Optimization Using SimRunner

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Agenda – Optimization w/ Simulation

- Scenario Manager – "Best Solution"
- What is SimRunner? When to use it.
- Setting up optimization project (ProModel,MedModel)
  - Objective Function
  - Input parameters
  - Analyzing Results
- Process Simulator & SimRunner
- Example projects using SimRunner

Optimization

Finding the best solution
for a System (model)
given some constraints (inputs)
driving toward a Goal (objective function)

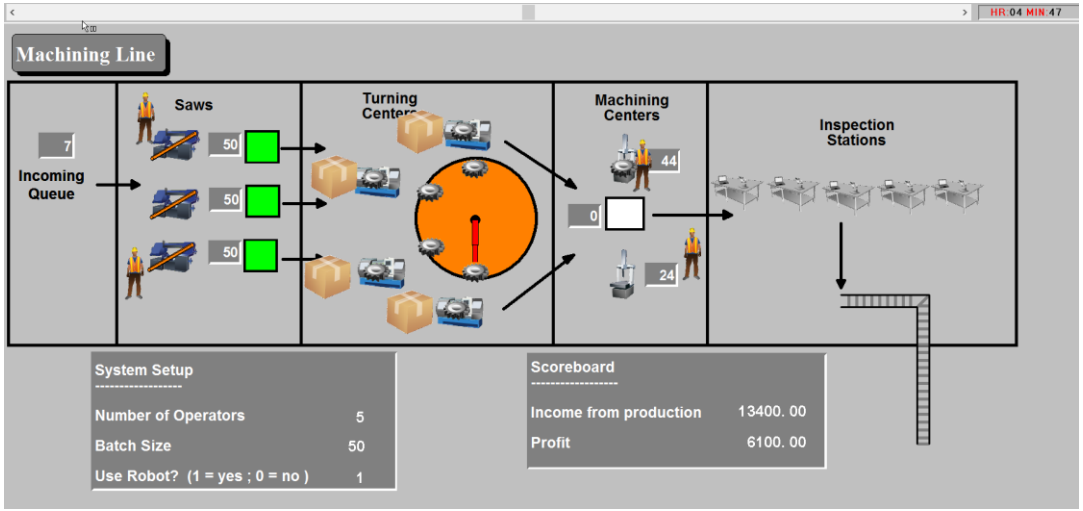
Poll #1

Perhaps We Could Do It Ourselves

- Finding the Right Solution….
  - Design of Experiments – DOE
  - Scenarios
  - Manually create the alternatives
- Run the model with selected Scenarios
- Have we found all the viable solutions?
- Have we found the BEST solution?

Scenarios to Find "Best" Solution

- Example model:
  Raw stock→Rough piece→Finished gear→Inspection
- Want to **maximize** profit
- Can change:
  Qty Operators
  Batch Size
  Use Robot or Not

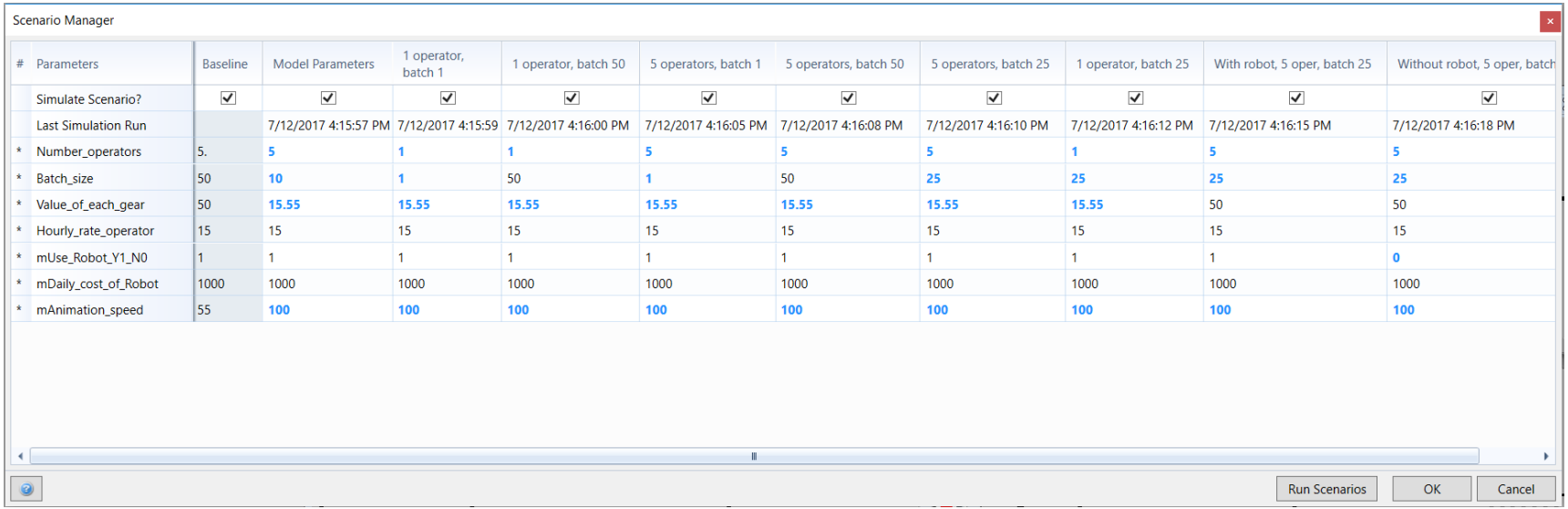


Scenarios

- Profit =
  Value of product * Qty Produced
  - Cost of raw material
  - Cost of Labor
  - Cost of Robot

Scenarios

- Run Scenarios…

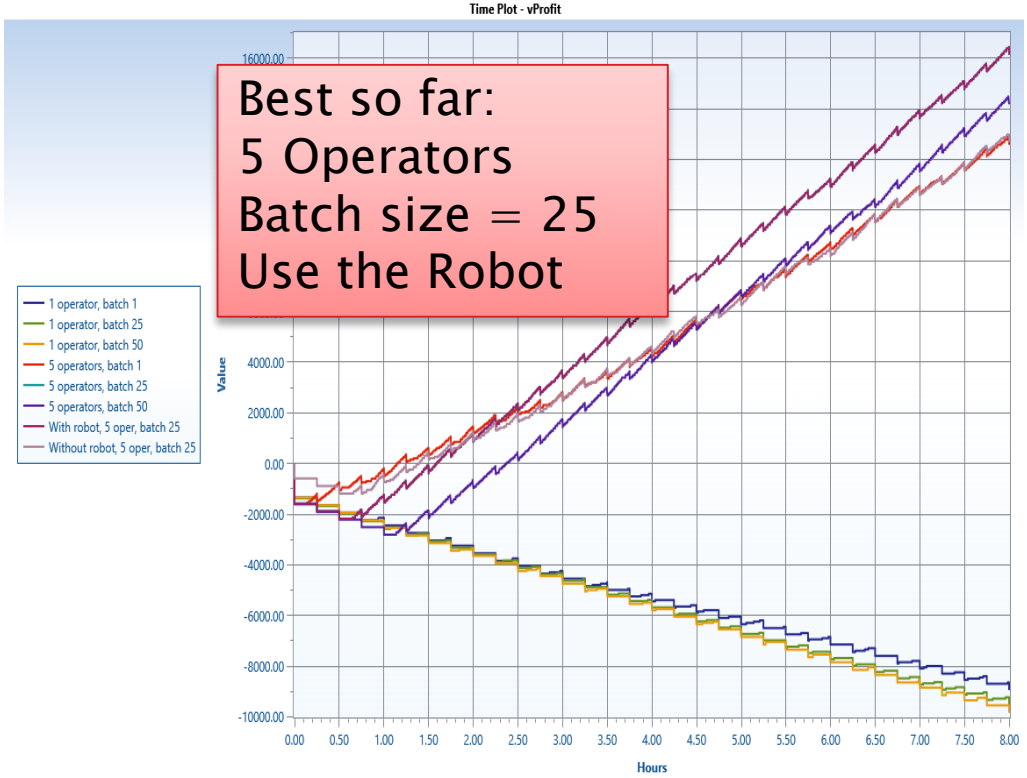

Scenario Manager

#	Parameters	Baseline	Model Parameters	1 operator, batch 1	1 operator, batch 50	5 operators, batch 1	5 operators, batch 50	5 operators, batch 25	1 operator, batch 25	With robot, 5 oper, batch 25	Without robot, 5 oper, batch
	Simulate Scenario?	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
	Last Simulation Run		7/12/2017 4:15:57 PM	7/12/2017 4:15:59	7/12/2017 4:16:00 PM	7/12/2017 4:16:05 PM	7/12/2017 4:16:08 PM	7/12/2017 4:16:10 PM	7/12/2017 4:16:12 PM	7/12/2017 4:16:15 PM	7/12/2017 4:16:18 PM
*	Number_operators	5.	5	1	1	5	5	5	1	5	5
*	Batch_size	50	10	1	50	1	50	25	25	25	25
*	Value_of_each_gear	50	15.55	15.55	15.55	15.55	15.55	15.55	15.55	50	50
*	Hourly_rate_operator	15	15	15	15	15	15	15	15	15	15
*	mUse_Robot_Y1_N0	1	1	1	1	1	1	1	1	1	0
*	mDaily_cost_of_Robot	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
*	mAnimation_speed	55	100	100	100	100	100	100	100	100	100

Run Scenarios | OK | Cancel

Scenarios

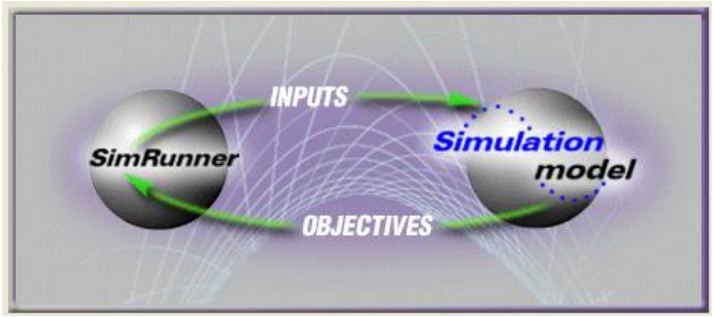
- Output Results… Choose the best.
- But have we built a scenario for the really best solution?



Scenarios

- How many Scenarios are possible?
  - Parameters choices * Parameters choices = BIG!!!
- For example:
  - Between 1 & 5 operators
  - Batch size between 1 & 50
  - Use a robot or not (2 choices)
  - Therefore: (5) * (50) * (2) = 500 Scenarios!!!
    Do you want to create 500 scenarios to find the right solution?
- Tip… Use ProActiveX.xlsb to rapidly create the scenarios
- BUT… How about letting SimRunner do the DOE (Design of Experiments) for you?
  And SimRunner will discard poor solutions!

SimRunner



- What it is…
  - Built-in tool in ProModel & MedModel
  - Automated DOE to find “optimal” system configuration
- When to use it…
  - Want to play with certain key system controls to:
    - **Maximize** throughput; **Minimize** WIP; **Maximize** utilization of key bottleneck machine; **Minimize** delays; **Min/Max** whatever

Poll # 2

Special Concerns

- This is pseudo-optimization, not pure optimization (like linear programming)
  - Find the best solution among all possible combinations
- Must have valid objective function
- Don't want too many cont
- Must have model that's been V&V'd

Verification:
Is the model built correctly?

Validation:
Does the model meet the benchmark correct results?

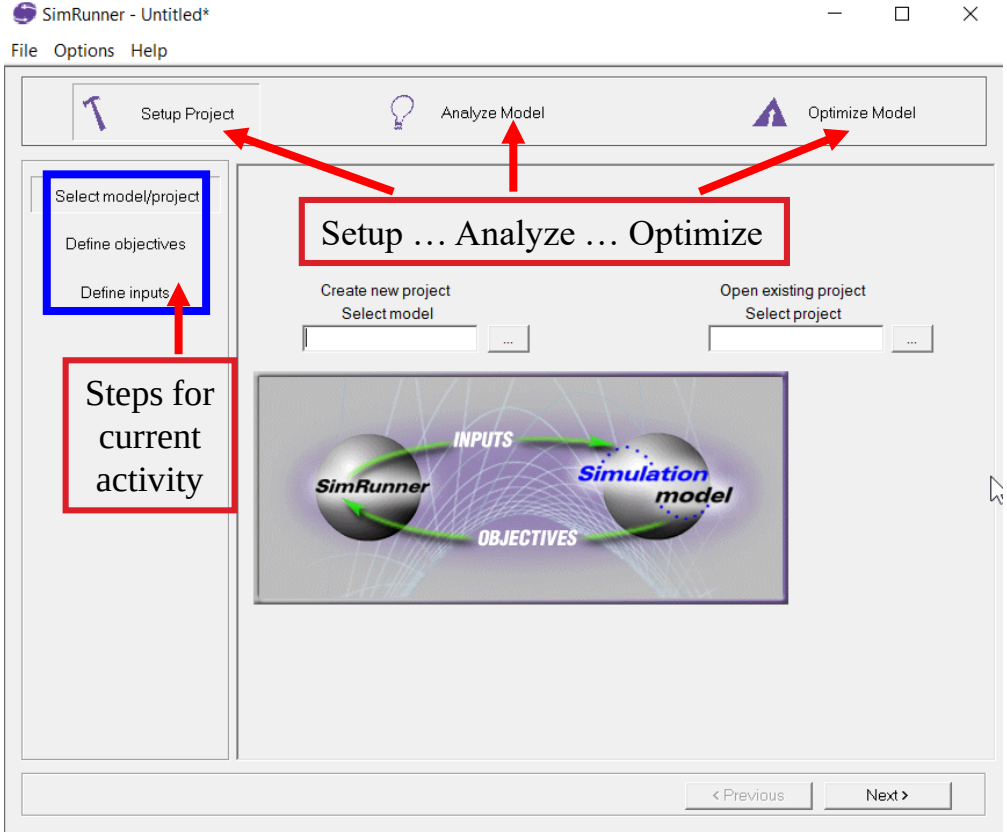
SimRunner & Process Simulator

- Process Simulator (PCS) does not have SimRunner
- However… PCS creates a .MOD file (PM/MM model)
- Therefore, after the PCS model has been V&V'd:
  - Use PM/MM w/ SimRunner!
  - >>> MUST have Promodel/MedModel to use SimRunner
- SimRunner needs Changeable Scenario MACROs
  - So, if PCS model has Scenario Parameters not Macros, must change over to Macros prior to creating .MOD

Steps for Using SimRunner

- Create simulation model
  - Scenario Parameter macros
  - Output metrics
- Open Simrunner (Simulation / SimRunner)
- Define Objective Function
- Define Input Factors
- Define Optimization control parameters
- Run Optimization
- Examine results … We have a winner!!!

SimRunner Three Main Parts



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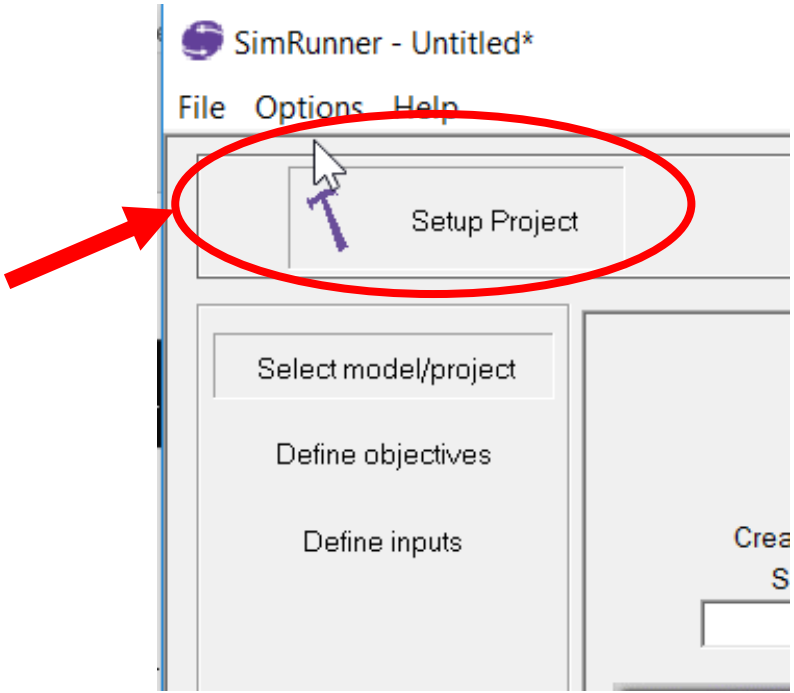
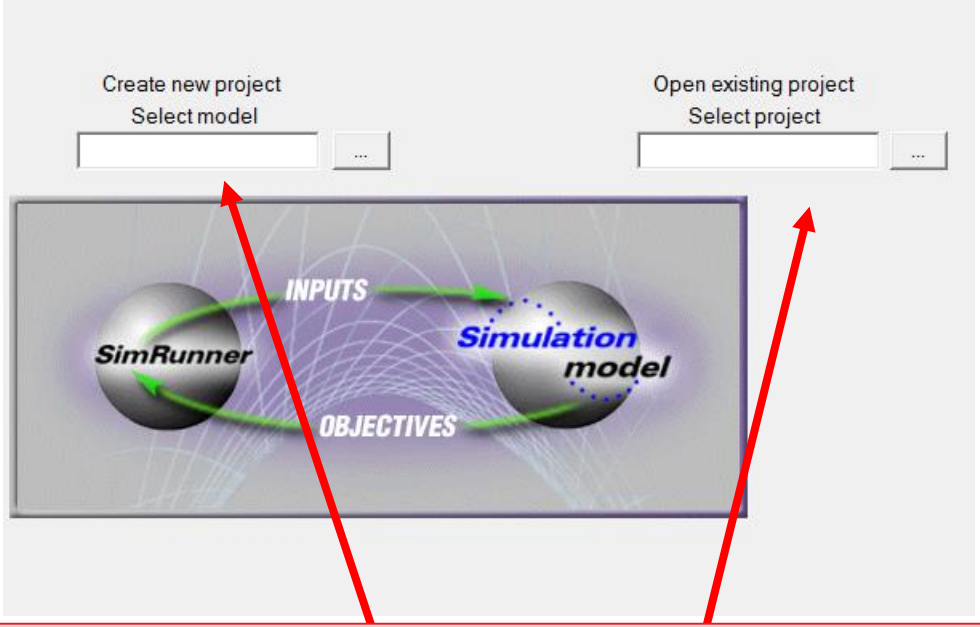
Set Up Project



Select Model/Project

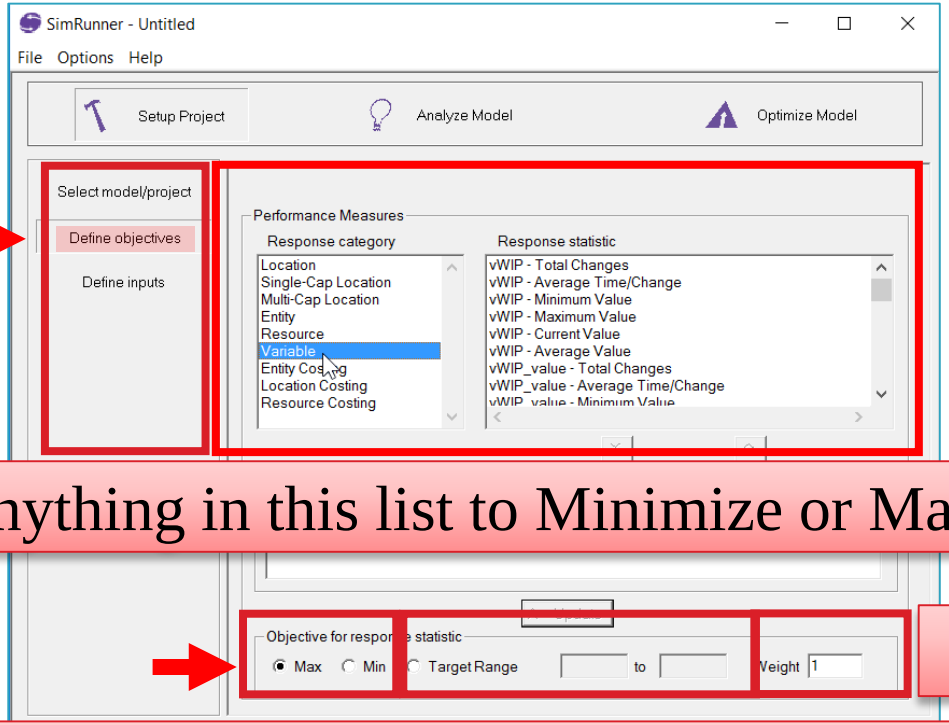


Select Model Name (if starting new Project) or Project Name (if previously created)

What is an Objective Function?

- GOAL!!
- Desired Minimize or Maximize of item(s)
- Equation that calculates desired metric
  - Example: v_Profit = v_Revenue – v_Cost
  - Example: v_WIP = (CONTENTS(x)+CONTENTS(y)+…)
  - …

Define Objectives



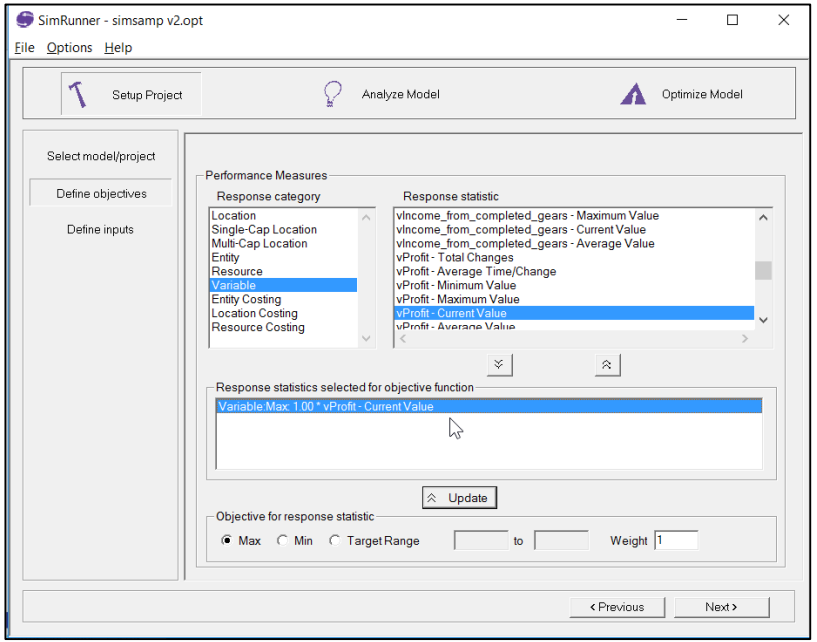
Pick anything in this list to Minimize or Maximize

Weight Factor

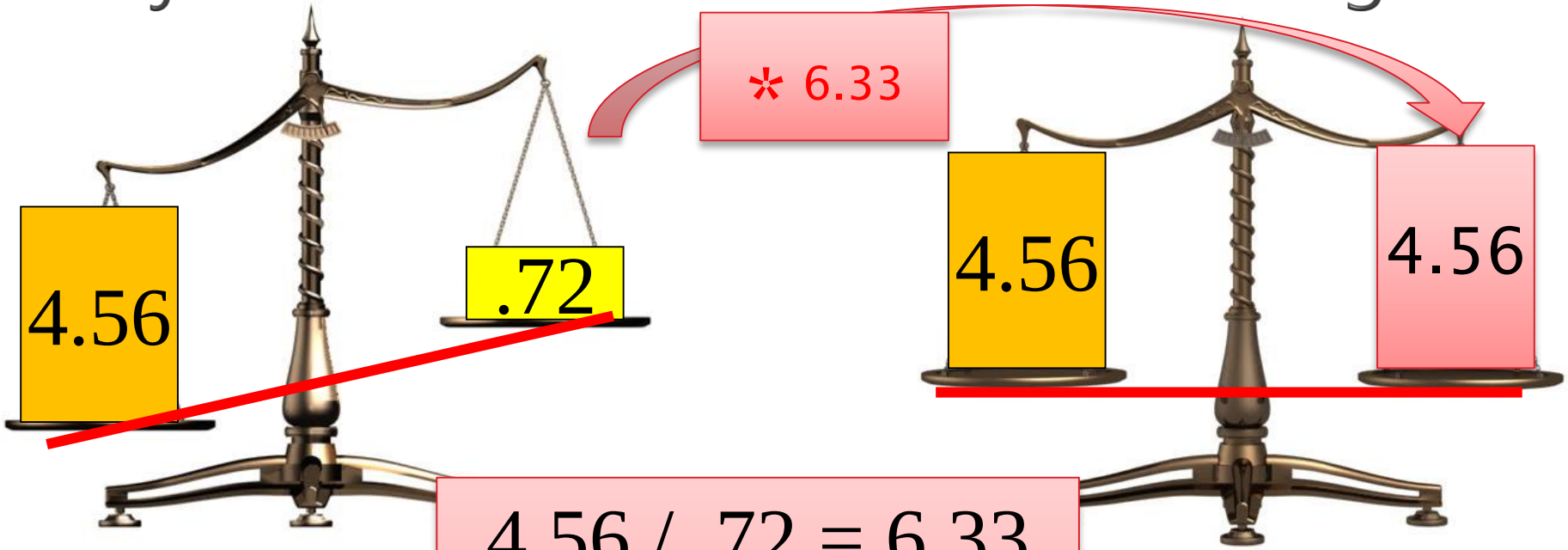
Target Range … For identifying Infeasible Solutions

Define Objective Function

- Choose Item
  - For this model: v_Profit – Current Value (current value = At the End of the Run)
- Choose:
  - Maximize or Minimize
  - Target Range, if any
  - Weight
- If you change something, don't forget to press the Update button



Objective Function - Statistical "Weight"



4.56 / .72 = 6.33

0.72 * 6.33 = 4.56

Weighting Factor

Objective Function - Statistical "Weight"

- For Example… Want to:
  - Maximize Throughput
    - Measure: Total Exits (big number)
  - Minimize WIP
    - Measure: Average Contents of Queue (medium size number)
  - Minimize Labor
    - Measure: Number of Units of Resource (small number)

These are dissimilar metrics with different ranges

Objective Function - Statistical "Weight"

- Identify ranges of each metric
  - Calculate averages
- Calculate relative contribution based on numeric value
  - Inverse… Adjustment for size of values
- Determine Importance of each metric (scale = 1 – 10)
  - Calculate the Relative Importance base upon the Maximum
- Calculate Weight Factor
  = Adj for Value * Relative Importance

(for 40 hour run)

Min/Max Items	Measurement	Min Value	Avg Value	Max Value	Avg Value Relative Contribution to Total	Adjustment for Value Size (1 / Contribution)	Importance (1-10)	Relative Importance	Weighting Factor
Maximize Throughput	Gear Total Exits	500	1750	3000	0.874	1.14	10	1.00	1.14
Minimize WIP	Q MC Average Contents	1	251	500	0.125	8.00	5	0.50	4.00
Minimize Labor	Units of Machinist	1	2.5	5	0.001	801.20	7	0.70	560.84
			=====		=====	=====	=====		=====
	Totals:		2003		1.000	810.34	22.00		565.98

Objective Function

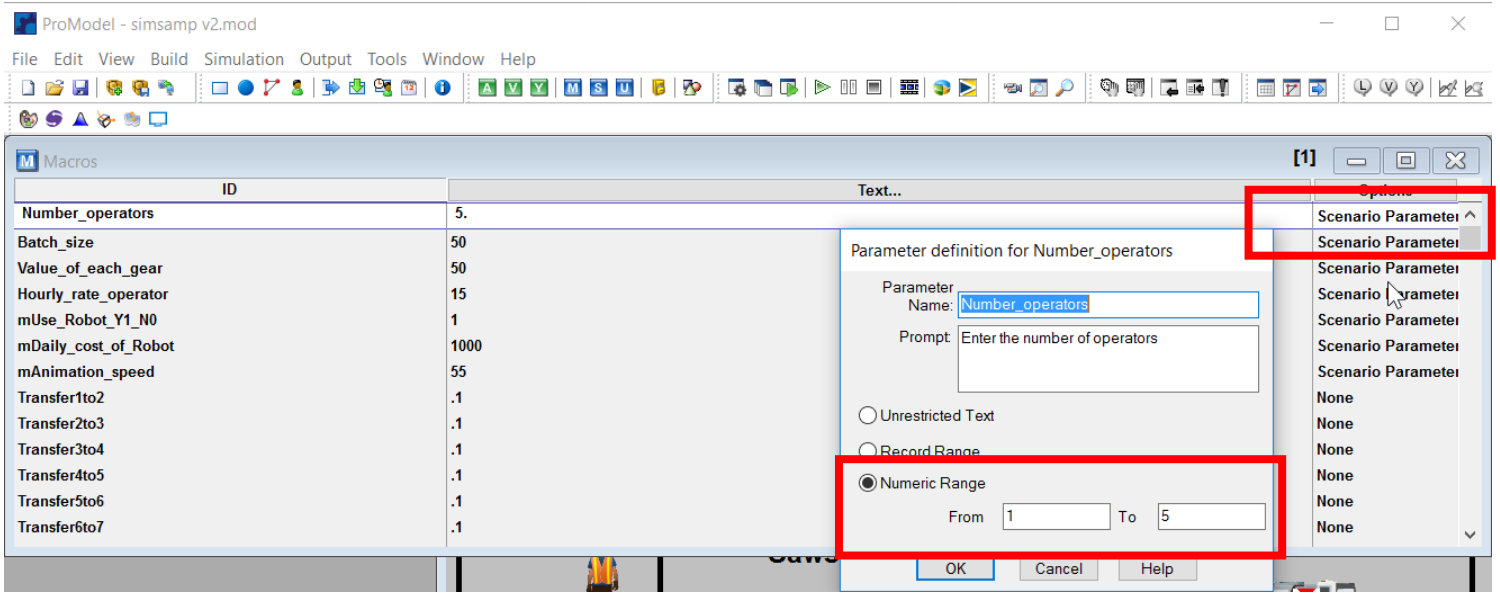
- OR…

Always calculate
the Goal in terms of
$$$

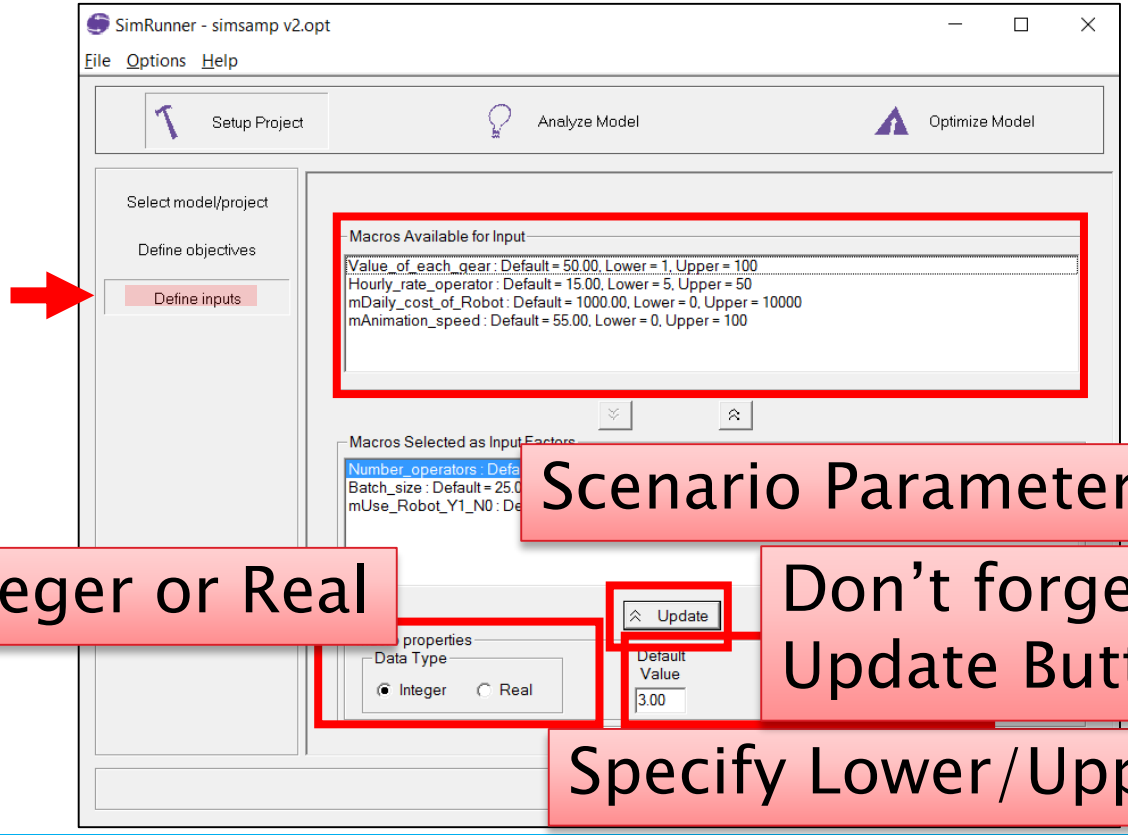
Poll #3

Define Inputs

- The Changeable Parameter to use for creating Scenarios must be numeric Scenario Macros



Define Inputs



Scenario Parameter Macros

Choose Integer or Real

Don't forget the Update Button

Specify Lower/Upper Limits

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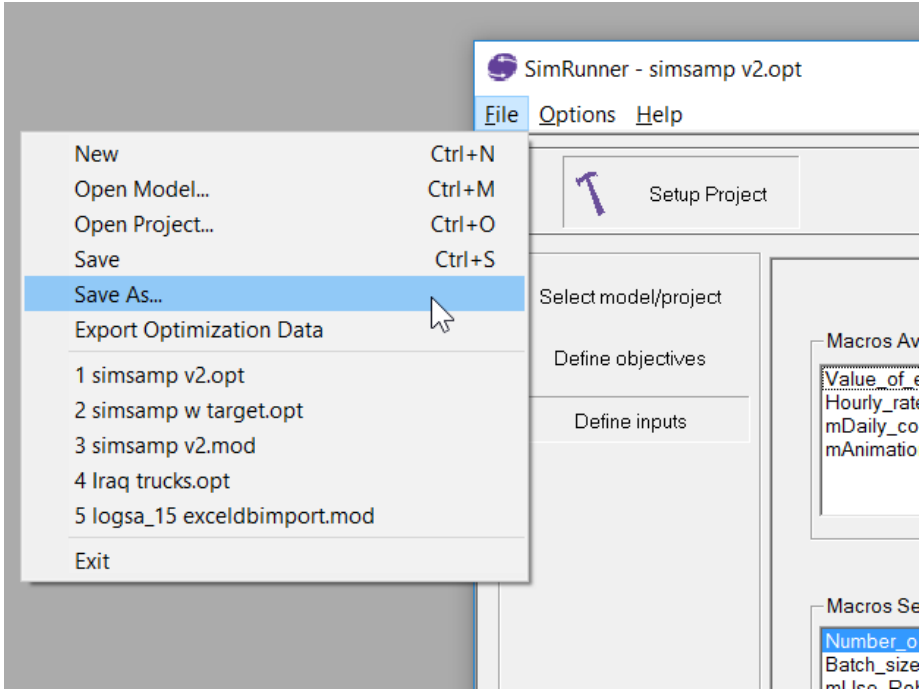
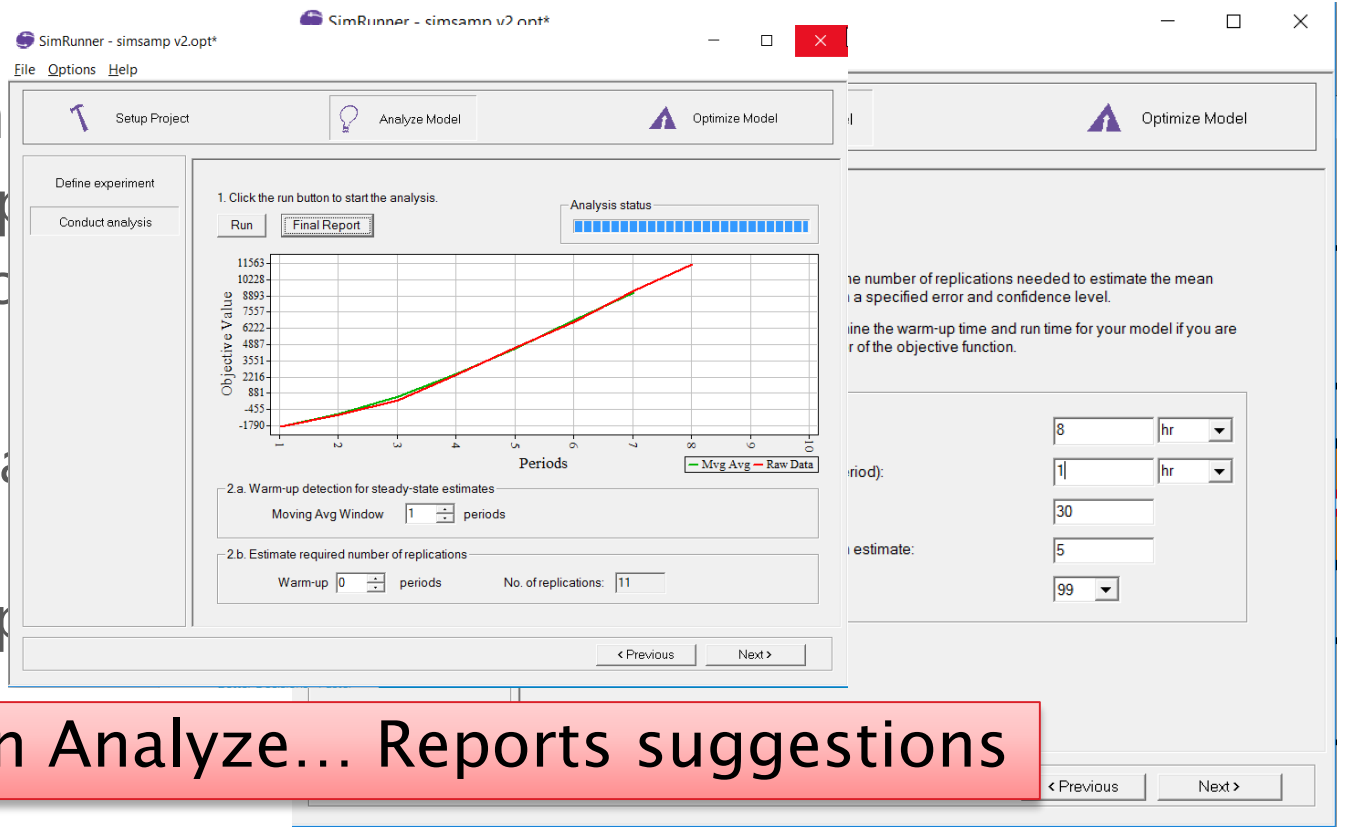
SimRunner Project

- Save the Project
  - Creates a .OPT file



Analyze the Model

- Helps determ
  - Number of rep
  - Warmup perio
- However…
  - ~30 Reps usua
  - You'll know if
    Warm-up is ap



Run Analyze… Reports suggestions

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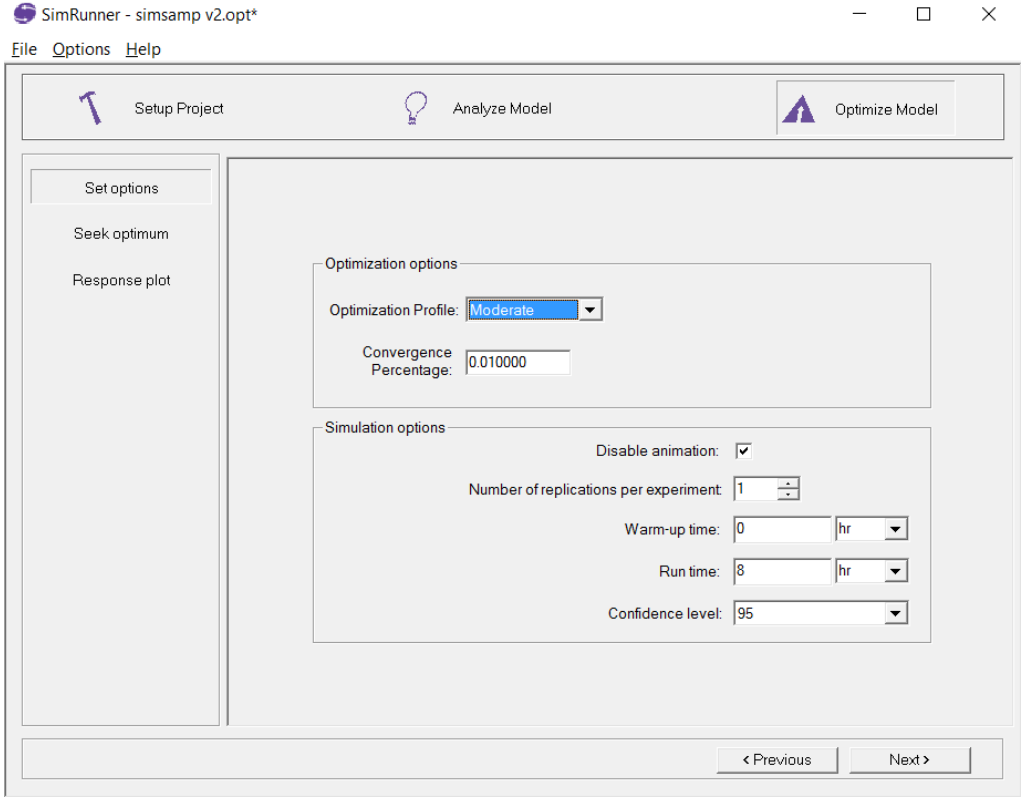
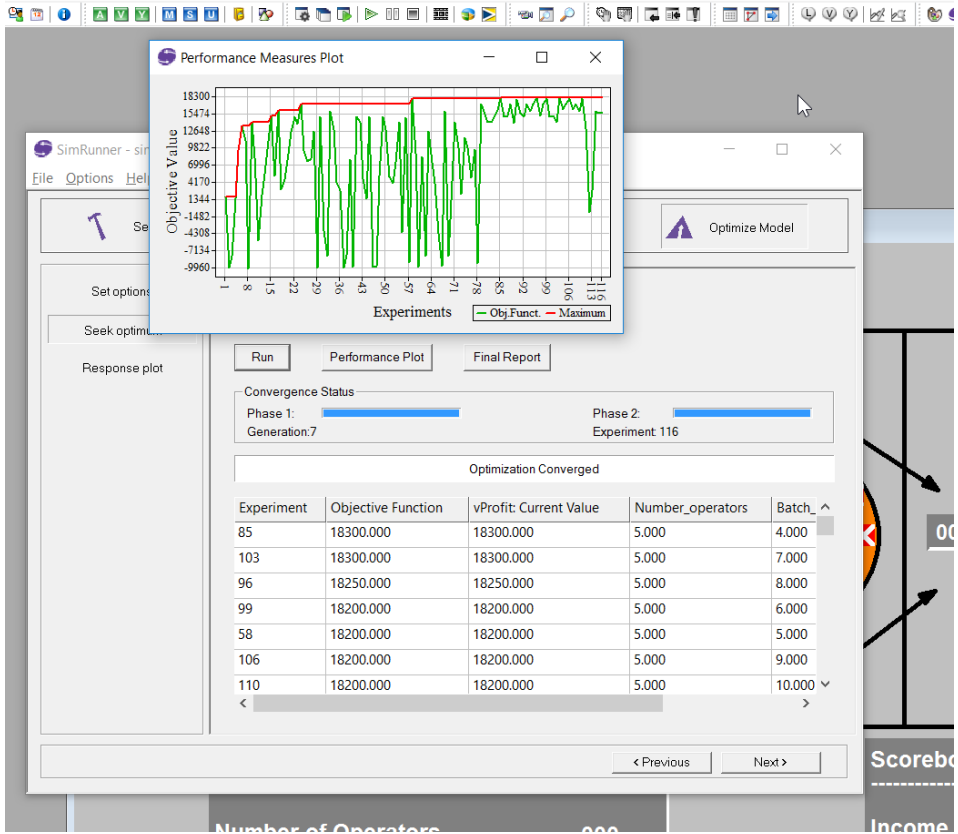
Run the Optimization - Settings

- Profile
  - Cautious, (more runs) Moderate, Aggressive (less runs)
  - Convergence %
- No Animation
- # of Replications
- Warmup/Run Time
- Confidence Level



Run the Optimization

- Run…
  - Results for each run…
    “Performance Plot”
    Green – Each run
    Red – Best so far
  - Table of Results
- When finished…
  “Optimization Converged”



Examine the Results

- Best solution is at the top
  - For our example:
    $18,300 profit for the day
    5 Operators
    Batch size: 4 or 7
    Yes, Use the Robot

Optimization Converged

Experiment	Objective Function	vProfit: Current Value	Number_operators	Batch_size	mUse_Robot_Y1_N0
85	18300.000	18300.000	5.000	4.000	1.000
103	18300.000	18300.000	5.000	7.000	1.000
96	18250.000	18250.000	5.000	8.000	1.000
99	18200.000	18200.000	5.000	6.000	1.000
58	18200.000	18200.000	5.000	5.000	1.000
106	18200.000	18200.000	5.000	9.000	1.000
110	18200.000	18200.000	5.000	10.000	1.000
90	18050.000	18050.000	5.000	3.000	1.000

Examine the Results

- But more can be gleaned…
  - What if someone doesn't show up for work (4 Operators instead of 5): Profit of only $17,260

Optimization Converged

Experiment	Objective Function	vProfit: Current Value	Number_operators	Batch_size	mUse_Robot_Y1_N0
85	18300.000	18300.000	5.000	4.000	1.000
103	18300.000	18300.000	5.000	7.000	1.000
96	18250.000	18250.000	5.000	8.000	1.000
99	18200.000	18200.000	5.000	6.000	1.000
58	18200.000	18200.000	5.000	5.000	1.000
106	18200.000	18200.000	5.000	9.000	1.000
110	18200.000	18200.000	5.000	10.000	1.000
90	18050.000	18050.000	5.000	3.000	1.000
79	17300.000	17300.000	5.000	14.000	1.000
105	17260.000	17260.000	4.000	9.000	1.000
24	17250.000	17250.000	5.000	13.000	1.000
93	17250.000	17250.000	5.000	15.000	1.000
95	17250.000	17250.000	5.000	12.000	1.000
88	17250.000	17250.000	5.000	11.000	1.000

Examine the Results

- Regarding the Batch Size…
  - How sensitive is the Profit?
    Not very ($250/day), for sizes 3,4,5,6,7,8,9,10
  - What if there are “standard” containers?
    Then don’t fill every hole

Optimization Converged

Experiment	Objective Function	vProfit: Current Value	**Number_operators**	Batch_size	mUse_Robot_Y1_N0
85	18300.000	18300.000	5.000	4.000	1.000
103	18300.000	18300.000	5.000	7.000	1.000
96	18250.000	18250.000	5.000	8.000	1.000
99	18200.000	18200.000	5.000	6.000	1.000
58	18200.000	18200.000	5.000	5.000	1.000
106	18200.000	18200.000	5.000	9.000	1.000
110	18200.000	18200.000	5.000	10.000	1.000
90	18050.000	18050.000	5.000	3.000	1.000
79	17300.000	17300.000	5.000	14.000	1.000

Examine the Results

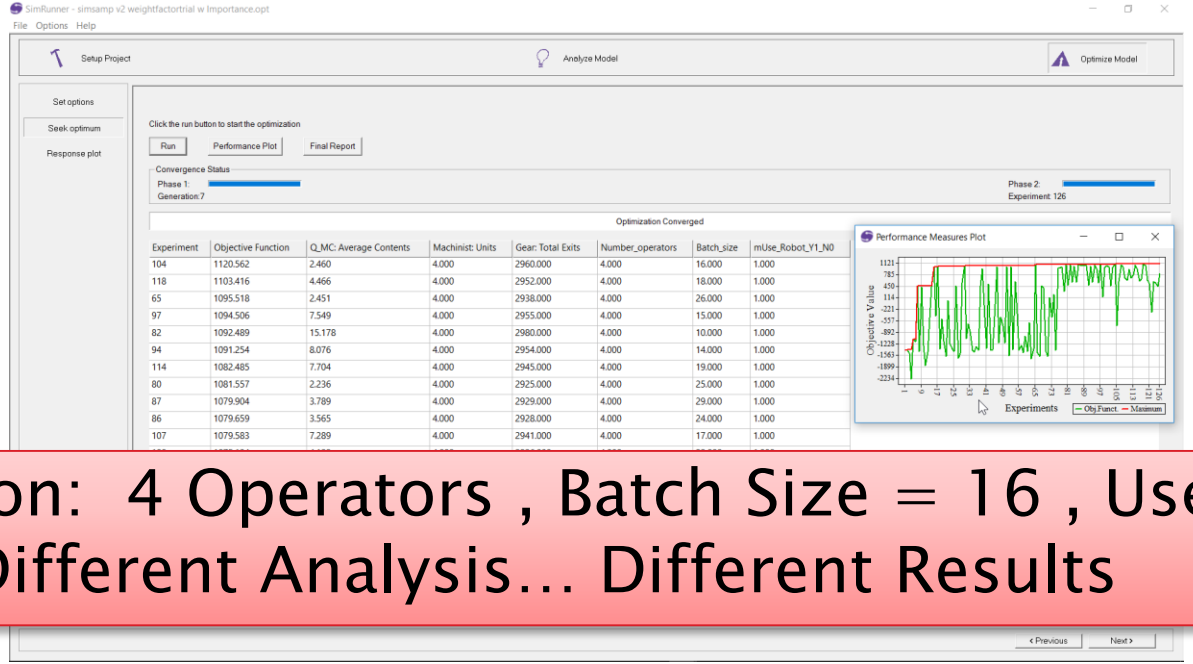
- Regarding the Robot…
  - What's it's worth?
    $13,600 - $18,300 = -$4,700 day loss without

Optimization Converged

Experiment	Objective Function	vProfit: Current Value	Number_operators	Batch_size	mUse_Robot_Y1_N0
81	14200.000	14200.000	5.000	47.000	1.000
9	14200.000	14200.000	5.000	50.000	1.000
89	14150.000	14150.000	5.000	42.000	1.000
23	13910.000	13910.000	4.000	50.000	1.000
6	13600.000	13600.000	5.000	13.000	0.000
111	13260.000	13260.000	4.000	2.000	1.000
50	13050.000	13050.000	5.000	11.000	0.000
34	13000.000	13000.000	5.000	28.000	0.000
63	12800.000	12800.000	5.000	37.000	0.000
28	12750.000	12750.000	5.000	6.000	0.000
21	12600.000	12600.000	5.000	1.000	1.000
74	11650.000	11650.000	5.000	3.000	0.000
7	11170.000	11170.000	3.000	13.000	1.000
14	11070.000	11070.000	3.000	26.000	1.000

Examine the Results

- How about if we don't use Profit?
  - Max Throughput, Min WIP, Min Labor – w/ Weights



Experiment	Objective Function	Q_MC: Average Contents	Machinist: Units	Gear: Total Exits	Number_operators	Batch_size	mUse_Robot_Y1_N0
104	1120.562	2.460	4.000	2960.000	4.000	16.000	1.000
118	1103.416	4.466	4.000	2952.000	4.000	18.000	1.000
65	1095.518	2.451	4.000	2938.000	4.000	26.000	1.000
97	1094.506	7.549	4.000	2955.000	4.000	15.000	1.000
82	1092.489	15.178	4.000	2980.000	4.000	10.000	1.000
94	1091.254	8.076	4.000	2954.000	4.000	14.000	1.000
114	1082.485	7.704	4.000	2945.000	4.000	19.000	1.000
80	1081.557	2.236	4.000	2925.000	4.000	25.000	1.000
87	1079.904	3.789	4.000	2929.000	4.000	29.000	1.000
86	1079.659	3.565	4.000	2928.000	4.000	24.000	1.000
107	1079.583	7.289	4.000	2941.000	4.000	17.000	1.000

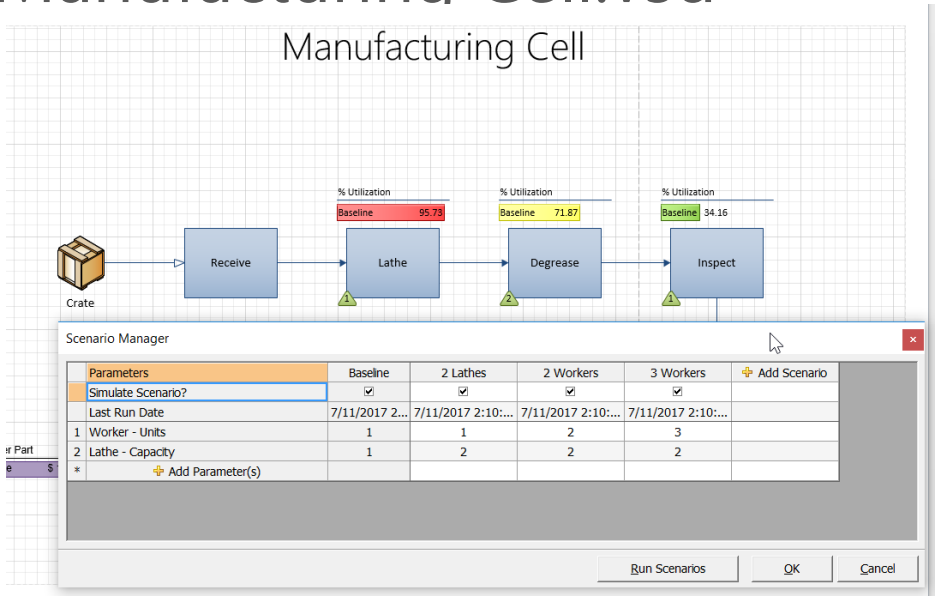
Best Solution: 4 Operators , Batch Size = 16 , Use Robot
Different Analysis… Different Results

Brief Pause…

Let’s take 5!

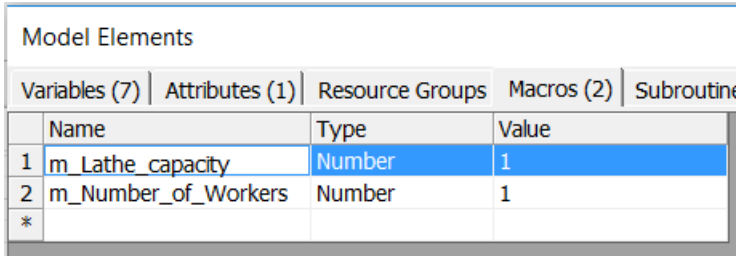
SimRunner & Process Simulator

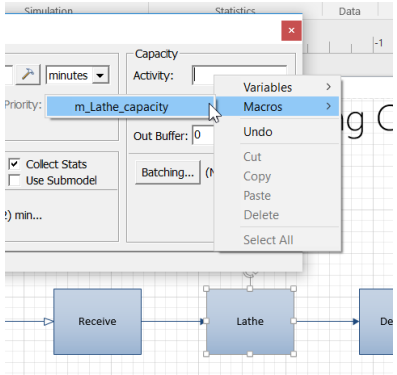
- Run PCS model… Creates .MOD for PM/MM
- Example: Manufacturing Cell.vsd

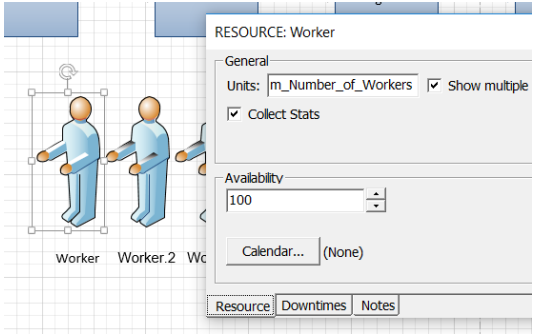


SimRunner & Process Simulator

- Create Macro **m_Lathe_capacity**
  - Apply it to Lathe Activity Capacity
- Create Macro **m_Number_Workers**
  - Apply it to Number of Units of the Worker







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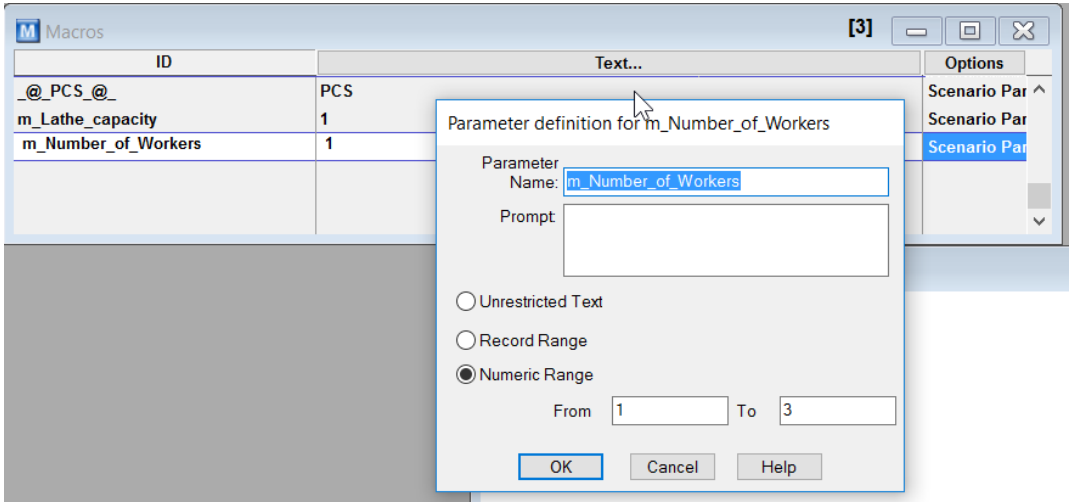
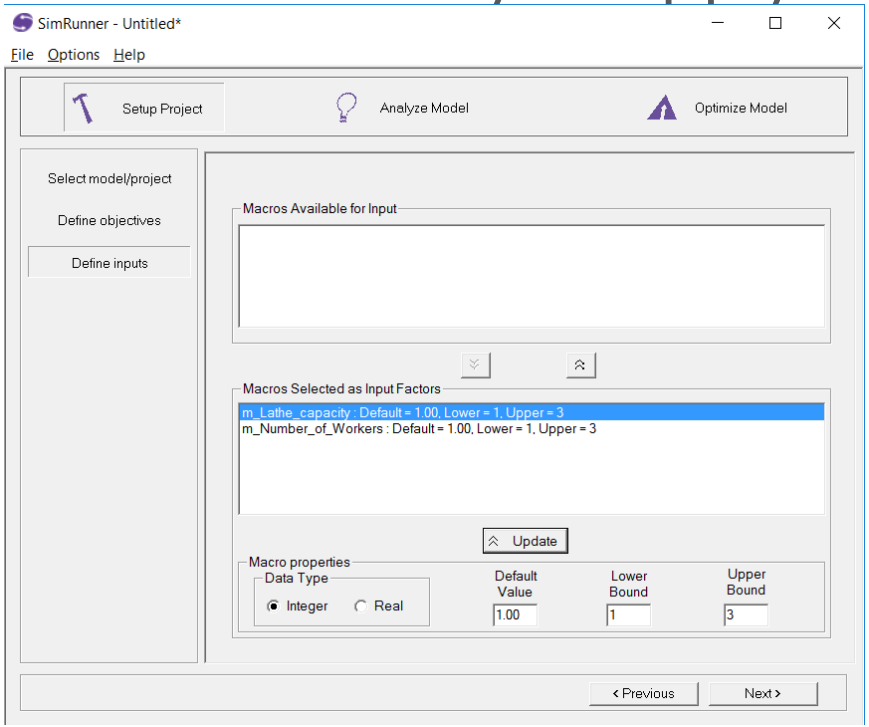
SimRunner & Process Simulator

- Run the PCS model to create the .MOD file
- Open the .MOD with ProModel
  - Make each Model Parameter as Scenario Macros



SimRunner & Process Simulator

- The model is now ready to apply SimRunner



Poll #4

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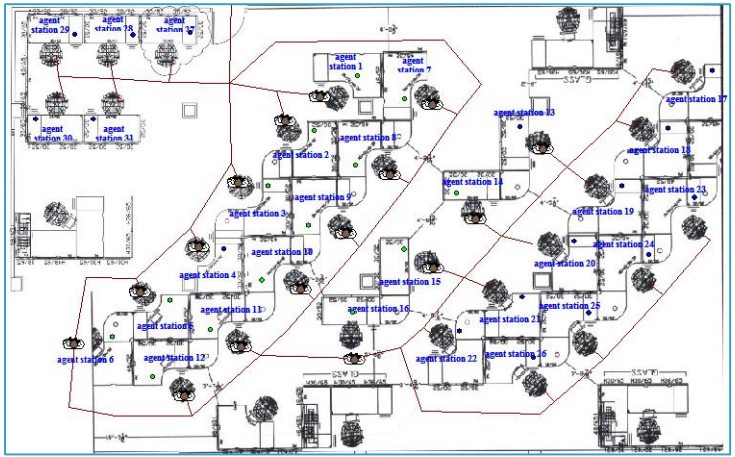
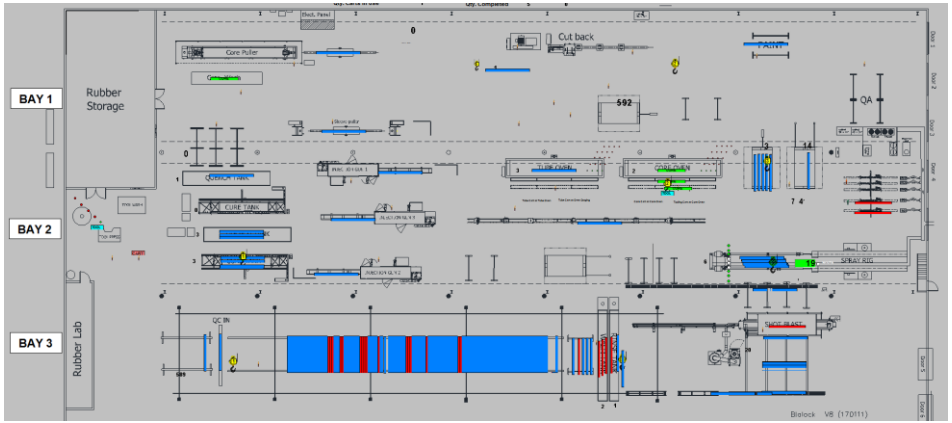
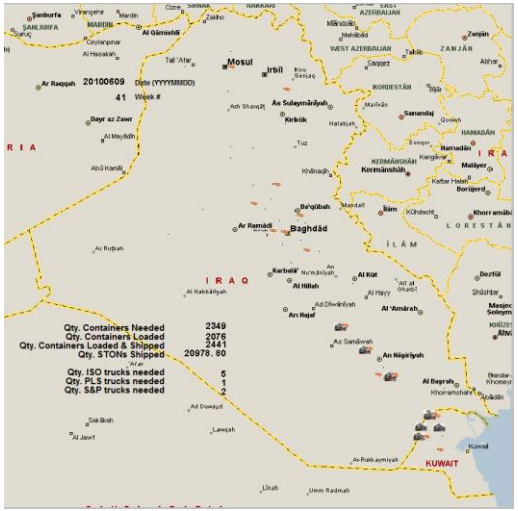
Example Projects

- Call Center
- Steel tube manufacturing
- Army – Iraq drawdown







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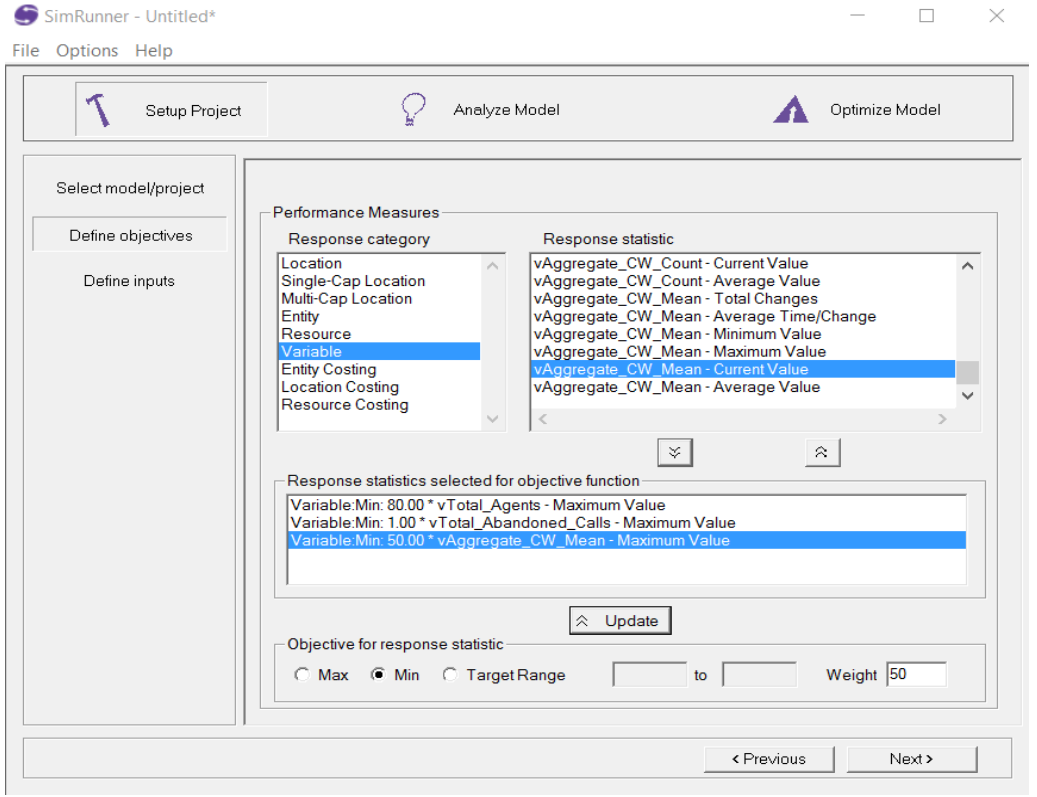
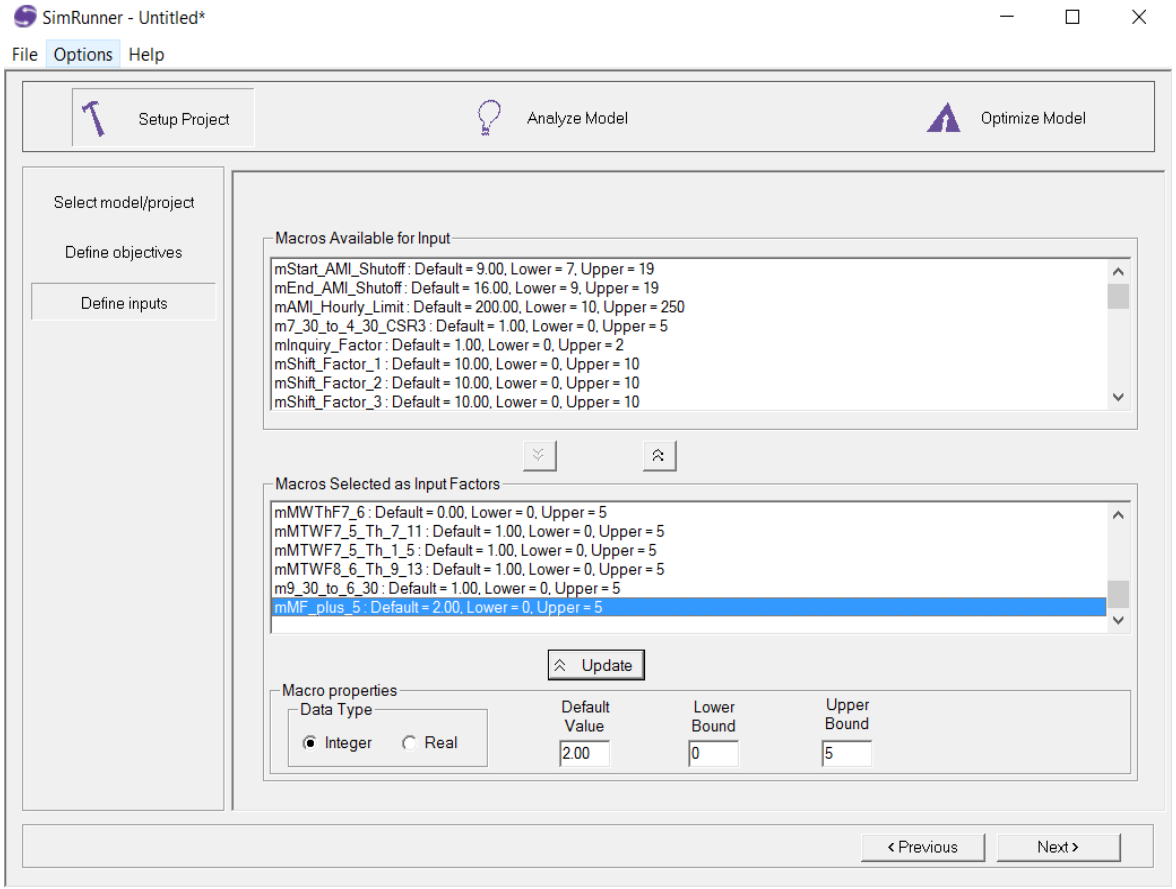
Call Center

- Objective: **Minimize** Qty of Agents & Abandoned Calls & Call Wait Time
- Weight factors… 80; 1; 50 (derived from experimentation & system knowledge)



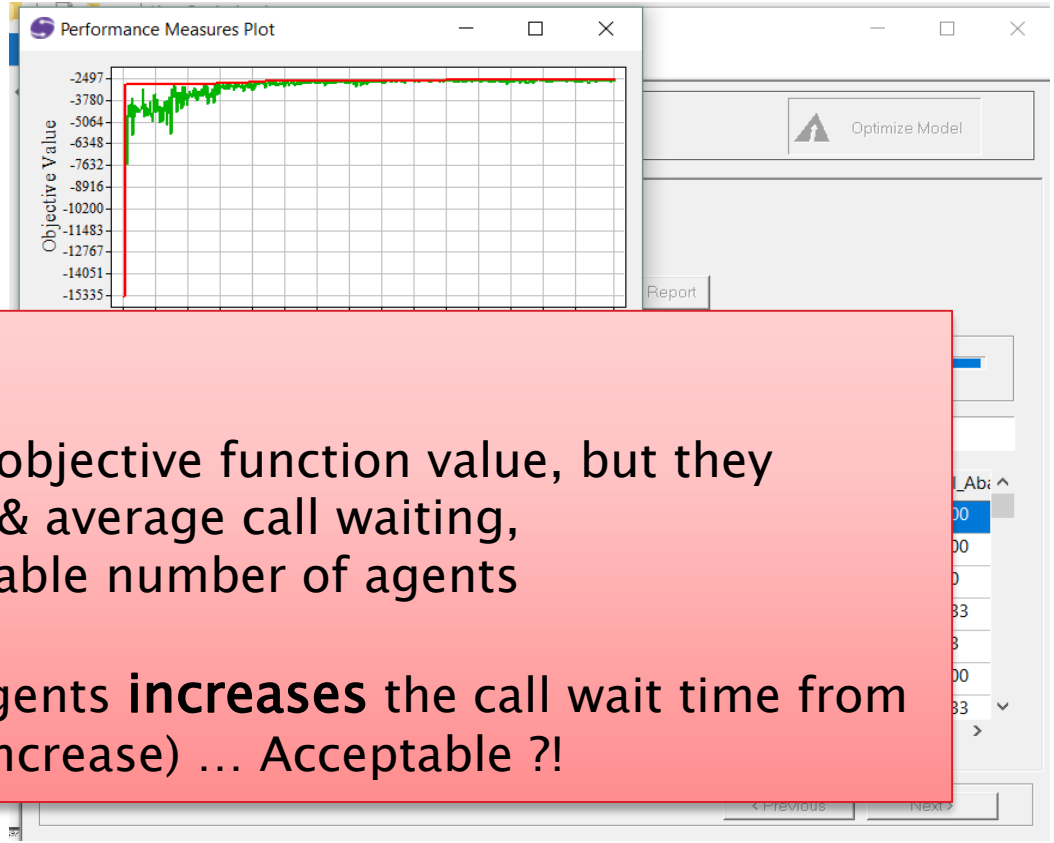
Call Center

- Input factors:
  Qty Agents
  on each Shift



Call Center

- 593 experiments run…
  Answer: 27-28 Agents



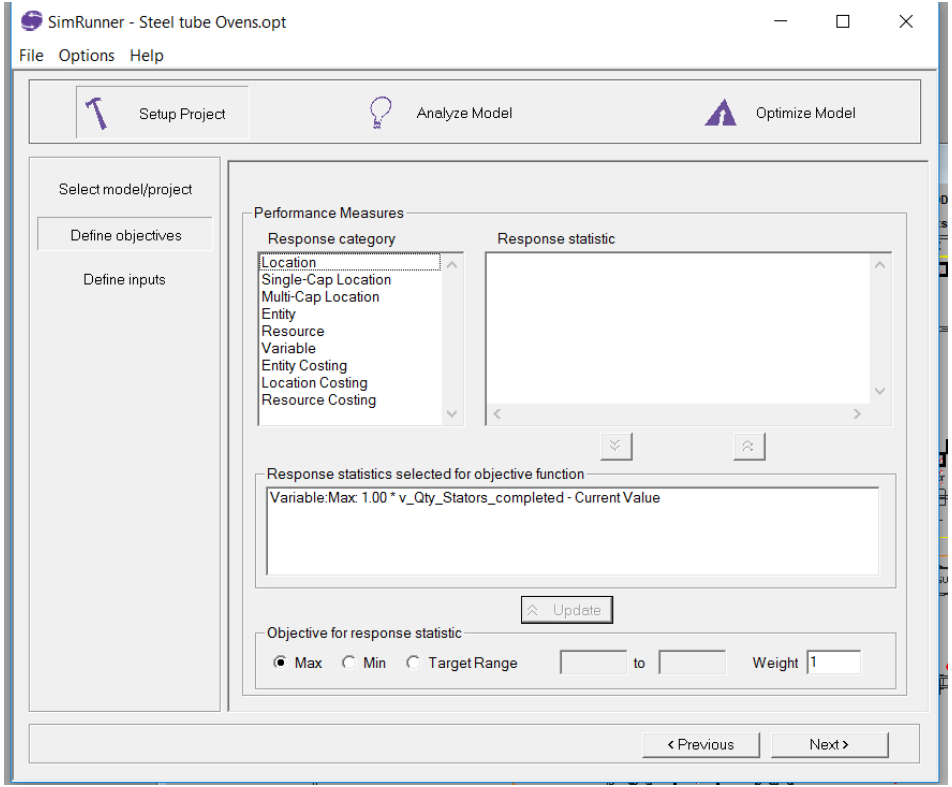
Key findings…

27-28 Agents, not the best objective function value, but they minimized abandoned calls & average call waiting,
while maintaining an acceptable number of agents

Decreasing from 28 to 27 agents **increases** the call wait time from 1.01 to 1.38 minutes (37% increase) … Acceptable ?!

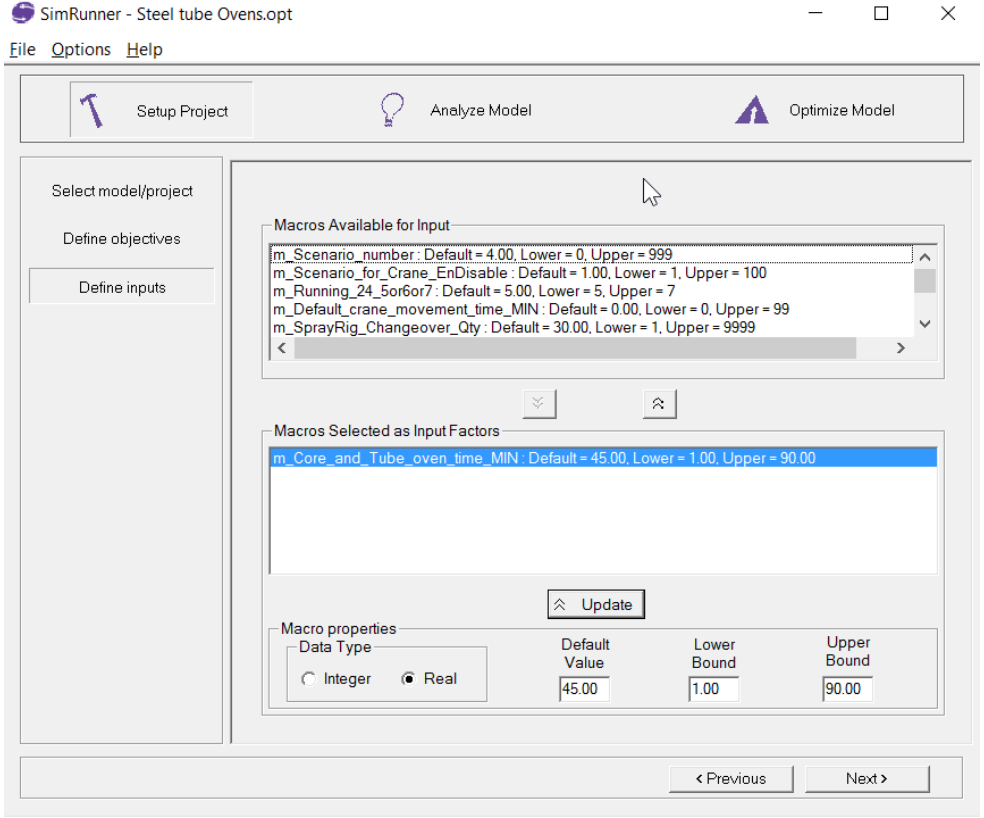
Steel Tube Manufacturing

- Objective:
  Determine
  viable Oven Times
  to **Maximize** Throughput



Steel Tube Manufacturing

- Input factor:
  Oven duration time

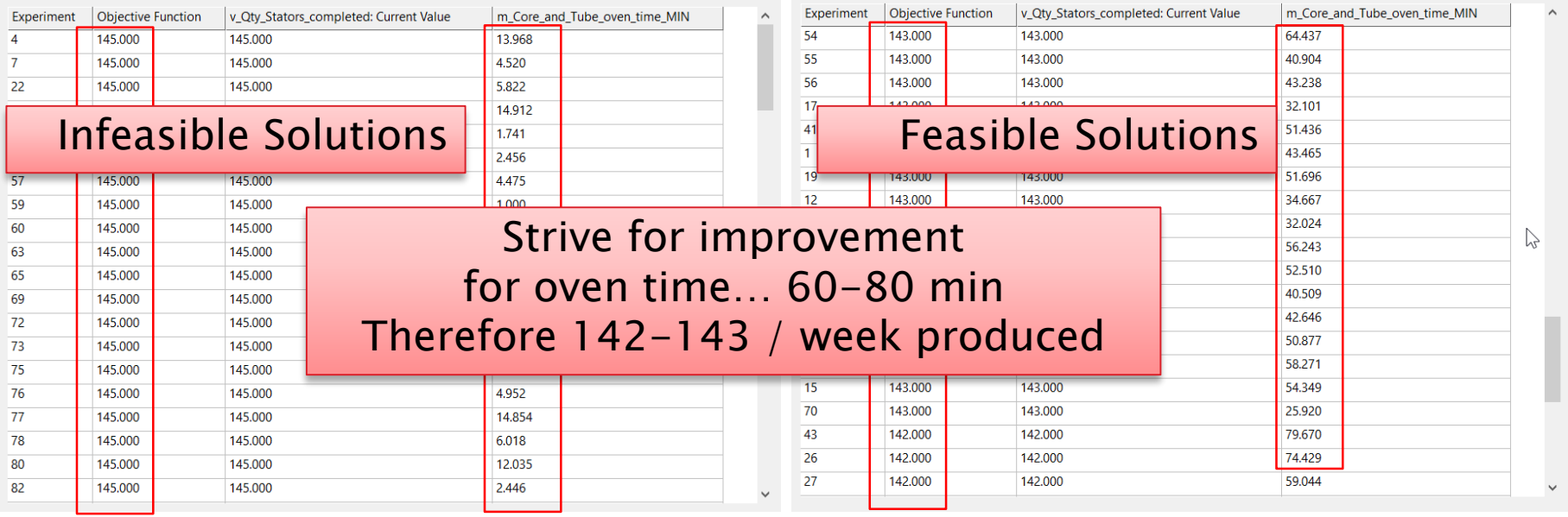


Steel Tube Manufacturing

- 107 experiments run…
  Answer: Oven time 60-80 min.
  - Best possible: 145/week,
    but infeasible for oven time too small
  - Currently 90 min. oven time; 136 units/week
  - Therefore, strive for **feasible improvement** for oven time to 60-80 min. … 142-143 / week

Steel Tube Manufacturing

- Use engineering judgement on the results



Experiment	Objective Function	v_Qty_Stators_completed: Current Value	m_Core_and_Tube_oven_time_MIN
4	145.000	145.000	13.968
7	145.000	145.000	4.520
22	145.000	145.000	5.822
			14.912
			1.741
			2.456
57	145.000	145.000	4.475
59	145.000	145.000	1.000
60	145.000	145.000	
63	145.000	145.000	
65	145.000	145.000	
69	145.000	145.000	
72	145.000	145.000	
73	145.000	145.000	
75	145.000	145.000	
76	145.000	145.000	4.952
77	145.000	145.000	14.854
78	145.000	145.000	6.018
80	145.000	145.000	12.035
82	145.000	145.000	2.446

Infeasible Solutions

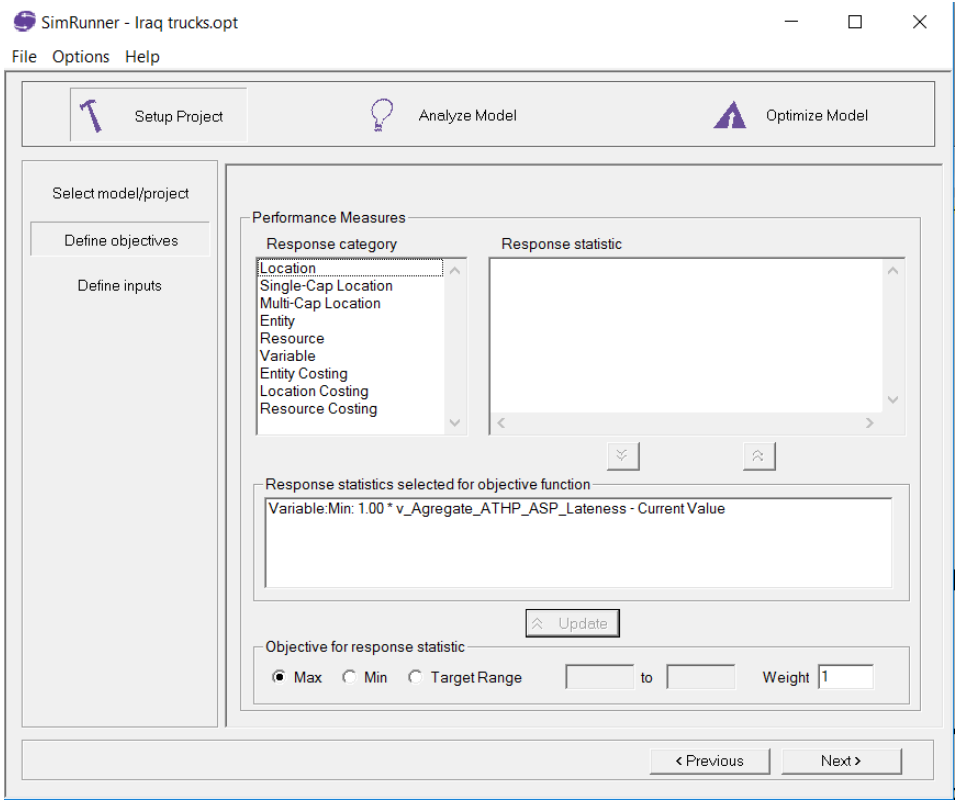
Experiment	Objective Function	v_Qty_Stators_completed: Current Value	m_Core_and_Tube_oven_time_MIN
54	143.000	143.000	64.437
55	143.000	143.000	40.904
56	143.000	143.000	43.238
17			32.101
41			51.436
1			43.465
19	143.000	143.000	51.696
12	143.000	143.000	34.667
			32.024
			56.243
			52.510
			40.509
			42.646
			50.877
			58.271
15	143.000	143.000	54.349
70	143.000	143.000	25.920
43	142.000	142.000	79.670
26	142.000	142.000	74.429
27	142.000	142.000	59.044

Feasible Solutions

Strive for improvement
for oven time… 60–80 min
Therefore 142–143 / week produced

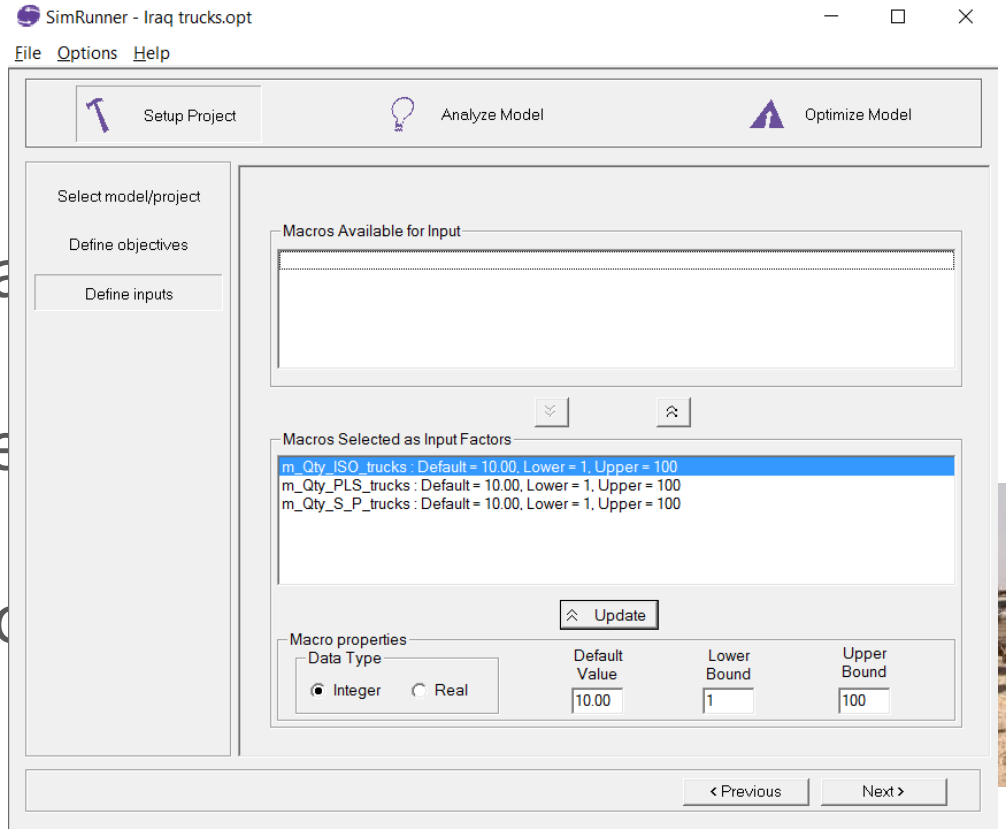
Army – Iraq Drawdown

- Objective:
  Want to **minimize** LATENESS of closing down storage facilities



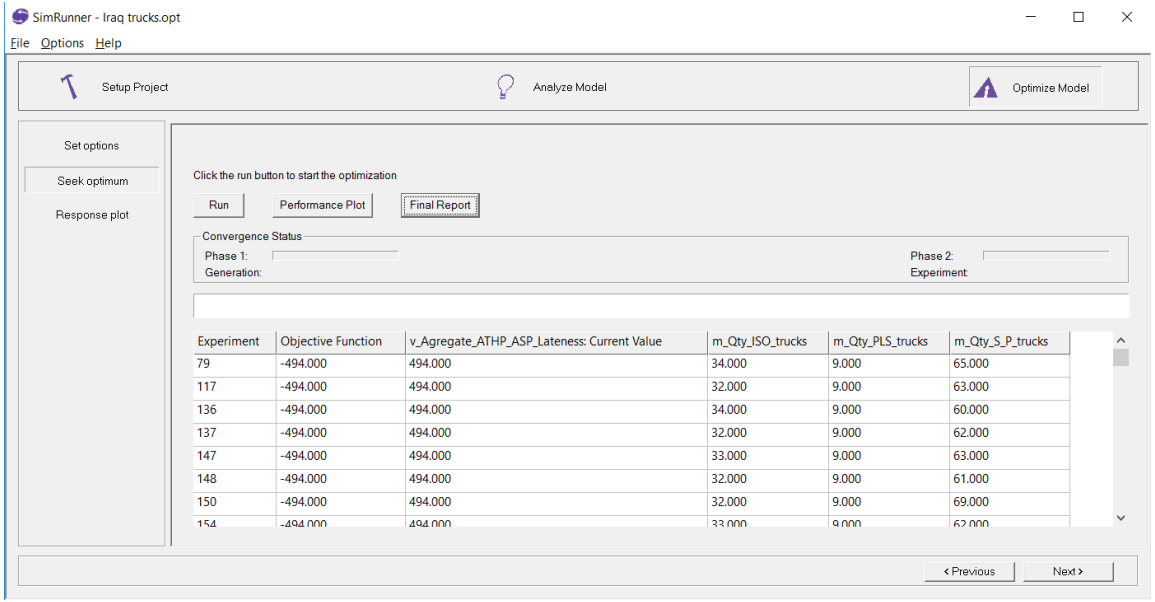
Army – Iraq Drawdown

- Input factors:
  Qty PLS trucks
  (palletized loa
  Qty ISO trucks
  (standard inte
  Qty SP trucks
  (special purpo



Army – Iraq Drawdown

- 166 experiments run…
  Answer:
  9 PLS trucks
  32-34 ISO trucks
  60-70 SP trucks

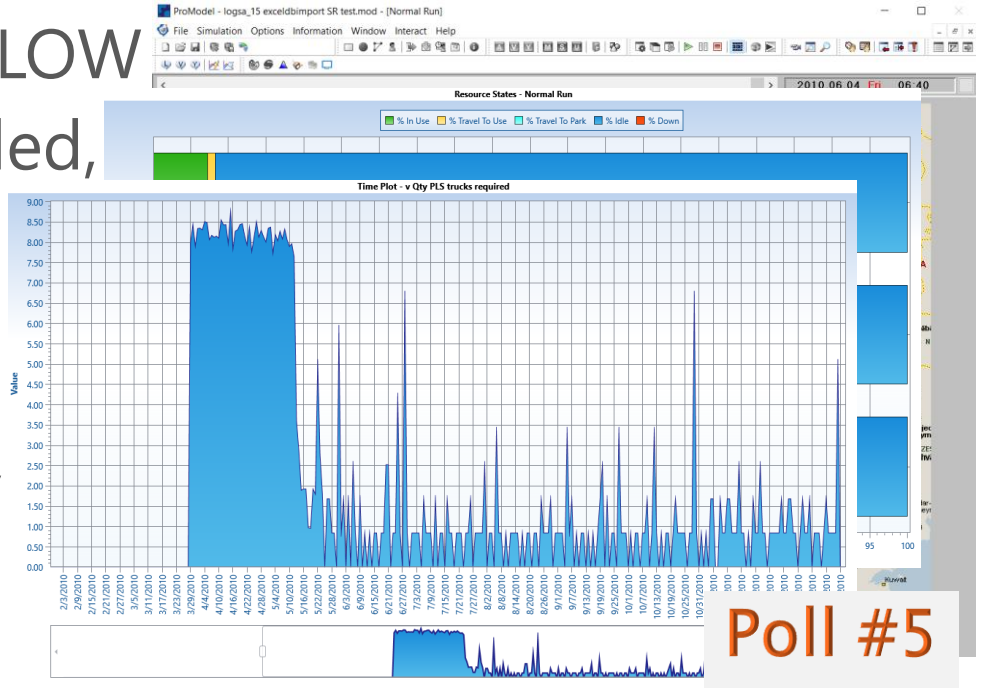


Army – Iraq Drawdown

- Thought!... Why not have unlimited Qty of trucks to Minimize the Lateness of facility closure?
- Because… We don't have unlimited Qty of trucks!
- Therefore… Choose the best solution within realistic constraints

Army – Iraq Drawdown

- Run just 9/34/65 scenario…
  - Utilization of trucks is LOW
  - But when they're needed, THEY'RE NEEDED!
  - Plot Qty trucks needed over time… Heavy PLS usage early



Poll #5

Thank You!

Questions ??

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