MGT 40750 – Quantitative Decision Modeling
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Process Simulation

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Process Simulation

Main Idea of Process Simulation:

- Suppose you have a real world process whose efficiency you want to improve.
- If there is *uncertainty* in this process (e.g., in the demand for a product, in the supply of some parts, in the time it takes to perform some of the work, in the quality of work, etc.), then it is often difficult to predict the effects of making various changes to the process.
- With the technique called process simulation, you build a model of your process in a computer and then *test the effects of changes* made to this computer model.
- If the model captures the essence of your real process, then this technique can help you *decide which changes to make* on the real process.

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Using simulation Johns Hopkins has successfully identified the areas that will allow them to automate steps to off load staff responsibilities

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Wyeth - Using SIMUL8 to Make Savings in Excess of $1m
Use of simulation between 2 projects, each of which took less than a month from start to finish, resulted in avoiding costs of between $1million to $2million.

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Nibco - The Confidence to Act
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- Hallmark Gift Manufacturer
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- Underwriting Administration
- Electronic Personnel Records System
- Purchasing Process

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- Emergency Room Model
- Point of Dispensing
- Optimizing Rehab Patient Scheduling
- Architecture Analysis for Banfield

SIMPROCESS Solutions

An easy to use, object-oriented, process modeling and analysis tool. It combines the simplicity of flowcharting with the power of simulation, statistical analysis, Activity-Based Costing (ABC), and animation. SIMPROCESS is ideal for rapid prototyping & proposals with results in a matter of hours.

There are many demonstration and reference models included with the SIMPROCESS installation under the Demos subdirectory in the models directory. Running these models and studying the techhiques used in building them will give a better appreciation for the activity modeling and advanced modeling constructs of SIMPROCESS. You can read more about these demos in chapter 5 of the Getting Started Manual.

In the left menu panel of this web page you will see links to some of our demos. Some of these contain descriptions and some also include the actual demo model that you may download.

Examples of Process Simulation

- Queuing systems
- Logistics systems
- Call centers
- Computer networks
- Manufacturing systems
- Health care systems
- Production scheduling
- Conveyor systems
- Inventory management

Basic steps in using process simulation

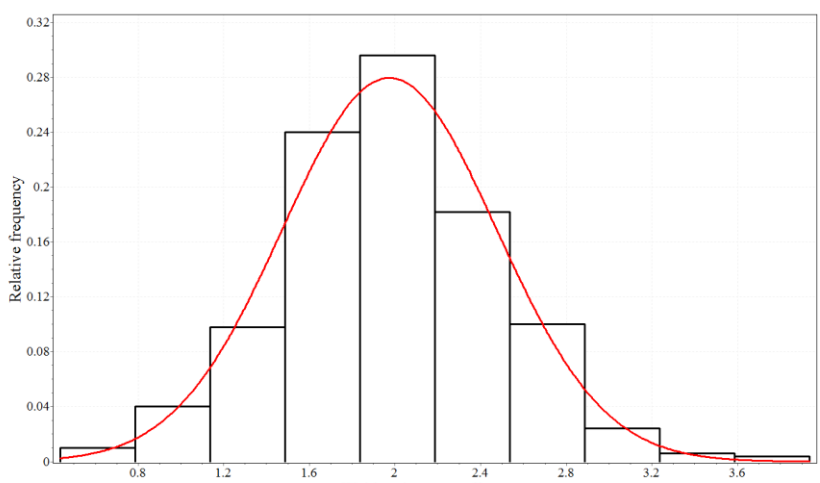
1. Draw a *process flow map* of the process.
2. Obtain *data*.
3. Input the model and data (typically in the form of *statistical distributions*) into computer.
4. Check that the computer simulation behaves like the real process (*validation*).
5. Perform *experiments* with the computer simulation by varying the values of variables of interest.
6. Analyze the results; look for combinations of the values of the variables that give the best performance.

Process Simulation – Waiting Lines

(SimQuick Chap 2)

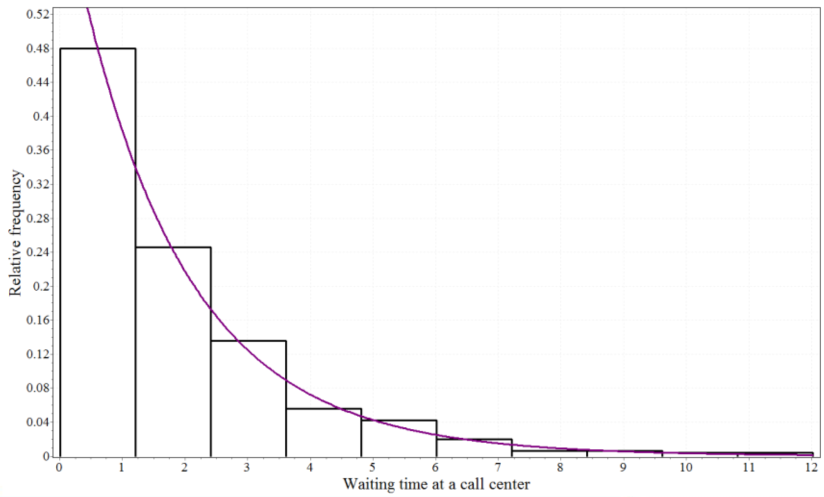
Review of Common Statistical Distributions

- Normal Distribution: Nor(m,s) in SimQuick



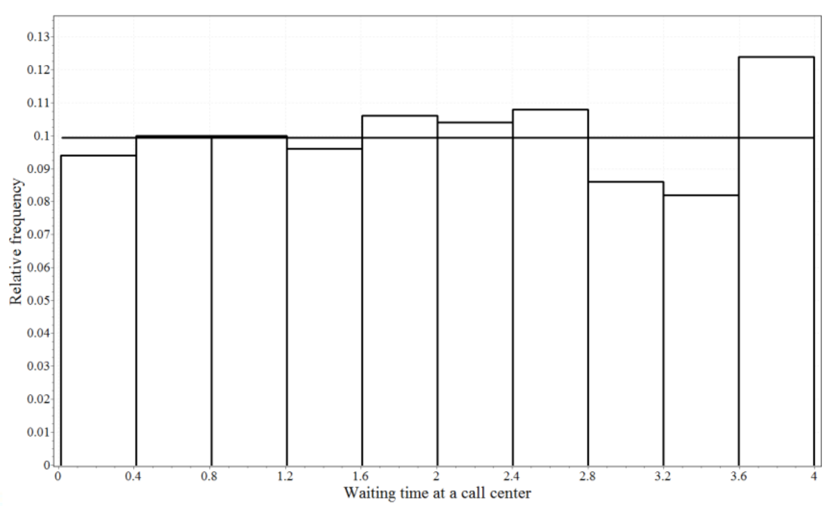
Review of Common Statistical Distributions

- Exponential Distribution: Exp(m) in SimQuick



Review of Common Statistical Distributions

- Uniform Distribution: Uni(a,b) in SimQuick



Example: A bank

- Consider the following process within a small bank: customers enter the bank, get into a single line, are served by a teller, and finally leave the bank. Currently, this bank has one teller working from 9am to 11am.
- Management is concerned that the wait in line seems to be too long. Therefore, they are considering two process improvement ideas:
  - Option 1: installing a new *automated check-reading machine* that can help the single teller serve customers more quickly
  - Option 2: adding an *additional teller* during these hours

- What should management do?

Example: A bank

- Process flow map:

- Five Elements in SimQuick
  - Entrances, Exits, Work Stations, Buffers, Decision Points

Example: A bank

- Question: What data to collect?
  - How long to serve a customer
  - How much time between customer arrivals
  - Capacity of line

Example: A bank

Some details based on data from the current process:

- We have observed that the amount of time between arrivals of customers can be approximated by an exponential distribution with a mean of 2 minutes.
- The line in this bank can only hold 8 people and if a person arrives when the line is full he/she does not get in line.
- We have observed that the service time by the teller can be approximated by a normal distribution with a mean of 2.4 minutes and a standard deviation of .5 minutes.

Example: A bank

Model in SimQuick:

Entrances:

1	
Name →	Door
Time between arrivals →	Exp(2)
Num. objects per arrival →	1
Output destination(s) ↓	
Line	

Buffers:

1			2	
Name →	Line		**Name →**	Served Customers
Capacity →	8		Capacity →	Unlimited
Initial # objects →	0		Initial # objects →	0
Output destination(s) ↓	Output group size ↓		Output destination(s) ↓	Output group size ↓
Teller	1			

Work Stations:

	1		
	Name →	Teller	
	Working time →	Nor(2.4,0.5)	
Output destination(s) ↓	# of output objects ↓	Resource name(s) ↓	Resource # units needed ↓
Served Customers	1		

Simulation controls:	
Time units per simulation →	120
Number of simulations →	30

Simulation Results

Return to Control Panel

Element types	Element names	Statistics	Overall means	Simulation Numbers 1	2	3	4	5
Entrance(s)	Door	Objects entering process	53.50	54	55	57	51	51
		Objects unable to enter	7.87	7	11	3	6	0
		Service level	0.88	0.89	0.83	0.95	0.89	1.00
Work Station(s)	Teller	Final status	NA	Working	Working	Working	Working	Working
		Final inventory (int. buff.)	0.00	0	0	0	0	0
		Mean inventory (int. buff.)	0.00	0.00	0.00	0.00	0.00	0.00
		Mean cycle time (int. buff.)	0.00	0.00	0.00	0.00	0.00	0.00
		Work cycles started	48.23	47	48	51	48	49
		Fraction time working	0.96	0.94	1.00	0.99	0.96	0.94
		Fraction time blocked	0.00	0.00	0.00	0.00	0.00	0.00
Buffer(s)	Line	Objects leaving	48.23	47	48	51	48	49
		Final inventory	5.27	7	7	6	3	2
		Minimum inventory	0.00	0	0	0	0	0
		Maximum inventory	7.53	8	8	8	8	5
		Mean inventory	4.28	4.17	6.13	4.23	4.29	1.34
		Mean cycle time	10.59	10.64	15.33	9.94	10.73	3.29
	Served Customers	Objects leaving	0.00	0	0	0	0	0
		Final inventory	47.23	46	47	50	47	48
		Minimum inventory	0.00	0	0	0	0	0
		Maximum inventory	47.23	46	47	50	47	48
		Mean inventory	22.80	22.55	23.37	24.61	22.09	24.14
		Mean cycle time	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite

Important Performance Measures for Processes

- The *service level* for each simulation is the fraction of demand that is satisfied.

  Service level for entrance = Objects entering process / (Objects entering process + Objects unable to enter)

  For our example, in simulation #1:

  Service level = 54 / (54 + 7) = .89

- The *overall mean service level* of the process is the mean of the service levels calculated for each simulation; in this example it equals .88.

Important Performance Measures for Processes

- The *mean cycle time* at a buffer is the mean amount of time an object takes to move through the buffer during a simulation.

  For our example, in simulation #1:

  Mean cycle time at Line = 10.64

- The *overall mean cycle time* at a buffer is the mean of the mean cycle times of the buffer for each simulation.

  In this example, the overall mean cycle time at Line = 10.59.

Option 1: Improving the system

We would like to analyze how would the performance of the bank be improved by the addition of a check-reading machine.

Suppose the addition of a check-reading machine would reduce *service time per customer* from Nor(2.4,.5) to Nor(2,.5).

How to change the original process simulation model?

Change working time for Teller to Nor(2,0.5)

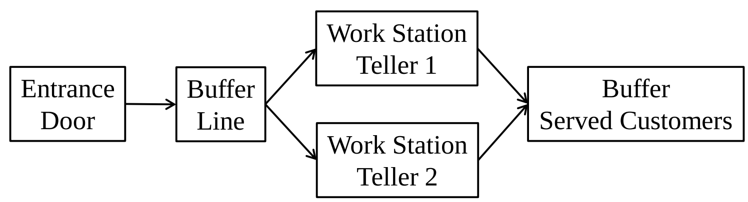
Option 1: Process Improvement Results

- Before the change,
  - Overall mean service level = 0.88.
  - Overall mean waiting time (i.e., overall mean cycle time at Line) = 10.59.
- After adding a check-reading machine,
  - Overall mean service level = 0.98.
  - Overall mean waiting time = 5.48.

Option 2: Improving the system

How would the performance of the bank be improved by the addition of a second teller?

Process flow map for adding a second teller:



Option 2: Process Improvement Results

- Before the change,
  - Overall mean service level = 0.88.
  - Overall mean waiting time (i.e., overall mean cycle time at Line) = 10.59.
- After adding a second teller,
  - Overall mean service level = 1.00.
  - Overall mean waiting time = 0.69.

Example: A bank with two tellers

Model in SimQuick:

Entrances:

1	
Name →	Door
Time between arrivals →	Exp(2)
Num. objects per arrival →	1
Output destination(s) ↓	
Line	

Buffers:

1	
Name →	Line
Capacity →	8
Initial # objects →	0
Output destination(s) ↓	Output group size ↓
Teller 1	1
Teller 2	1

2	
Name →	Served Customers
Capacity →	Unlimited
Initial # objects →	0
Output destination(s) ↓	Output group size ↓

Work Stations:

	1		
	Name →	Teller 1	
	Working time →	Nor(2.4,0.5)	
Output destination(s) ↓	# of output objects ↓	Resource name(s) ↓	Resource # units needed ↓
Served Customers	1		

	2		
	Name →	Teller 2	
	Working time →	Nor(2.4,0.5)	
Output destination(s) ↓	# of output objects ↓	Resource name(s) ↓	Resource # units needed ↓
Served Customers	1		

Example: An airport security system

- The passenger security process at one terminal of a medium sized airport works as follows:

- Between 8am and 10am, one passenger arrives every half-minute (on average, according to an exponential distribution) at the security area.
- Arriving passengers immediately enter a single line (with a large capacity).
- After waiting in line, each passenger goes through one of two inspection stations, which involves walking through a metal detector and running any carry-on baggage through a scanner. The amount of time for this inspection can be approximated by a normal distribution with a mean of 1 minute and a standard deviation of .1 minutes.

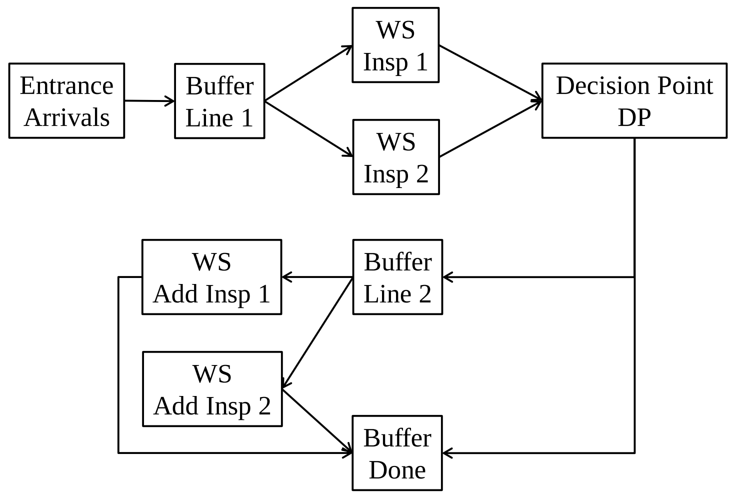
Example: An airport security system

- After completing this inspection, 10% of the passengers are randomly selected for an additional inspection, which typically involves a more thorough search of the person’s carry-on baggage.
- There are two stations for this additional inspection; the amount of time for it can be approximated by a normal distribution with a mean of 5 minutes and a standard deviation of 1 minute.

- We need a new element in SimQuick to model this system.

Decision Point

Process Flow Map: An airport security system



Example: An airport security system

Model in SimQuick:

Entrances:

1	
Name →	Arrivals
Time between arrivals →	Exp(0.5)
Num. objects per arrival →	1
Output destination(s) ↓	
Line 1	

Buffers:

1	
Name →	Line 1
Capacity →	Unlimited
Initial # objects →	0
Output destination(s) ↓	Output group size ↓
Insp 1	1
Insp 2	1

2	
Name →	Line 2
Capacity →	Unlimited
Initial # objects →	0
Output destination(s) ↓	Output group size ↓
Add Insp 1	1
Add Insp 2	1

3	
Name →	Done
Capacity →	Unlimited
Initial # objects →	0
Output destination(s) ↓	Output group size ↓

Work Stations:

	1		
	Name →	Insp 1	
	Working time →	Nor(1,0.1)	
Output destination(s) ↓	# of output objects ↓	Resource name(s) ↓	Resource # units needed ↓
DP	1		

	2		
	Name →	Insp 2	
	Working time →	Nor(1,0.1)	
Output destination(s) ↓	# of output objects ↓	Resource name(s) ↓	Resource # units needed ↓
DP	1		

	3		
	Name →	Add Insp 1	
	Working time →	Nor(5,1)	
Output destination(s) ↓	# of output objects ↓	Resource name(s) ↓	Resource # units needed ↓
Done	1		

	4		
	Name →	Add Insp 2	
	Working time →	Nor(5,1)	
Output destination(s) ↓	# of output objects ↓	Resource name(s) ↓	Resource # units needed ↓
Done	1		

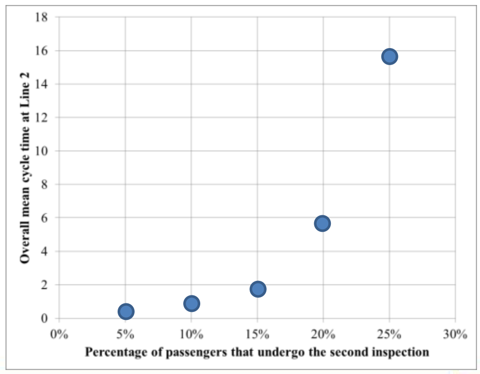
Decision Point:

1	
Name →	DP
Output destinations ↓	Percents ↓
Line 2	10
Done	90

Simulation controls:	
Time units per simulation →	120
Number of simulations →	50

Sensitivity Analysis

- The key statistics for airport management are the passenger waiting times. Management is interested in examining the effect on waiting time of increasing the percentage of passengers that undergo the second inspection.
- Record the overall mean cycle time at Line 2 with varying percentages of 5%, 10%, 15%, 20%, 25%.



The New York Times

December 27, 2010

Disney Tackles Major Theme Park Problem: Lines

By BROOKS BARNES

ORLANDO, Fla. — Deep in the bowels of Walt Disney World, inside an underground bunker called the Disney Operational Command Center, technicians know that you are standing in line and that you are most likely annoyed about it. Their clandestine mission: to get you to the fun faster.

To handle over 30 million annual visitors — many of them during this busiest time of year for the megaresort — Disney World long ago turned the art of crowd control into a science. But the putative Happiest Place on Earth has decided it must figure out how to quicken the pace even more. A cultural shift toward impatience — fed by video games and smartphones — is demanding it, park managers say. To stay relevant to the entertain-me-right-this-second generation, Disney must evolve.

And so it has spent the last year outfitting an underground, nerve center to address that most low-tech of problems, the wait. Located under Cinderella Castle, the new center uses video cameras, computer programs, digital park maps and other whiz-bang tools to spot gridlock before it forms and deploy countermeasures in real time.

In one corner, employees watch flat-screen televisions that depict various attractions in green, yellow and red outlines, with the colors representing wait-time gradations.

If Pirates of the Caribbean, the ride that sends people on a spirited voyage through the Spanish Main, suddenly blinks from green to yellow, the center might respond by alerting managers to launch more boats.

Another option involves dispatching Captain Jack Sparrow or Goofy or one of their pals to the queue to entertain people as they wait. “It’s about being nimble and quickly noticing that, ‘Hey, let’s make sure there is some relief out there for those people,’ ” said Phil Holmes, vice president of the Magic Kingdom, the flagship Disney World park.

What if Fantasyland is swamped with people but adjacent Tomorrowland has plenty of elbow room? The operations center can route a miniparade called “Move it! Shake it! Celebrate It!” into the less-populated pocket to siphon guests in that direction. Other technicians in the command center monitor restaurants, perhaps spotting that additional registers need to be opened or dispatching greeters to hand out menus to people waiting to order.

"These moments add up until they collectively help the entire park," Mr. Holmes said.

In recent years, according to Disney research, the average Magic Kingdom visitor has had time for only nine rides — out of more than 40 — because of lengthy waits and crowded walkways and restaurants. In the last few months, however, the operations center has managed to make enough nips and tucks to lift that average to 10.

"Control is Disney's middle name, so they have always been on the cutting edge of this kind of thing," said Bob Sehlinger, co-author of "The Unofficial Guide: Walt Disney World 2011" and a writer on Disney for Frommers.com. Mr. Sehlinger added, "The challenge is that you only have so many options once the bathtub is full."

Disney, which is periodically criticized for overreaching in the name of cultural dominance (and profits), does not see any of this monitoring as the slightest bit invasive. Rather, the company regards it as just another part of its efforts to pull every possible lever in the name of a better guest experience.

The primary goal of the command center, as stated by Disney, is to make guests happier — because to increase revenue in its $10.7 billion theme park business, which includes resorts in Paris and Hong Kong, Disney needs its current customers to return more often. "Giving our guests faster and better access to the fun," said Thomas O. Staggs, chairman of Walt Disney Parks and Resorts, "is at the heart of our investment in technology."

Disney also wants to raise per-capita spending. "If we can also increase the average number of shop or restaurant visits, that's a huge win for us," Mr. Holmes said.

Disney has long been a leader in technological innovation, whether that means inventing cameras to make animated films or creating the audio animatronic robots for the attraction It's a Small World.

Behind-the-scenes systems — typically kept top secret by the company as it strives to create an environment where things happen as if by magic — are also highly computerized. Ride capacity is determined in part by analyzing hotel reservations, flight bookings and historic attendance data. Satellites provide minute-by-minute weather analysis. A system called FastPass allows people to skip lines for popular rides like the Jungle Cruise.

But the command center reflects how Disney is deepening its reliance on technology as it thinks about adapting decades-old parks, which are primarily built around nostalgia for an America gone by, for 21st century expectations. "It's not about us needing to keep pace with technological change," Mr. Staggs said. "We need to set the pace for that kind of change."

For instance, Disney has been experimenting with smartphones to help guide people more efficiently. Mobile Magic, a $1.99 app, allows visitors to type in "Sleeping Beauty" and receive directions to where that princess (or at least a costumed stand-in) is signing autographs. In the future, typing in “hamburger” might reveal the nearest restaurant with the shortest wait.

Disney has also been adding video games to wait areas. At Space Mountain, 87 game stations now line the queue to keep visitors entertained. (Games, about 90 seconds in length, involve simple things like clearing runways of asteroids). Gaming has also been added to the queue for Soarin’, an Epcot ride that simulates a hang glider flight.

Blogs that watch Disney’s parks have speculated that engineers (“imagineers,” in the company’s parlance) are also looking at bigger ideas, like wristbands that contain information like your name, credit card number and favorite Disney characters. While Disney is keeping a tight lid on specifics, these devices would enable simple transactions like the purchase of souvenirs — just pay by swiping your wristband — as well as more complicated attractions that interact with guests.

“Picture a day where there is memory built into these characters — they will know that they’ve seen you four or five times before and that your name is Bobby,” said Bruce E. Vaughn, chief creative executive at Walt Disney Imagineering. “Those are the kinds of limits that are dissolving so quickly that we can see being able to implement them in the meaningfully near future.”

Dreaming about the future was not something on Mr. Holmes’s mind as he gave a reporter a rare peek behind the Disney operations veil. He had a park to run, and the command center had spotted trouble at the tea cups.

After running smoothly all morning, the spinning Mad Tea Party abruptly stopped meeting precalculated ridership goals. A few minutes later, Mr. Holmes had his answer: a new employee had taken over the ride and was leaving tea cups unloaded.

“In the theme park business these days,” he said, “patience is not always a virtue.”

WIRED

Airlines Try Smarter Boarding

Dave Demerjian 05.09.06

It's the announcement that every frequent flier dreads: "Ladies and gentlemen, we have a very full flight today. Please step out of the aisle and into your row as quickly as possible so that other passengers are able to reach their seats."

But the chaos of aircraft boarding may soon go the way of the 727. Several major airlines are working to develop more efficient ways to board an aircraft, using computer simulations to come up with mathematically proven -- if counterintuitive -- boarding models with names like the "rotating zone system" and the "reverse pyramid."

For cash-strapped airlines, improving the boarding process has become more than a customer service issue. "An airplane only generates revenue when it is in the air," explains David Swierenga, a former Air Transport Association of America economist and president of aviation consulting company AeroEcon. Swierenga says that by speeding "turnaround," an industry term for the amount of time an aircraft spends on the ground between flights, airlines can keep their planes in the air longer.

"An airplane that spends an hour on the ground between flights might fly five trips a day," he explains. "Cut the turnaround time to 40 minutes, and maybe that same plane can complete six or seven flights a day." More flights mean more paying passengers, and ultimately, more revenue.

Many factors contribute to turnaround time, including baggage handling, refueling and aircraft cleaning. But a 1998 Boeing study shows that passenger boarding plays a significant role.

America West Airlines, which became US Airways after a recent merger, has led the way in rethinking passenger boarding, working with engineers at Arizona State University to develop a system that speeds the process by reducing interference between passengers.

According to Tim Lindemann, US Airways' managing director of airport services, streamlining the boarding process was one part of a larger effort to reduce turnaround times at what was then America West. "We were looking at every possible way to shave time off the process," he says.

Convinced that there was a statistical solution to the problem, Lindemann approached Arizona State University's industrial engineering department. "We have a great university in our backyard, and hoped they could help," he says. "The engineers there immediately understood the problem we were trying to solve, because they had witnessed it themselves. They had been on our flights."

Professor René Villalobos and graduate student Menkes van den Briel began reviewing boarding systems used by other airlines. "The conventional wisdom was that boarding from back to front was most effective," says van den Briel. The engineers looked at an inside-out strategy that boards planes from window to aisle, and also examined a 2002 simulation study that claimed calling passengers individually by seat number was the fastest way to load an aircraft.

The two then developed a mathematical formula that measured the number of times passengers were likely to get in each other's way during boarding. "We knew that boarding time was negatively impacted by passengers interfering with one another," explains van den Briel. "So we built a model to calculate these incidents."

Villalobos and van den Briel looked at interference resulting from passengers obstructing the aisle, as well as that caused by seated passengers blocking a window or middle seat. They applied the equation to eight different boarding scenarios, looking at both front-to-back and outside-in systems. "Ultimately, the issue America West needed to address was time," explains van den Briel. "We figured a system that reduced interference between passengers would also cut boarding time."

Van den Briel then spent two days at Los Angeles International Airport, where America West was filming actual passengers as they boarded, positioning one camera on the Jetway and another inside the aircraft. He spent the next two weeks analyzing these tapes, clocking the times it took passengers to complete certain tasks. "You can't imagine how boring this was," he says, laughing.

He and Villalobos used this passenger data to build a computer-simulation model that validated the results of their analytical work. "The analytical model gave us the information we needed to design a new system," Villalobos explains, "but we needed a simulation that would allow us to test our method against others."

Villalobos and van den Briel presented America West with a boarding approach called the reverse pyramid that calls for simultaneously loading an aircraft from back to front and outside in. Window and middle passengers near the back of the plane board first; those with aisle seats near the front are called last. "Our research showed that this method created the fewest incidents of interference between passengers," Villalobos explains, "and was therefore the fastest."

US Airways' Lindemann says the airline has enjoyed significant improvements since implementing the reverse pyramid in 2003, including a 21 percent decrease in departure delays in the first three months following the system's launch, and a two-minute reduction in average boarding time.

Other carriers appear to have taken note. Last July, AirTran Airways launched a boarding system that the airline's Judy Graham-Weaver refers to as a rotating zone system. AirTran first seats the back five rows of the plane, then the front five, and continues rotating back-front-back until boarding is complete. Graham-Weaver says that this system is one reason AirTran enjoys turnaround times in the 20- to 30-minute range.

United Airlines is using a boarding strategy it calls "Wilma," which stands for "window-middle-aisle." This outside-in system boards all window passengers first, followed by those with middle seats and, finally, those seated in the aisle. Like the AirTran and US Airways systems, Wilma offers pre-boarding for first-class passengers, elite frequent fliers and those requiring extra assistance.

Southwest Airlines takes a low-tech approach to boarding, placing passengers into one of three groups based on their check-in time, and allowing them to take any open seat once their group is called. Representative Whitney Eichinger says that this method has served Southwest well since it began flying in 1971, and that the airline enjoys some of the quickest turnaround times in the industry.

Van den Briel says that while Southwest's open seating might seem like an invitation for chaos, it actually illustrates a tendency among passengers to self-organize when left to their own devices. "Passengers who are free to sit anywhere usually do a good job staying out of each other's way," he explains. "Without having studied it in detail, I would imagine that an open boarding model is faster than assigned seating."

Villalobos and van den Briel designed the reverse pyramid for single-aisle aircraft, but America West's merger with US Airways means that the airline now operates wide-body Airbus and Boeing planes. Villalobos believes the reverse pyramid can be modified to work successfully with these aircraft, but admits that bigger planes create additional opportunities for passenger interference. Lindemann says US Airways will roll out the reverse pyramid systemwide once the two carriers have adopted a single reservation system.

In 2007, Airbus will begin deliveries of its A380 super jumbo, capable of seating up to 555 passengers. Airbus' Clay McConnell says that his company has addressed customer concerns about the time required to load the A380 by making all 16 of the aircraft's doors large enough to board passengers comfortably.

"An airline could simultaneously load the aircraft from two different gates," he says. "Or, they could board people from the back using stairs." McConnell says Airbus' research shows that the boarding process for an A380 will be only five minutes longer than that for a Boeing 747-400, despite the fact that the Airbus plane can carry up to 140 more passengers.

While the reverse pyramid was designed to address airplane boarding, its creators believe the model has other potential applications.

"Someone called and asked if it could be used to shorten the time it takes to evacuate a building," Villalobos says. "I told him it was something we could definitely look into."

Process Simulation – Inventory

(SimQuick Chap 3)

Example: A Grocery Store (an "order-up-to" policy)

- Management at a grocery store has received some complaints from customers that the store occasionally runs out of SuperWheat bread, which is baked by the SuperBread Company. Here is how the inventory process presently works.
- A truck from the SuperBread bakery drops off several types of loaves of freshly baked bread at the grocery store every other day.
- For each type of bread from the bakery, there is designated space on the shelves of the store and in the back of the store (the total space allotted to each type of bread depends on the demand for that type of bread).
- The driver drops off enough loaves for each type so the designated space for each type of bread is filled. (This is a simple version of what is sometimes referred to as an order-up-to inventory policy.)
- The store has designated enough space to hold 70 loaves of SuperWheat bread.

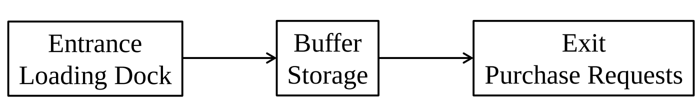
Example: A Grocery Store (an "order-up-to" policy)

- An examination of sales records (at times when there is SuperWheat on the shelf) shows that the time between purchases of a loaf of SuperWheat is .3 hours on average (with an exponential distribution).
- Management estimates that this demand pattern should be the same for the next 30 working days.
- The store is open 12 hours per day, 7 days per week.
- Management wants to determine the amount of storage space that should be designated for SuperWheat bread so that 99% of the customer demand is satisfied.

- We need a new element in SimQuick to model this system.

  Exit

Process Flow Map: A Grocery Store



Example: A grocery store

Model in SimQuick:

Entrances:

1	
Name →	Loading Dock
Time between arrivals →	24
Num. objects per arrival →	200
Output destination(s) ↓	
Storage	

Buffers:

1	
Name →	Storage
Capacity →	70
Initial # objects →	0
Output destination(s) ↓	Output group size ↓
Purchase Requests	1

Exit:

1	
Name →	Purchase Requests
Time between departures →	Exp(0.3)
Num. objects per departure →	1

Simulation controls:	
Time units per simulation →	360
Number of simulations →	30

Simulation Results		Return to Control Panel						
Element types	**Element names**	**Statistics**	**Overall means**	**Simulation Numbers** 1	2	3	4	5
Entrance(s)	Loading Dock	Objects entering process	1043.53	1033	1043	1050	1043	1047
		Objects unable to enter	1956.47	1967	1957	1950	1957	1953
		Service level	0.35	0.34	0.35	0.35	0.35	0.35
Buffer(s)	Storage	Objects leaving	1043.30	1033	1043	1050	1043	1046
		Final inventory	0.23	0	0	0	0	1
		Minimum inventory	0.00	0	0	0	0	0
		Maximum inventory	70.00	70	70	70	70	70
		Mean inventory	30.61	31.99	31.43	28.89	30.16	30.11
		Mean cycle time	10.56	11.15	10.85	9.90	10.41	10.36
Exit(s)	Purchase Requests	Objects leaving process	1043.30	1033	1043	1050	1043	1046
		Object departures missed	169.13	135	163	216	224	174
		Service level	0.86	0.88	0.86	0.83	0.82	0.86

Another important performance measure for processes:

Service level for exit = Objects leaving process / (Objects leaving process + Objects departures missed)

Questions:

- What's the current service level?

  <u>.86</u>

- How to achieve 99% service level?

  <u>Increase storage: we want the smallest storage size to get 99% service level.</u>

Process Simulation – Manufacturing

(SimQuick Chap 4)

A Production Game

- **Main Idea**:
  - Consider a linear flow factory with a balanced line.
  - First, we want to determine its *throughput* (total # of units produced).
  - Second, we want to improve its throughput.

A Production Game

The factory and the product:

1. The factory consists of five work centers, WC1, …, WC5, arranged in a line.
2. Each work center has a worker assigned to it.
3. The factory produces a single product that must be processed through WC1, …, WC5, in order.
4. There is variability in the processing time of each unit at each work center.
5. Units can only be positioned directly in front of each worker and they *cannot be stacked up*. (Hence if the worker at WC3 has finished a unit, but the worker at WC4 is still processing a unit, then the worker at WC3 cannot start on a new unit even if the worker at WC2 has finished one.)

The starting conditions:

1. There is at least one day’s worth of raw materials.
2. The work centers are idle.

Tasks of the game:

1. Estimate how many finished products can be produced in one day. (One day is one eight hour shift of factory time, which equals *five minutes* of game time.)
2. Play the game and record the actual throughput.
3. Identify the main source of problems in this factory.
4. Propose some ways to improve the throughput and test these with simulation.

Production Game: Data Collection and Analysis

We would like to analyze the *working time* of a work station in the production game.

Step 1: Pick your favorite work station → Work Station #___

Step 2: Record the working times of the work station you picked in the following table.

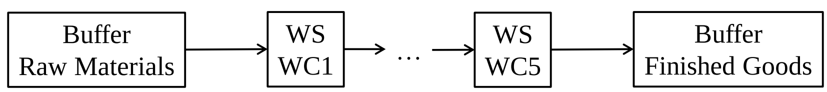
Product ID	Working Time (in seconds)	Product ID	Working Time (in seconds)
1		26	
2		27	
3		28	
4		29	
5		30	
6		31	
7		32	
8		33	
9		34	
10		35	
11		36	
12		37	
13		38	
14		39	
15		40	
16		41	
17		42	
18		43	
19		44	
20		45	
21		46	
22		47	
23		48	
24		49	
25		50	

Step 3: Draw the histogram of the working times based on the data you collected in Step 2.

Step 4: Use a statistical distribution to describe the pattern you observe in Step 3.

A Production Game

- Draw the process flow map.



- Set up SimQuick to simulate the production game.

  Estimate working time of WSs using Uni(a,b)

A Production Game

- What is the overall mean throughput?

  Final inventory of Finished Goods

- What is the overall mean cycle time of the process?

  Add all potential delays together including working times of work stations, cycle times of internal buffers of work stations, and cycle times of buffers.

- What is the utilization of a work station?

  Fraction time working of the work station

How to improve the throughput of the process?

- One easy solution is to add buffers – work-in-process (WIP) inventory

Concepts involved in manufacturing processes

- Throughput of a process:
  - Number of good units produced during some time period
- Cycle time of a process
  - The mean amount of time it takes one unit to go from the start to the finish of a process.
- Work-in-process (WIP) Inventory
- Utilization of a work station
- Causes of variability in a manufacturing process:
  - Processing times of machines/workers
  - Quality of output of machines/workers
  - Demand of customers (at end of process; i.e., the last “machine”)
  - Reliability of suppliers (at beginning of process; i.e., the first “machine”)

Principles from the production game (relationships between the concepts)

- As work-in-process inventory increases (from near zero):
  - Inventory costs increase.
  - Throughput of process increases (to a point, after which it remains the same).
  - Cycle time of process increases.

- As variability decreases, throughput of process increases.

Demo of graphical simulation packages

- AnyLogic
  - www.anylogic.com
- Simulation Visualization
  - https://www.runthemodel.com