Discrete Event Simulation for QPM – Can it Really be That Easy?
Agenda

- Introduction
- Background
  - QPM
  - Discrete Event Simulation
- Case study
  - Using discrete event simulation for QPM
Introduction – Who we are

Optimal Solutions & Technologies (OST, Inc)

Washington DC-based, founded in 1999

Core competencies
- Integrated IT solutions
- Managed Services
- Management consulting
- Research, development & engineering

CMMI L3 (CMMI-DEV v1.2)

ISO 9001:2008 certified

ANSI 748 compliant
Background

QPM
- Requires PPM’s and PPB’s
- Most intimidating for us!

Discrete Event Simulation
- Step-by-step or Succession of events
- Time Matters!
- Events are not allowed in between time units
- Non – stochastic/deterministic
Our case study...
Our business problem

- Invoices were late resulting in
  - Customer complaints
  - Financial exposure

Possible solutions

- Add more staff (implies increases overhead cost)
- Improve the process to make it LEAN

What we want to cover today?

Steps we took

Resources we used

Mapping to “requirements”
(step-by-step guide)

* Demonstration steps are captured in Appendix for your reference
What we did...

- Data
- Baseline
- Process
- Model
- Hot Spots
- Action

What we found useful:
- Process Model Tutorial
  http://www.processmodel.com/support/tutorials.html

What we found useful:
(3) A Practical Approach for Building CMMI Process Performance Models
http://www.sei.cmu.edu/library/abstracts/presentations/28apr2009webinar.cfm
# Data Collection

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<th>Notes</th>
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<tr>
<td>In office - 7/27</td>
<td>FAA-ESVMS (Jun)</td>
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<tr>
<td>Generated cover sheet</td>
<td>10:30-10:32</td>
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<tr>
<td>Run proj staffing &amp; check outstanding ts report</td>
<td>11:22-11:23</td>
</tr>
</tbody>
</table>
| resolve ts issues                         | 11:25-11:25         (
| Generate billing report                   | 11:25-11:25         |
| Resolve billing report issues             | 11:25-11:25         |
| Initialize invoice                        | 12:26-12:29         |
| Populate labor                            | 12:28-12:29         |
| Generate expense report                   | 12:29-12:30         |
| resolve expense issues                    | NA                  |
| Populate ODCs and enter G&A expense       | NA                  |
| Print and check (inv check reports & contract only) | 11:31-12:35 |
| Generate additional reports               | NA                  |
| PM approval (scan, send, & check for response) | 11:43-12:44 |
| Get Signed                                |                     |
| Redate, scan & upload, and copy           | 11:47-11:49         |
| Sent                                      | 12:49-12:50         |
| Notify Linda                              | 12:49-12:50         |
| Entered into contract tracking            | 12:49-12:50         |
| Marked off master chart                   | 12:49-12:50         |
| Add to quarterly reporting                | 12:49-12:50         |
| Notes                                     | NA                  |

What we found useful: (2) Process Performance Baselines and Models: Duh, I Don’t Get It, Diane Mizukami (Williams)
Minitab

Graphical Summary

All screen shots are presented in the Appendix for your reference.
Recap

- Build as-is model
- Collect data
- Assess data quality and integrity
- Build PPB’s
  - Minitab
  - Statfit
What we did...

1. Data
2. Baseline
3. Process Model
4. Hot Spots
5. Action
All screen shots are presented in the Appendix for your reference.
Recap

- Run the simulation
- Identify hot spots
- Run “What-If” scenarios
- Take Action
What we did…

- Data
- Baseline
- Model
- Hot Spots
- Action
- Hypothesis Test
- Process Model
Hypothesis tests

All screen shots are presented in the Appendix for your reference.
Recap

- Select the right test
- Interpret the results
- Update your model
- Evaluate results
- Repeat steps if needed
Confidence Intervals and Prediction Intervals

- **Prediction Interval (PI)**
  - Expected interval for next data point

- **Confidence Interval (CI)**
  - Expected interval for the central tendency (mean or median)

- **Beware!! Don’t use CI’s to make a prediction!!**
Determining Confidence Intervals

Determining Prediction Intervals

All screen shots are presented in the Appendix for your reference.
Lessons Learned

- Start with a simple model
- Check the model with intuition
- Quantify savings in $ if possible
- Keep your stakeholders engaged
  - Share positive and negative news
1. Identify or Reconfirm Business Goals
2. Identify the sub-processes/process
3. Identify Outcomes to Predict (y’s)
4. Identify Controllable factors (x’s) to predict outcomes
5. Include Uncontrollable x factors
6. Collect Data
7. Assess Data Quality and Integrity – *Not covered today*
8. Identify data types of all y outcomes and x factors
9. Create PPBs
10. Select the proper analytical technique and/or type of regression equation
11. Create Predictions with both Confidence and Prediction Intervals
12. Statistically manage sub-processes with PPMs
13. Take Action Based on PPM Predictions
14. Maintain PPMs including calibration and reconfirming relationships
15. Use PPMs to assist in CAR and OID

Ensures mapping to requirements and compliance!
What’s missing from QPM compliance?

Goal 1

- Objectives
- Selecting sub processes
- Taking action

Goal 2

- Applying analytical techniques
- Monitoring performance
- Actual records
Any Questions?
Thank You!
Appendix- Tools and step-by-step guide
Tools Used

**Access Database**
- To create database
- Easy to access data

**Minitab**
- Used to Plot I-MR charts, Summary charts, Individual charts
- Stat fit, creating baseline, plotting Hot spots, Produce average.

**Process Model**

**@Risk**
- Produce Prediction Interval
Process Steps

Collect Data Phase-1 (Access)

Check for outliers (Mtb)

Create baselines (Stat fit)

Model Phase-1 (PM)

Create new baselines? (Stat fit)

Hypothesis Test (Mtb)

Check for outliers (Mtb)

Collect Data Phase-2 (Access)

Model Phase-2 (PM)

Prediction Interval (@risk)
Process Steps

1. Collect Data Phase-1 (Access)
2. Check for outliers (Mtb)
3. Create baselines (Stat fit)
4. Model Phase-1 (PM)
5. Collect Data Phase-2 (Access)
6. Hypothesis Test (Mtb)
7. Check for outliers (Mtb)
8. Create new baselines? (Stat fit)
9. Model Phase-2 (PM)
10. Prediction Interval (@risk)
Collect Data

Collecting Data

- Access Database
- Gather Information
- Store Information

- XL Sheet

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
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In office 9/3/2020 HUD-eGrants Nov
Access Database

- Easy to store and retrieve data as needed
- Multiple Phases can be stored
- Easy to access data using Queries
Process Steps

Collect Data Phase-1 (Access)

Check for outliers (Mtb)

Create baselines (Stat fit)

Model Phase-1 (PM)

Collect Data Phase-2 (Access)

Create new baselines? (Stat fit)

Hypothesis Test (Mtb)

Check for outliers (Mtb)

Model Phase-2 (PM)

Prediction Interval (@risk)
Outliers: An observation that is numerically distant from the rest of the data points.
This can be done by Plotting I-MR Charts.

I-MR Chart: Is a graphical tool that displays process variation over time. It signals when a process may be going out of control and shows where to look for sources of special cause variation.
I-MR Charts Using Minitab

Select I-MR charts

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Options in I-MR chart

Select Variables to plot I-MR chart
I-MR Chart

I-MR Chart of CoverSheet

Outliers

UCL=6.49
\bar{X}=2.56
LCL=-1.37

UCL=4.823
MR=1.476
LCL=0
Process Steps

1. Collect Data Phase-1 (Access)
2. Check for outliers (Mtb)
3. Create baselines (Stat fit)
4. Model Phase-1 (PM)
5. Collect Data Phase-2 (Access)
6. Check for outliers (Mtb)
7. Hypothesis Test (Mtb)
8. Create new baselines? (Stat fit)
9. Model Phase-2 (PM)
10. Prediction Interval (@risk)
Stat Fit using Process Model
Stat Fit

Auto Fit

Data points from Minitab
### Fit of Distribution

**Auto::Fit of Distributions**

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<th>rank</th>
<th>acceptance</th>
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<tr>
<td>Inverse Gaussian[0., 3.11, 10.]</td>
<td>66.8</td>
<td>do not reject</td>
</tr>
<tr>
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<tr>
<td>Pearson 5[0., 0.936, 2.22]</td>
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<tr>
<td>Pareto</td>
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</tr>
<tr>
<td>Johnson SB</td>
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Select do not reject variables to get time interval.
### Distribution Graph

#### Auto::Fit of Distributions

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<td>Johnson SB</td>
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Double Click it will produce Following graph
Export data to text file
Time Interval

Save as Text file

Copy this value and paste it in Process Model
Process Steps

1. Collect Data Phase-1 (Access)
2. Check for outliers (Mtb)
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4. Model Phase-1 (PM)
5. Collect Data Phase-2 (Access)
6. Create new baselines? (Stat fit)
7. Hypothesis Test (Mtb)
8. Check for outliers (Mtb)
9. Prediction Interval (@risk)
10. Model Phase-2 (PM)
Invoice


People

Initialize And Populate Invoice → Resolve Expense Report And Issues

Populate ODC And Enter GA

Print And Check

Scan Send Check for app

Get Signature

Redate Scan Upload Copy

Send

Notify Linda

Enter into contract tracking

Update master tracker - END
Update time interval in to particular Process

```
(a, 4.71, 27.9)
```
### Phase-1 Summary

**Entity Summary** (Times in Scoreboard time units)

<table>
<thead>
<tr>
<th>Entity Name</th>
<th>Qty Processed</th>
<th>Average Cycle Time (Minutes)</th>
<th>Average VA Time (Minutes)</th>
<th>Average Cost</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invoice</td>
<td>63.66</td>
<td>19467.3</td>
<td>149.66</td>
<td>249.43</td>
<td>(Average)</td>
</tr>
<tr>
<td>Invoice</td>
<td>3.82</td>
<td>1236</td>
<td>10.53</td>
<td>17.56</td>
<td>(Std. Dev.)</td>
</tr>
<tr>
<td>Invoice</td>
<td>56</td>
<td>17259.7</td>
<td>126.04</td>
<td>210.07</td>
<td>(Min)</td>
</tr>
<tr>
<td>Invoice</td>
<td>72</td>
<td>22512.6</td>
<td>174.34</td>
<td>290.57</td>
<td>(Max)</td>
</tr>
<tr>
<td>Invoice</td>
<td>62.23</td>
<td>19005.8</td>
<td>145.72</td>
<td>242.88</td>
<td>(95% C.I. Low)</td>
</tr>
<tr>
<td>Invoice</td>
<td>65.09</td>
<td>19928.8</td>
<td>153.59</td>
<td>255.99</td>
<td>(95% C.I. High)</td>
</tr>
<tr>
<td>HardInvoice</td>
<td>16.33</td>
<td>20359.8</td>
<td>178.11</td>
<td>296.86</td>
<td>(Average)</td>
</tr>
<tr>
<td>HardInvoice</td>
<td>3.82</td>
<td>1441.94</td>
<td>12.29</td>
<td>20.49</td>
<td>(Std. Dev.)</td>
</tr>
<tr>
<td>HardInvoice</td>
<td>8</td>
<td>18085.7</td>
<td>152.53</td>
<td>254.23</td>
<td>(Min)</td>
</tr>
<tr>
<td>HardInvoice</td>
<td>24</td>
<td>23480.9</td>
<td>203.04</td>
<td>338.41</td>
<td>(Max)</td>
</tr>
<tr>
<td>HardInvoice</td>
<td>14.90</td>
<td>19821.4</td>
<td>173.52</td>
<td>289.20</td>
<td>(95% C.I. Low)</td>
</tr>
<tr>
<td>HardInvoice</td>
<td>17.76</td>
<td>20898.2</td>
<td>182.70</td>
<td>304.51</td>
<td>(95% C.I. High)</td>
</tr>
</tbody>
</table>

**Average time for Phase-1**: 149.66 minutes
Process Steps

1. Collect Data Phase-1 (Access)
2. Check for outliers (Mtb)
3. Create baselines (Stat fit)
4. Model Phase-1 (PM)
5. Create new baselines? (Stat fit)
6. Hypothesis Test (Mtb)
7. Check for outliers (Mtb)
8. Prediction Interval (@risk)
9. Model Phase-2 (PM)
10. Collect Data Phase-2 (Access)
Repeat as in Phase 1
Process Steps

1. **Collect Data Phase-1** (Access)
   - Check for outliers (Mtb)
   - Create baselines (Stat fit)
   - Model Phase-1 (PM)

2. **Check for outliers** (Mtb)
3. **Create baselines** (Stat fit)
4. **Model Phase-1** (PM)
5. **Collect Data Phase-2** (Access)

6. **Create new baselines?** (Stat fit)
7. **Hypothesis Test** (Mtb)
8. **Prediction Interval** (@risk)
9. **Model Phase-2** (PM)
Hypothesis Test using Minitab

- Retrieving data from Access database
- Plotting charts such as I-MR charts, Summary Charts, and Individual Charts (For difference in phases)

These Charts are plotted to check for P-value for further analysis to check for Normality and Equal-Variance
The P-value is the probability of obtaining a test statistic at least as extreme as the one that was actually observed, assuming that the null hypothesis is true.

All tests are run at 95% confidence limit.

2 independent samples
As per SEI’s Job Aid
### Appropriate Analysis: Types of Hypothesis Tests

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Interval or Ratio (Parametric Tests)</th>
<th>Ordinal (Non-Parametric Tests)</th>
<th>Nominal</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td># Samples</td>
<td>Mean</td>
<td>Variance</td>
<td>Median</td>
<td>Variance / Fit</td>
</tr>
<tr>
<td>1 Sample</td>
<td>1-sample t test</td>
<td>1-sample Wilcoxon Signed Ranks test</td>
<td>1 sample Kolmogorov-Smirnov Goodness of Fit test</td>
<td>&gt;2 cells</td>
</tr>
<tr>
<td></td>
<td>Chi-Square test</td>
<td>Mann Whitney U test</td>
<td>Wilcoxon matched pairs</td>
<td>Chi-Square test</td>
</tr>
<tr>
<td>2 Samples</td>
<td>Normal F test</td>
<td>Independent Medians</td>
<td>Siegel-Tukey test</td>
<td>Fisher Exact test (1-way ANOVA); Chi-Square test</td>
</tr>
<tr>
<td></td>
<td>Paired t test</td>
<td>Not Normal</td>
<td>Not Normal</td>
<td>Moses test</td>
</tr>
<tr>
<td>3+ Samples</td>
<td>ANOVA (1 &amp; 2 way ANOVA; Balanced ANOVA; GLM) MANOVA (General &amp; Balanced)</td>
<td>Independent Kruskal-Wallis 1-way ANOVA</td>
<td>Friedman 2-way ANOVA</td>
<td>Van der Waerden Normal scores test</td>
</tr>
<tr>
<td></td>
<td>Normal Bartlett test</td>
<td>Levene test</td>
<td>Levene test</td>
<td></td>
</tr>
</tbody>
</table>

Current sample data
Normality Test – Summary chart Minitab Tool

Summary Graph
Select variable to plot summary graph
Summary Graph

Check for P Value

Summary for CoverSheet

Anderson-Darling Normality Test
A-Squared  4.81
P-Value <  0.005

<table>
<thead>
<tr>
<th>Mean</th>
<th>StDev</th>
<th>Variance</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5185</td>
<td>1.5534</td>
<td>2.4131</td>
<td>2.09035</td>
<td>3.87361</td>
<td>27</td>
</tr>
</tbody>
</table>

| Minimum | 1st Quartile | Median | 3rd Quartile | Maximum | | 95% Confidence Interval for Mean | 1.9040 | 3.1330 |
|---------|-------------|--------|-------------|---------| | 95% Confidence Interval for Median | 2.0000 | 2.0000 |
| 1.0000 | 2.0000     | 2.0000 | 2.0000     | 7.0000  | | 95% Confidence Interval for StDev | 1.2233 | 2.1289 |
Variance Test – 2 Variance Test
Select two columns to be sampled for Variance
Variance Test Graph

Test for Equal Variances for CoverSheet, Coversheet_1

95% Bonferroni Confidence Intervals for StDevs

Check for P Value
Non-Parametric Test for Median

Nonparametric test

Mann-Whitney test
Select particular data sample to be tested

Select Samples to be tested

Mann-Whitney

First Sample: CoverSheet
Second Sample: 'Coversheet_1'
Confidence level: 95.0
Alternative: not equal

Select
Help
OK
Cancel
Test for Equal Variances for CoverSheet, Coversheet_1

Mann-Whitney Test and CI: CoverSheet, Coversheet_1

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoverSheet</td>
<td>27</td>
<td>2.000</td>
</tr>
<tr>
<td>Coversheet_1</td>
<td>24</td>
<td>2.000</td>
</tr>
</tbody>
</table>

Point estimate for ETA1-ETA2 is -0.000
95.1 Percent CI for ETA1-ETA2 is (-0.001, 0.000)
N = 668.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.5334
The test is significant at 0.4485 (adjusted for ties)
Stacking two Columns for Checking Non-Parametric Variance

Stacking Columns
Select columns to be stacked

We can select required column to be stacked.
<table>
<thead>
<tr>
<th>ComboCoversheet</th>
<th>SubComboCoversheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>CoverSheet Phase_2</td>
</tr>
<tr>
<td>2</td>
<td>CoverSheet Phase_2</td>
</tr>
<tr>
<td>*</td>
<td>CoverSheet Phase_2</td>
</tr>
<tr>
<td>2</td>
<td>CoverSheet Phase_2</td>
</tr>
<tr>
<td>2</td>
<td>CoverSheet Phase_2</td>
</tr>
<tr>
<td>2</td>
<td>CoverSheet Phase_2</td>
</tr>
<tr>
<td>2</td>
<td>CoverSheet Phase_2</td>
</tr>
<tr>
<td>*</td>
<td>CoverSheet Phase_2</td>
</tr>
<tr>
<td>5</td>
<td>CoverSheet Phase_2</td>
</tr>
<tr>
<td>2</td>
<td>CoverSheet Phase_2</td>
</tr>
<tr>
<td>1</td>
<td>CoverSheet Phase_2</td>
</tr>
<tr>
<td>2</td>
<td>CoverSheet Phase_2</td>
</tr>
<tr>
<td>2</td>
<td>CoverSheet Phase_2</td>
</tr>
<tr>
<td>2</td>
<td>CoverSheet Phase_2</td>
</tr>
<tr>
<td>2</td>
<td>CoverSheet Phase_2</td>
</tr>
<tr>
<td>7</td>
<td>CoverSheet Phase_2</td>
</tr>
</tbody>
</table>
Non-Parametric Test for Variance

Equal Variance Test
Select particular data point for Variance test

Phase-1

Phase-2
Result For Equal Variance

Test for Equal Variances for ComboCoversheet

- **F-Test**
  - Test Statistic: 0.20
  - P-Value: 0.000

- **Levene's Test**
  - Test Statistic: 1.01
  - P-Value: 0.321

Check for P Value
Test for Individuals Graphs

Select Individual to Plot charts
Select data point for Individual Chart
Individual chart

Stages gives the option to select sub stage of data point.
Individual Chart

I Chart of ComboCoversheet by SubComboCoversheet

CoverSheet Phase_2

Coversheet Phase_1

UCL=4.062

\( \bar{X} = 2.333 \)

LCL=0.605

Difference between Phase-1 & Phase-2
Process Steps

1. Collect Data Phase-1 (Access)
2. Collect Data Phase-2 (Access)
3. Check for outliers (Mtb)
4. Check for outliers (Mtb)
5. Create baselines (Stat fit)
6. Create baselines (Stat fit)
7. Model Phase-1 (PM)
8. Model Phase-2 (PM)
9. Hypothesis Test (Mtb)
10. Hypothesis Test (Mtb)
11. Create new baselines? (Stat fit)
12. Prediction Interval (@risk)
13. Prediction Interval (@risk)