

# Fundamental Simulation Concepts

Chapter 2

Last revision June 7, 2003

### Simulation Dynamics: The Event-Scheduling "World View"

- Identify characteristic events
- Decide on logic for each type of event to
  - Effect state changes for each event type
  - Observe statistics
  - Update times of future events (maybe of this type, other types)
- Keep a simulation clock, future event calendar
- Jump from one event to the next, process, observe statistics, update event calendar
- Must specify an appropriate stopping rule
- Usually done with general-purpose programming language (C, FORTRAN, etc.)



### **Events for the Simple Processing System**

#### Arrival of a new part to the system

- Update time-persistent statistical accumulators (from last event to now)
  - Area under Q(t)
  - Max of Q(t)
  - Area under B(t)
- "Mark" arriving part with current time (use later)
- If machine is idle:
  - Start processing (schedule departure), Make machine busy, Tally waiting time in queue (0)
- Else (machine is busy):
  - Put part at end of queue, increase queue-length variable
- Schedule the next arrival event

### Events for the Simple Processing System (cont'd.)

#### Departure (when a service is completed)

- Increment number-produced stat accumulator
- Compute & tally time in system (now time of arrival)
- Update time-persistent statistics (as in arrival event)
- If queue is non-empty:
  - Take first part out of queue, compute & tally its waiting time in queue, begin service (schedule departure event)
- Else (queue is empty):
  - Make the machine idle (Note: there will be no departure event scheduled on the future events calendar, which is as desired)

### Events for the Simple Processing System (cont'd.)

#### The End

- Update time-persistent statistics (to end of the simulation)
- Compute final output performance measures using current (= final) values of statistical accumulators
- After each event, the event calendar's top record is removed to see what time it is, what to do
- Also must initialize everything

# Some Additional Specifics for the Simple Processing System

- Simulation clock variable (internal in Arena)
- Event calendar: list of event records:
  - [Entity No., Event Time, Event Type]
  - Keep ranked in increasing order on Event Time
  - Next event always in top record
  - Initially, schedule first Arrival, The End (Dep.?)
- State variables: describe current status
  - Server status B(t) = 1 for busy, 0 for idle
  - Number of customers in queue Q(t)
  - Times of arrival of each customer now in queue (a list of random length)



### Simulation by Hand

- Manually track state variables, statistical accumulators
- Use "given" interarrival, service times
- Keep track of event calendar
- "Lurch" clock from one event to the next
- Will omit times in system, "max" computations here (see text for complete details)

# Simulation by Hand: Setup

System	Clock	B(t)	Q(t)		Arrival times of custs. in queue	Event calenda	ar			
Number of completed waiting times in queue	Total of waiting ti	mes in que	eue	Area Q(t)	a under	Area under <i>B</i> ( <i>t</i> )				
Q(t) graph	4 3 - 2 - 1 - 0		ı		ı	,				
B(t) graph	0 2 1 - 0 0		5		10	15	20			
Interarrival times	Time (Minutes)									
Service times	·	1.73, 1.35, 0.71, 0.62, 14.28, 0.70, 15.52, 3.15, 1.76, 1.00, 2.90, 1.76, 3.39, 4.52, 4.46, 4.36, 2.07, 3.36, 2.37, 5.38,								

# Simulation by Hand: t = 0.00, Initialize

System	Clock 0.00	B(t) 0	Q(t) 0		Arrival times of custs. in queue <empty></empty>	Ever [1, [–,	nt calenda 0.00, 20.00,	ar Arr] End]		
Number of completed waiting times in queue 0	Total of waiting til	mes in que	eue	Area Q(t) 0.00		Area <i>B</i> ( <i>t</i> )	under			
0	4			0.00	,	0.00				
Q(t) graph	3 - 2 - 1 - 0		ı		ı	Ţ				
B(t) graph	0 2 1 - 0 0		5		10	15		20		
	0	0 5 10 15 Time (Minutes)								
Interarrival times	1.73, 1.3	1.73, 1.35, 0.71, 0.62, 14.28, 0.70, 15.52, 3.15, 1.76, 1.00,								
Service times	2.90, 1.70	6, 3.39, 4.	52, 4.	46, 4	.36, 2.07, 3.36, 2.37	, 5.38	3,			

# Simulation by Hand: t = 0.00, Arrival of Part 1

System	Clock	B(t)	Q(t)		Arrival times of	Eve	nt calenda	ar		
					custs. in queue	[2,	1.73,	Arr]		
	0.00	1	0		<empty></empty>	[1,	2.90,	Dep]		
				ı		[—,	20.00,	End]		
Number of	Total of	_			a under		a under			
completed waiting times in queue	waiting times in queue			Q(t)		B(t)				
1	0.00			0.00		0.00	)			
	4 —									
Q(t) graph	3 -									
a(t) graph	2 -									
	1 -		ı		T	T				
	0		5		10	15		20		
D(A) graph	2									
B(t) graph	1 0		ī							
	0	ţ	5		10	15		20		
		Time (Minutes)								
Interarrival times	1,73, 1.3	<b>73</b> , 1.35, 0.71, 0.62, 14.28, 0.70, 15.52, 3.15, 1.76, 1.00,								
Service times	280, 1.7	<b>2</b> 0, 1.76, 3.39, 4.52, 4.46, 4.36, 2.07, 3.36, 2.37, 5.38,								

### Simulation by Hand: t = 1.73, Arrival of Part 2

System 2 1	Clock 1.73	B(t)	Q(t)		Arrival times of custs. in queue (1.73)	Eve [1, [3, [-,	nt calenda 2.90, 3.08, 20.00,	ar Dep] Arr] End]	
Number of completed waiting	Total of waiting ti	mes in que	eue	Area Q(t)	a under	Area B(t)	a under		
times in queue	0.00			0.00	)	1.73	3		
Q(t) graph	4 3 - 2 - 1 - 0				1				
B(t) graph	0 2 1 0 0		5		10	15		20	
Into required time as	17612	Time (Minutes)							
Interarrival times	_	1,73, 1,25, 0.71, 0.62, 14.28, 0.70, 15.52, 3.15, 1.76, 1.00,							
Service times	<b>2.8</b> 0, 1.7	<b>20</b> , 1.76, 3.39, 4.52, 4.46, 4.36, 2.07, 3.36, 2.37, 5.38,							

# Simulation by Hand: t = 2.90, Departure of Part 1

System	Clock	B(t)	Q(t)		Arrival times of	Eve	nt calenda	ar	
			,		custs. in queue	[3,	3.08,	Arr]	
	2.90	1	0		<empty></empty>	[2,	4.66,	Dep]	
						[-,	20.00,	End]	
Number of	Total of			Area	a under	Area	a under		
completed waiting	waiting ti	mes in que	eue	Q(t)		B(t)			
times in queue 2	1.17			1.17	•	2.90	)		
	4 —					!			
O(A) arranda	3 -								
Q(t) graph	2 -								
	1 - 0		ı		1				
	0	;	5		10	15		20	
B(t) graph	2 1	•							
	0	Į.	5		10	15		20	
	Time (Minutes)								
Interarrival times	1,73, 1,85, 0.71, 0.62, 14.28, 0.70, 15.52, 3.15, 1.76, 1.00,								
Service times	280, 17	2.80, 1.76, 3.39, 4.52, 4.46, 4.36, 2.07, 3.36, 2.37, 5.38,							

# Simulation by Hand: t = 3.08, Arrival of Part 3

System	Clock	B(t)	Q(t)		Arrival times of		nt calenda		
3 2	3.08	1	1		custs. in queue (3.08)	[4, [2, [–,	3.79, 4.66, 20.00,	Arr] Dep] End]	
Number of completed waiting times in queue	Total of waiting ti	mes in que	eue	Area Q(t)	a under	Area B(t)	a under		
2	1.17			1.17		3.08	3		
Q(t) graph	4 3 - 2 - 1 - 0								
B(t) graph	0 2 1 0 0	<b></b> ••	5		10	15		20	
	Time (Minutes)								
Interarrival times	1,73, 1,2	1,73, 1,25, 0,71, 0.62, 14.28, 0.70, 15.52, 3.15, 1.76, 1.00,							
Service times	280, 17	280, 176, 3.39, 4.52, 4.46, 4.36, 2.07, 3.36, 2.37, 5.38,							

### Simulation by Hand: t = 3.79, Arrival of Part 4

System 4 3 2	Clock 3.79	B(t)	Q(t) 2		Arrival times of custs. in queue (3.79, 3.08)	Eve [5, [2, [-,	nt calenda 4.41, 4.66, 20.00,	ar Arr] Dep] End]	
Number of	Total of	maa in au			a under		a under		
completed waiting times in queue	waiting til	mes in que	eue	Q(t)		B(t)			
2	1.17			1.88		3.79	)		
Q(t) graph	4 3 - 2 - 1 - 0					1			
	0	;	5		10	15		20	
B(t) graph	2 1								
	0	ţ	5		10	15		20	
	Time (Minutes)								
Interarrival times	1,73, 1,25, 0,71, 0,82, 14.28, 0.70, 15.52, 3.15, 1.76, 1.00,								
Service times	280, 176, 3.39, 4.52, 4.46, 4.36, 2.07, 3.36, 2.37, 5.38,								

### Simulation by Hand: t = 4.41, Arrival of Part 5

System 5 4 3 2	Clock 4.41	B(t)	Q(t) 3		Arrival times of custs. in queue (4.41, 3.79, 3.08)	Eve [2, [6,	nt calenda 4.66, 18.69, 20.00,	ar Dep] Arr] End]	
Number of completed waiting times in queue 2	Total of waiting ti	mes in que	eue	Area Q(t) 3.12	a under	Area <i>B</i> ( <i>t</i> ) 4.41	a under		
Q(t) graph	4 3 - 2 - 1 - 0		1		ı				
B(t) graph	0 2 1 0 0	••••	5		10	15		20	
Interarrival times	Time (Minutes) 1,73, 1,35, 0,71, 0,82, 14,28, 0.70, 15.52, 3.15, 1.76, 1.00,								
Service times	1400, JA	2,80, 1,76, 3.39, 4.52, 4.46, 4.36, 2.07, 3.36, 2.37, 5.38,							

### Simulation by Hand: t = 4.66, Departure of Part 2

System 5 4 3	Clock 4.66	B(t)	Q(t) 2		Arrival times of custs. in queue (4.41, 3.79)	Eve [3, [6,	nt calenda 8.05, 18.69, 20.00,	ar Dep] Arr] End]		
Number of completed waiting times in queue 3	Total of waiting tile	mes in que	eue	Area Q(t) 3.87		Area <i>B</i> ( <i>t</i> )				
Q(t) graph	4 3 - 2 - 1 - 0		1		ı	ı				
B(t) graph	0 2 1 0 0		5		10	15		20		
Interestival times	Time (Minutes)									
Interarrival times	اقرا (کردا	1,76, 1,35, 0,71, 0,62, 14,28, 0.70, 15.52, 3.15, 1.76, 1.00,								
Service times	2.80, 1.7	<b>2</b> 0, <b>1</b> .76, <b>3</b> .39, 4.52, 4.46, 4.36, 2.07, 3.36, 2.37, 5.38,								

# Simulation by Hand: t = 8.05, Departure of Part 3

System	Clock	B(t)	Q(t)		Arrival times of	Eve	nt calenda	ar	
					custs. in queue	[4,	12.57,	Dep]	
5 4	8.05	1	1		(4.41)	[6,	18.69,	Arr]	
						[-,	20.00,	End]	
Number of	Total of	•		Area	a under	Area	a under		
completed waiting times in queue	waiting ti	aiting times in queue				B(t)			
4	7.01			10.6	55	8.05	5		
	4 —		1						
Q(t) graph	3 -	***							
1,(4) 9, 3,1	2 -				1				
			T		• 	ı			
	0		5		10	15		20	
B(t) graph	2 1	00 0 00			•				
	0		5		10	15	į	20	
	Time (Minutes)								
Interarrival times	1,7%, 1,3%, 0,71, 0,62, 14,28, 0.70, 15.52, 3.15, 1.76, 1.00,								
Service times	2,20, 1,76, 3,39, 4,52, 4.46, 4.36, 2.07, 3.36, 2.37, 5.38,								

### Simulation by Hand: t = 12.57, Departure of Part 4

System		Q(t)		Arrival times of custs. in queue		Event calenda [5, 17.03,	ar Dep]	
5	12.57	1	0		oucie, iii quouc	()	[6, 18.69, [-, 20.00,	Arr] End]
Number of	Total of	•	•	Area	a under		Area under	
completed waiting times in queue	waiting ti	mes in que	eue	Q( <i>t</i> )			B(t)	
5	15.17	.17			7		12.57	
	4						I	
Q(t) graph	3 - 2 -				1			
			Т		,		ı	
	0		5		10		15	20
B(t) graph	2	***	_		•			
	0		5		10		15	20
					Time (Minutes)			
Interarrival times	1,75, 1,25, 0,71, 0,62, 14,28, 0.70, 15.52, 3.15, 1.76, 1.00,							
Service times	2,80, 1,76, 3,39, 4,52, 4,46, 4.36, 2.07, 3.36, 2.37, 5.38,							

# Simulation by Hand: t = 17.03, Departure of Part 5

System	Clock 17.03	B(t) 0	Q(t) 0		Arrival times of custs. in queue ()	Eve [6, [–,	nt calenda 18.69, 20.00,	ar Arr] End]		
Number of completed waiting times in queue	Total of waiting ti	mes in que	eue	Area Q(t)	a under	Area B(t)	a under			
5	15.17			15.1	7	17.0	17.03			
Q(t) graph	4 3 - 2 - 1 - 0		ī							
B(t) graph	0 2 1 0 0	<b>***</b>	5 , 5		10	15 - 15	1	20		
latera missal time a	Time (Minutes)									
Interarrival times	1,75, 1,25, 0,71, 0,82, 14,28, 0.70, 15.52, 3.15, 1.76, 1.00,									
Service times	2,80, 1,76, 3,39, 4,52, 4,46, 4.36, 2.07, 3.36, 2.37, 5.38,									

### Simulation by Hand: t = 18.69, Arrival of Part 6

System 6	Clock 18.69	B(t)	Q(t) 0		Arrival times of custs. in queue ()	Eve [7, [-, [6,	nt calenda 19.39, 20.00, 23.05,	ar Arr] End] Dep]	
Number of	Total of		•		a under		a under		
completed waiting times in queue	waiting ti	eue	ue $Q(t)$			B(t)			
6	15.17				7	17.0	17.03		
Q(t) graph	4 3 - 2 - 1 - 0								
	0	:	5		10	15		20	
B(t) graph	2 1	•••••	1		•				
	0		5		10	15		20	
					Time (Minutes)				
Interarrival times	1,73, 1,2	5, 0,71, 0,	<b>32</b> , 14	128,	0. <b>1</b> 0, 15.52, 3.15,	1.76, 1	.00,		
Service times	280, 17	6, 3,29, 4,	<del>5</del> 2, 4	46, 4	<b>%</b> 6, 2.07, 3.36, 2.3	37, 5.38	3,		

### Simulation by Hand: t = 19.39, Arrival of Part 7

System	Clock	B(t)	Q(t)		Arrival times of	Eve	nt calenda	ar	
76	19.39	`´  1	1		custs. in queue (19.39)	[–, [6,	20.00, 23.05,	End] Dep]	
	10.00	•	•		(10.00)	[8,	34.91,	Arr]	
Number of	Total of			Area	under	Area	a under		
completed waiting times in queue	waiting times in queue			Q(t)		B(t)			
6	15.17			15.1	7	17.73			
	4								
Q(t) graph	3 -								
,, , ,	2 - 1 - 0						•		
	0	5	5		10	15	-	20	
B(t) graph	2			•					
	0	5	5		10	15	•	20	
	Time (Minutes)							-	
Interarrival times	1,73, 1,25, 0,71, 0,82, 14.28, 9.10, 15.52, 3.15, 1.76, 1.00,								
Service times	280, 176, 389, 482, 446, 486, 2.07, 3.36, 2.37, 5.38,								

# Simulation by Hand: t = 20.00, The End

System	Clock	B(t)	Q(t)		Arrival times of custs. in queue	Eve [6,	nt calenda 23.05,	ar Dep]	
	20.00	1	1		(19.39)	[8,	34.91,	Arr]	
Number of	Total of	•			a under		a under		
completed waiting times in queue	waiting ti	eue	Q(t)		B(t)				
6	15.17			15.7	8	18.34			
	4								
Q(t) graph									
	1 - 0					,	•		
	0	Ę	5		10	15		20	
B(t) graph	2 1 0	<b>***</b>		•					
	0	5	5		10	15		20	
	Time (Minutes)								
Interarrival times	1,73, 1,25, 0,71, 0,82, 14.28, 0.10, 15.52, 3.15, 1.76, 1.00,								
Service times	2,80, 1,76, 3,39, 4,52, 4,46, 4,86, 2.07, 3.36, 2.37, 5.38,								

### Simulation by Hand: Finishing Up

Average waiting time in queue:

Total of times in queue 
$$=$$
  $\frac{15.17}{6} = 2.53$  minutes per part

• Time-average number in queue:

$$\frac{\text{Area under } Q(t) \text{ curve}}{\text{Final clock value}} = \frac{15.78}{20} = 0.79 \text{ part}$$

Utilization of drill press:

$$\frac{\text{Area under } B(t) \text{ curve}}{\text{Final clock value}} = \frac{18.34}{20} = 0.92 \text{ (dimension less)}$$

### Complete Record of the Hand Simulation

П							Statistical Accumulators											
	Finished		Var	iables	Attributes					Statistic	al Accui	mulators				Ev	ent Calend	ar
Entity	T im e	Event	l		Arrival Times						57		1		1			
No.	t	Type	Q(t)	B(t)	(In Queue) In Se	rvice	P	N	$\Sigma_{WQ}$	W Q *	$\Sigma TS$	TS*	Jo	0.*	$J_B$		No., Time	
Ш																[1,	0.00,	Arr]
11 -	0.00	Init	0	0	()	_	0	0	0.00	0.00	0.00	0.00	0.00	0	0.00	[-,	20.00,	End]
Ц																		
Ш																[2,	1.73,	Arr]
1 1	0.00	Arr	-0	1	()	0.00	0	1	0.00	0.00	0.00	0.00	0.00	0	0.00	[1,	2.90,	Dep]
H																[-,	20.00,	End]
11 .																[1,	2.90,	Dep]
2	1.73	Arr	1	1	(1.73)	0.00	0	1	0.00	0.00	0.00	0.00	0.00	1	1.73	[3,	3.08,	Arr]
Н																[-,	20.00	End]
11 .		_					_									[3,	3.08,	Arr]
	2.90	Dep	0	1	()	1.73	1	2	1,17	1.17	2.90	2.90	1.17	1	2.90	[2,	4.66,	Dep]
Н																[-,	20.00,	End]
11 .			١.					_								[4,	3.79,	Arr]
3	3.08	Arr	1	1	(3.08)	1.73	1	2	1.17	1.17	2.90	2.90	1.17	1	3.08	[2,	4.66,	Dep]
Н			-													[-,	20.00,	End]
II .														_		[5,	4.41,	Arr]
4	3.79	Arr	2	1	(3.79, 3.08)	1.73	1	2	1,17	1.17	2.90	2.90	1.88	2	3.79	[2,	4.66,	Dep]
Н			-													-,	20.00,	End1
11 .			١.													[2,	4.66,	Dep]
5	4,41	Arr	3	1	(4.41, 3.79, 3.08)	1.73	1	2	1.17	1.17	2.90	2.90	3.12	3	4.41	[6,	18.69,	Arr]
H																<u>[-,</u>	20.00,	End]
11 .						2.00	_		2.75	1.50	5.03	2.02				[3,	8.05,	Dep]
2	4.66	Dep	2	1	(4.41, 3.79)	3.08	2	3	2.75	1.58	5.83	2.93	3.87	3	4.66	[6,	18.69,	Arr]
Н	•		-													[-,	20.00,	End]
11 .	0.05		١.			2.70			2.01		10.00	4.07	10.65		0.05	[4,	12.57,	Dep]
3	8.05	Dep	1	1	(4.41)	3.79	3	4	7.01	4.26	10.80	4.97	10.65	3	8.05	[6,	18.69,	Arr]
H			-	•												<u>[-,</u>	20.00,	End]
1 4	12.57	Dep	0	1	()	4.41	4	5	15.17	8.16	19.58	8.78	15.17	3	12.57	[5,	17.03,	Dep]
11 7	1 2 , , , /	Бер	١ ،			4.41	-	.,	13.17	0.10	19,50	0.70	13.17	,,	12.57	[6,	18.69, 20.00,	Arr]
H -	1.7.03		-						15.15	0.16	22.20	10.60			17.02	-,		End]
5	17.03	Dep	0	0	()	-	5	5	15.17	8.16	32.20	12.62	15.17	3	17.03	[6,	18.69,	Arr]
H																I-,	20.00	End]
6	18.69	Arr	0	1	0	18.69	5	6	15.17	8.16	32.20	12.62	15.17	3	17.03	[7,	19.39,	Arr]
"	10.07	AII				.0.07	,	U	1,7,1/	0.10	32,20	12.02		,,	17.03	[-,	20.00,	End]
H													•			[6,	23.05.	Dep]
1 7	19.39	Arr	1	1	(19.39)	18 69	5	6	15.17	8.16	32.20	12.62	15.17	3	17.73	[-,	20.00,	End]
11 '	. 7.07	74.11	Ι.		(17.37)	.0.07		v	1,5,17	0.10	32,20	12.02		.,	17.73	[6, [8,	23.05, 34.91,	Dep]
H	20.00	E - 4	,		(10.30)	10.60	-		15.12	0.16	22.20	10.60	15.20		10.24			
-	20.00	End	1	1	(19.39)	18.69	5	6	15.17	8.16	32.20	12.62	15.78	3	18.34	[6,	23.05,	Dep]
Ш																[8,	34.91,	Arr]



# **Event-Scheduling Logic via Programming**

- Clearly well suited to standard programming language
- Often use "utility" libraries for:
  - List processing
  - Random-number generation
  - Random-variate generation
  - Statistics collection
  - Event-list and clock management
  - Summary and output
- Main program ties it together, executes events in order

### Simulation Dynamics: The Process-Interaction World View

- Identify characteristic entities in the system
- Multiple copies of entities co-exist, interact, compete
- "Code" is non-procedural
- Tell a "story" about what happens to a "typical" entity
- May have many types of entities, "fake" entities for things like machine breakdowns
- Usually requires special simulation software
  - Underneath, still executed as event-scheduling
- The view normally taken by Arena
  - Arena translates your model description into a program in the SIMAN simulation language for execution



#### **Randomness in Simulation**

- The above was just one "replication" a sample of size one (not worth much)
- Made a total of five replications:

		Re	plicatio	n	Sa	mple	95%	
Performance Measure	1	2	3	4	5	Avg.	Std. Dev.	Half Width
Total production	5	3	6	2	3	3.80	1.64	2.04
Average waiting time in queue	2.53	1.19	1.03	1.62	0.00	1.27	0.92	1.14
Maximum waiting time in queue	8.16	3.56	2.97	3.24	0.00	3.59*	2.93*	3.63*
Average total time in system	6.44	5.10	4.16	6.71	4.26	5.33	1.19	1.48
Maximum total time in system	12.62	6.63	6.27	7.71	4.96	7.64*	2.95*	3.67*
Time-average number of parts in queue	0.79	0.18	0.36	0.16	0.05	0.31	0.29	0.36
Maximum number of parts in queue	3	1	2	1	1	1.60*	0.89*	1.11*
Drill-press utilization	0.92	0.59	0.90	0.51	0.70	0.72	0.18	0.23

Note substantial variability across replications

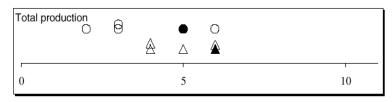
- Confidence intervals for expected values:
  - In general,  $\overline{X} \pm t_{n-1,1-\alpha/2} s I \sqrt{n}$
  - For expected total production,  $3.80 \pm (2.776)(1.64/\sqrt{5})$  $3.80 \pm 2.04$

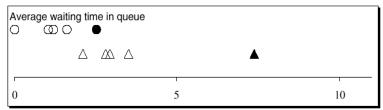


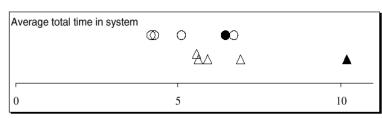
### **Comparing Alternatives**

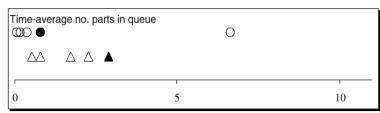
- Usually, simulation is used for more than just a single model "configuration"
- Often want to compare alternatives, select or search for the best (via some criterion)
- Simple processing system: What would happen if the arrival rate were to double?
  - Cut interarrival times in half
  - Rerun the model for double-time arrivals
  - Make five replications

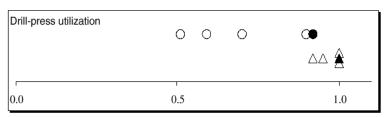
### Results: Original vs. Double-Time Arrivals











- Original circles
- Double-time triangles
- Replication 1 filled in
- Replications 2-5 hollow
- Note variability
- Danger of making decisions based on one (first) replication
- Hard to see if there are really differences
- Need: Statistical analysis of simulation output data

### **Overview of a Simulation Study**

- Understand the system
- Be clear about the goals
- Formulate the model representation
- Translate into modeling software
- Verify "program"
- Validate model
- Design experiments
- Make runs
- Analyze, get insight, document results

