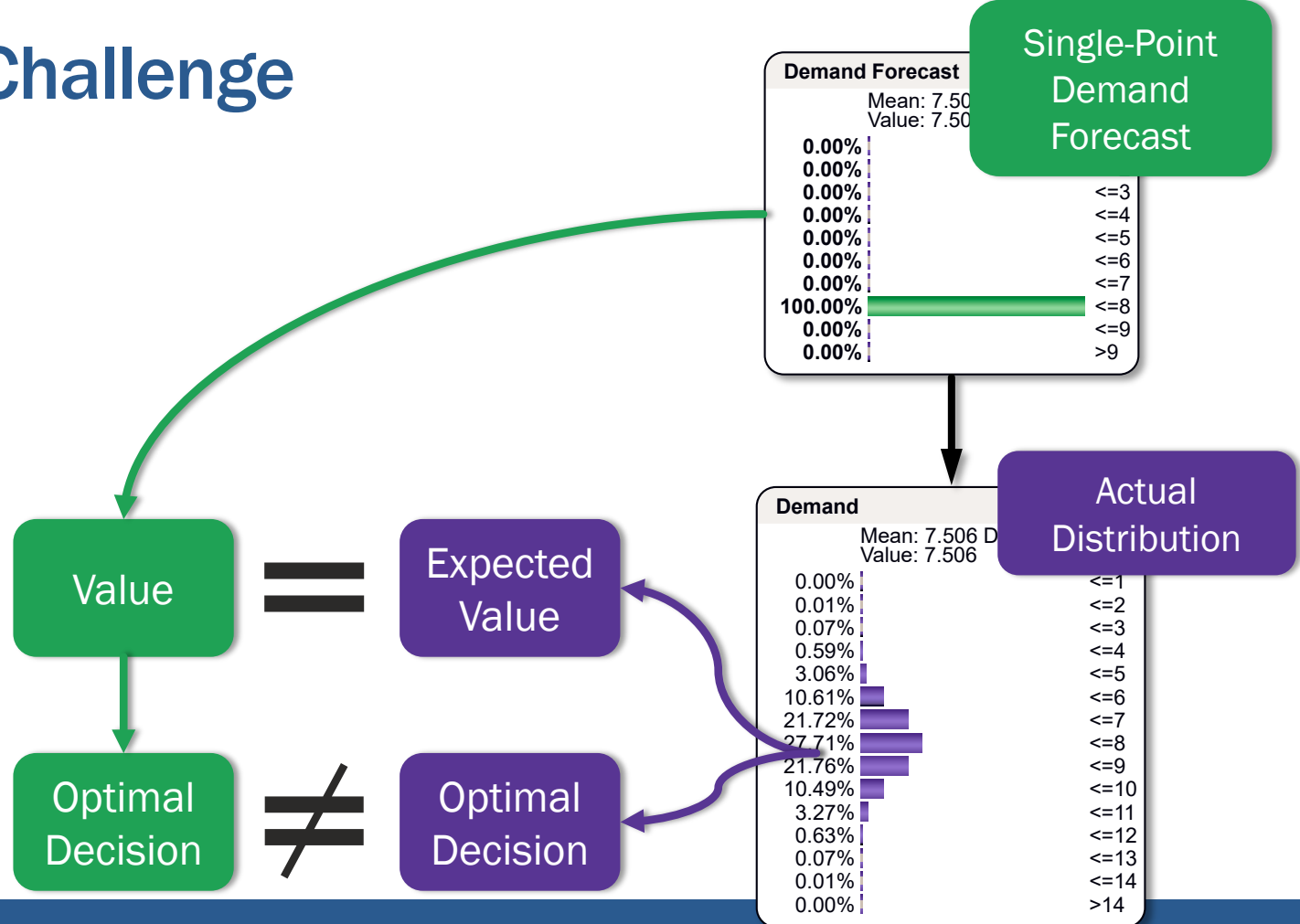


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# Challenge





**Demand**

Mean: 6.624 Dev: 2.499  
Value: 6.624

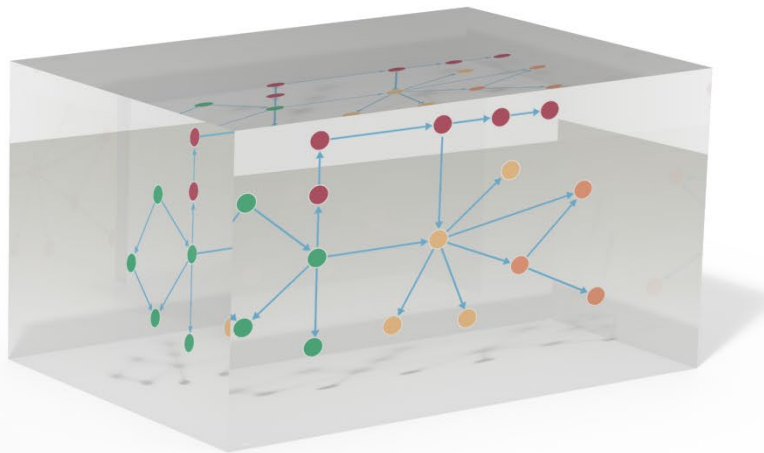
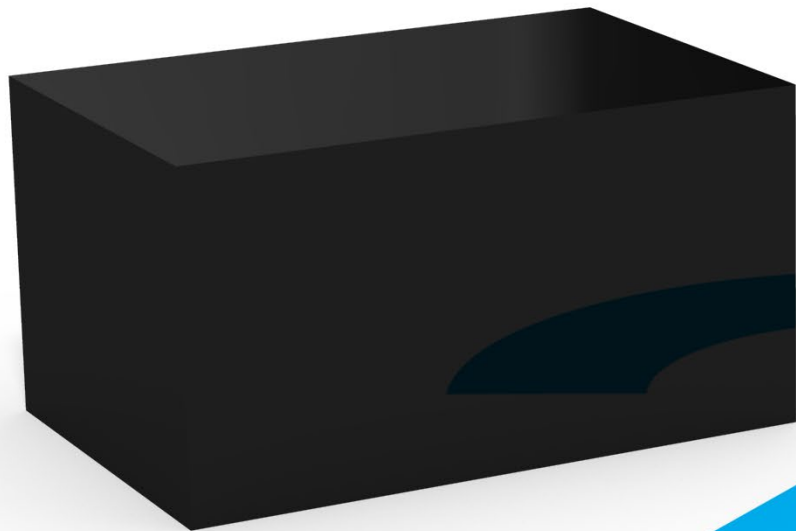
2.55%	█	<=1
3.43%	█	<=2
4.13%	█	<=3
5.34%	█	<=4
7.80%	█	<=5
11.93%	█	<=6
16.07%	█	<=7
17.62%	█	<=8
15.04%	█	<=9
9.61%	█	<=10
4.55%	█	<=11
1.52%	█	<=12
0.36%	█	<=13
0.06%	█	<=14
0.01%	█	>14

 **Distributions Required**

# Objective

**explicit** *adj* **1** stated or sh  
ing plainly and openly. ■  
*explicitus* straightforward

# Objective



# Case Study Caveat



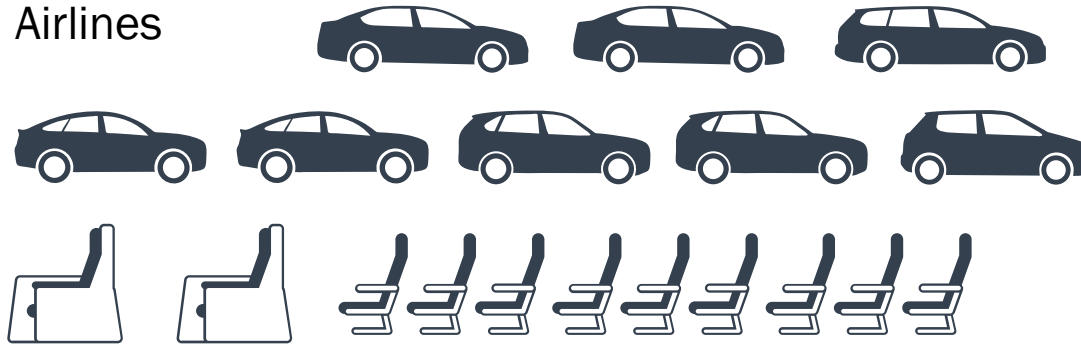
**SIMPLIFIED  
EXAMPLE!**

# Case Study

## Business Capacity/Inventory Planning Under Uncertainty



- Applicable to many industries, e.g.,
  - Car Rental
  - Hotels
  - Airlines





# Case Study

## Required Business Planning Assumptions

- Demand
- Profit per Unit Sold/Rented
- Cost per Unsold Unit (per Day)
- Cost per “Oversold” Unit (i.e., customer is denied service)

### Note

- This is a new business, i.e., we have no historical data.



Economy



*First*

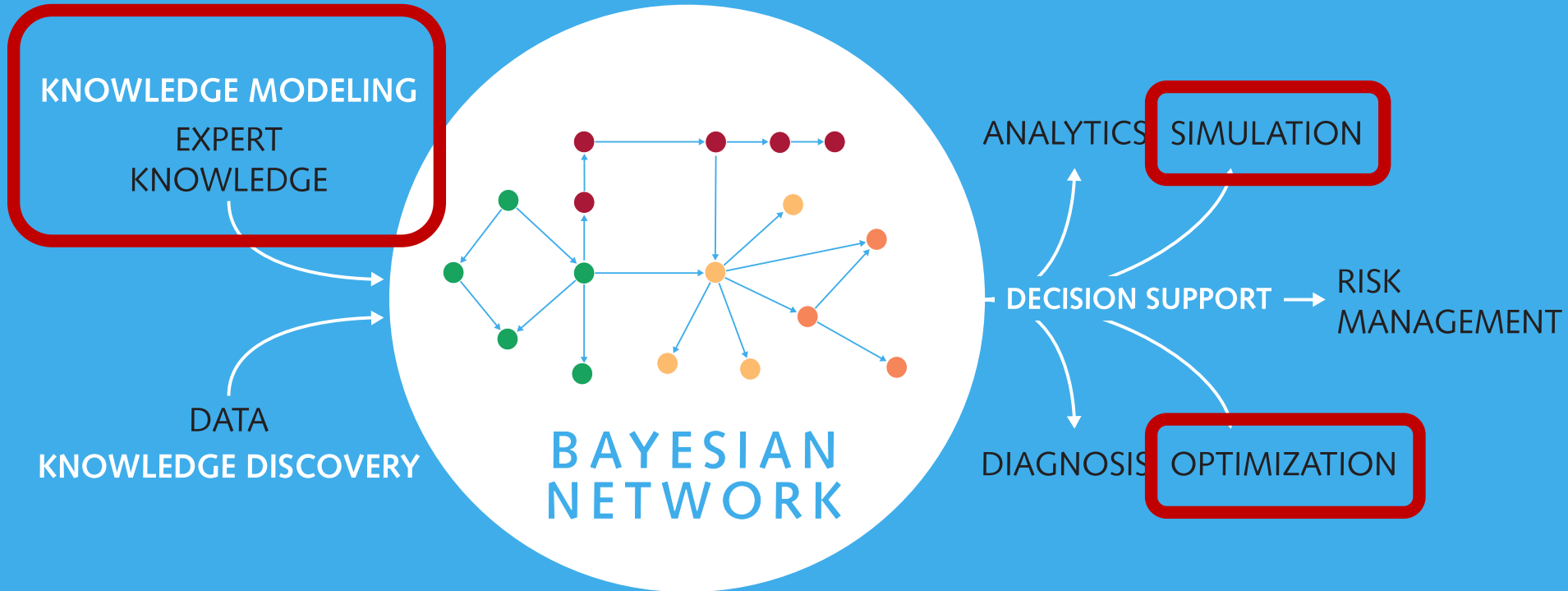


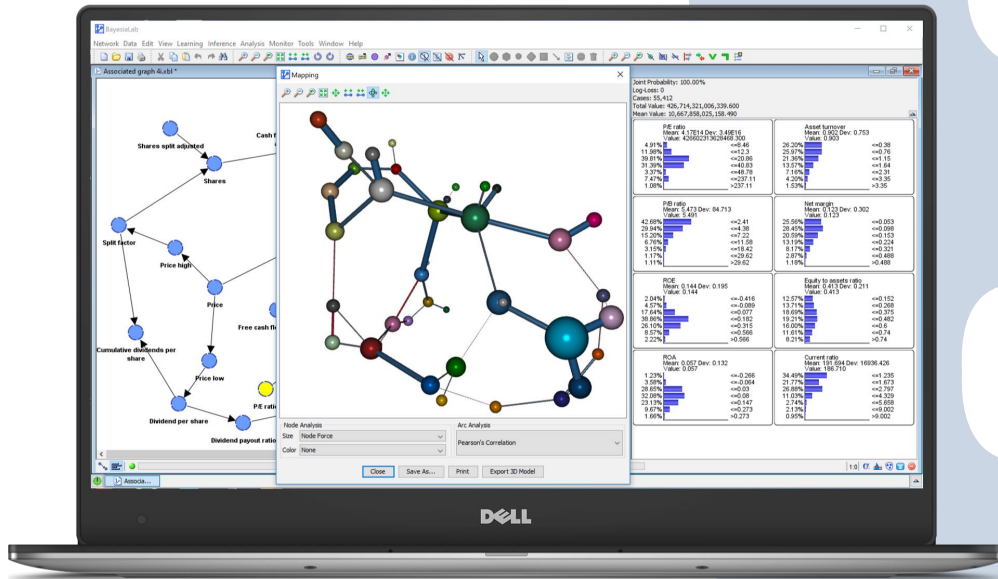
# Case Study

## Typical Planning Questions

- Given the demand forecast and other business assumptions, what is the optimal capacity/inventory level?
- Given a uncertainty in the forecasts, as represented by distributions, how should the target capacity be adjusted?

# Today's Workflow





A desktop software for:

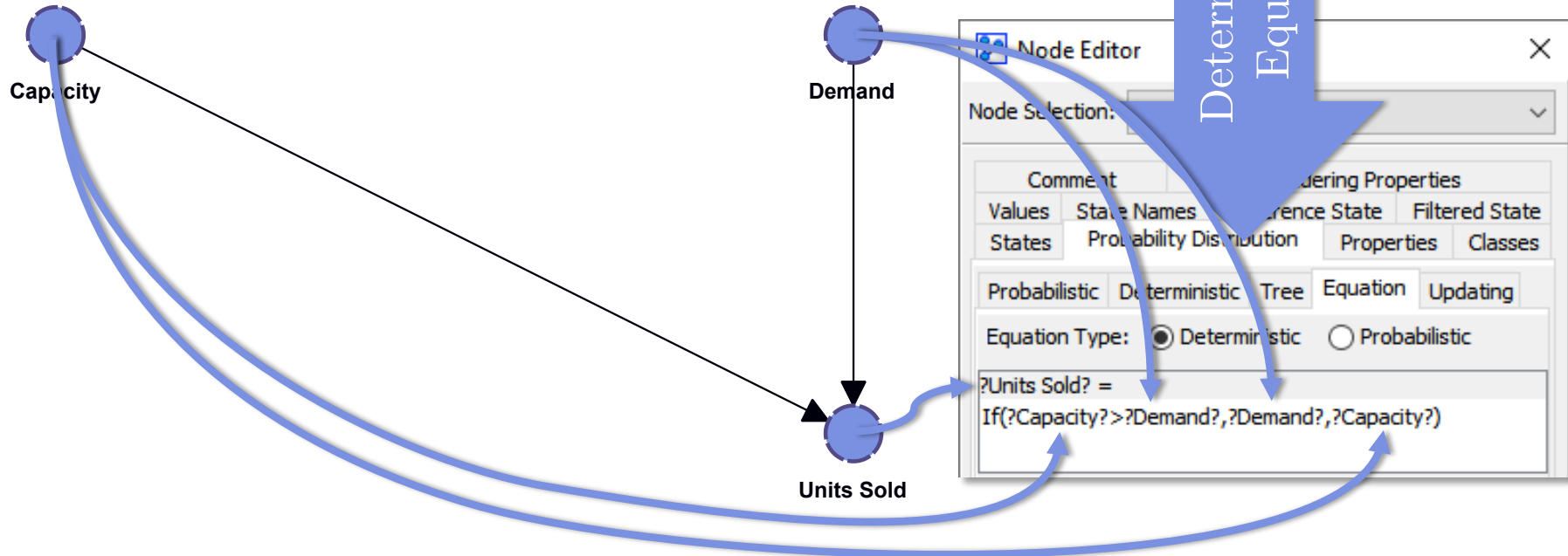
- encoding
- learning
- editing
- performing inference
- analyzing
- simulating
- optimizing

with Bayesian networks.



# Building a Bayesian Network in BayesiaLab

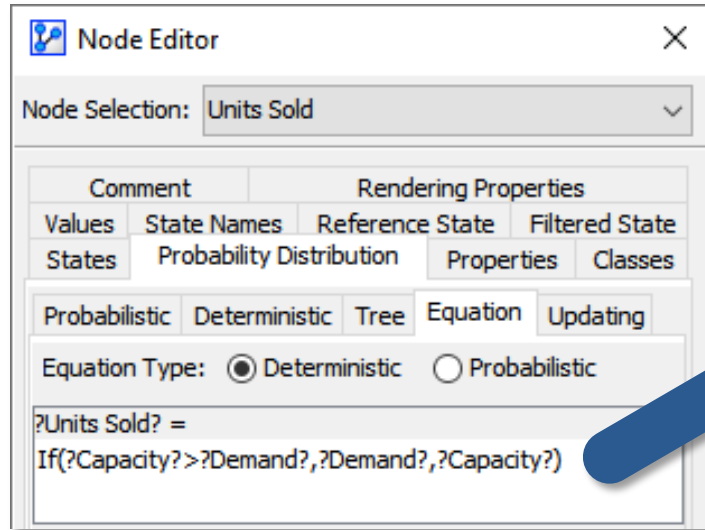
## Business Model





# Building a Bayesian Network

- Equation Produces Conditional Probability Table (CPT)



Node Editor

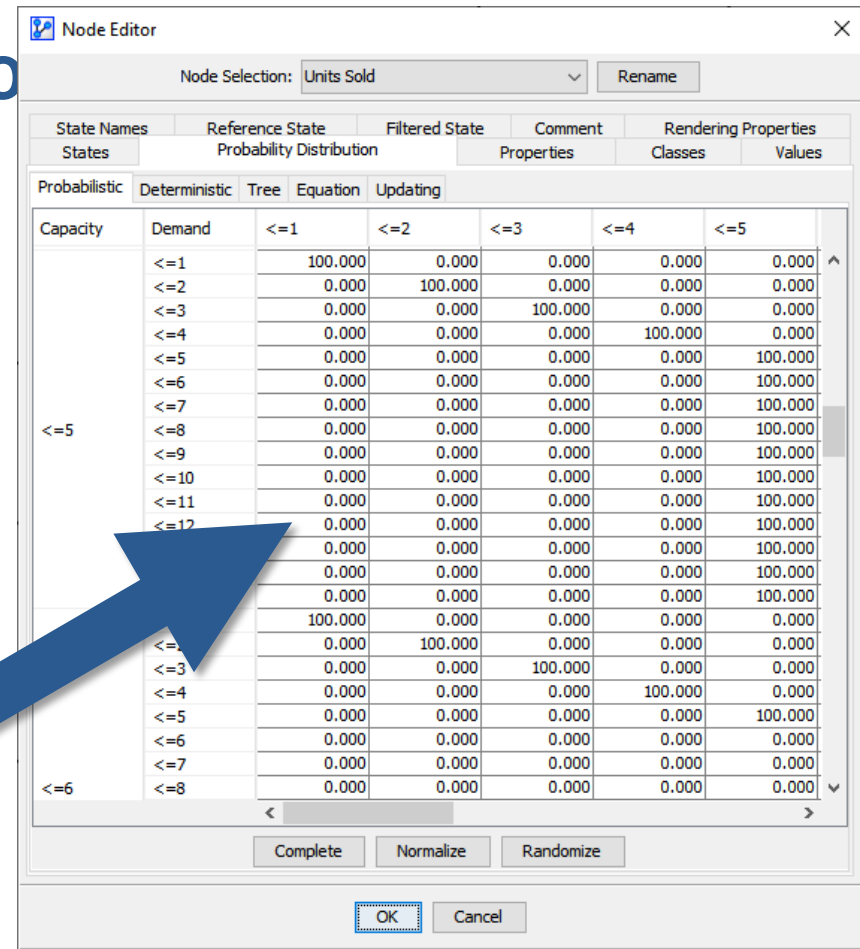
Node Selection: Units Sold

Comment	Rendering Properties
Values	State Names
States	Reference State
	Filtered State
	Properties
	Classes
	Values

Probabilistic Deterministic Tree Equation Updating

Equation Type:  Deterministic  Probabilistic

?Units Sold? =  
If(?Capacity? > ?Demand?, ?Demand?, ?Capacity?)



Node Editor

Node Selection: Units Sold

State Names	Reference State	Filtered State	Comment	Rendering Properties		
States	Probability Distribution	Properties	Classes	Values		
Capacity	Demand	<=1	<=2	<=3	<=4	<=5
<=1	<=1	100.000	0.000	0.000	0.000	0.000
<=2	<=2	0.000	100.000	0.000	0.000	0.000
<=3	<=3	0.000	0.000	100.000	0.000	0.000
<=4	<=4	0.000	0.000	0.000	100.000	0.000
<=5	<=5	0.000	0.000	0.000	0.000	100.000
<=6	<=6	0.000	0.000	0.000	0.000	100.000
<=7	<=7	0.000	0.000	0.000	0.000	100.000
<=8	<=8	0.000	0.000	0.000	0.000	100.000
<=9	<=9	0.000	0.000	0.000	0.000	100.000
<=10	<=10	0.000	0.000	0.000	0.000	100.000
<=11	<=11	0.000	0.000	0.000	0.000	100.000
<=12	<=12	0.000	0.000	0.000	0.000	100.000
<=13	<=13	0.000	0.000	0.000	0.000	100.000
<=14	<=14	0.000	0.000	0.000	0.000	100.000
<=15	<=15	100.000	0.000	0.000	0.000	0.000
<=16	<=16	0.000	100.000	0.000	0.000	0.000
<=17	<=17	0.000	0.000	100.000	0.000	0.000
<=18	<=18	0.000	0.000	0.000	100.000	0.000
<=19	<=19	0.000	0.000	0.000	0.000	100.000
<=20	<=20	0.000	0.000	0.000	0.000	100.000
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<=30	<=30	0.000	0.000	0.000	0.000	100.000
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<=33	<=33	0.000	0.000	0.000	0.000	100.000
<=34	<=34	0.000	0.000	0.000	0.000	100.000
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<=36	<=36	0.000	0.000	0.000	0.000	100.000
<=37	<=37	0.000	0.000	0.000	0.000	100.000
<=38	<=38	0.000	0.000	0.000	0.000	100.000
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<=40	<=40	0.000	0.000	0.000	0.000	100.000
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<=42	<=42	0.000	0.000	0.000	0.000	100.000
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<=45	<=45	0.000	0.000	0.000	0.000	100.000
<=46	<=46	0.000	0.000	0.000	0.000	100.000
<=47	<=47	0.000	0.000	0.000	0.000	100.000
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<=49	<=49	0.000	0.000	0.000	0.000	100.000
<=50	<=50	0.000	0.000	0.000	0.000	100.000
<=51	<=51	0.000	0.000	0.000	0.000	100.000
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<=58	<=58	0.000	0.000	0.000	0.000	100.000
<=59	<=59	0.000	0.000	0.000	0.000	100.000
<=60	<=60	0.000	0.000	0.000	0.000	100.000
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<=65	<=65	0.000	0.000	0.000	0.000	100.000
<=66	<=66	0.000	0.000	0.000	0.000	100.000
<=67	<=67	0.000	0.000	0.000	0.000	100.000
<=68	<=68	0.000	0.000	0.000	0.000	100.000
<=69	<=69	0.000	0.000	0.000	0.000	100.000
<=70	<=70	0.000	0.000	0.000	0.000	100.000
<=71	<=71	0.000	0.000	0.000	0.000	100.000
<=72	<=72	0.000	0.000	0.000	0.000	100.000
<=73	<=73	0.000	0.000	0.000	0.000	100.000
<=74	<=74	0.000	0.000	0.000	0.000	100.000
<=75	<=75	0.000	0.000	0.000	0.000	100.000
<=76	<=76	0.000	0.000	0.000	0.000	100.000
<=77	<=77	0.000	0.000	0.000	0.000	100.000
<=78	<=78	0.000	0.000	0.000	0.000	100.000
<=79	<=79	0.000	0.000	0.000	0.000	100.000
<=80	<=80	0.000	0.000	0.000	0.000	100.000
<=81	<=81	0.000	0.000	0.000	0.000	100.000
<=82	<=82	0.000	0.000	0.000	0.000	100.000
<=83	<=83	0.000	0.000	0.000	0.000	100.000
<=84	<=84	0.000	0.000	0.000	0.000	100.000
<=85	<=85	0.000	0.000	0.000	0.000	100.000
<=86	<=86	0.000	0.000	0.000	0.000	100.000
<=87	<=87	0.000	0.000	0.000	0.000	100.000
<=88	<=88	0.000	0.000	0.000	0.000	100.000
<=89	<=89	0.000	0.000	0.000	0.000	100.000
<=90	<=90	0.000	0.000	0.000	0.000	100.000
<=91	<=91	0.000	0.000	0.000	0.000	100.000
<=92	<=92	0.000	0.000	0.000	0.000	100.000
<=93	<=93	0.000	0.000	0.000	0.000	100.000
<=94	<=94	0.000	0.000	0.000	0.000	100.000
<=95	<=95	0.000	0.000	0.000	0.000	100.000
<=96	<=96	0.000	0.000	0.000	0.000	100.000
<=97	<=97	0.000	0.000	0.000	0.000	100.000
<=98	<=98	0.000	0.000	0.000	0.000	100.000
<=99	<=99	0.000	0.000	0.000	0.000	100.000
<=100	<=100	0.000	0.000	0.000	0.000	100.000

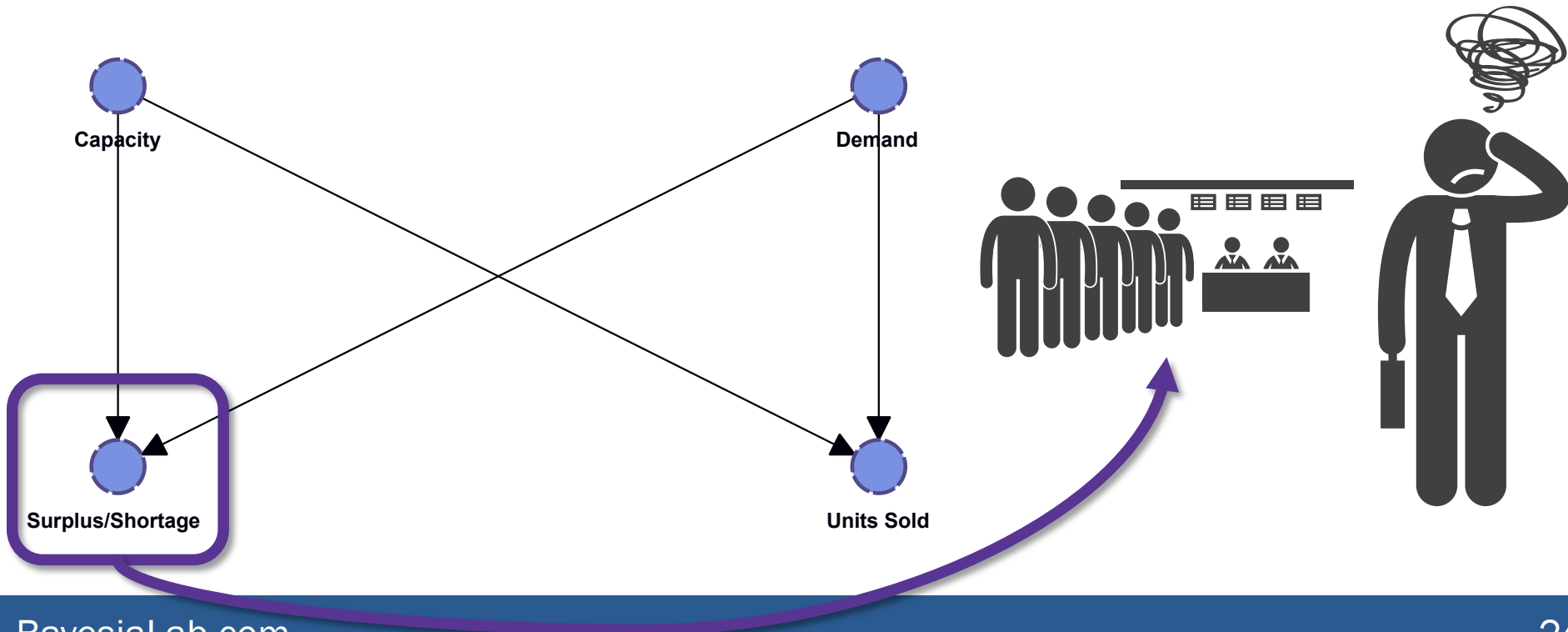
Complete Normalize Randomize

OK Cancel



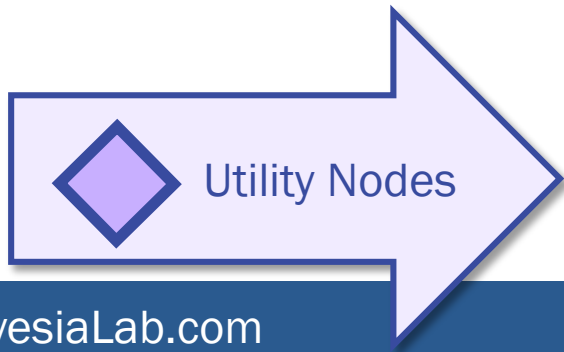
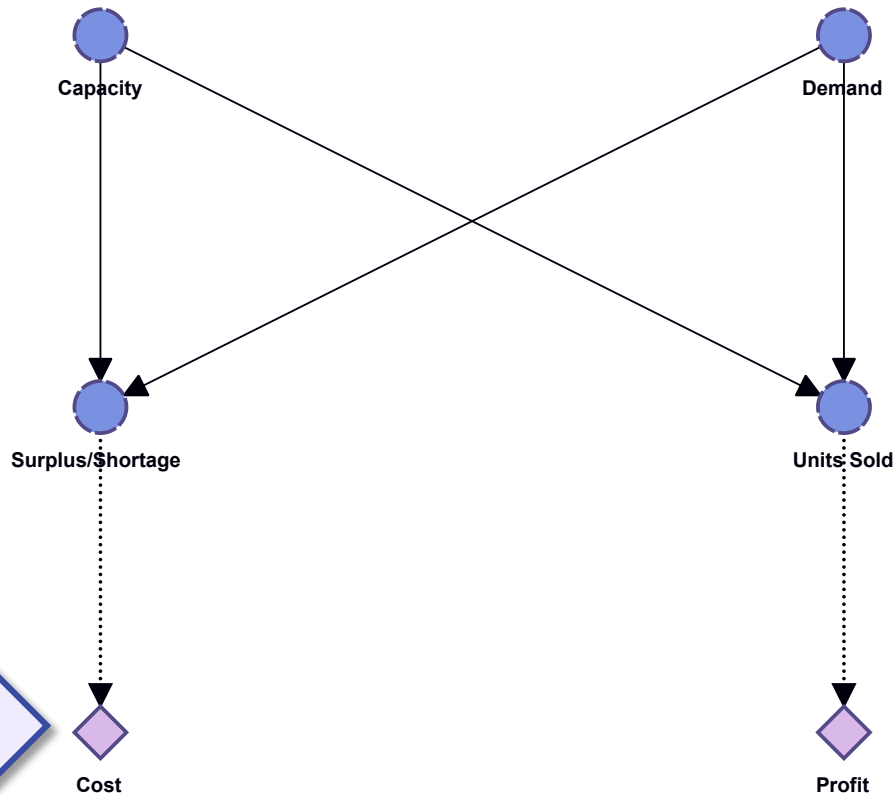
# Building a Bayesian Network

## Business Model



# Building a Bayesian Network

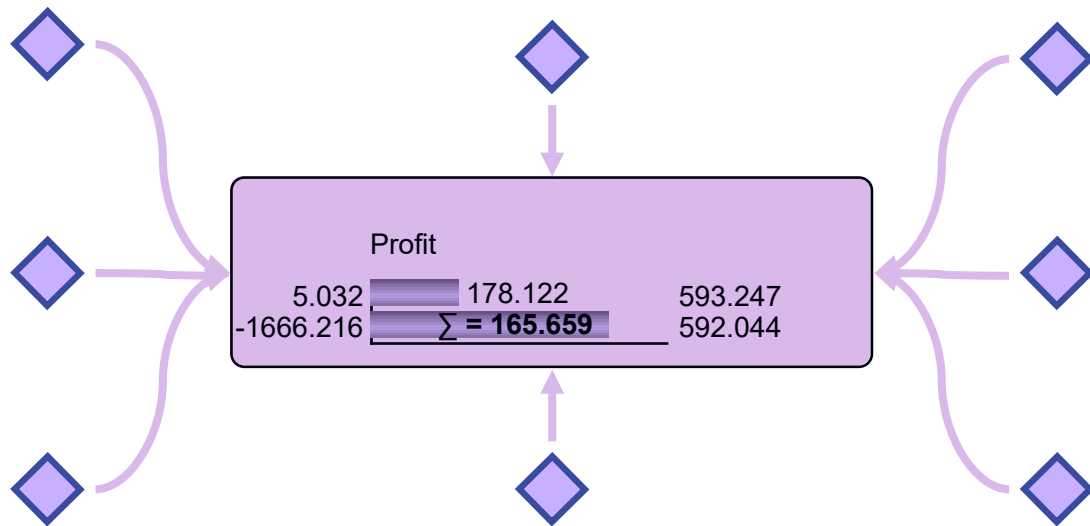
## Business Model



# Building a Bayesian Network

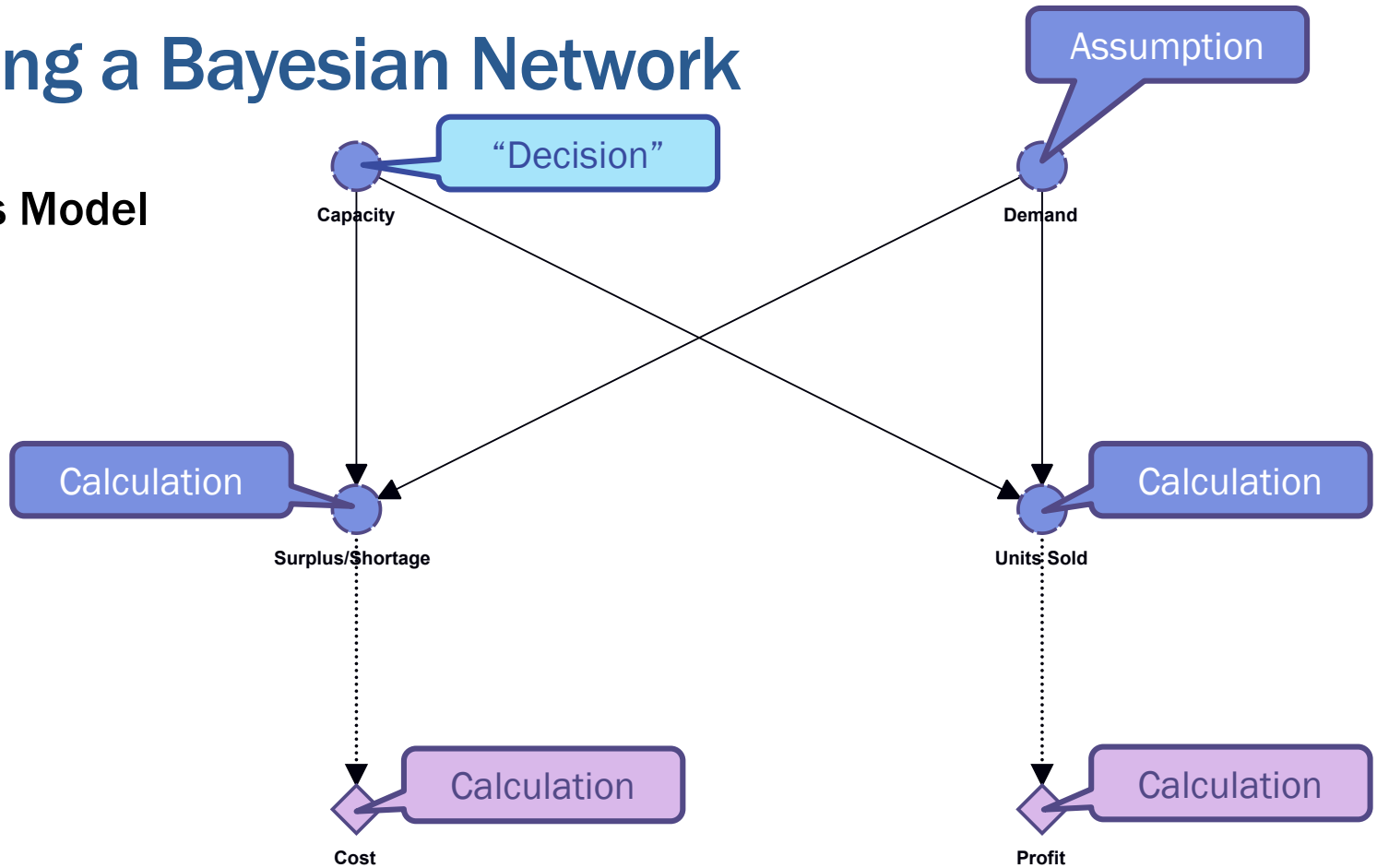
## Utility Nodes

- BayesiaLab adds the values of all Utility Nodes automatically in the background.



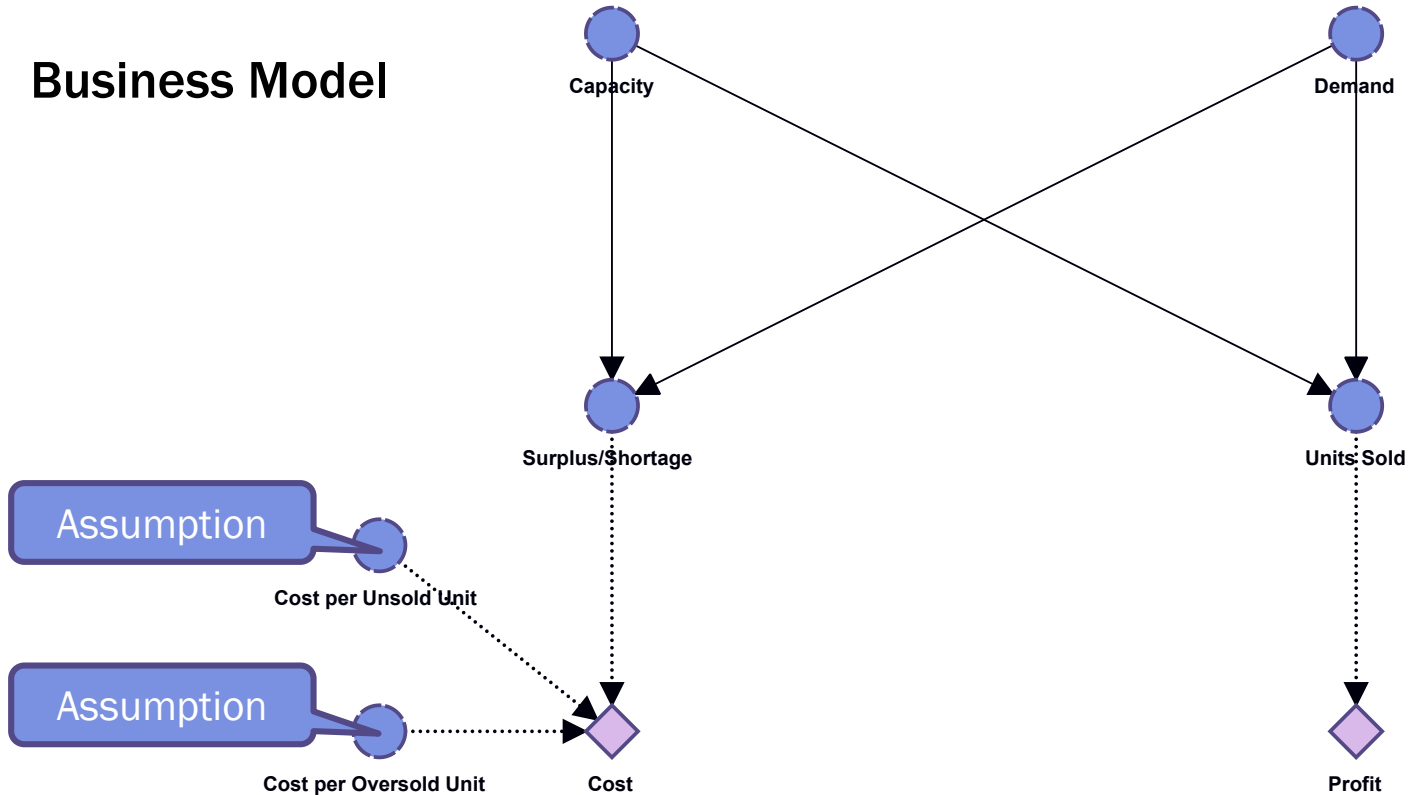
# Building a Bayesian Network

## Business Model



# Building a Bayesian Network

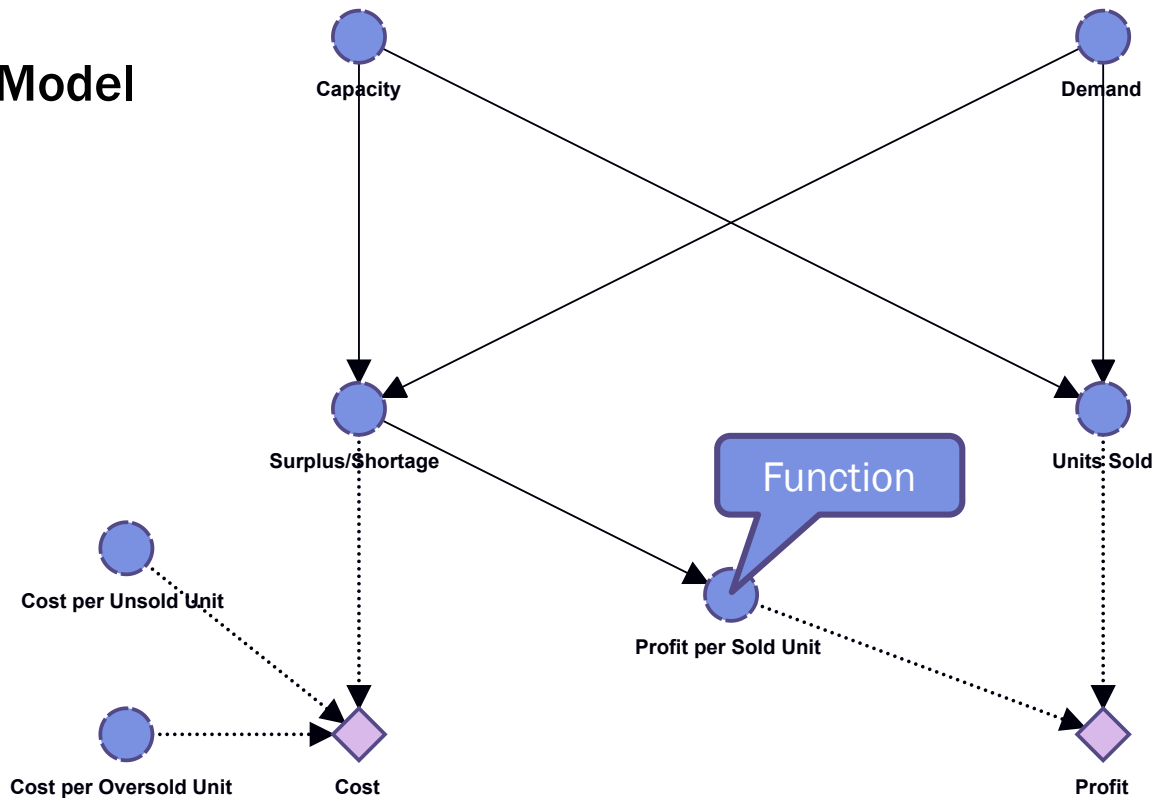
## Business Model





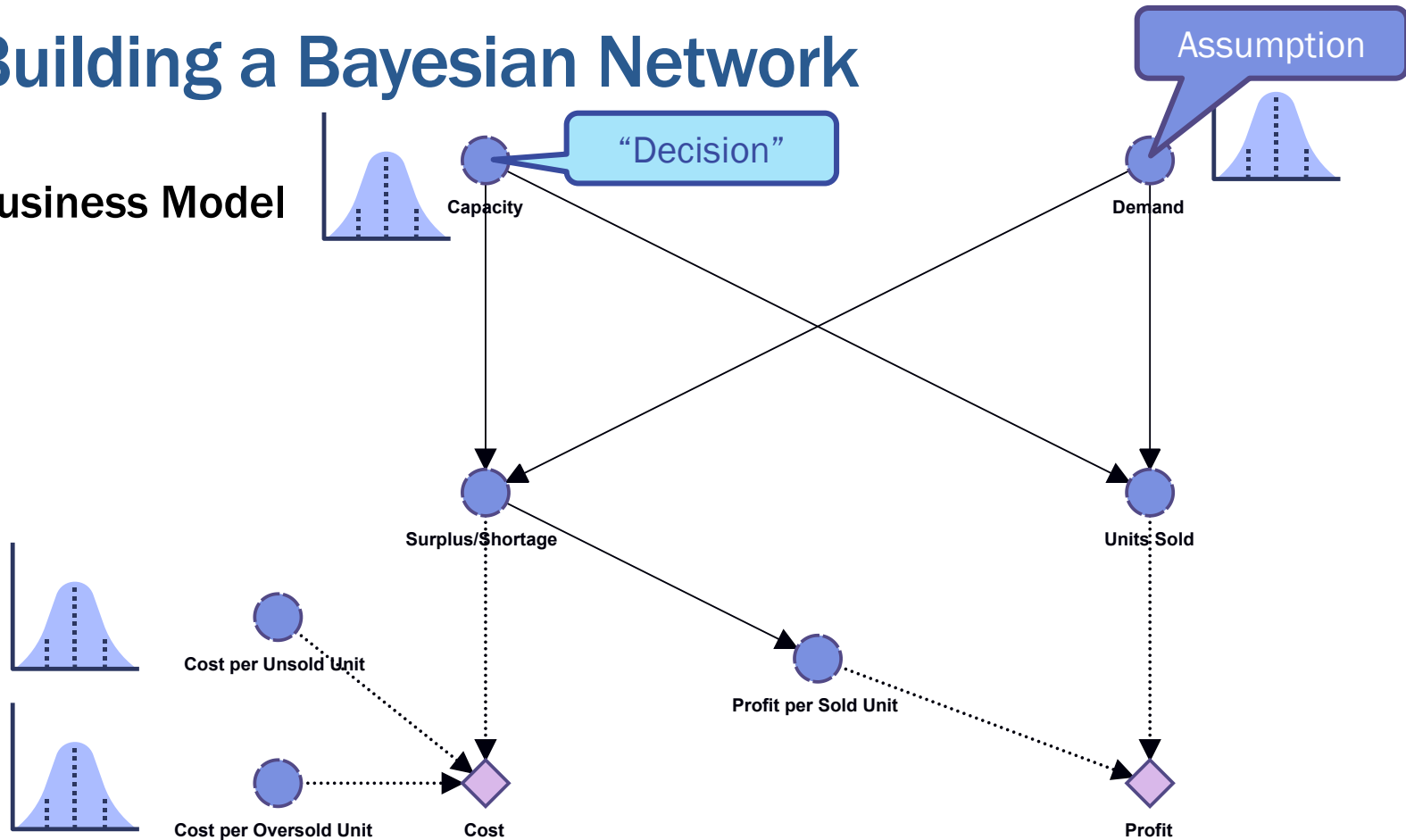
# Building a Bayesian Network

## Business Model



# Building a Bayesian Network

Business Model



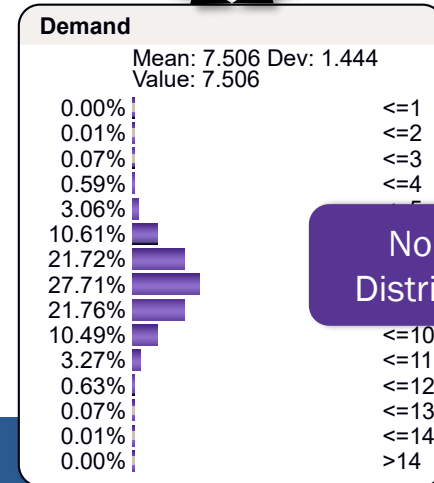
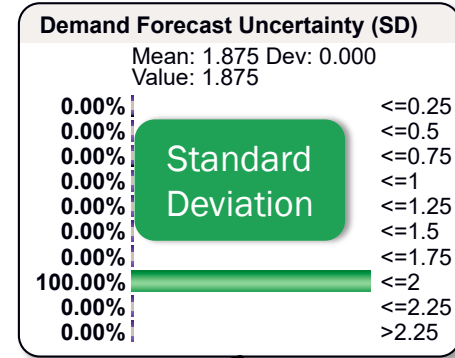
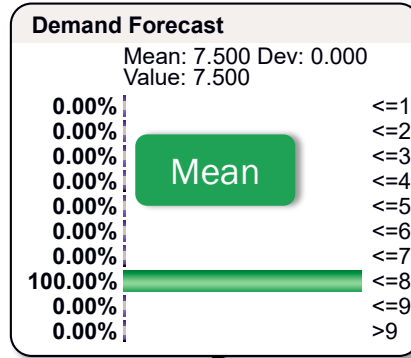
# Building a Bayesian Network

## Synthesizing Distributions

- For convenience, we generate the distributions of the assumptions parametrically, using mean and standard deviation.
- It's an easy way to think about assumptions.

Note: we could use entirely arbitrary distributions for our assumptions.

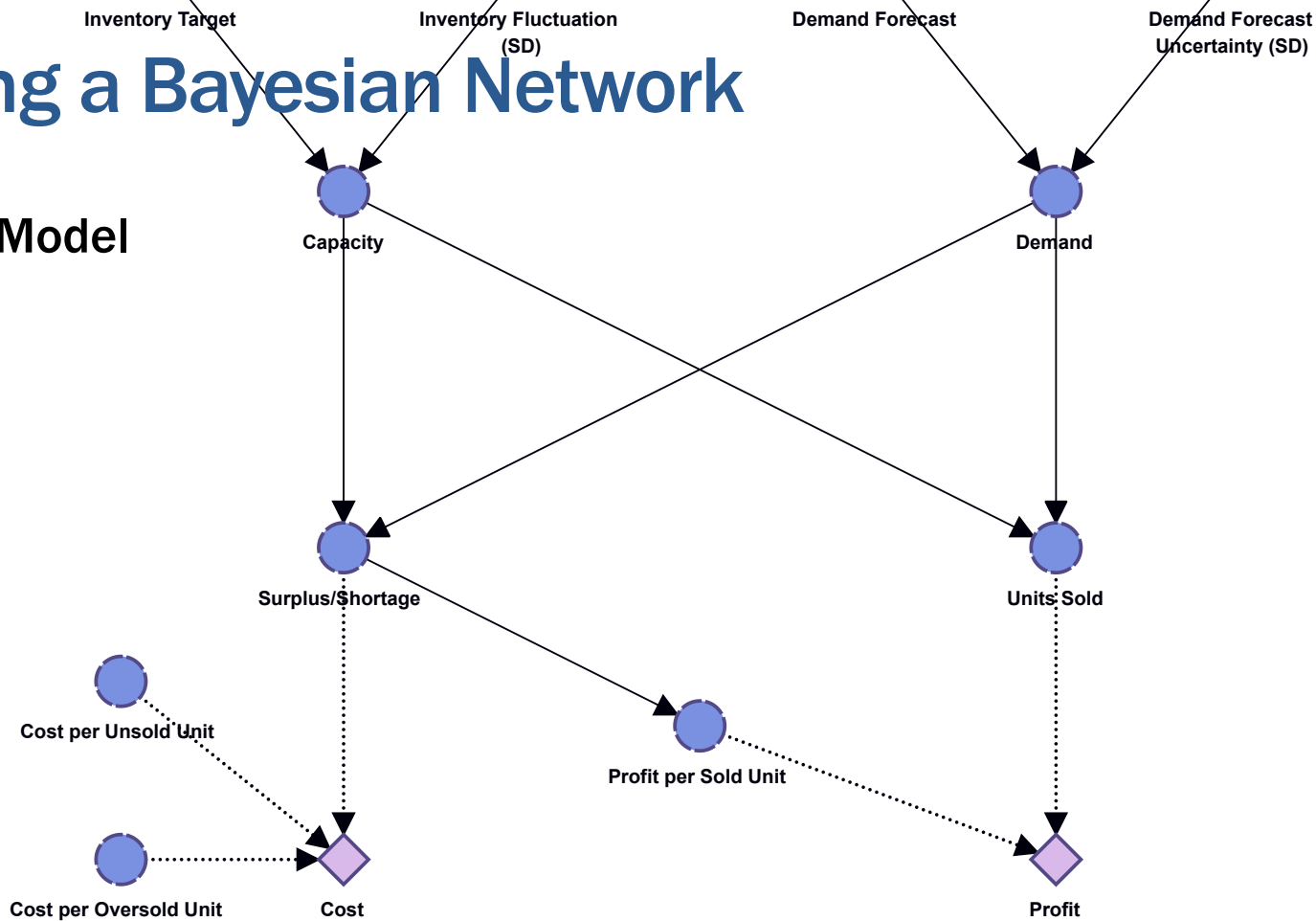
Demand		
Mean: 7.049 Dev: 3.760 Value: 7.049		
9.32%		<=1
4.87%		<=2
2.23%		<=3
6.81%		<=4
5.13%		<=5
13.74%		<=6
2.18%		<=7
7.07%		<=8
22.78%		<=9
1.55%		<=10
0.67%		<=11
19.85%		<=12
0.11%		<=13
0.04%		<=14
3.58%		>14



Normal Distribution

# Building a Bayesian Network

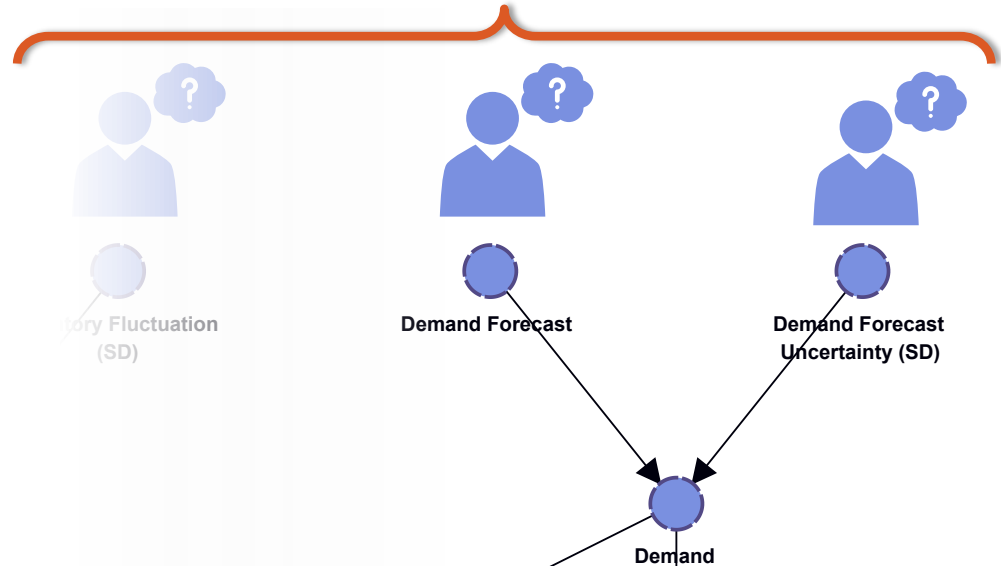
## Business Model



# Building a Bayesian Network

## Business Model

Judgment, Assessment, Guess, Estimate, Forecast, etc.



# Building a Bayesian Network

## Business Model

Judgment, Assessment, Guess, Estimate, Forecast, etc.



Node Editor

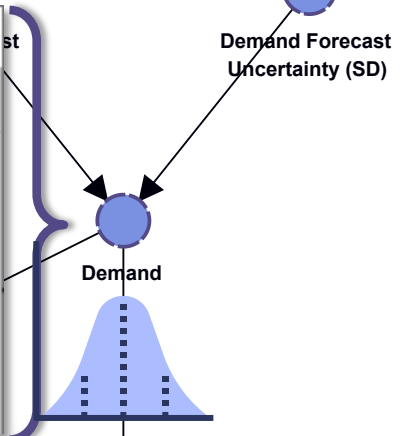
Node Selection: Demand Rename

Reference State	Filtered State	Comment	Rendering Properties
States	Probability Distribution	Properties	Classes
Values	State Names		

Probabilistic  Deterministic  Tree  Equation  Updating

Equation Type:  Deterministic  Probabilistic

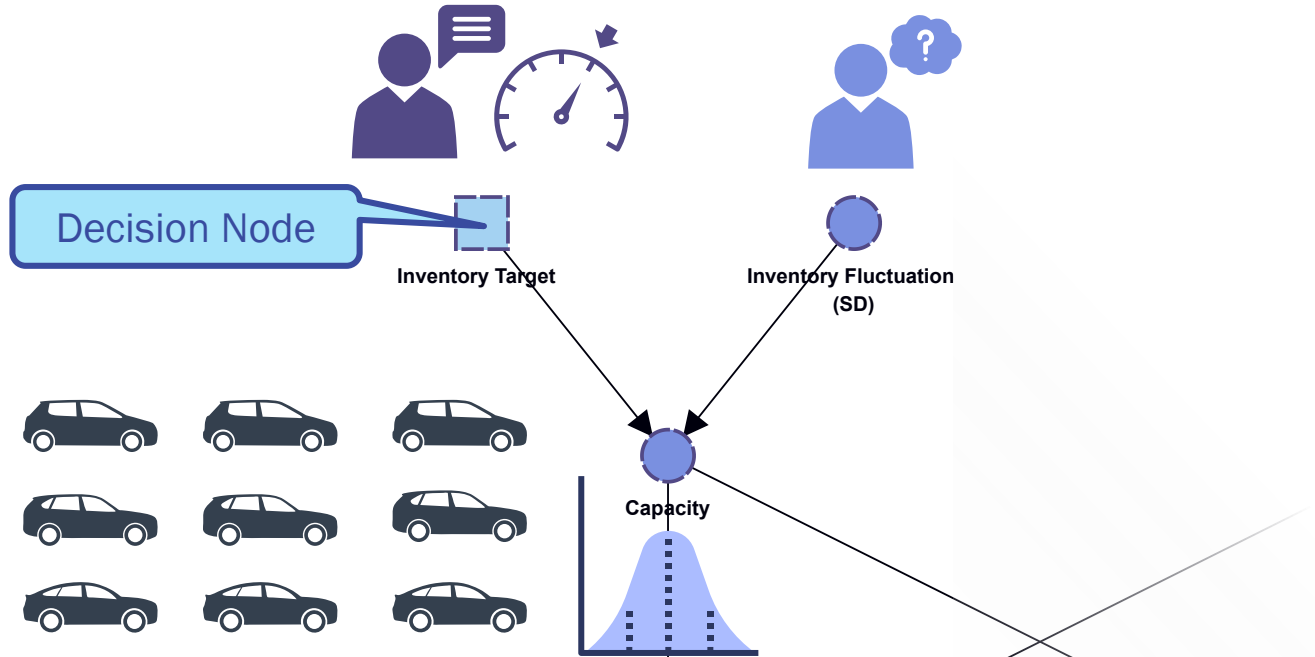
$P(?Demand? | ?Demand Forecast?, ?Demand Forecast Uncertainty (SD)?) =$   
 $Normal(?Demand?, ?Demand Forecast?, ?Demand Forecast Uncertainty (SD)?)$



Probabilistic Equation

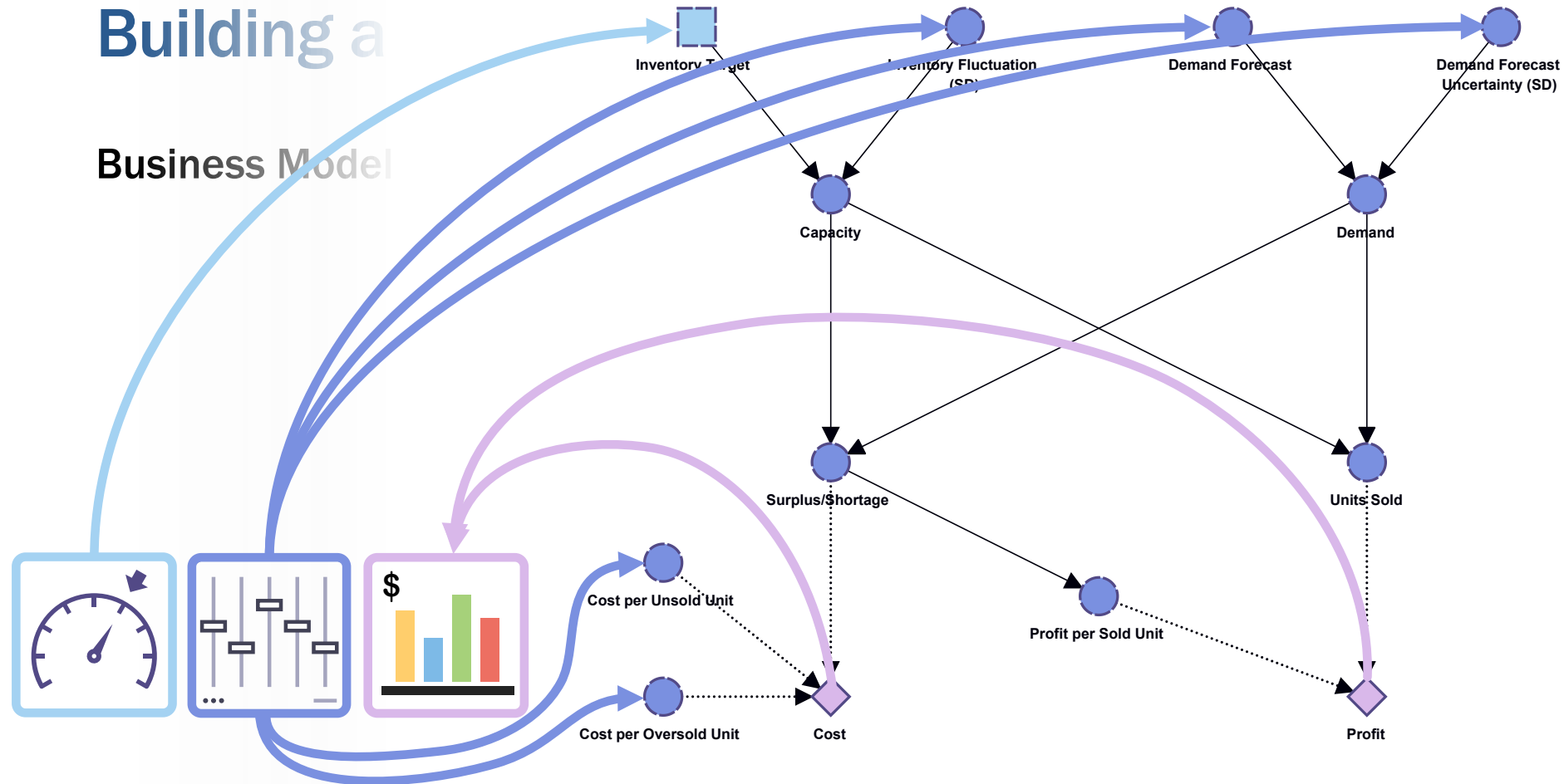
# Building a Bayesian Network

## Business Model



# Building a

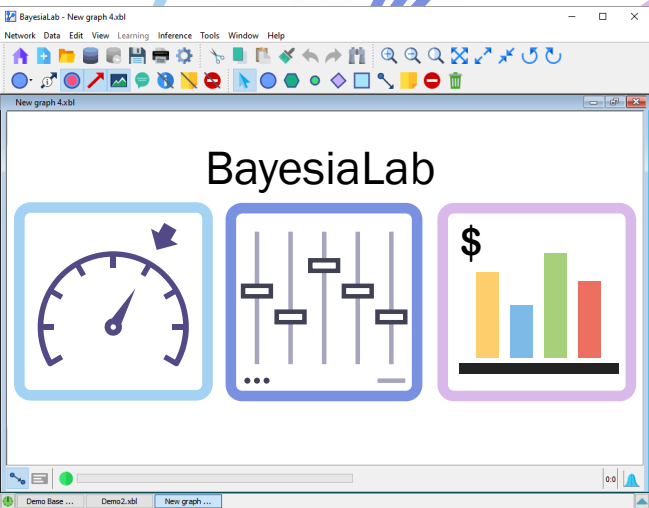
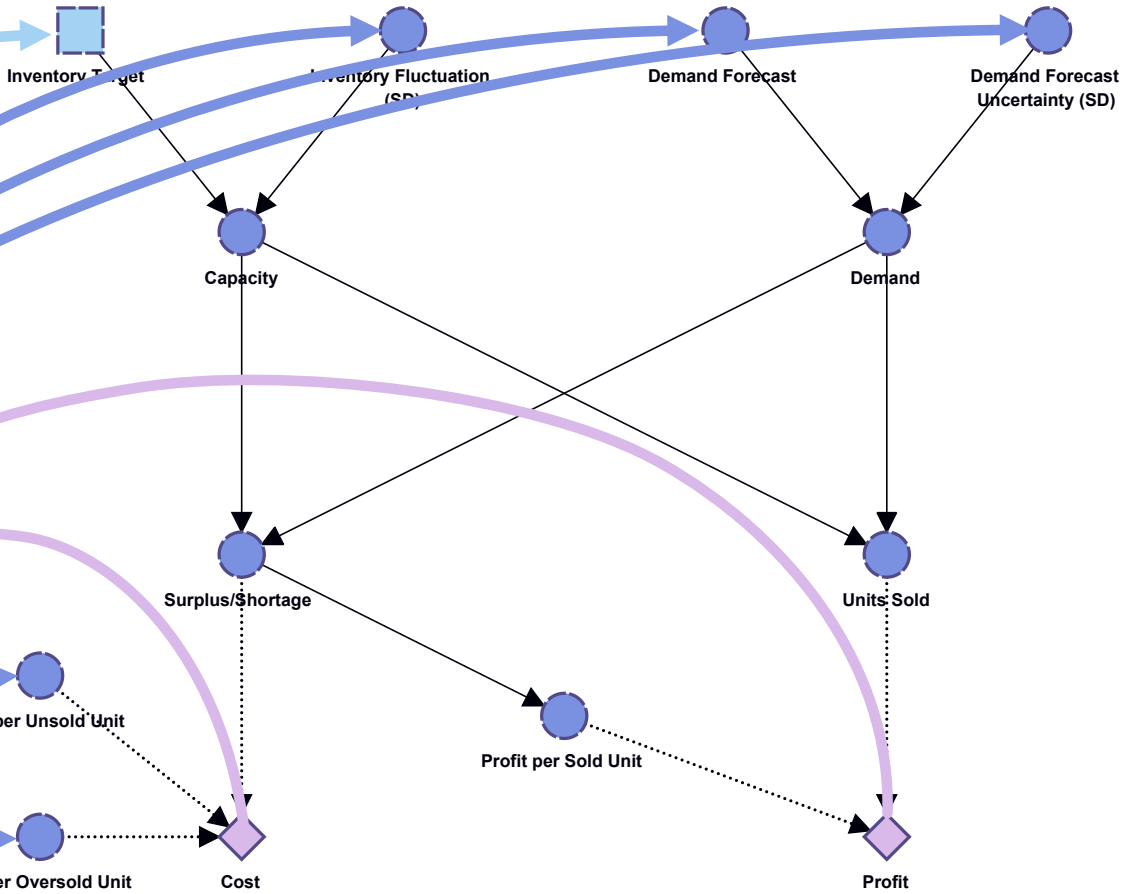
# Business Model





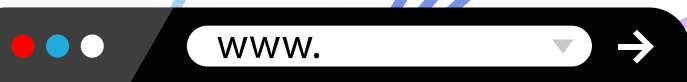
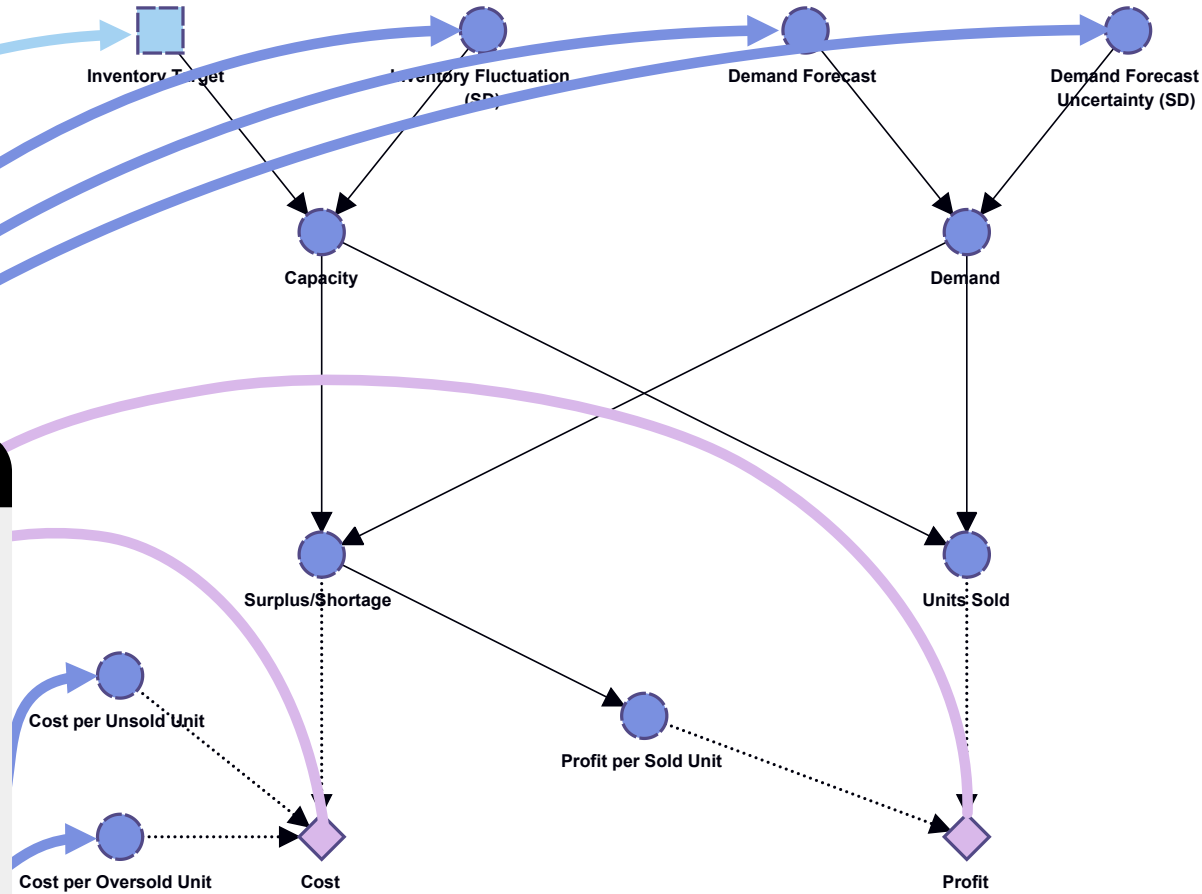
# Building a

# Business Model

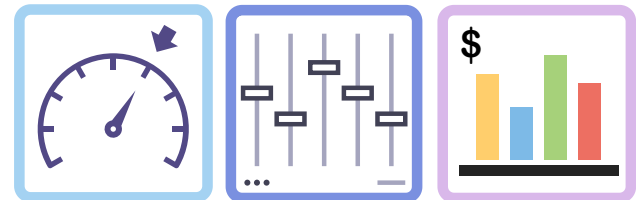


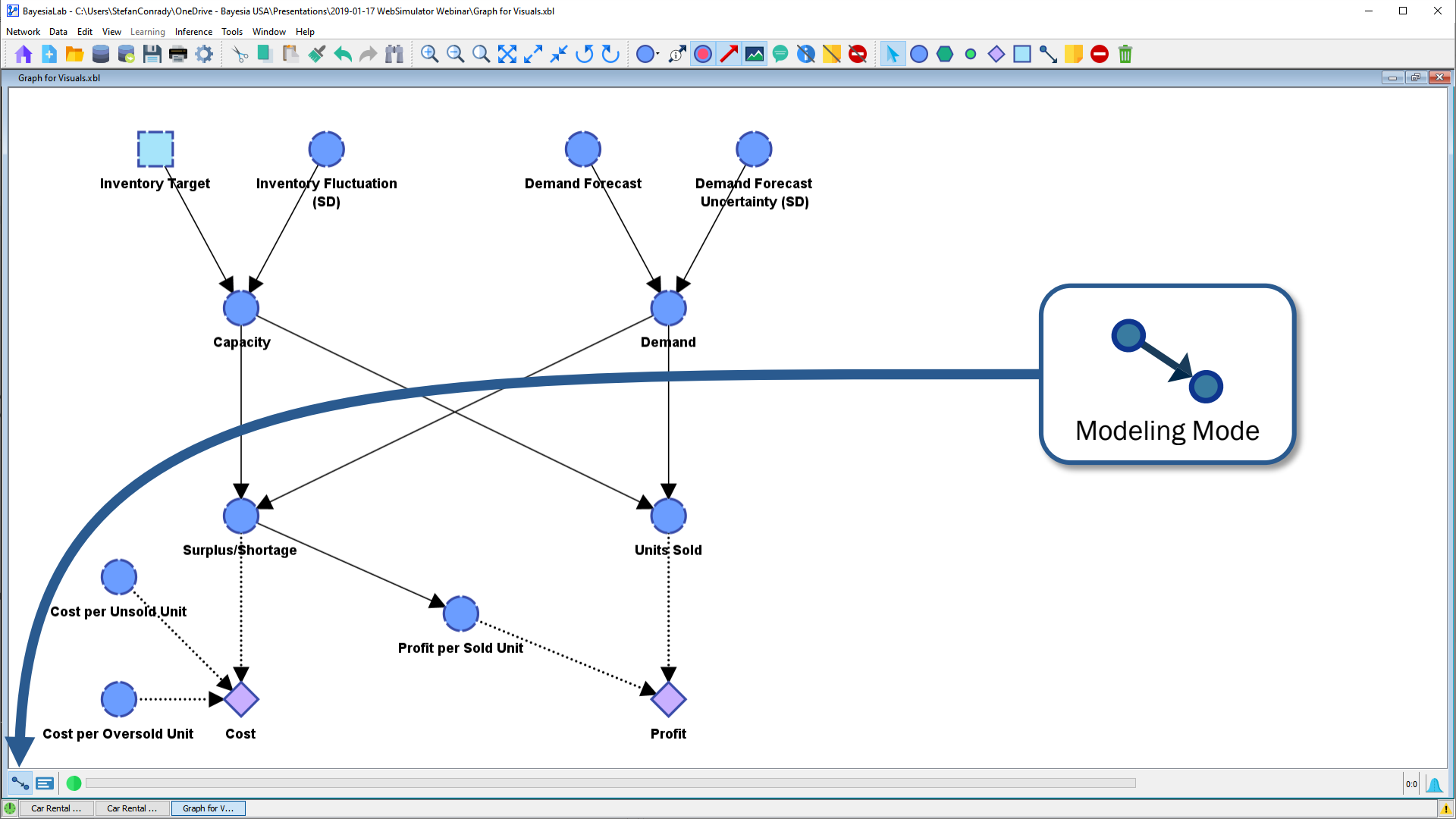
# Building a

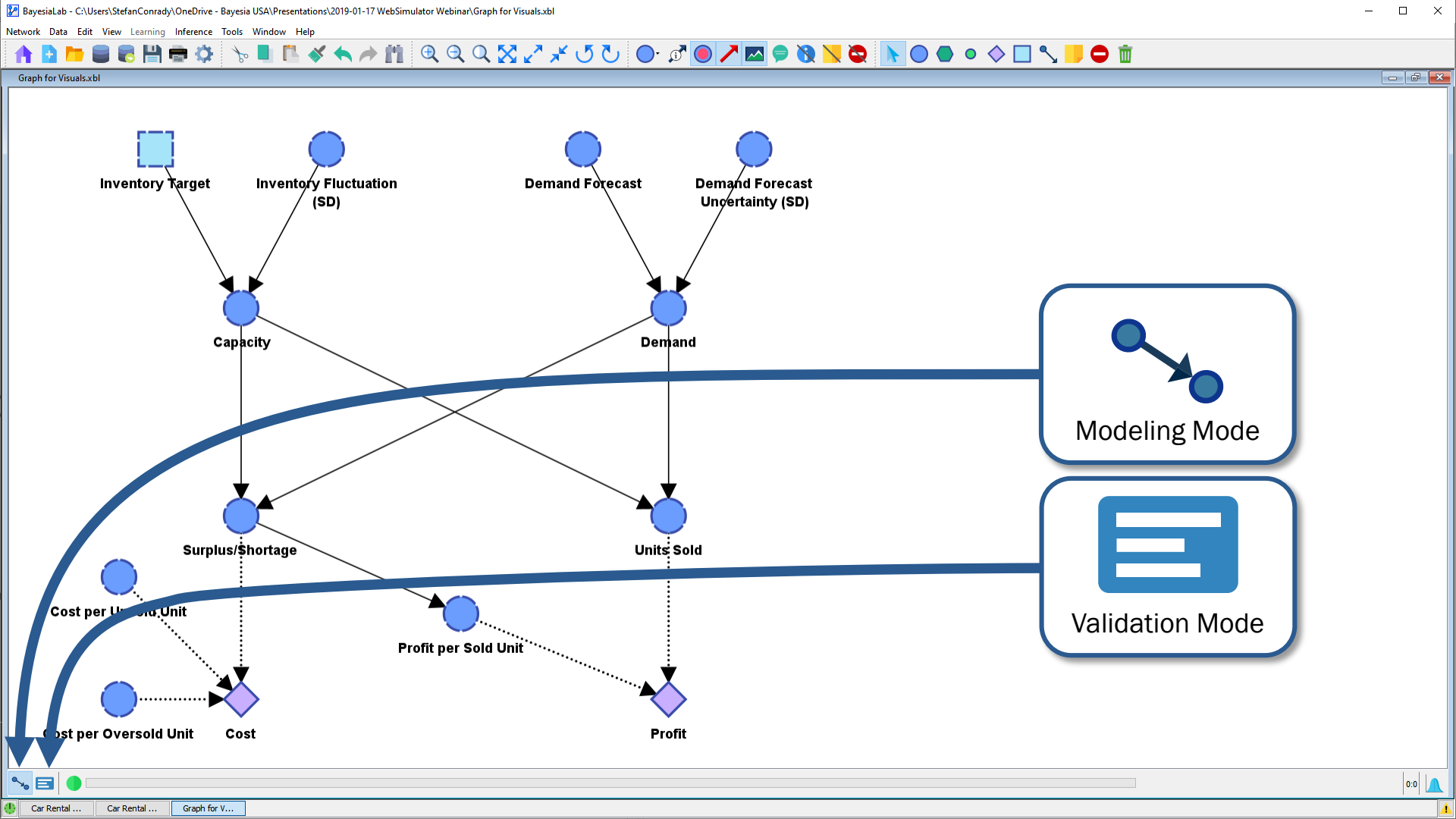
# Business Model

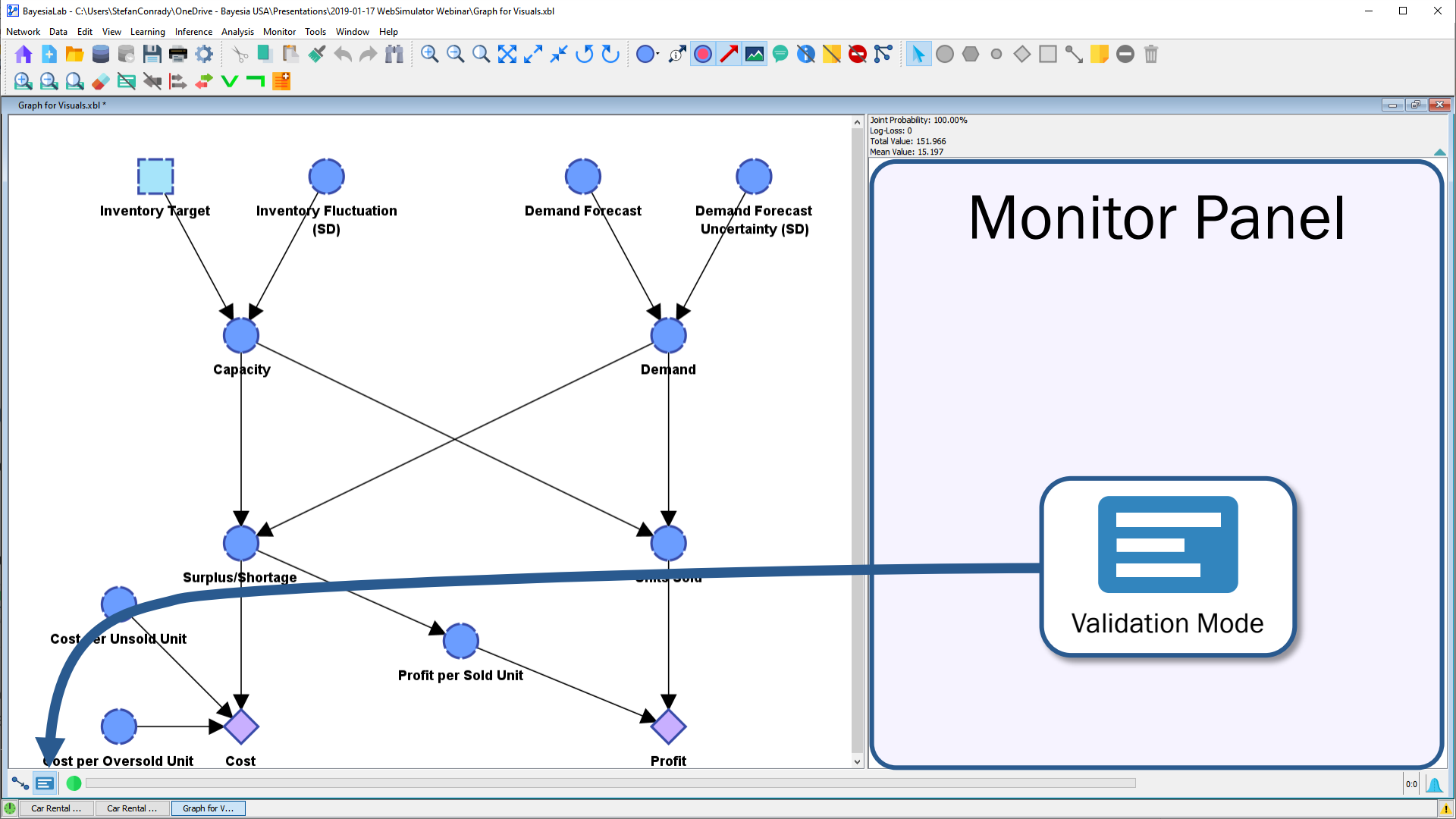


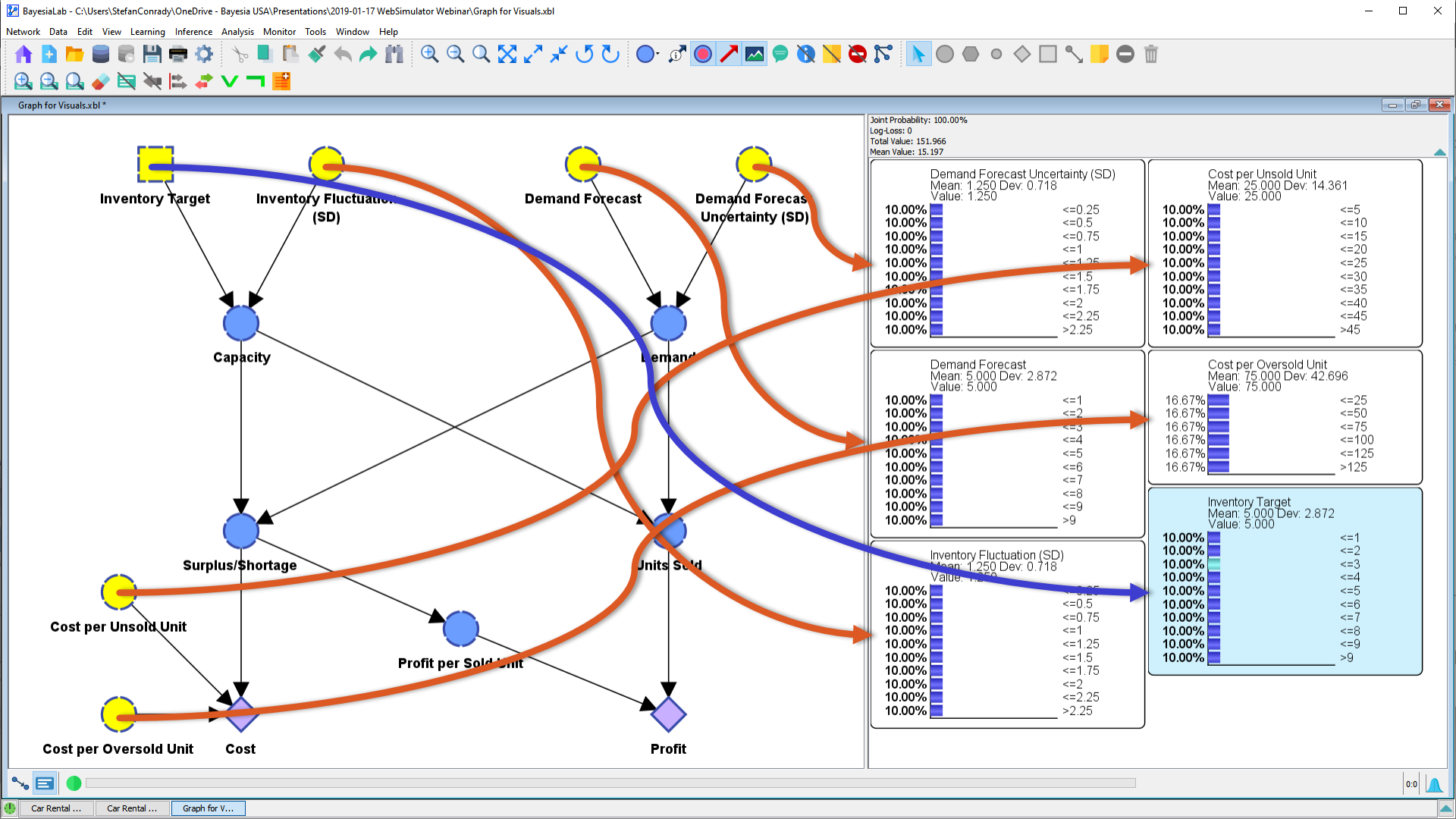
## BayesiaLab WebSimulator

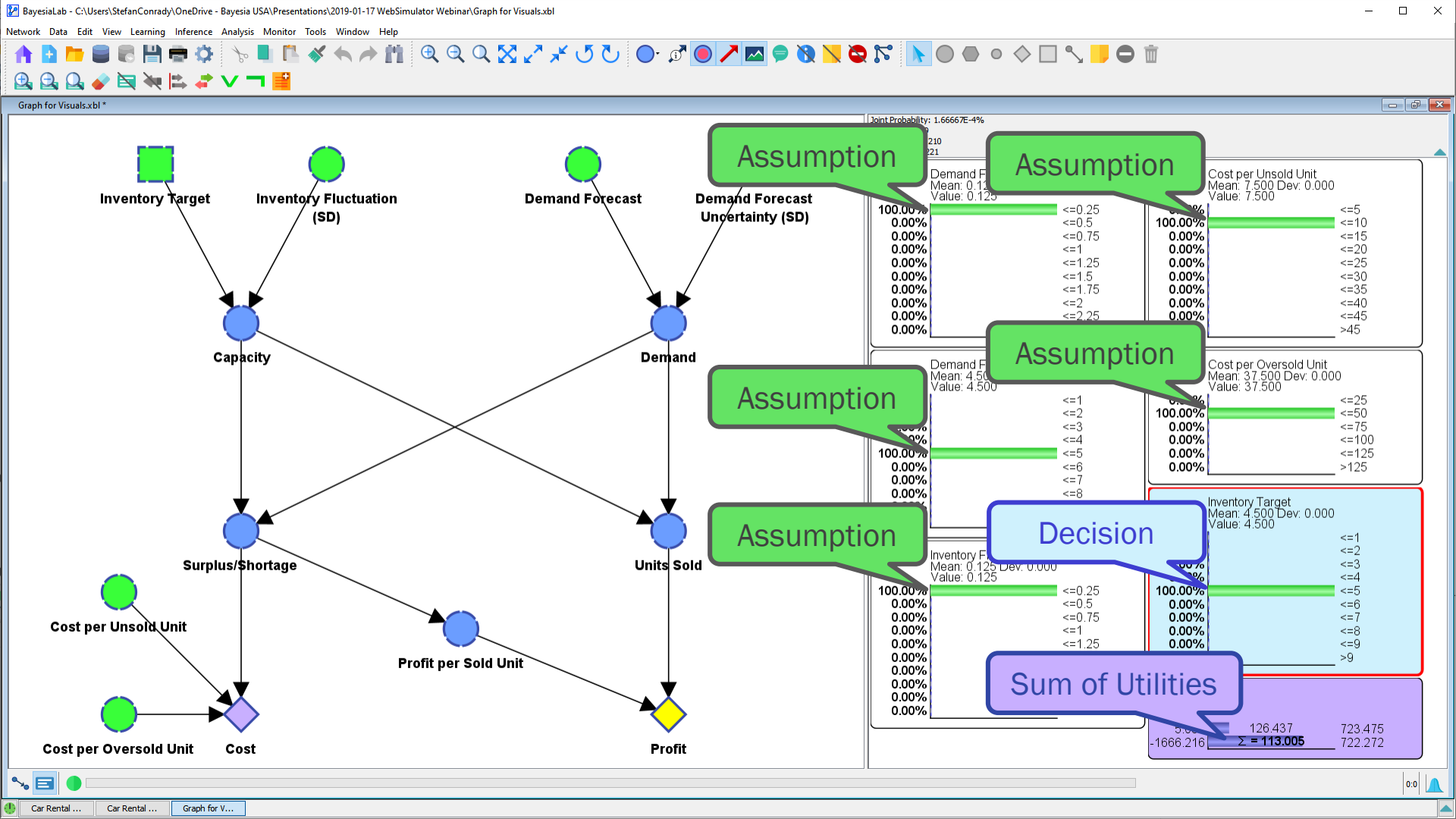


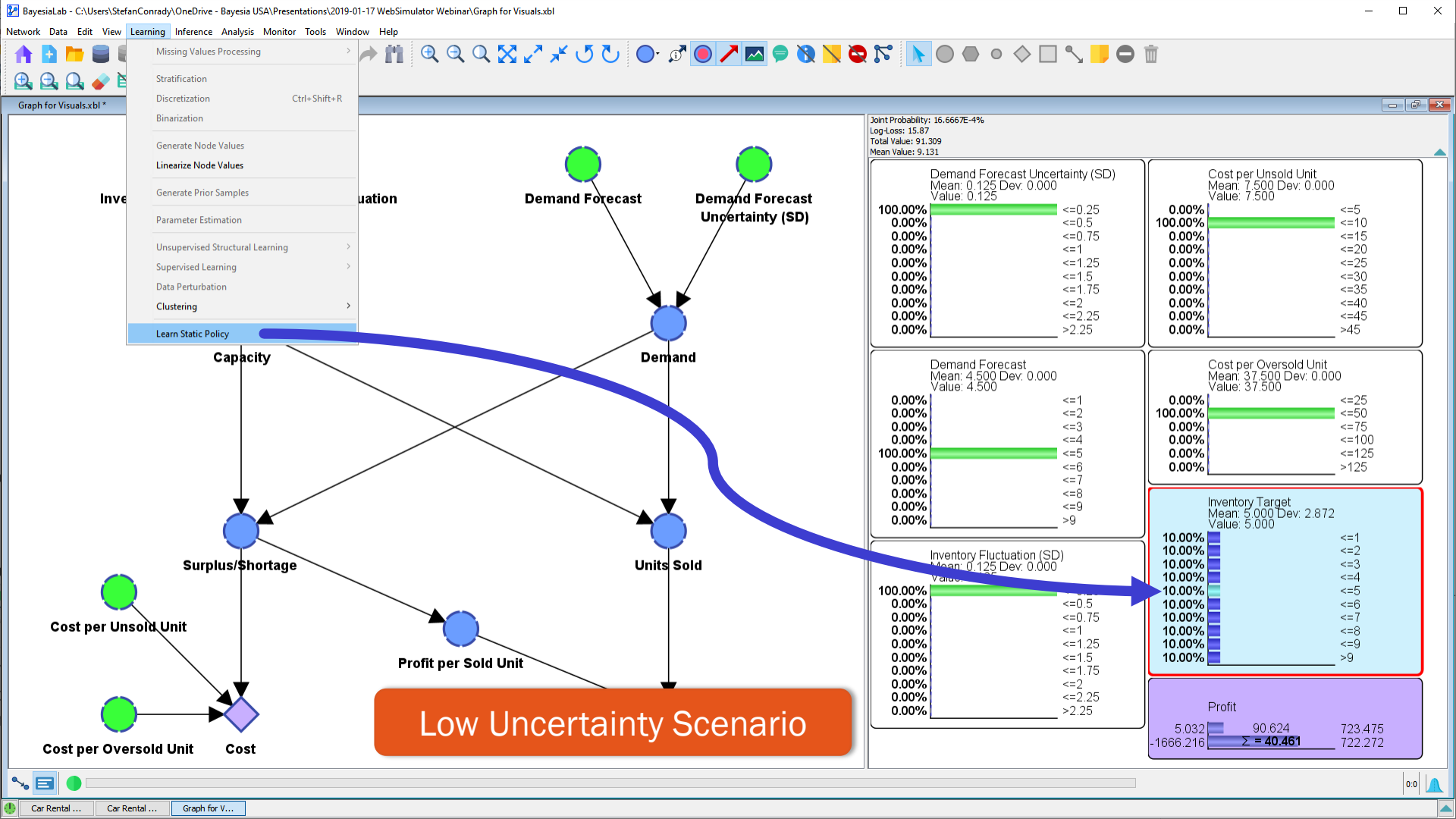




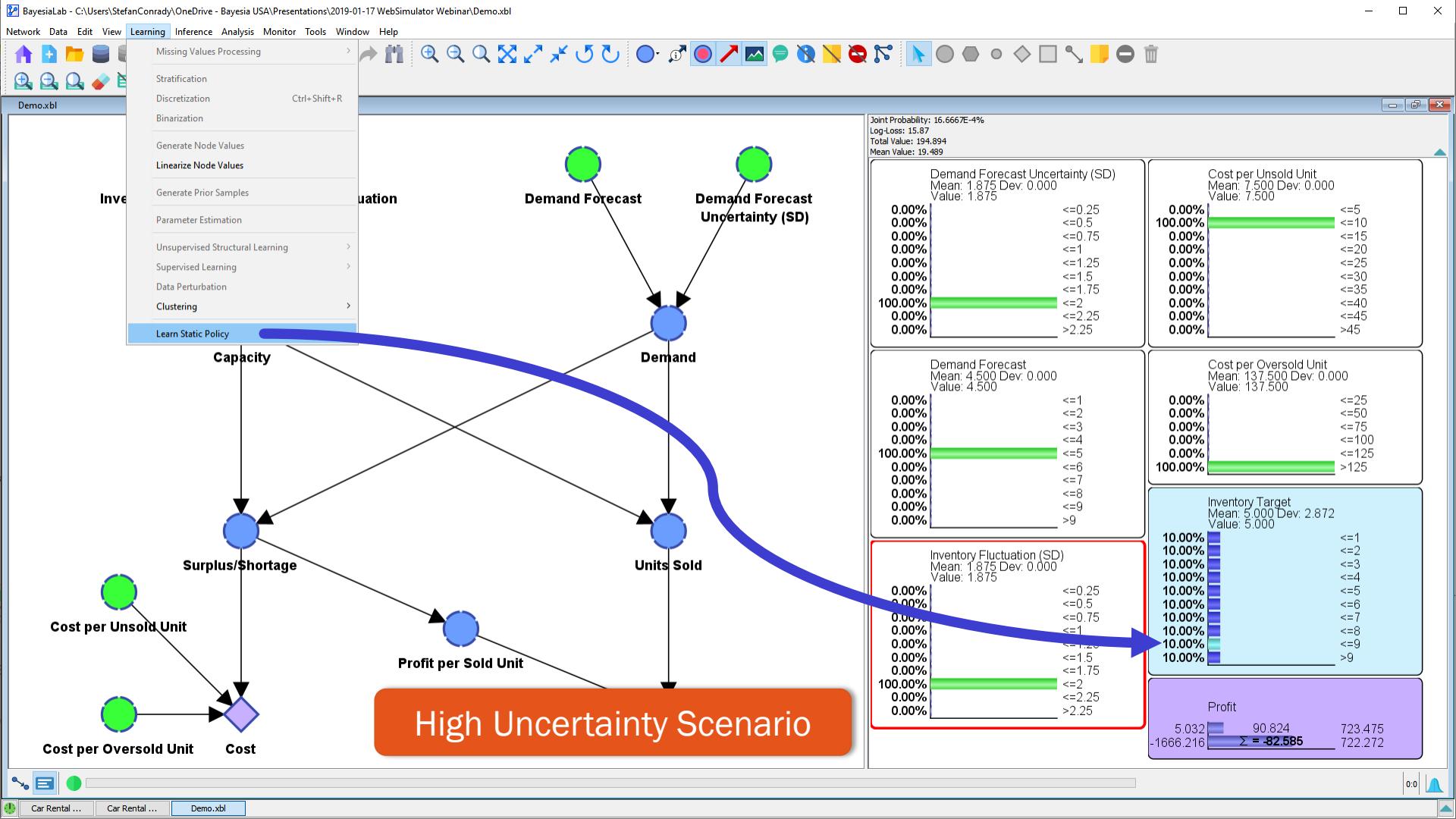


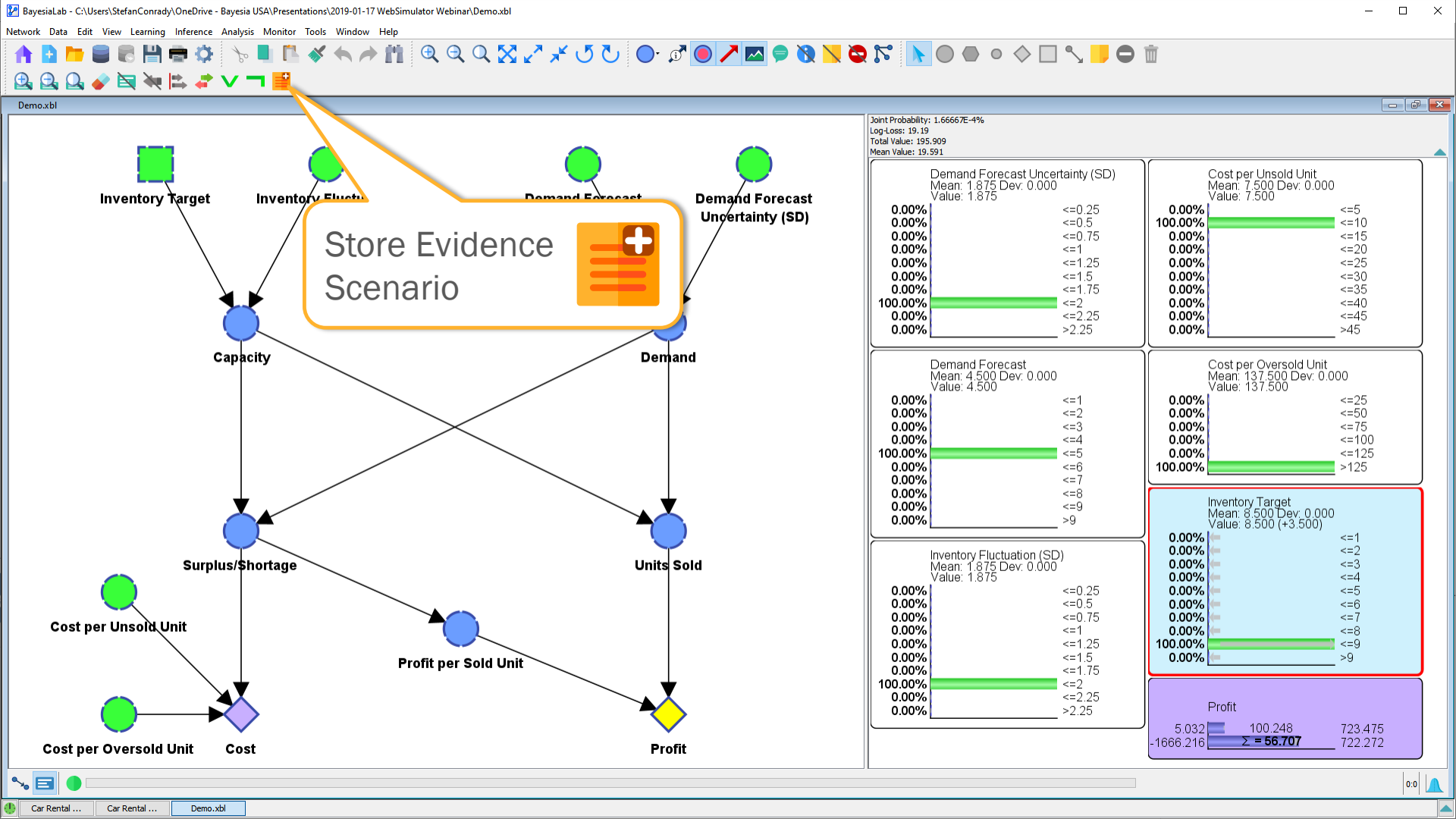


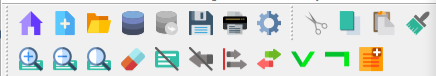




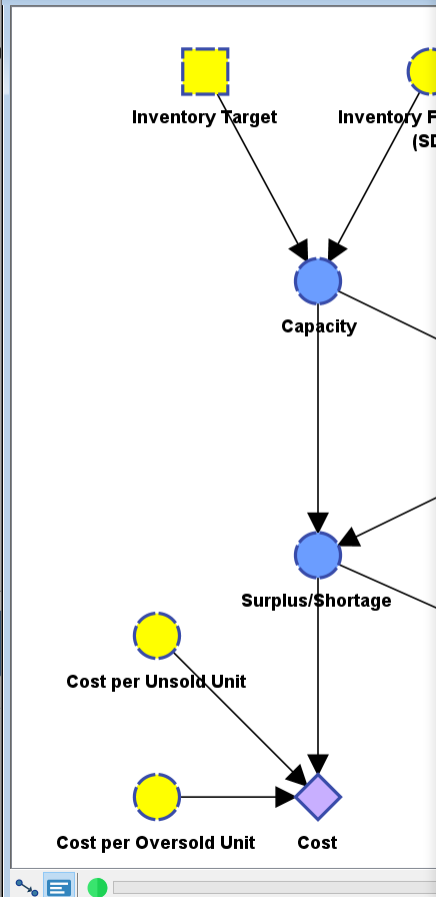








Demo.xbl



### WebSimulator Editor

Available Nodes

- Units Sold
- Cost
- Cost per Oversold Unit
- Inventory Target
- Profit per Sold Unit
- Cost per Unsold Unit
- Surplus/Shortage
- Capacity
- Demand
- Inventory Fluctuation (SD)
- Demand Forecast Uncertainty (SD)
- Profit
- Demand Forecast

Available Metrics

- Joint Probability
- Log Loss
- Global Utility

Simulator Inputs Outputs

Name: Demo  
 Title: Demo  
 Author: Stefan Conrady  
 Field of Study: Management Science and Operations Research  
 Analysis Type: Decision Support  
 Theme Color:

Description

Network created on 1/15/19, 2:55 PM by StefanConrady.

Description Picture:

Logo Picture:

Logo URL:

Font Size: Normal

Input Layout: Flow

History Layout: Flow

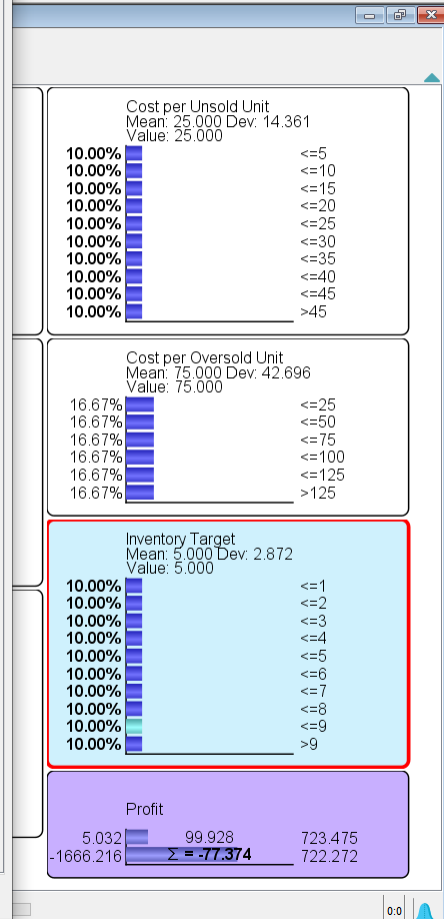
Output Layout: Flow

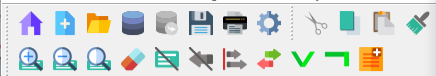
Show Variations:

Reference State:

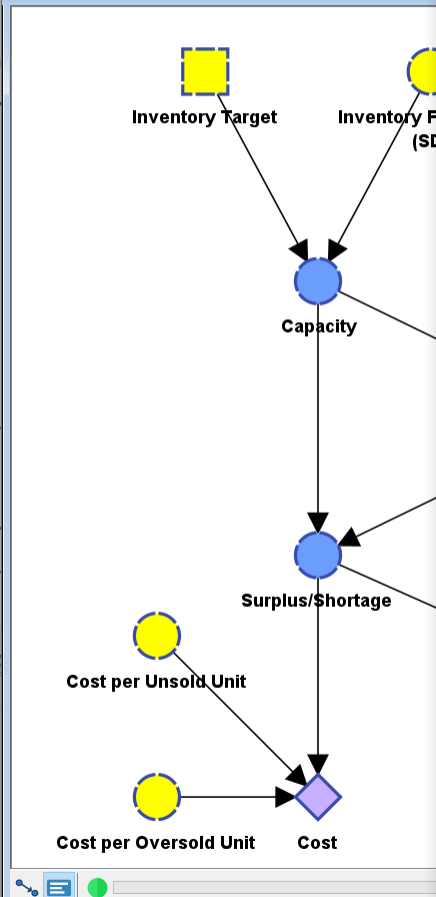
Targets:

OK Cancel Preview





Demo.xbl



### WebSimulator Editor

Available Nodes

- Units Sold
- Cost
- Cost per Oversold Unit
- Inventory Target**
- Profit per Sold Unit
- Cost per Unsold Unit
- Surplus/Shortage
- Capacity
- Demand
- Inventory Fluctuation (SD)
- Demand Forecast Uncertainty (SD)
- Profit
- Demand Forecast

Available Metrics

- Joint Probability
- Log Loss
- Global Utility

Simulator Inputs Outputs

- Demand Forecast Mean
- Inventory Fluctuation (SD) Mean
- Cost per Unsold Unit Mean
- Cost per Oversold Unit Mean
- Inventory Target States**

Displayed Name:

Input Type:  Switches  ComboBox

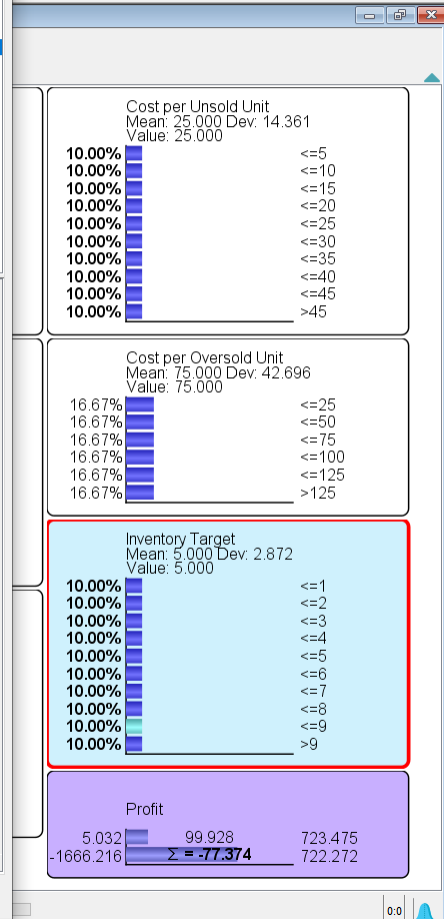
Font Color:

Component Image:

Image Size:

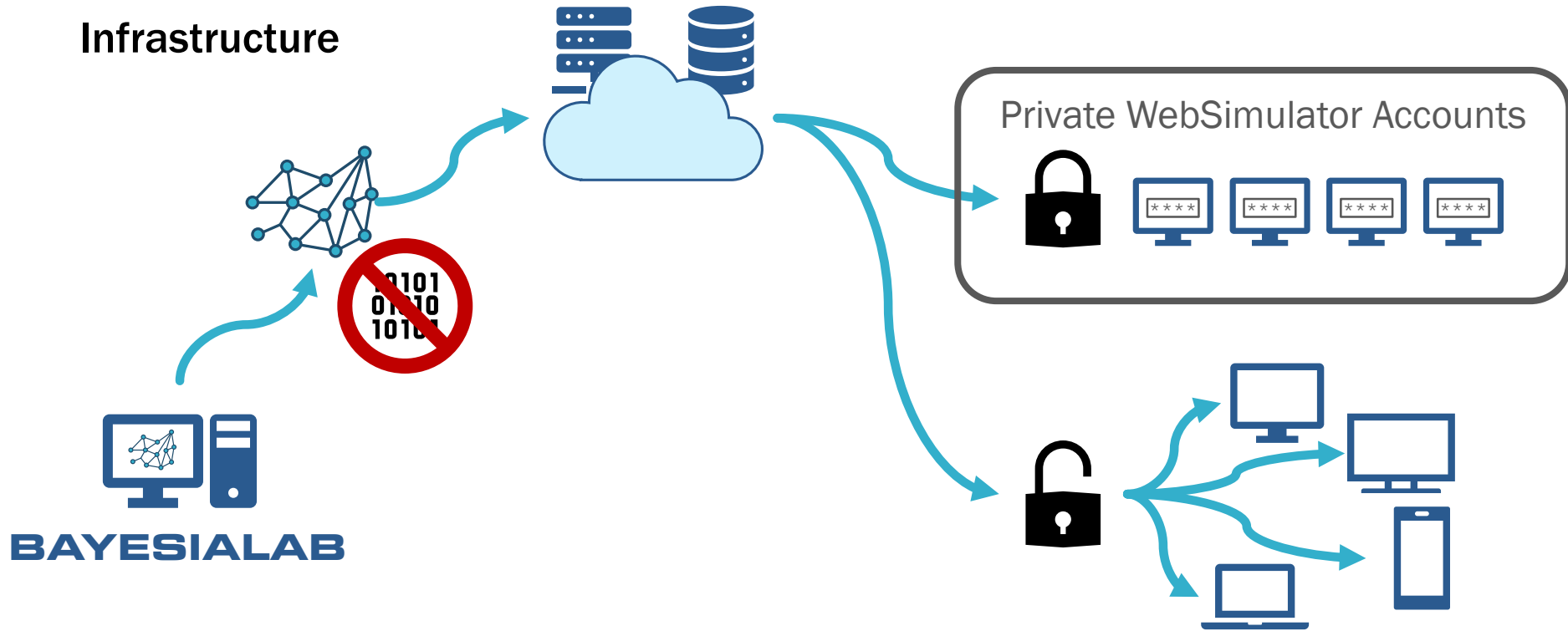
Paragraph  12 pt **B** *I* U

Description



# BayesiaLab WebSimulator

Infrastructure



Models Field of Study Analysis Type Model Type

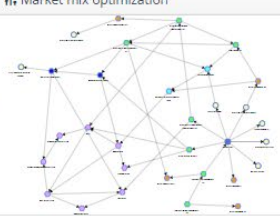
Recent Addition

Conversion Rate Optimization



Conversion Rate Optimization

Market mix optimization



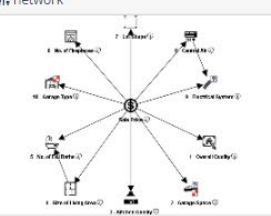
Market mix optimization

network



network

network




network

Marketing Mix Modelling - Sales



Marketing Mix Modelling - Sales

Conversion rate optimization



Ecommerce Simulator


Most Popular

French Personal Traffic Accidents



Car Accidents

Customer Experience model



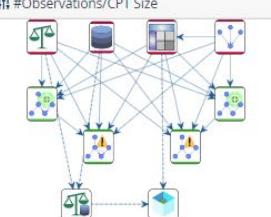
Customer Experience model

World Cup 2018 - Group C Stage Matches




World Cup 2018

#Observations/CPT Size



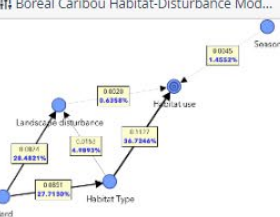
Meta Model: #Observations/CPT Size

Predict your PISA scores



PISA Scores

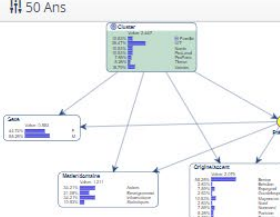
Boreal Caribou Habitat-Disturbance Mod...



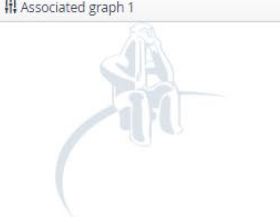
Boreal Caribou Habitat-Disturbance

All Models

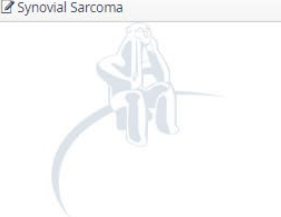
50 Ans



Associated graph 1



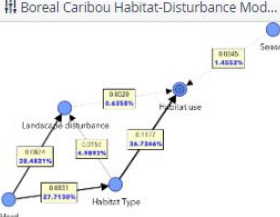
Synovial Sarcoma



Best Buy Sales Key Drivers Analysis



Boreal Caribou Habitat-Disturbance Mod...




Amount of Bullying





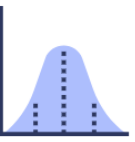
### Inventory Target



State  $\leq 6$

Observed


### Inventory Fluctuation (SD)



Mean

Observed

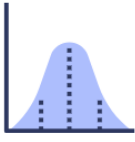
### Demand Forecast



Mean

Observed


### Demand Forecast Uncertainty (SD)



Mean

Observed


### Cost per Unsold Unit



Mean

Observed


### Cost per Oversold Unit



Mean

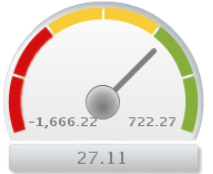

Observed

### Surplus/Shortage



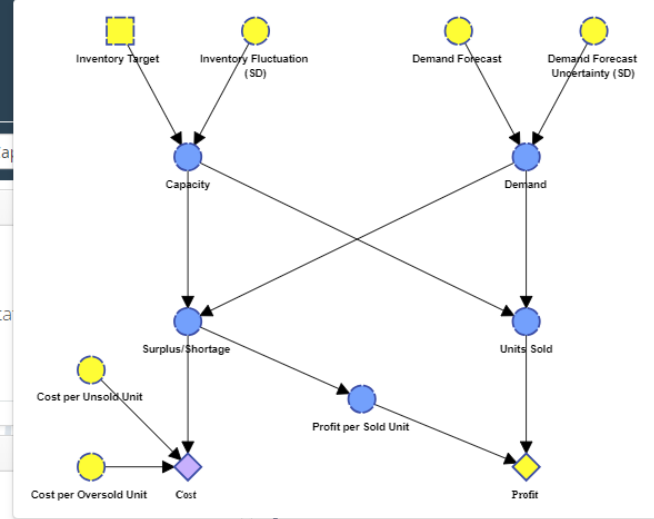
$\leq -9$	0.0
$\leq -8$	0.0
$\leq -7$	0.2
$\leq -6$	0.7
$\leq -5$	2.4
$\leq -4$	6.1
$\leq -3$	11.9
$\leq -2$	17.8
$\leq -1$	20.9
$\leq 0$	18.2
$\leq 1$	12.2
$\leq 2$	6.3
$\leq 3$	2.4
$\leq 4$	0.7
$\leq 5$	0.2
$\leq 6$	0.0
$\leq 7$	0.0
$\leq 8$	0.0

### Overall Utility

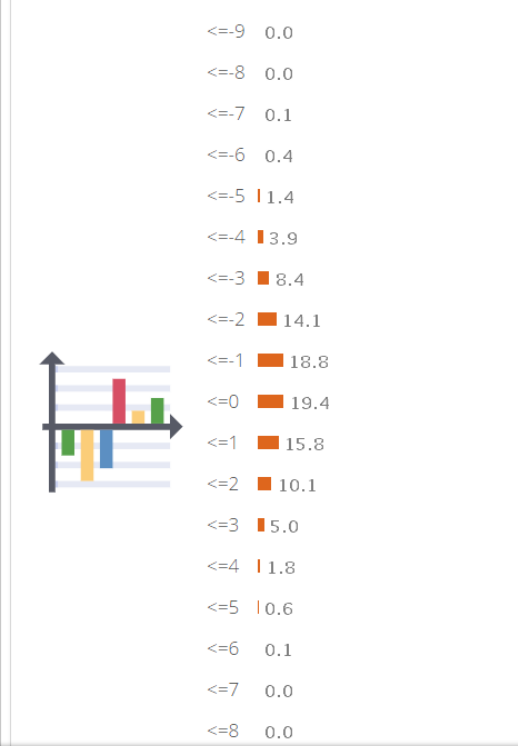


-1,666.22 722.27

27.11



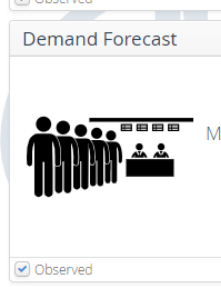
Surplus/Shortage



Inventory Target



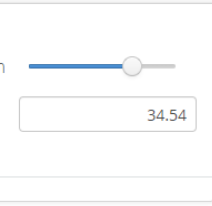
Demand Forecast



Cost per Unsold Unit



Cost per Oversold Unit





# Question



Couldn't I  
have done  
this with  
Excel?

# Probably Not...

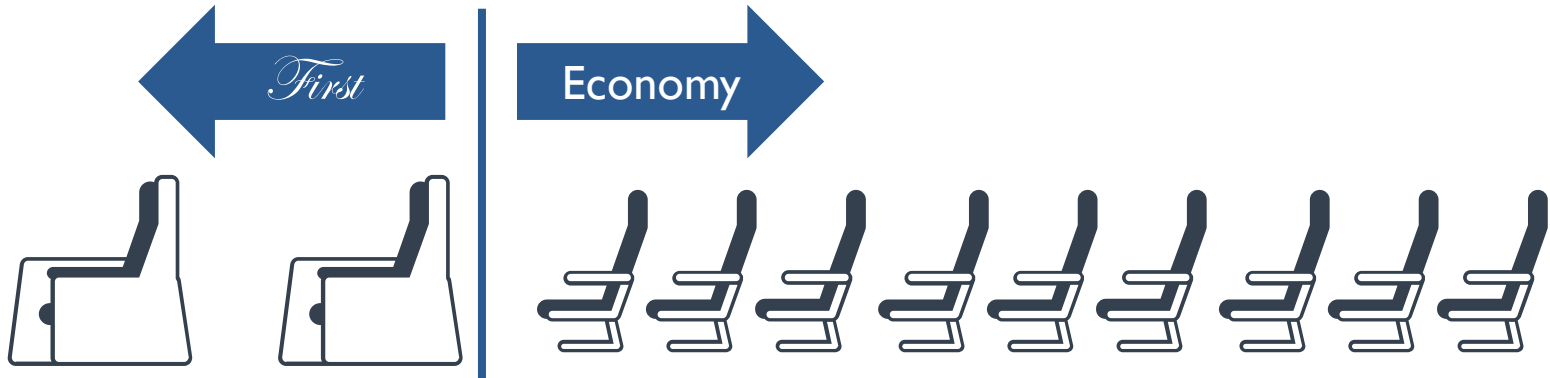
## Why Not Excel & Monte Carlo Simulation?

- Because of many degrees of freedom for decision scenarios, the computational demands would grow exponentially in a spreadsheet. Searching for solutions would only be possible in trivial cases.
- The model structure of a Bayesian network can be reviewed intuitively. There are no hidden relationships between variables.
- Bayesian networks work “natively” with distributions instead of running thousands of single-point calculations.
- Distributions are visible for each variable at all times, so checking a model is easy.

# Building a Bayesian Network

## Homework Assignment: “Upgrading” the Example

- We now have two classes of service, Economy and First.
- Customers can be upgraded but not downgraded.
- How does that effect our capacity planning?





**In Conclusion...**

# BayesiaLab Courses Around the World in 2019

- January 23–25  
Cape Town, South Africa
- January 29–31  
Pretoria, South Africa
- February 27–28  
Dubai, UAE
- March 19–21  
Washington, D.C.
- April 2–4  
Amsterdam, Netherlands
- May 8–10  
Singapore
- May 13–15  
Sydney, Australia
- May 21–23  
Paris, France
- June 12–14  
Seattle, WA



Learn More & Register: [bayesia.com/events](https://bayesia.com/events)

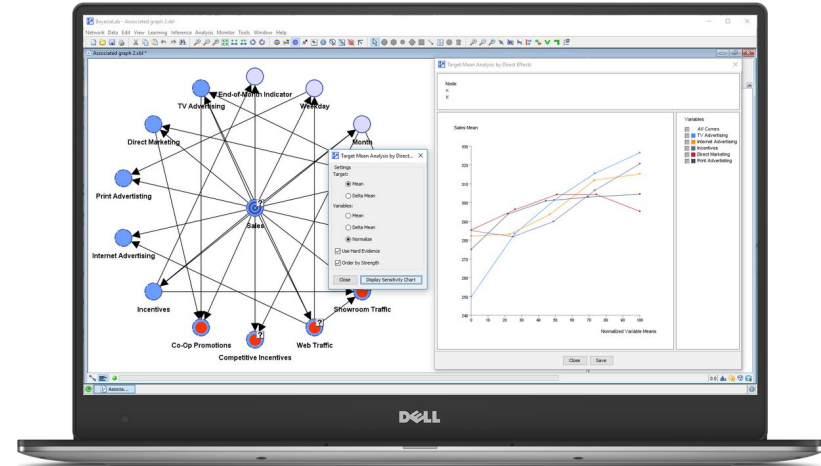




# BayesiaLab Trial

## Try BayesiaLab Today!

- Download Demo Version (10-Node Limit):  
[www.bayesia.com/trial-download](http://www.bayesia.com/trial-download)
- Apply for Unrestricted Evaluation Version:  
[www.bayesia.com/evaluation](http://www.bayesia.com/evaluation)



# User Forum: bayesia.com/community

The screenshot shows the BayesiaLab user forum interface. At the top left is the BayesiaLab logo. A navigation menu includes: BayesiaLab Software, Bayesian Networks, User Guide & Library, User Forum (highlighted), BayesiaLab Store, Courses & Events, Learning Resources, News Feed, and About. Below the navigation is a dark blue search bar with a hamburger menu icon on the left, a search input field containing "This Category" and "Search", and "Log In" and "Register" links on the right. The main content area has a breadcrumb "BayesiaLab Seminars" and a "START NEW TOPIC" button. A topic list header shows "Latest", "New", and "Top" tabs. The first topic is "Webinar on Diagnostic Decision Support with Bayesian Networks" by stefanconrady, posted "a minute ago". It includes a profile picture, a description, and interaction icons for replies (0), likes (0), and views (0). The footer shows a language selector set to "English".



**7<sup>th</sup> Annual BayesiaLab Conference**  
**North Carolina Biotechnology Center**  
**October 10–11, 2019, Research Triangle Park, NC**



# Thank You!



[stefan.conrady@bayesia.us](mailto:stefan.conrady@bayesia.us)



[BayesianNetwork](#)



[linkedin.com/in/stefanconrady](https://www.linkedin.com/in/stefanconrady)



[facebook.com/bayesia](https://www.facebook.com/bayesia)