香港城市大學
City University of Hong Kong

# 396EM Airline Operations and Scheduling / 6075MAA Airline Scheduling and Operations

## Lecture 7a
## Experimental Design for Queuing Simulation (Results Analysis and Interpretation )


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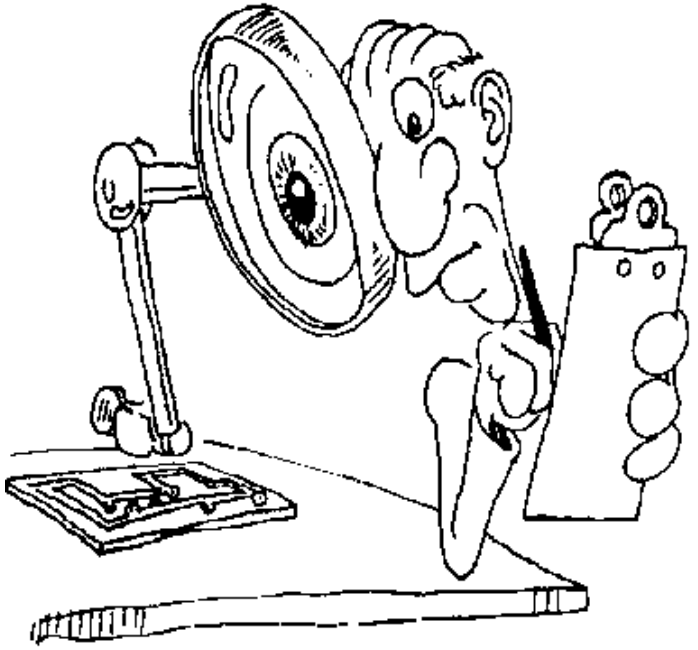
# Outline of the Lecture

- Experimental Design for Queuing Simulation
- Experimentation designs
- Collection of simulation results
- Probability Concept
- Result Analysis and Interpretation
  - Confidence Interval
  - Key Performance Indicators
  - Improvement
- Typical KPIs for arrival / departure
- Simul8's basic building blocks
  - Randomness
  - Batching
  - Resources

# Experimentation

- Modelling and Analysis of Results



# Experimentation

- Experimenter's first goal is to understand the process!
- Experiments are used to study effects of parameters as they are set at various levels.
- Experimentation is one mechanism for identifying causation, which is a step toward understanding how one set of factors influence another set of factors.

# Goals of Experimentation

- To maximise the ability to test the current situation.

- To facilitate generation of new improvement situations.

# Experimental Design Process

- Identify the suggested scenario/experiment.
- Define the measures of success (KPI –Key Performance Indicators)
- Run the experiment
- Collect and analyse the data
- Determine and verify the response
- Act on the results

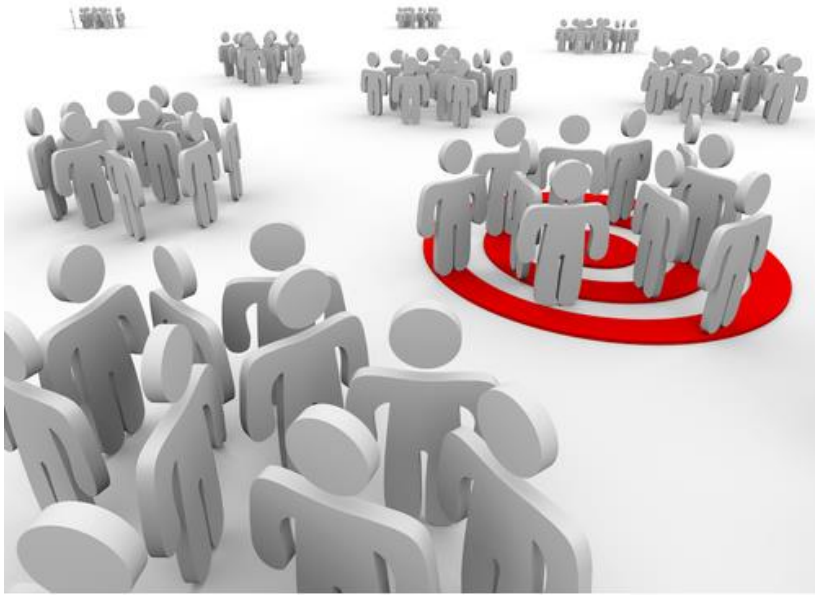
# Key Performance Indicators

- Total costs
- Total simulation time
- Mechanic team utilisation
- Business revenue
- Service team utilisation
- Work centres' utilization / idle times
- Number of services of each service team member
- Customers' average waiting times
- Queue at each work centre
- ……

# The “As-Is” Simulation Modelling

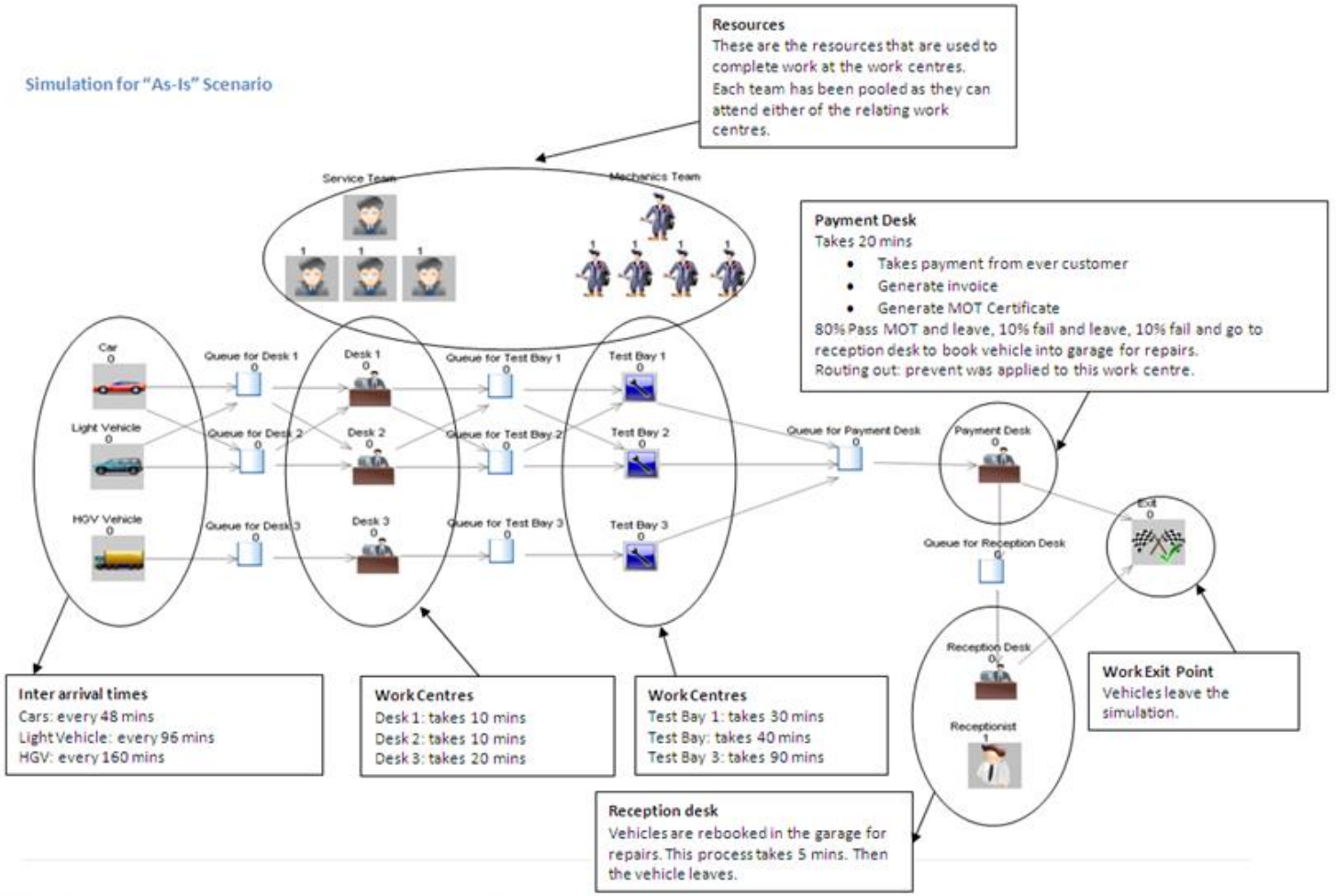
- “As-Is” simulation is used to describe and analyse the current situation to identify bottleneck(s).

- The user describes the system.



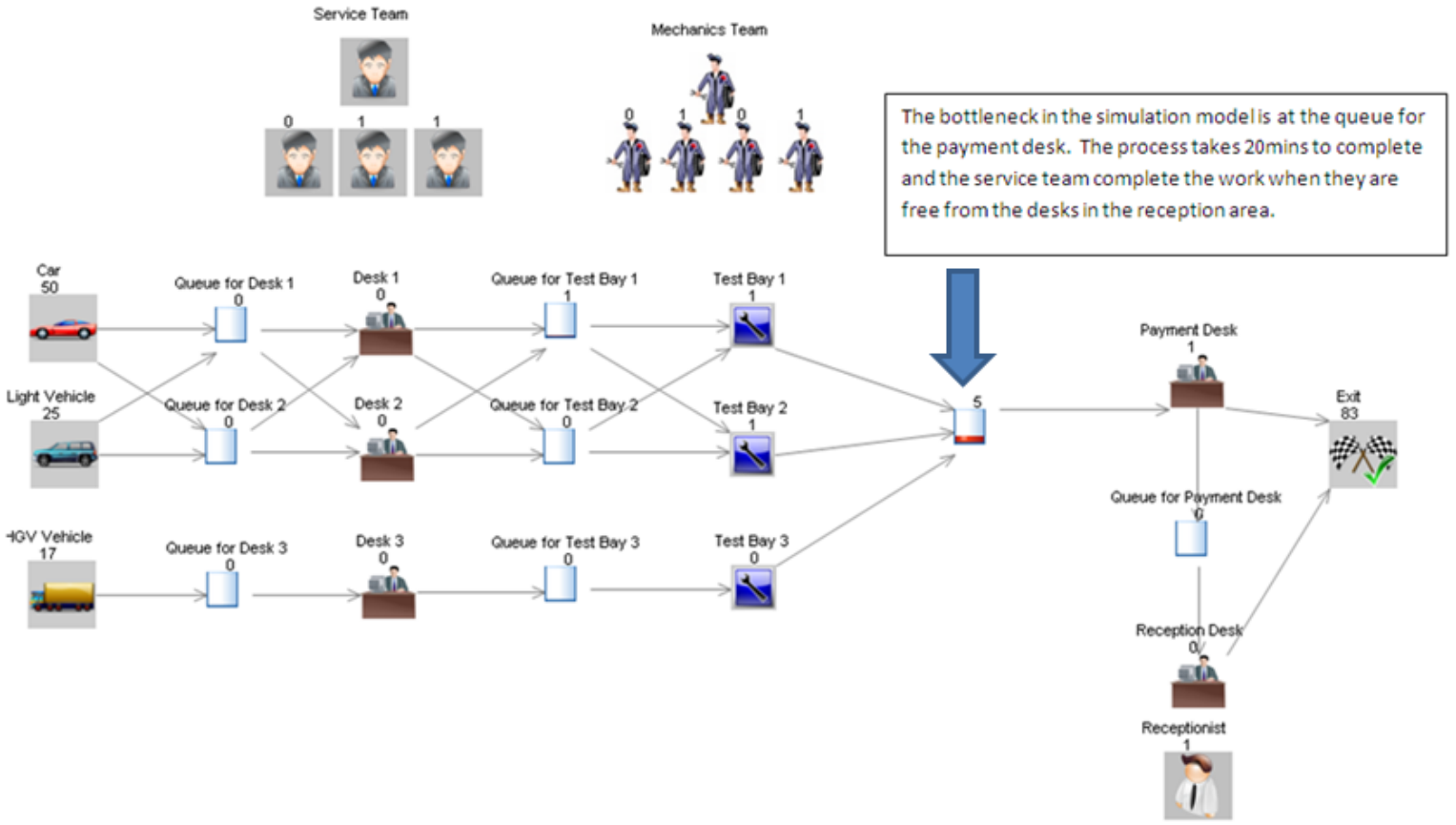
The “As-Is” workforce allocation

# Example: "As-Is" Model Before Run




**Raminder Kaur**: ***Mock Assignment for the "B&T Garage" Problem 2011***

# Example: “As-Is” Model After Run




**Raminder Kaur**: ***Mock Assignment for the “B&T Garage” Problem 2011***

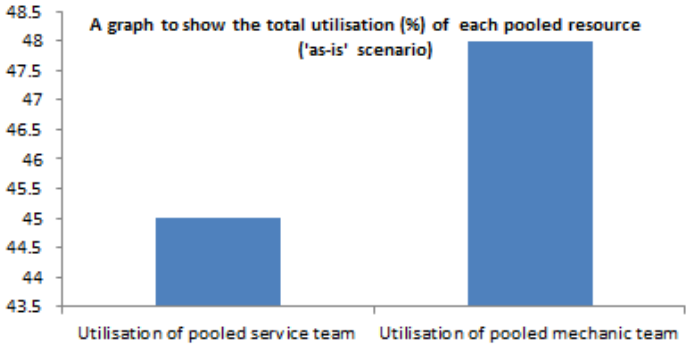
# Example: "As-Is" Model Results

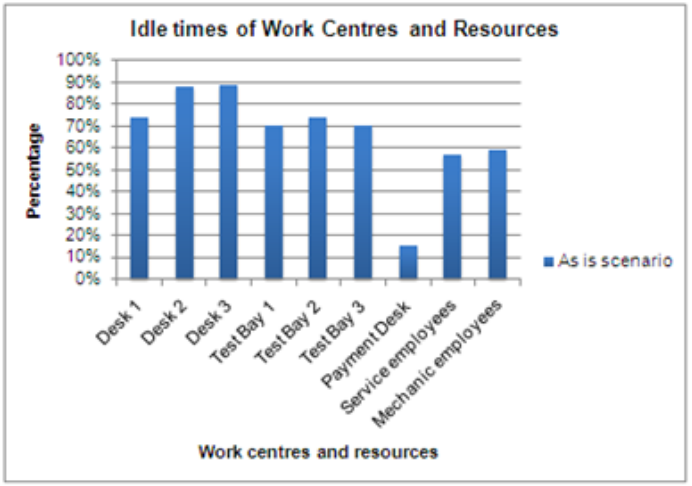
| Vehide Type | Amount per day | Cost per MOT (£) | Total Cost of all MOT's (£) |
|---|---|---|---|
| Cars | 10 | 39.99 | 399.9 |
| Light Vehicles | 5 | 55 | 275 |
| HGV | 3 | 99.99 | 299.97 |
| | | | |
| | | Total cost per day (£) | 974.87 |
| | | Total cost Per week (£) | 4874.35 |

| Service Team | Hourly rate (£) | Total hours worked per week | Total cost per week (£) |
|---|---|---|---|
| ST1 | 6 | 36 | 216 |
| ST2 | 6 | 40 | 240 |
| ST3 | 6 | 40 | 240 |
| | | Total per week (£) | 696 |

| Mechanic Team | Hourly rate (£) | Total hours per week | Total cost per week (£) |
|---|---|---|---|
| M1 | 12 | 40 | 480 |
| M2 | 12 | 40 | 480 |
| M3 | 12 | 40 | 480 |
| M4 | 12 | 40 | 480 |
| | | Total Cost per week (£) | 1920 |
| | | | |
| | | Total Labour costs (£) | 2616 |
| | | Total Revenue (£) | 2258.35 |

***LynnEmery: Mock Assignment for the "B&T Garage" Problem 2011***




***Kerrie Martin: Mock Assignment for the "B&T Garage" Problem 2011***

# Simulation Run and Analysis

**Probabilistic Simulation** (also called stochastic)

One or more of the independent variables are probabilistic (random) e.g. service / inter-arrival time.

- To measure performance of the simulation system.
- Also to determine if more runs needed till results are consistent.

# Probability Concept


- Probability is our way of formally describing our world and evaluating uncertainties.

- The probability of an event occurring is written as a fraction, a decimal or a percentage, e.g. the probability of getting an even number on rolling a dice is ½ or 0.5 or 50%

# Reasons for Probabilistic Modelling

- The input parameters for the models depend on various external factors:
  - Because of these factors, realistic models are subject to randomness caused by systematic variation of the input parameters.
- A deterministic model does not consider these variations.
- An effective model should take into consideration the randomness associated with various input data. (More realistic models)

# Source of Randomness

The following are some sources of randomness in simulated queuing systems:

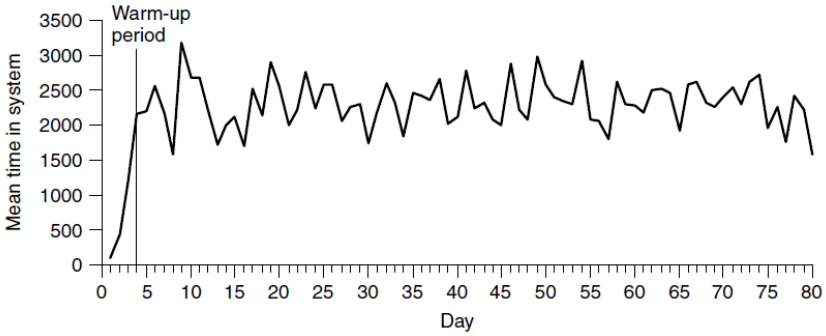
- Arrivals of customers
- Service / Waiting times
- Queue time in normal / peak hours
- Queue length
- Service down time
- Others, e.g., sick leave of a staff

# Controlling the Simulation Experiment

- The purpose of running more than one experiment is that to cover as many solution possibilities through generating different simulation parameters at each simulation run.

- The average solution of these simulation runs can probably be considered as a near estimate for the real life situation.

# Simulation Warm-up and Replications




- The purpose of the warm-up is to prepare the simulation model to more mature state after randomizing its inputs and to eliminate the transient state.

E.g., in order to run a trial of 5 replicated automatically using SIMUL8:

- Confirm that the **Warm-Up Period** is **480** and the Results Collection Period is **2400** and run the model.
- Use Trials / Conduct Trial

# Replication of Simulation Runs

- Multiple replications of simulations
  - run with same parameters except for the random numbers
  - aim to obtain a better estimate of mean performance.
  - Number of replications required?

| | Mean time in system | | | | | |
|---|---|---|---|---|---|---|
| Day | Repl. 1 | Repl. 2 | Repl. 3 | Repl. 4 | Repl. 5 | Mean |
| 1 | 93.98 | 56.88 | 142.04 | 110.87 | 82.32 | 97.22 |
| 2 | 618.08 | 501.71 | 292.19 | 672.74 | 135.28 | 444.00 |
| 3 | 1737.02 | 1162.92 | 336.36 | 1538.36 | 1291.77 | 1213.29 |
| 4 | 1769.77 | 953.53 | 3895.80 | 1069.59 | 3098.86 | 2157.51 |
| 5 | 1663.22 | 3006.68 | 1346.40 | 2837.09 | 2118.00 | 2194.28 |
| 6 | 2425.34 | 1495.23 | 2731.65 | 2855.38 | 3314.20 | 2564.36 |
| 7 | 1611.92 | 1798.13 | 1922.52 | 1797.52 | 3680.18 | 2162.05 |
| 8 | 2885.21 | 1185.96 | 1706.25 | 1548.68 | 544.49 | 1574.12 |
| 9 | 1986.58 | 3628.20 | 2958.04 | 3194.36 | 4104.93 | 3174.42 |
| 10 | 2521.63 | 2122.12 | 2537.90 | 2181.94 | 4068.63 | 2686.44 |
| . | . | . | . | . | . | . |
| . | . | . | . | . | . | . |
| . | . | . | . | . | . | . |

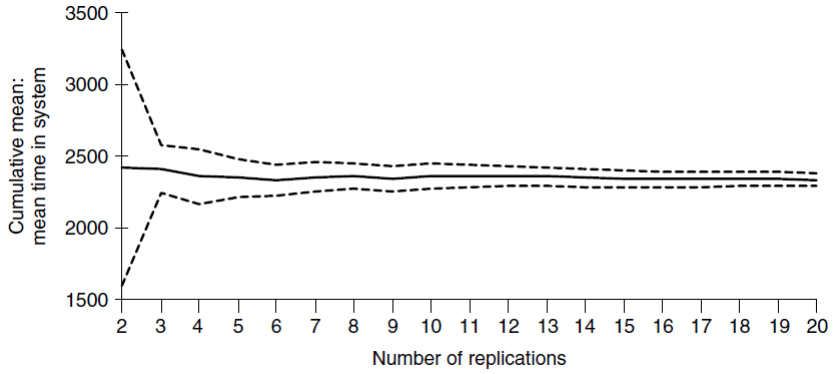
*Confidence interval* is a statistical means for showing how accurately the mean  average of a value is being estimated.

# Confidence Interval

Usually, a significance level of 5% is selected – it gives 95% probability that the value of the true mean lies within the confidences intervals.

Confidence Interval Methods:

It can trace the replication results by using tables or plotting graphs.




| Replication | Mean time in system | Cumulative mean | Standard deviation | 95% Confidence interval | | |
|---|---|---|---|---|---|---|
| | | | | Lower interval | Upper interval | % deviation |
| 1 | 2484.72 | 2484.72 | n/a | n/a | n/a | n/a |
| 2 | 2354.64 | 2419.68 | 91.980 | 1593.27 | 3246.08 | 34.15% |
| 3 | 2396.47 | 2411.94 | 66.406 | 2246.98 | 2576.90 | 6.84% |
| 4 | 2196.91 | 2358.18 | 120.414 | 2166.58 | 2549.79 | 8.13% |
| 5 | 2321.74 | 2350.89 | 105.547 | 2219.84 | 2481.95 | 5.57% |
| 6 | 2247.03 | 2333.58 | 103.489 | 2224.98 | 2442.19 | 4.65% |
| 7 | 2489.73 | 2355.89 | 111.392 | 2252.87 | 2458.91 | 4.37% |
| 8 | 2396.50 | 2360.97 | 104.123 | 2273.92 | 2448.02 | 3.69% |
| 9 | 2207.35 | 2343.90 | 110.039 | 2259.32 | 2428.48 | 3.61% |
| 10 | 2530.37 | 2362.55 | 119.333 | 2277.18 | 2447.91 | 3.61% |
| 11 | 2358.83 | 2362.21 | 113.215 | 2286.15 | 2438.27 | 3.22% |
| 12 | 2321.83 | 2358.84 | 108.574 | 2289.86 | 2427.83 | 2.92% |
| 13 | 2346.77 | 2357.91 | 104.005 | 2295.06 | 2420.76 | 2.67% |
| 14 | 2223.44 | 2348.31 | 106.192 | 2287.00 | 2409.62 | 2.61% |
| 15 | 2276.51 | 2343.52 | 103.995 | 2285.93 | 2401.11 | 2.46% |
| 16 | 2310.23 | 2341.44 | 100.813 | 2287.72 | 2395.16 | 2.29% |
| 17 | 2302.12 | 2339.13 | 98.076 | 2288.70 | 2389.55 | 2.16% |
| 18 | 2418.72 | 2343.55 | 96.980 | 2295.32 | 2391.78 | 2.06% |
| 19 | 2339.05 | 2343.31 | 94.253 | 2297.88 | 2388.74 | 1.94% |
| 20 | 2193.30 | 2335.81 | 97.679 | 2290.10 | 2381.53 | 1.96% |

SIMUL8 supports *Results Manager* which can collect the results from replications and estimate number of runs which may led the results to fall into the confidence intervals.

# Experiments (Scenarios)

- A narrative description of what people do and experience as they try to make use of computer systems and applications.
- Scenarios can be used to describe present **"As-Is" Scenario**.
- Most often used to describe possible futures **"What-If" Scenarios**.

# “What-If” Scenarios

When “As-Is” simulation run falls into an expected confident level and expected KPIs are collected, design “What-if” scenarios to find problems, improvement, alternatives, etc:

Scenario 1: *Reduce* service employees to 2

Scenario 2: *Reduce* mechanic employees to 2

Scenario 3: *Reduce* the quantity of reception desks

Scenario 4: *Modify* the work shift patterns of each employee resource

Scenario 5: *Modify* resource responsibilities and work centre locations

Scenario 6: *Make* One Customer Service Employee Part Time

……

# Popular Scenarios for Queuing

- Add more resources for the existing service in order to reduce the service time of the current service(s).
- Adopt more than one service (work centre) with multiple queues if required.
- Manipulate the queue organisation (circulate, percent, uniform, label, etc)
- Change the service pattern (FCFS, LCFS, Priority, etc).
- Adopt more than one working shift.

# KPI for Airline departure

- Average queue time / persons
- Maximum queue time / persons
- Service counter's utilization rate
- Service time for different passenger type?
- Others …

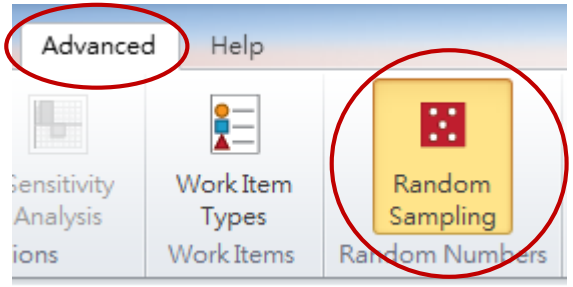
- Queue time / System time

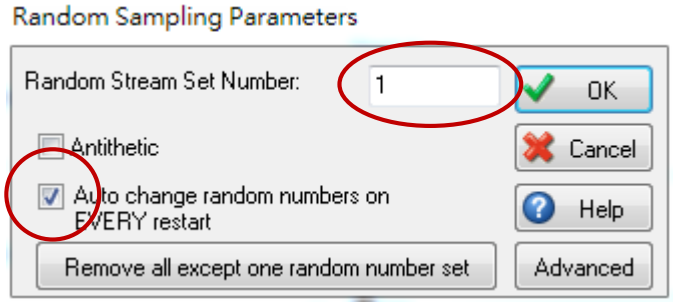
# KPI for airport/airline arrival

- Maximum queue time
- Service utilization rate
- Service time for different passenger types?
- Any others?
  - Average queue time may not be favorable to focus on as all passengers arrive at the same time, queue time varies from zero to maximum and “average” seemed not significant

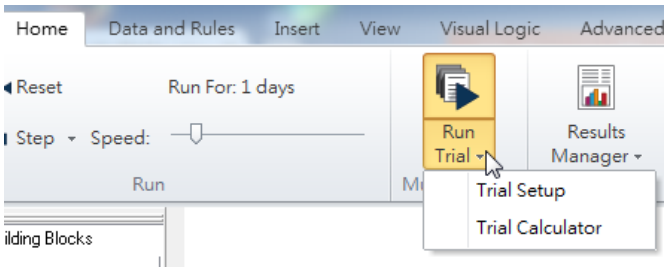
# More for SIMUL8

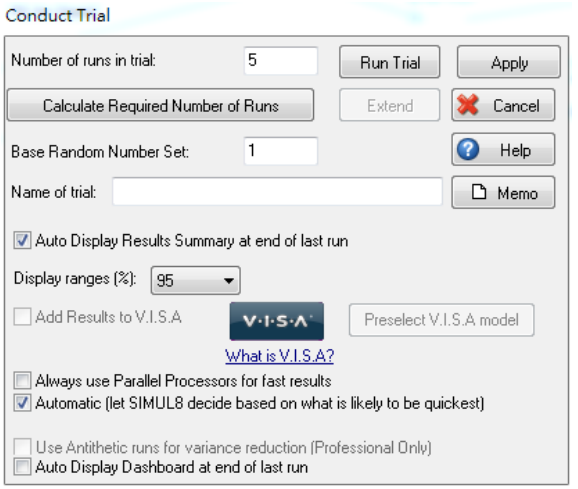
# Random sampling

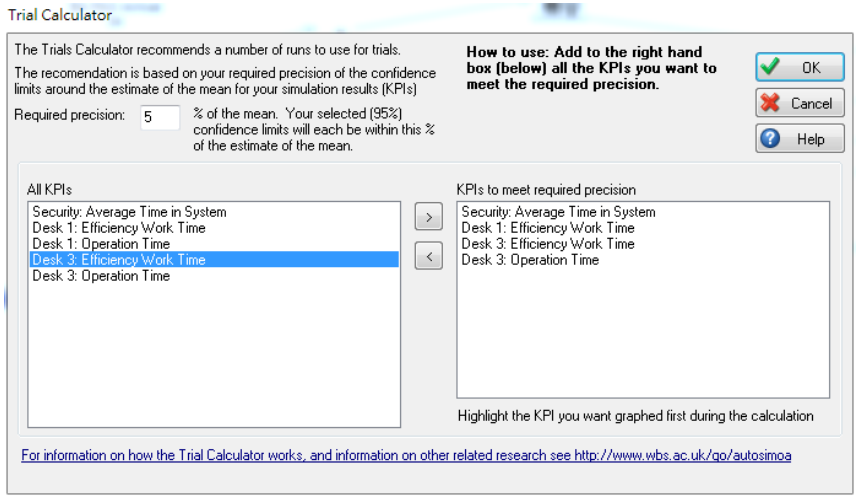


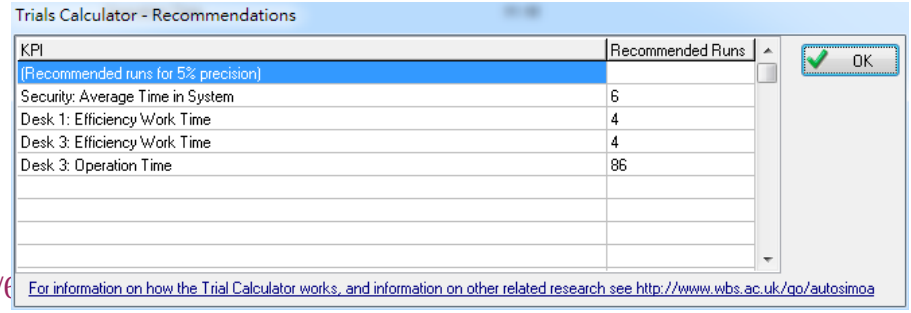



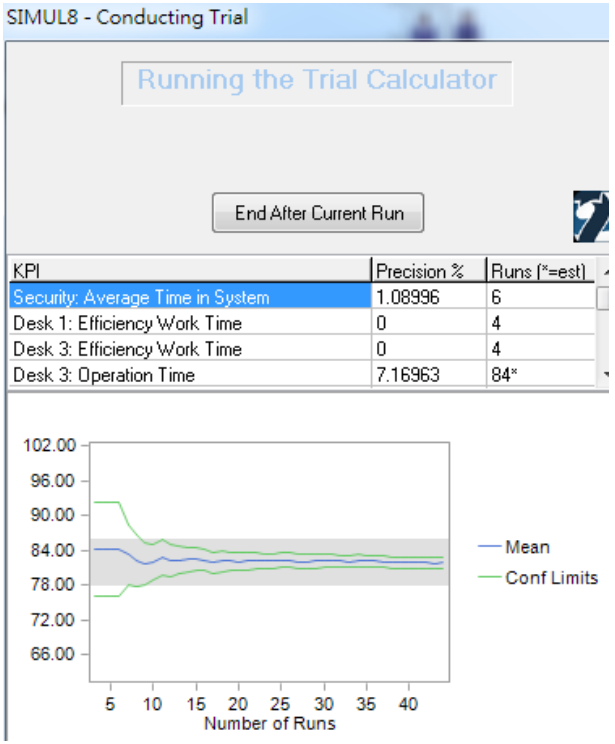
# Multiple runs



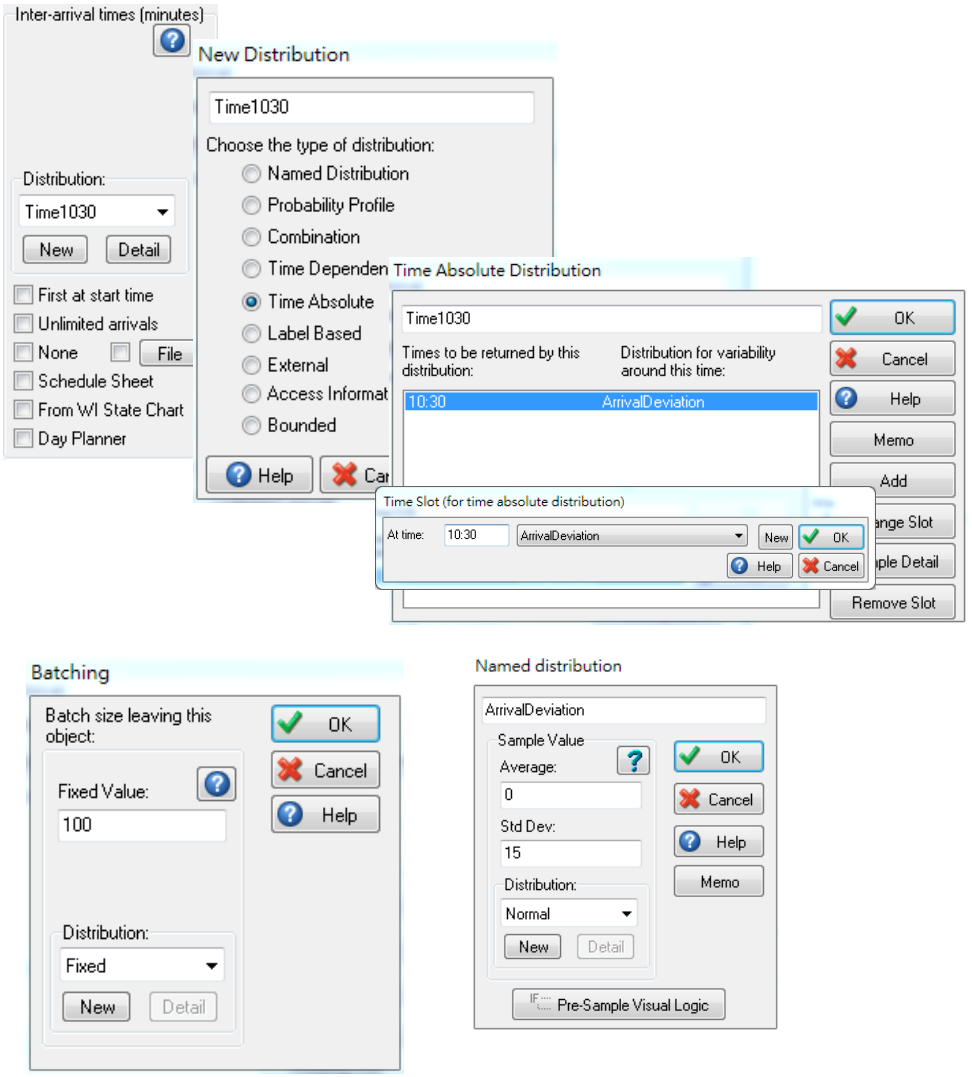



# Start Point: Batching

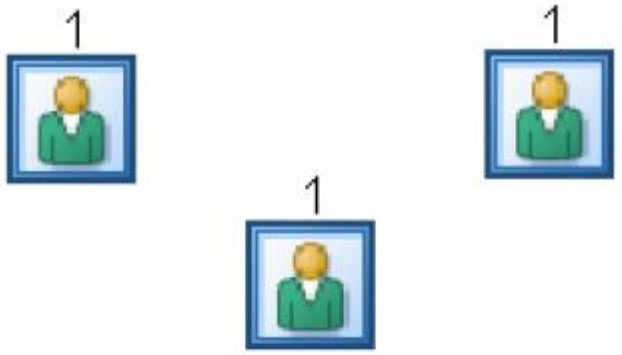
- This control the number of items which arrive at one time.

- if an “arrival” occurs at time 10:30 and the number of items set to leave the “Start Point” is “Fixed” 100, then 100 items of the specified work item type will arrive at 10:30.



# Resource

- Resources are items in the simulation that are required at Activities in order for the Activity to work on a work item.




- Resources can be shared between all Activities which use them. These are known as “shared” or “floating” resources because they float between the Activities which require them.


- Examples of “resources” are:
  - Labour
  - Special Fitments of machines
  - Beds in a hospital ward

# Assigning Resources to an Activity

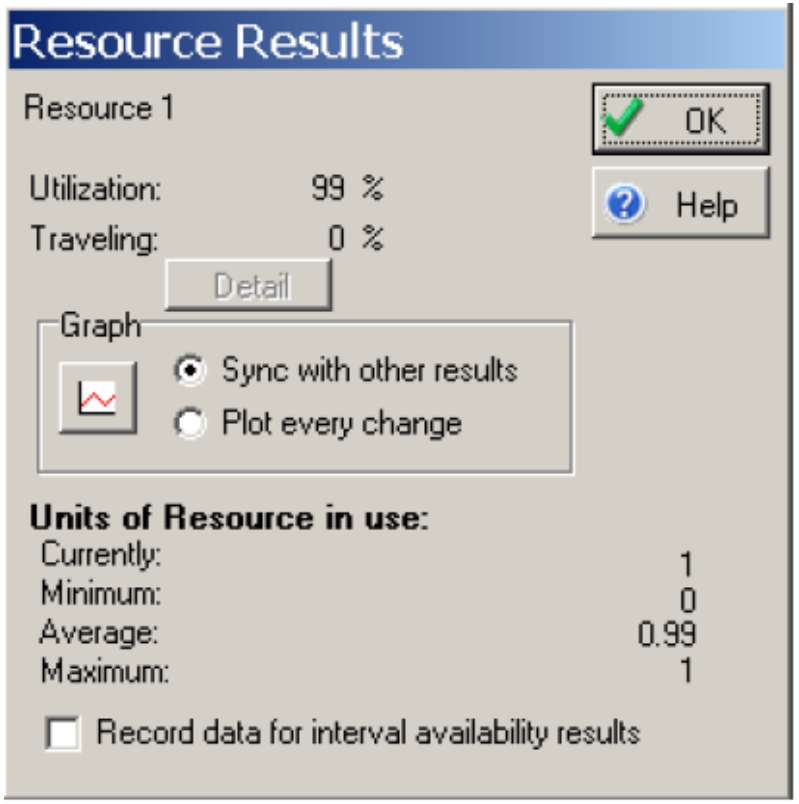
- One resource of the same type can allocated to different Activities
  - Specify quantity of the resource
  - An activity needs to wait if insufficient quantity
  - “Exceed” quantiy will be on “standby”

- Different resources can be assigned to an Activity

# Resource Utilisation

- Resource utilisation is an important parameter that affects business application performance.

- Resource utilisation is the cost of the project in terms of business system resources.




What does high utilisation rate with high achieved queue mean? Suggest scenarios to reduce the queue by maintaining the same utilisation rate. Can you?

# Sharing a Resource Between More Than One Activity

- Simul8 Resources move between Activities.
- A travel time can be imposed using Travel option in the resource dialog.
- How To:
  - Select the Travel button and then the resource Activity in the Form list.
  - Select the Activity the resource will travel to and then set the travel time in time units.

# Pool of Resources

- Resources can be pooled so that (for example) Fitters can fit and Operators can operate or either Operators or Fitters can polish.

- A pooled resource is one which does not really exist but instead is a combination of other resources.

- If task A can be performed by people A , task B can be performed by people B and task C can be performed by either A or B people. Create a pooled resource called C and use the Pooled check box (in the resource dialog) so that either A or B can be used whenever an Activity is seeking resource type C.

- To make use of a resource at an Activity: In the Activity dialog, click the resource button and Add the resource to the list of resources required at that Activity.

# References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