G54SIM-Simulation for Decision Support

Report

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1. Group Activity:

A task was allotted to every group where every group was working for the "Airport Consulting" company that aimed to offer their services to the Heathrow Airport. The reason behind this task was to analyse the entire system and identify potential projects to work on, which would improve the service operations, with the help of simulation studies at the Heathrow Airport.

Potential areas where simulation has been used:

- Airport Capacity
- Departure
- Arrival
- Security Check
- Transport
- Air Traffic
- Baggage

Potential projects identified:

- Overall airport capacity utilisation
- Flow of traffic during departure time
- Air traffic control problem
- Baggage handling system
- Flow of traffic during arrival time
- Security check for ground and travelling crew

Agent-based Simulation:

- Agent-Based model to support decision making in vehicle allocation
- In flight planning and scheduling
- In automation
- In staff performance

So to rank these projects, a ranking criterion was used:

- Project Cost
- Customer Satisfaction
- Rate of return
- Project Duration
- Information Availability

- Simulation has been used
- Cost Reduction

Project scores:

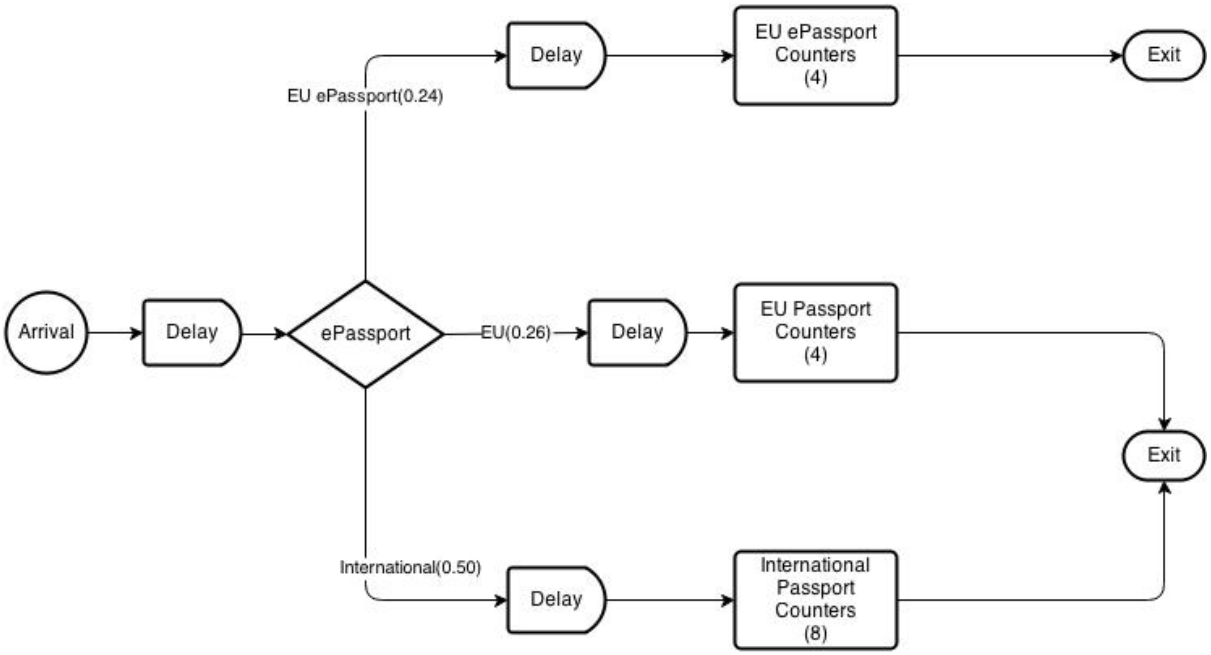
	COST	TIME	USED	CUSTOMER	ROR	COST REDUCTION	∑
P1	1	1	1	2	2	3	10
P2	**2**	**2**	**2**	**3**	**1**	**3**	**13**
P3	2	2	2	3	1	2	12
P4	2	2	2	2	1	1	10
P5	3	3	1	2	1	1	11
P6	1	1	2	3	2	1	10
P7	2	2	3	3	1	1	12

After which the group decided to work on the project: "**Flow of traffic during departure time."**

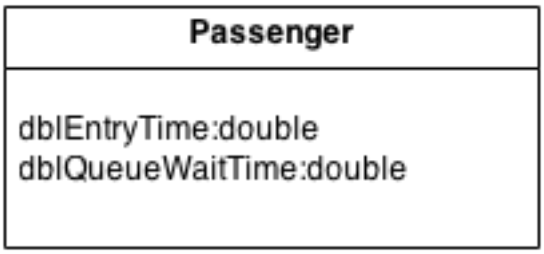
Next, the group organised a focus group meeting. The benefit of organising a focus group meeting was to perform a qualitative research in which the group were asked about their opinions, ideas and feedback about the project chosen. The group members play different roles so as to improve upon the discussion. Being 5 members in a group, 2 members became the Airport Project Managers (stakeholders) while other 3 wrote the project proposal. During the meeting, the members explained the managers the reason of choosing "Departure time" as the most potential project. Statistical data shows that the passenger spends more than 45 minutes during the departure process which includes: Check-in, Security check and Board the flight. Various suggestions and ideas were raised up. The members described the conceptual model to the stakeholders and also provided suggestions to the managers:

- Alternative Facility: Pay extra and no more waiting. (Economy class passengers can pay extra money and shift themselves in first class check-in queues.)
- Add temporary check-in and security counters during peak season.
- Saving time with online check-in and self-printed boarding cards.
- Have a staff member initiate contact with the passengers early in the queue.

Process Flow Diagram:



Class Diagram:



2. Conceptualisation:

Problem Statement: Develop a Discrete Event Simulation model to improve the operations of "Immigration and Passport check" area in the arrival section of Terminal 4.

Objective: To serve all the passengers within 15 minutes.

Constraints:

- Three different types of arrival: those with EU passports, those with International passports and those with EU ePassoprts.
- Overall 12 counters that can be used for either checking EU passports or international passports.
- 4 EU ePassport counters.

Experimental factors (Inputs):

- Array of passengers: EU , EU ePassport and International Passengers

- Service time
- Arrival rate
- Number of counters/servers for International and EU passengers
- Number of counters/servers for EU ePassport holders
- Drive through time
- Delays

Response (Outputs):

- Queue length
- Maximum queue size for each counter
- Throughput
- Waiting time
- Total time in system for International and EU passengers.
- Total time in system for EU ePassport holders
- Number of total passengers going through the immigration check every day
    - EU through throughput.
    - International throughput.
    - EU ePassport throughput.
- System Wait Time Graphs for
    - EU ePassport Passengers
    - EU passengers
    - International Passengers

Model Content (Scope and level of detail):

Model Scope	Detail	Decision	Justification
Passengers		Include	Flow through service process
Queue at service counter		Include	Required for responses
Service Counters	Service time	Include	Required for responses

Model Level of Detail	Detail	Decision	Comments
Passengers	Inter-Arrival time	Include	Distribution
	Type of Arrivals	Include	Represented in Service Time
Counters	Service Time	Include	Distribution
Queues	Queuing	Include	Required for responses
	Capacity	Exclude	Assumption: Unlimited
	Queue Behaviour	-	-
	-jockey, balk, leave	Exclude	Not well understood
	-join shortest queue	Include	Well understood

Assumption(s):

1. Unlimited Queue capacity.
2. The probability for the passenger distribution was assumed to be 0.24 for EU ePassport holders, 0.26 for EU passengers, and 0.50 for International Passengers.
3. 8 counters for international passengers and 4 counters for EU passengers.

Simplification:

- 24/7 service;
- Using triangular distributions for modelling delays
- No arrival patterns considered.

3. Implementation.

Computer model using Anylogic was implemented using the real world statistics and considering problems faced by "Immigration and Passport check" services at the Heathrow airport for Terminal 4.

Model Data:

- **Arrival rate**: The arrival rate is the rate at which they enter the immigration queue. For the simulation model, arrival rate was chosen to be 8. This data was chosen based on the statistical data was collected using online research. Following estimates were found:

Number of Passengers volume for terminal 4 in 2012 = 10.4 million

Number of Passengers arriving per hour = 594 (approx.)

Passengers arriving per minute = 9.89 (approx.)

Percentage of Transfer Passengers = 18

Passengers that reach the Immigration Counters per minute = 7.9 (approx.) Considering the transfer passengers having connecting flight the arrival rate was assumed to be 7.9 as they don't have to go through the immigration services.

- **Delays:** Four delays have been used in the model keeping in mind the real world scenario. The first delay is when the passengers arrive at the airport there is a delay when they select a different queue based on the type of passport. The remaining three delays have been used before each service counters to keep the model to be realistic considering there will be delays before the passengers are being served.

- **Service time**: The rate at which the passengers are served at the service counter. For this data, concept of triangular distribution was used. This is used to get stable results.

    1. EU ePassport Gates: triangular (1, 1.2, 1.5), as the passengers holding an EU epassport would not require much time to be serviced at the gates.

2. EU passports: triangular (1.25, 1.9, 2.4), as the passengers holding EU passports would have to show less documents at the service counters for verification.

3. International passports: triangular (1.5, 1.9, 2.4), as these passengers are required to show more documents for verification as compared to EU passport holders.

- **Probablities**: The passengers are distributed using the probability functionality in the select output. The passengers on arrival are separated into three queues based on the type of the passport the hold. Probability of 0.24 for EU ePassport passengers, 0.26 foe EU passengers, 0.50 for international passengers is assumed.

- **Resource Pool:** Defines a set of resource units that can be seized and released by entities using Service objects. For EU ePassport, resource pool is given as 4. For the International and EU passport holders, there are 12 service counters, out of which 4 have been allocated for the EU counters and the remaining 8 for the International counters considering the probabilities used.

- **Parameters:** Two parameters are used in the model.

    1. **dblRunTime:** Default value of 144000.0(which is equal to 100 days) is specified as the system is supposed to run for 100 days.

    2. **dblDriveThroughTime:** Default value of 10 minutes is used. This time is basically the time required for the passenger to walk from the arrival point to the exit.

- **Events:** evnWritePerDay was used to write the data into the excel files and to get the graphical histograms for the required outputs. 1440 is being used as the first occurrence and recurrence rate so that it generates 100 days data.

- **Variables:** 10 different variables have been declared for various purposes.

    1. **intepasscounterQSizeMax:** Displays the maximum queue size for the ePassport counters.

    2. **inteucounterQSizeMax:** Displays the maximum queue size for the EU Passport counters.

    3. **intintercounterQSizeMax:** Displays the maximum queue size for the International Passport counters.

    4. **intThroughputPerDay:** Used to calculate the throughput for the passport counters.

    5. **dblTimeInSystemPerDay:** Used to calculate average time for passport counters.

    6. **intepassThroughputPerDay:** Used to calculate the throughput for the ePassport counters.

7. **dblepassTimeInSystemPerDay:** Used to calculate average time for ePassport counters.
8. **IntObjectiveTrue:** Used for checking the objective percentage.
9. **percentageObjective:** Used for calculating the percentage.
10. **objective:** Set an objective.(set to 15)

- **Parameter Variation:** Allows running model with different model parameters and analysing how some certain parameters affect the model behaviour. Number of runs is specified to be 20. This allows the user to run the model 20 times in a go. The parallel evaluation functionality helps the simulation model to produce similar results. Two variables are declared:
    1. **intMyStudentID:** Initial value is defined to be 169(last 3 digits of the Student ID number).
    2. **intCurrentSeed:** Displays the sum of intMyStudentID and the current iteration.
- **Graphical Data:** Three graphs have been provided using the systemWaitTime and systemWaitTimeepass and systemWaitTimeeu data which show the SystemWaitTime for the ePassport and passengers with international and EU passport.
- **Connectivity:** 4 excel files have been used in the model to populate the required outputs. Event evnWritePerDay is used to populate these files.
    1. **fileThroughputPerDay**: Throughput for the International and EU passengers is populated in this file.
    2. **fileAverageTimeInSystemPerDay:** AverageTime for the International and EU passengers is populated in this file.
    3. **fileepassThroughputPerDay:** Throughput for EU passengers with ePassport is populated in this file.
    4. **fileepassAverageTimeInSystemPerDay:** AverageTime for EU passengers with ePassport is populated in this file.

4. Experimental Design

1. **Conceptual Model Validation**: The Conceptual Model was designed for the real world scenario, the content, the assumptions and the simplifications were assessed throughout the designing phase. The scope, level of detail, justification and comments provided in the model content The service time is realistically adjusted for the stability and also the validity of the model.

2. **Data validation**: The data in this simulation model are generation of passenger entities with an arrival rate which is calculated from a referenced source and has sufficient validity. The real scenario of transfer passengers or VIP persons

travelling is taken into consideration. Since they do not have to go through the immigration checks the arrival rate is further reduced to replicate real world scenario.

3. **White-Box Validation:**

1. Validation checks for the model with respect to code.
2. High arrival rate, service time, delays.
3. Analysis of Histograms.
4. Various ranges of values were tested and the outputs were analysed.

4. **Black-Box Validation:** The real world inputs were used for the model assuming that the outputs of the model would be approximately similar to the real world outputs.

5. **Experimental validation:**

   a. **Warm up period:** Running the model until it reaches a realistic condition and collecting results only after this point. For estimating the warm up period, Welch's method is chosen. Based on the graphs generated, warm up period warm up period was considered to be of 6 days (Appendix)
   b. **Run length:** The experiment run length should be at least 10 X warm up period. So the run length of 100 days has been considered. (Appendix)
   c. **Number of Replications:** 20. (Appendix)

5. Experimentation:

1. Throughput

						Significance level	5.0%	
						Confidence interval		
Replication	Scenario 1 result	Scenario 2 result	Difference	Cum. mean difference	SD	Lower interval	Upper interval	Conclusion
1	8470.72	9068.53	-597.81	-597.81	n/a	n/a	n/a	n/a
2	8460.44	9058.05	-597.62	-597.71	0.135	-598.93	-596.50	S1<S2
3	8462.00	9059.00	-597.00	-597.48	0.423	-598.52	-596.43	S1<S2
4	8484.78	9064.11	-579.33	-592.94	9.079	-607.39	-578.49	S1<S2
5	8485.95	9062.45	-576.50	-589.65	10.764	-603.02	-576.29	S1<S2
6	8480.44	9065.83	-585.39	-588.94	9.784	-599.21	-578.67	S1<S2
7	8473.93	9044.34	-570.41	-570.41	11.349	-580.91	-559.92	S1<S2
8	8476.32	9056.34	-580.02	-585.51	10.739	-594.49	-576.53	S1<S2
9	8473.30	9060.67	-587.37	-585.72	10.064	-593.45	-577.98	S1<S2
10	8483.22	9063.47	-580.24	-585.17	9.645	-592.07	-578.27	S1<S2
11	8464.77	9062.07	-597.31	-586.27	9.855	-592.89	-579.65	S1<S2
12	8476.23	9062.39	-586.16	-586.26	9.396	-592.23	-580.29	S1<S2
13	8463.50	9059.60	-596.10	-596.10	9.401	-601.78	-590.42	S1<S2
14	8481.49	9058.49	-577.00	-586.30	9.420	-591.74	-580.87	S1<S2
15	8485.88	9059.21	-573.33	-585.44	9.676	-590.80	-580.08	S1<S2
16	8468.98	9062.56	-593.59	-585.95	9.567	-591.05	-580.85	S1<S2
17	8469.44	9055.07	-585.64	-585.93	9.264	-590.69	-581.17	S1<S2
18	8482.67	9067.24	-584.57	-585.86	8.993	-590.33	-581.38	S1<S2
19	8500.79	9062.51	-561.72	-561.72	10.346	-566.71	-556.74	S1<S2
20	8465.23	9066.81	-601.57	-585.43	10.762	-590.47	-580.40	S1<S2

2. Average time

						Significance level	5.0%	
						Confidence interval		
Replication	Scenario 1 result	Scenario 2 result	Difference	Cum. mean difference	SD	Lower interval	Upper interval	Conclusion
1	8.30	167.52	-159.23	-159.23	n/a	n/a	n/a	n/a
2	8.35	185.41	-177.06	-168.14	12.607	-281.41	-54.87	S1<S2
3	8.26	170.33	-162.08	-166.12	9.578	-189.91	-142.33	S1<S2
4	8.38	142.93	-134.55	-158.23	17.614	-186.25	-130.20	S1<S2
5	8.38	194.01	-185.63	-163.71	19.567	-188.00	-139.41	S1<S2
6	8.34	179.47	-171.12	-164.94	17.761	-183.58	-146.30	S1<S2
7	8.29	68.59	-60.30	-149.99	42.747	-189.53	-110.46	S1<S2
8	8.37	230.70	-222.32	-159.04	47.119	-198.43	-119.64	S1<S2
9	8.40	213.41	-205.01	-164.14	46.664	-200.01	-128.27	S1<S2
10	8.33	140.84	-132.51	-160.98	45.118	-193.26	-128.70	S1<S2
11	8.33	179.53	-171.20	-161.91	42.914	-190.74	-133.08	S1<S2
12	8.35	96.18	-87.83	-155.74	46.168	-185.07	-126.40	S1<S2
13	8.31	149.97	-141.65	-154.65	44.375	-181.47	-127.84	S1<S2
14	8.45	181.57	-173.11	-155.97	42.918	-180.75	-131.19	S1<S2
15	8.40	212.27	-203.87	-159.16	43.167	-183.07	-135.26	S1<S2
16	8.42	255.17	-246.75	-164.64	47.102	-189.74	-139.54	S1<S2
17	8.33	153.80	-145.46	-163.51	45.843	-187.08	-139.94	S1<S2
18	8.35	101.33	-92.97	-159.59	47.480	-183.20	-135.98	S1<S2
19	8.44	247.41	-238.97	-163.77	49.606	-187.68	-139.86	S1<S2
20	8.28	112.49	-104.21	-160.79	50.086	-184.23	-137.35	S1<S2

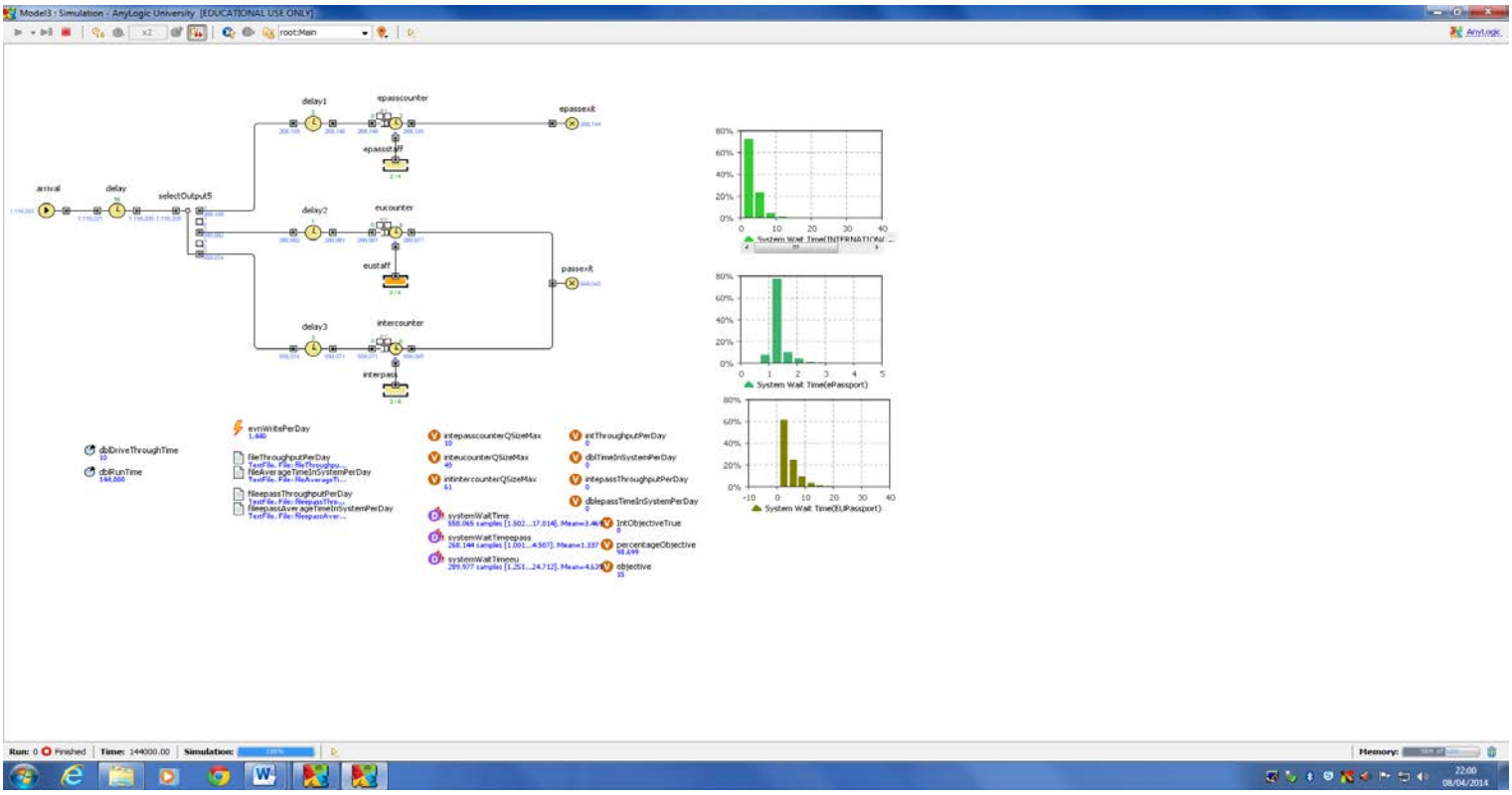
Conclusion: The objective of the model was to serve all the passengers within 15 minutes and hence the model is validated as the responses show that less than 95% of the passengers are served within 15 minutes. After performing simulation studies using the real world statistics the services can be improved either by:

1. Adding additional service counters.

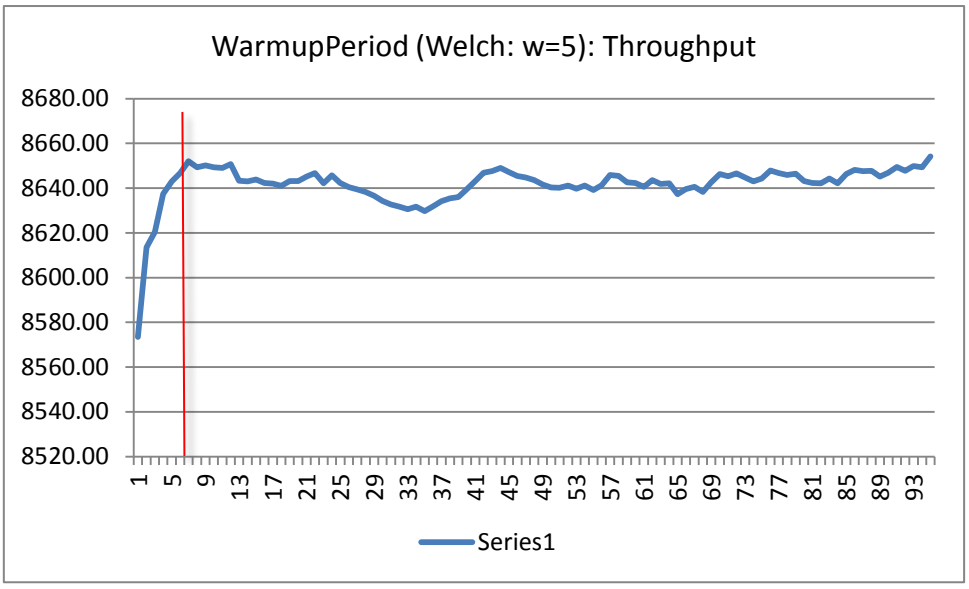
2. Reducing service time.

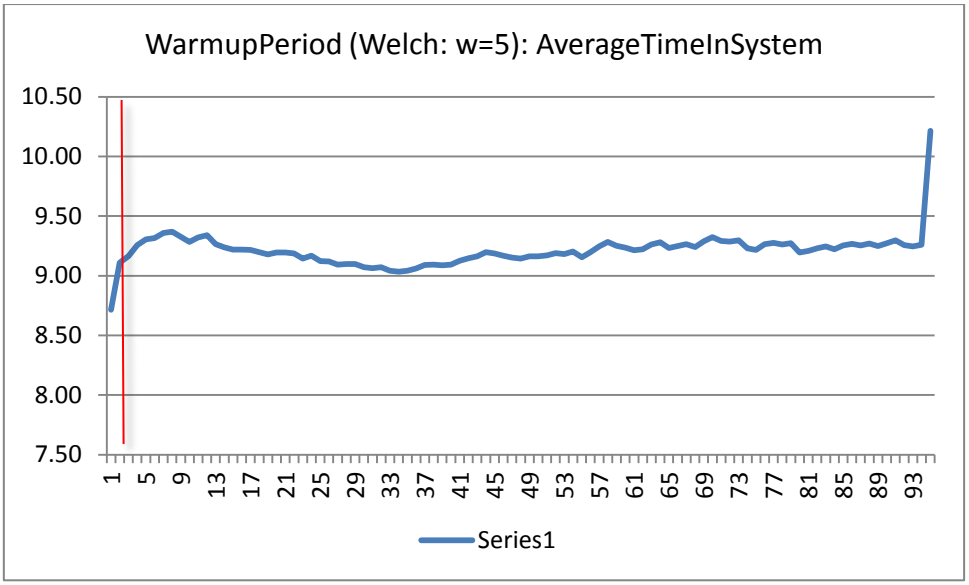
6. Appendix:

1. Model output

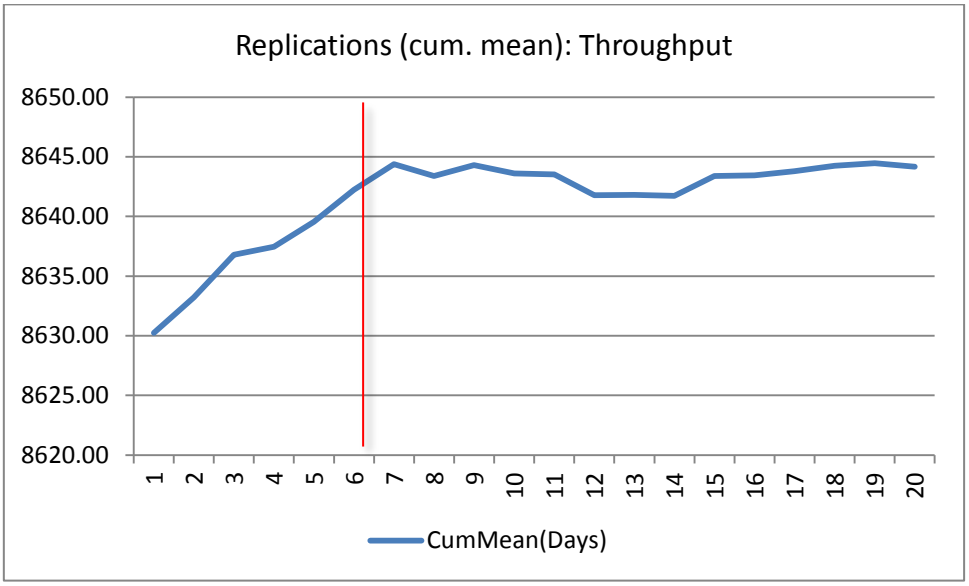


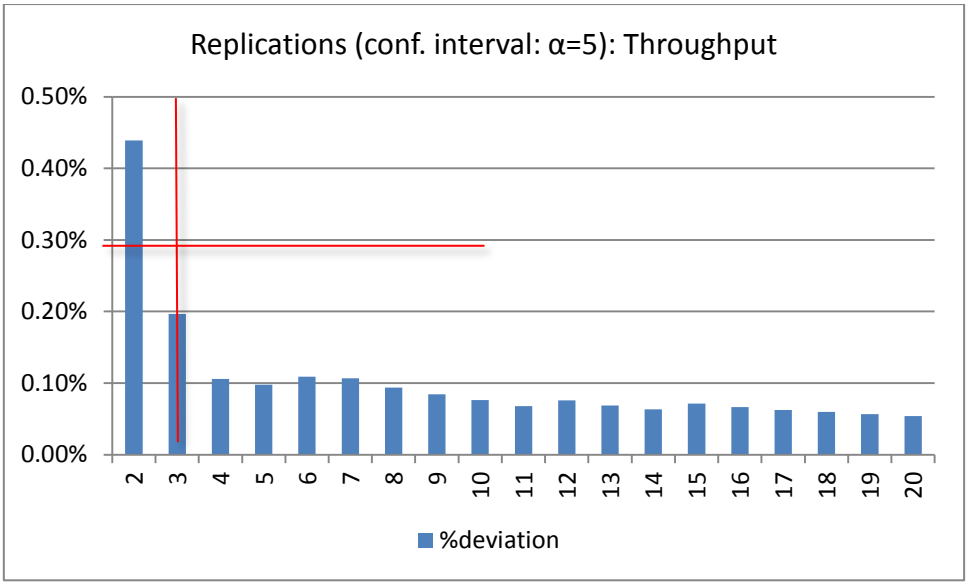
2. Warm up period:

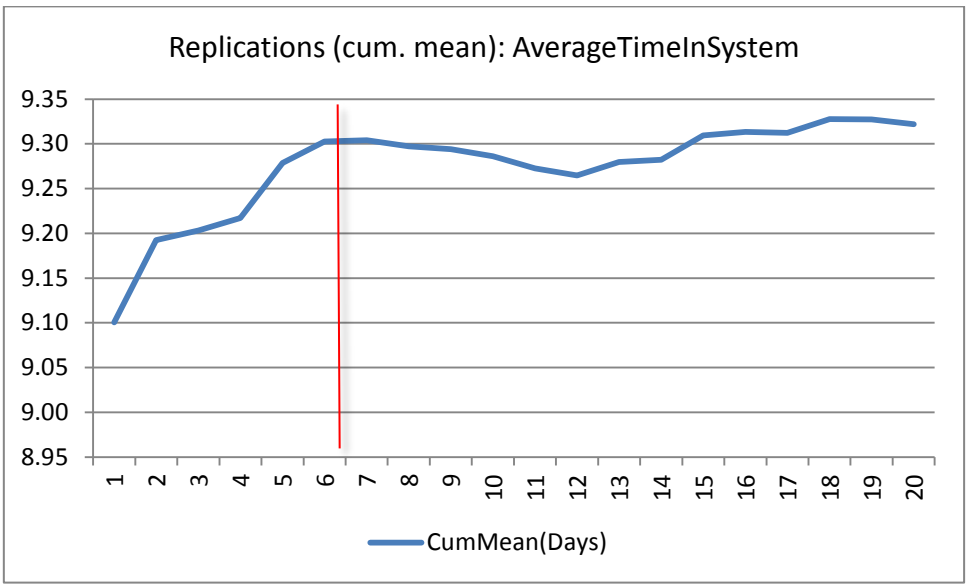




3. Number of Replications:




Replications (conf. interval: α=5): Throughput
0.50%
0.40%
0.30%
0.20%
0.10%
0.00%
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
%deviation


Replications (cum. mean): AverageTimeInSystem
9.35
9.30
9.25
9.20
9.15
9.10
9.05
9.00
8.95
1
2
3
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5
6
7
8
9
10
11
12
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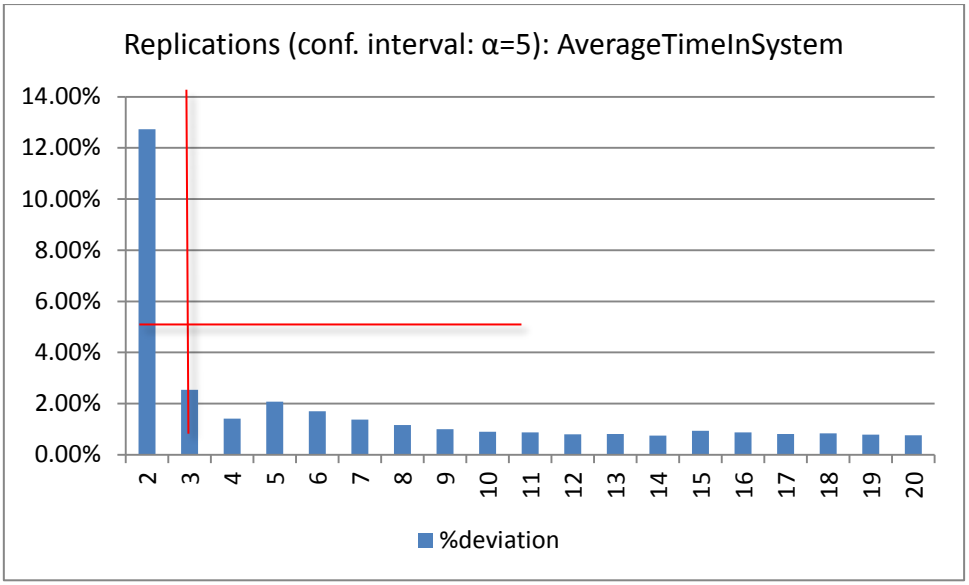
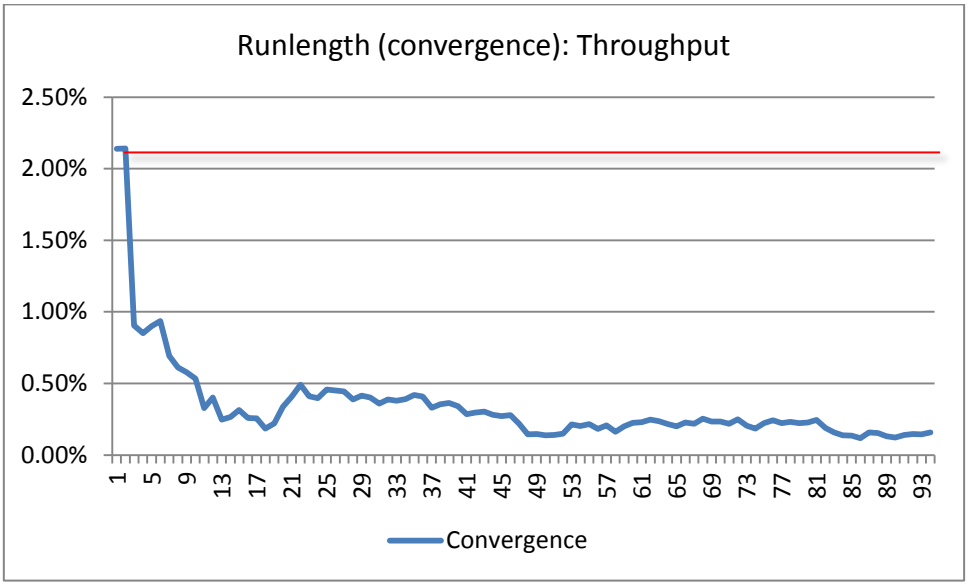
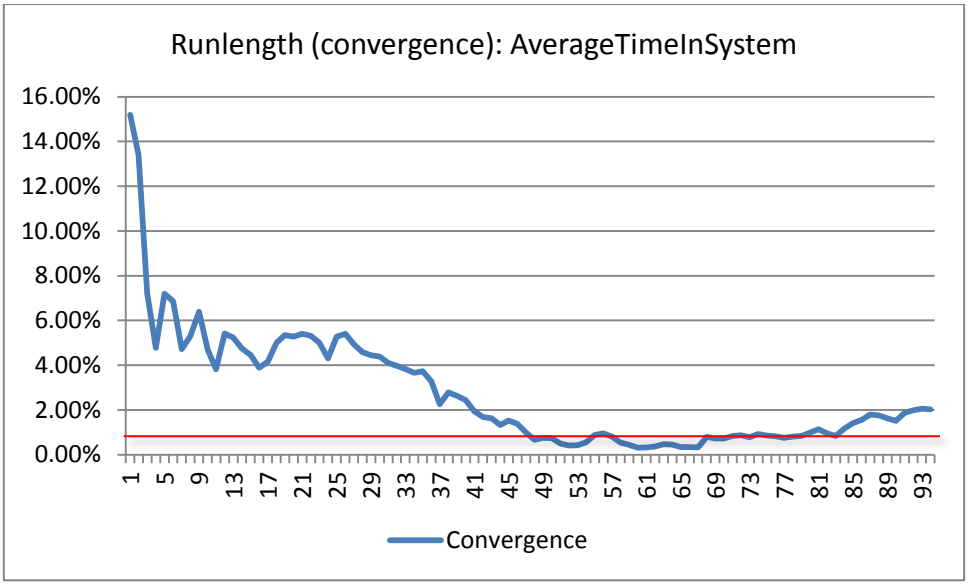
14
15
16
17
18
19
20
CumMean(Days)


Replications (conf. interval: α=5): AverageTimeInSystem
14.00%
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
%deviation

4. **Run length:**


Runlength (convergence): Throughput
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93
Convergence


Runlength (convergence): AverageTimeInSystem
16.00%
14.00%
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
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Convergence