

The Center for Hospitality Research

Hospitality Leadership Through Learning



ServiceSimulator: v1.19 Instructions

Cornell Hospitality Tools

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by Gary M. Thompson, Ph.D.



Cornell University

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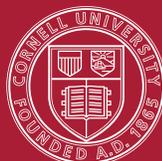
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ServiceSimulator

v1.19

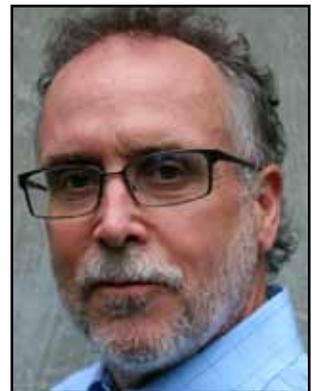
by Gary M. Thompson

EXECUTIVE SUMMARY

Model Purpose: ServiceSimulator was designed as a free tool for modeling service operations. The tool includes seven sample files that correspond to seven sample problems that involve how to address staffing issues relating to different scenarios of customer traffic, in operations as diverse as hair salons, quick-service restaurants, and call centers. The scenarios are given at the end of this document. Videos are also available that show how to construct models for the seven sample problems. In the documentation below, we use the models relating to Example 4 (an instructor of trainees at a hair salon), Example 5 (managing food waste at a quick-service counter), and Example 6 (customers arriving and waiting for service at a hair salon).

ABOUT THE AUTHOR

Gary M. Thompson, Ph.D., is professor of operations management at the Cornell University School of Hotel Administration (gmt1@cornell.edu), where he teaches undergraduate and graduate courses in service operations management. His research, which focuses on wine cellars, restaurant operations, scheduling conferences, and on workforce staffing and scheduling, has appeared in a number of outlets. He has consulted for several prominent hospitality companies and is the founder and president of Thoughtimus, Inc., a small software development firm focusing on scheduling products.



ServiceSimulator v1.19

by Gary M. Thompson

Instructions:

You will need to install *ServiceSimulator* on your computer. After installing it, you can start the software using the Start, *ServiceSimulator* and *ServiceSimulator* menu choices. The sample models (Example 1.ssdf through Example 7.ssdf) can be found on the desktop. Normal file manipulation features can be found in the File menu in *ServiceSimulator*.

Below is a walkthrough of the screens and data that will be required to create a model. The screen shots from *ServiceSimulator* are presented in the order in which you'll see them in the tool, beginning with the instructions screen.

Data Inputs:

"Instructions" Screen (shown on the next page)

On this screen, you define the terms that *ServiceSimulator* will use for the service being modeled:

- "Capabilities" are the characteristics that link operations to resources. "Attributes" may be another appropriate descriptor.
- "Locations" are the places at which work is performed. Multiple operations can be performed at each location. "Stations" may be a more applicable word in some services.
- "Resources" are what (or who) actually performs the work. The word "Employees" may be more appropriate if only people are being tracked.
- "Customers" are who (or what) is being served. "Jobs," "Clients," and "Guests" are other common descriptors. This example uses the term "Client."

Instructions screen

On this screen, you should define the terms ServiceSimulator should use for the service being modeled. Once you define the terms, click the 'Apply' button to apply them to the current model.

	Singular	Plural	Model Description
Term for 'Capabilities'	<input type="text" value="Skill"/>	<input type="text" value="Skills"/>	
Term for 'Characteristics'	<input type="text" value="Attribute"/>	<input type="text" value="Attributes"/>	
Term for 'Locations'	<input type="text" value="Station"/>	<input type="text" value="Stations"/>	
Term for 'Resources'	<input type="text" value="Employee"/>	<input type="text" value="Employees"/>	
Term for 'Customers'	<input type="text" value="Client"/>	<input type="text" value="Clients"/>	

Definitions

'Capabilities' are the characteristics that link operations to resources. 'Skills' or 'Attributes' may be other appropriate descriptors.

'Characteristics' apply to 'Customers'. You can define rules that change the value of these items as customers move through the service.

'Locations' are the places at which work is performed. Multiple operations can be performed at each location. 'Stations' may be a more applicable word in some services.

'Resources' are what (or who) actually performs the work. The word 'Employees' may be more appropriate if only people are being tracked.

'Customers' are who (or what) is being served. 'Jobs', 'Clients', and 'Guests' are other common descriptors.

Steps in Creating a Model

Because there are interrelationships between the different simulation elements, you will need to develop the model in steps:

1. Begin by defining the basic simulation elements: Capabilities, Characteristics, Locations, Resources and Customers. Provide only the information that is specific to each element and unrelated to other elements.
2. Define the inter-relationships of the simulation elements. For example, you will need to define the Location and Operation at which each Customer arrives.
3. You will need to define some general parameters that control the simulation (via the 'General Parameters' tab).
4. After defining the simulation elements and the general parameters, you can run the simulation from the 'Simulation' tab. Results will also be displayed on that tab.

You may find it helpful to review the Examples document and the corresponding Example models. Watching the video that shows how to use the software would also be a good idea.

- “Characteristics” apply to “Customers’. You can define rules that change the value of these items as customers move through the service. This example uses the term “Attributes.’
Once you define the terms, click the “Apply” button to apply them to the current model.
Because there are interrelationships between the different simulation elements, you will need to develop a model in steps:
 - Begin by defining some general parameters that control the simulation (via the “General Parameters” tab, shown on the next page).
- Define the basic simulation elements: capabilities and characteristics (Exhibit 3), locations (Exhibit 4), resources (Exhibit 6), and customers (Exhibit 7). Provide only the information that is specific to each element (and unrelated to other elements).
- Define the inter-relationships of the simulation elements. For example, you will need to define the location and operation at which each customer arrives.
- After defining the simulation elements (and the general parameters), you can run the simulation from the “Simulation” tab (Exhibit 9). Results will also be displayed on that tab.

General parameters screen

General Simulation Parameters

Number of Weeks to Simulate: 100
 Number of Replications: 1
 Maximum Employee Cost:

Maximum number of alternatives to evaluate: 100

Client Volume Levels: Minimum: 1, Maximum: 1, # of Increments: 1

Continuous (24x7) Operations
 Clear waiting Clients at end of operating day

	Day Start	Day Finish
Use Sun <input checked="" type="checkbox"/>	08:00	16:00
Use Mon <input checked="" type="checkbox"/>	08:00	16:00
Use Tue <input checked="" type="checkbox"/>	08:00	16:00
Use Wed <input checked="" type="checkbox"/>	08:00	16:00
Use Thu <input checked="" type="checkbox"/>	08:00	16:00
Use Fri <input checked="" type="checkbox"/>	08:00	16:00
Use Sat <input checked="" type="checkbox"/>	08:00	16:00

Use Times as Default Values for all Employees and Clients

Information

On this screen you specify general parameters that control the simulation: the number of weeks to be simulated and the number of times the simulation should be replicated (repeated). You must also identify which days to simulate, and the daily operating hours of the service being simulated. Unless you specify continuous operations, each day is simulated separately.

The volume level information allows you to evaluate the effect of increases in customer volumes.

“General Parameters” Screen

The screen capture shows the General Parameters screen for the Example 4.ssd file, which involves a trainer and two trainees in a hair salon. On this screen, you specify general parameters that control the simulation: the number of weeks to be simulated and the number of times the simulation should be replicated (repeated). In the illustration, the simulation is running for 1 replication of 100 weeks. This would yield similar results to running the simulation for 100 replications of 1 week.

The maximum resource cost field can be useful if you are exploring the effects of different staff sizes, but wish to limit the total amount spent on resources (per hour). Leaving this field blank results in the simulator treating the hourly total resource cost as unconstrained.

The maximum number of alternatives to evaluate applies when you allow the tool to investigate different numbers of resources. While the limit is 1,000 alternatives, it is recommended that you use a lower number (usually less than 100) while building and debugging your model.

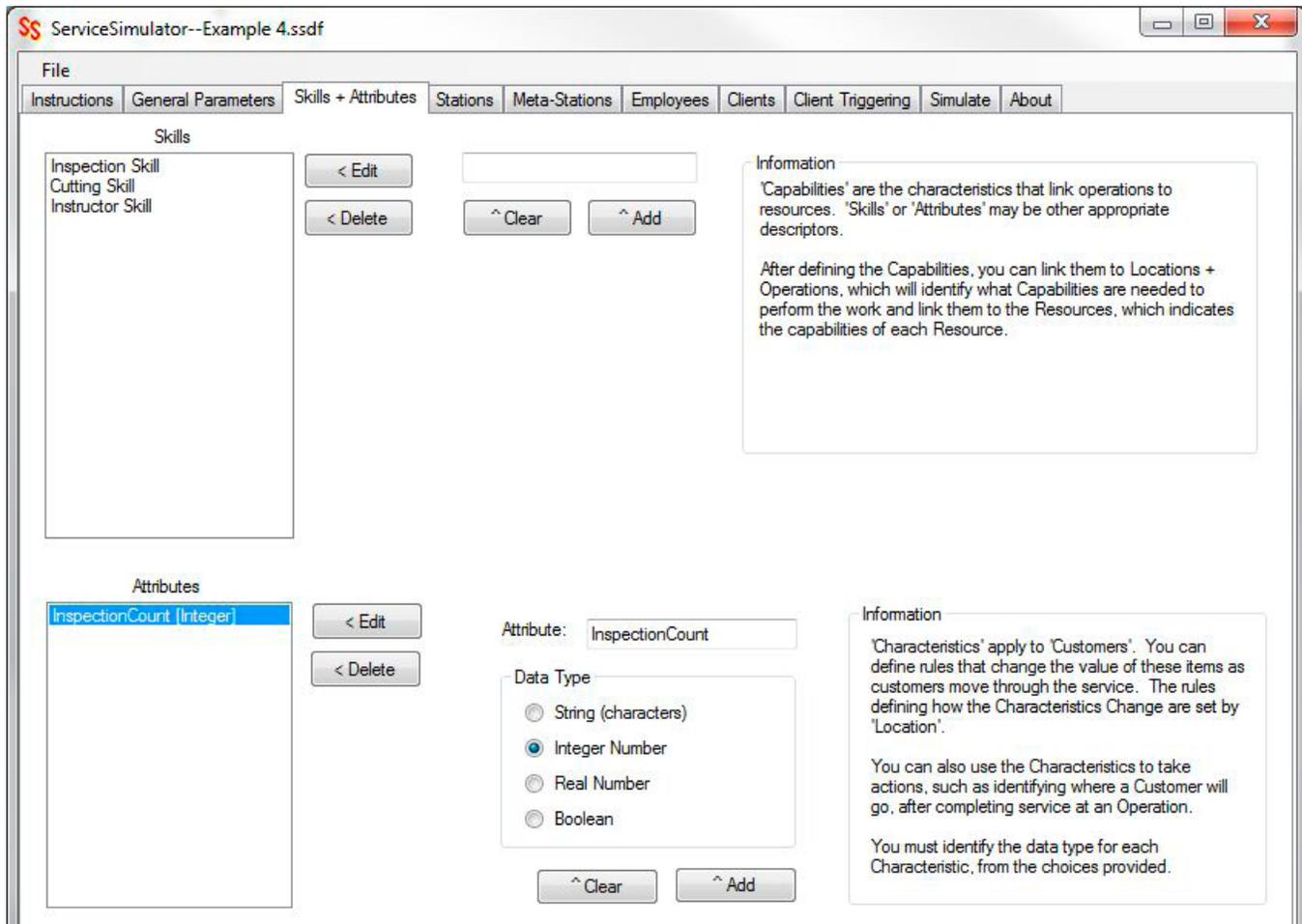
With those specifications in place, *ServiceSimulator* enables you to evaluate how a fixed staffing level responds

to varying levels of customer demand. For example, if you specify a minimum volume level of 1, a maximum volume of 1.5, and 10 increments, then *ServiceSimulator* will evaluate customer demand levels of 1.0, 1.05, 1.10, ..., 1.45, and 1.50 times the customer volumes specified on the Customers screen (see Exhibit 7).

Specifying that the operations are continuous means that the simulation will mimic a 24x7 service, while leaving this unselected will simulate each day independently. If you do not specify continuous operations, then you must also identify which days to simulate, and the daily (operating) hours of the service being simulated. If the operations are not continuous, you also have the option of how customers will be handled at the end of each day. If you select the “clear waiting customers at the end of operating day” option, then any customers who are still in the queue at closing time will be served. If this option is not selected, any customers who are still in the queue at closing time are turned away and counted as being a denied customer.

If you select the “Use Times as Default Values” option, then any resource or customer you add to the model will be initialized with the same hours as the operating hours.

Capabilities & Characteristics screen



“Capabilities & Characteristics” Screen

As noted earlier, “Capabilities” are the characteristics that link operations to resources. This example uses the term “Attributes.” The capabilities are identified in a list format. For the hair salon instructor, those are inspection skill, cutting skill, and instructor skill. If you find you need to define additional capabilities as you continue to build a model, you can always add them.

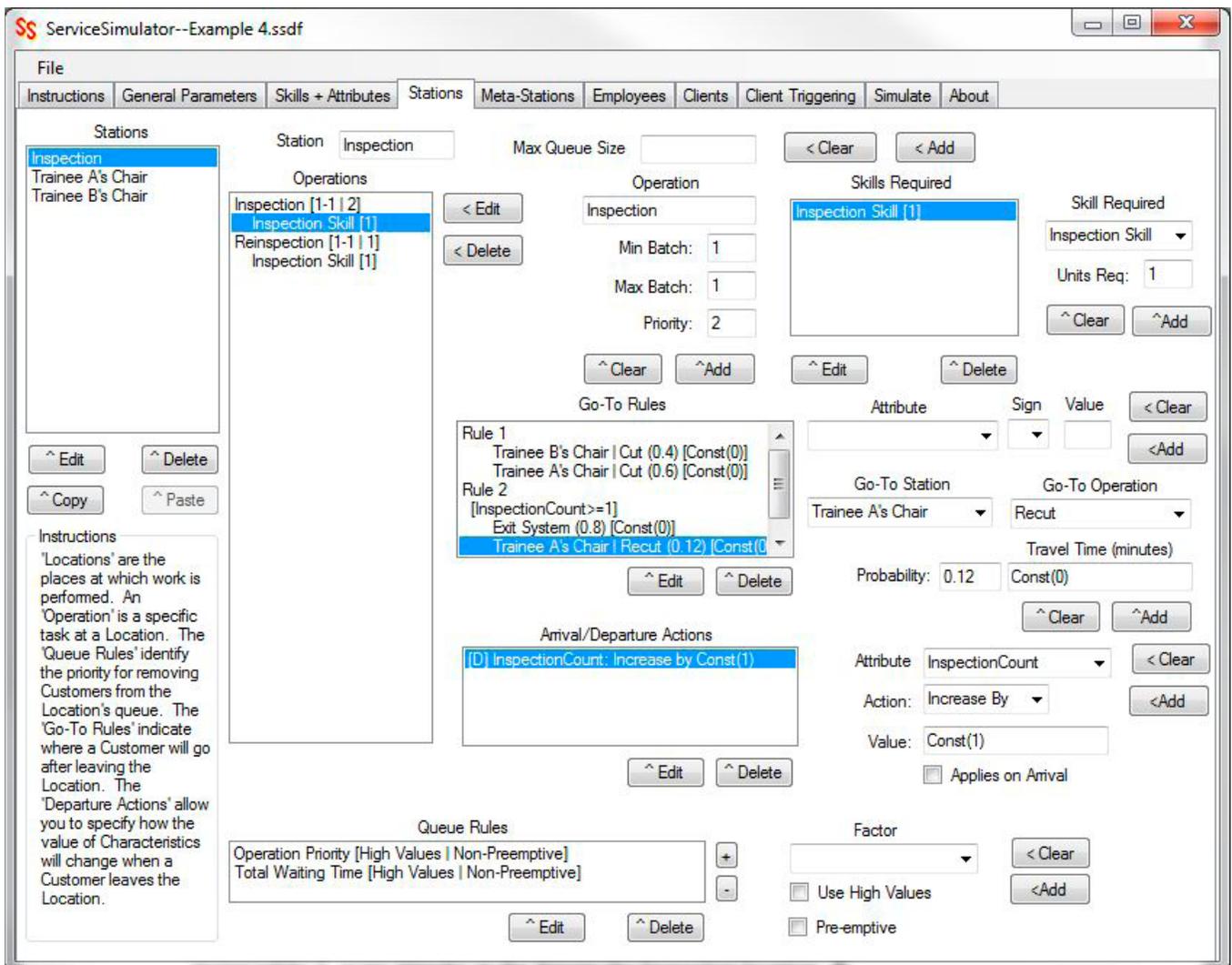
After defining the capabilities, you can link them to locations (specifically, operations), which will identify what capabilities are needed to perform the work. Capabilities can also be linked to Resources to identify the capabilities of each resource. Exhibit 3 shows a screen capture of the Capabilities & Characteristics screen, for the Example 4.ssd model.

“Characteristics” apply to customers. Again, this example uses the term “Attributes.” Characteristics are useful if you wish to link actions in the model to customers’ characteristics.

You can define rules that change the value of these items as customers move through the service. The rules defining how the characteristics change are set by location. You can also use the characteristics to take actions, such as identifying where a customer will go, after completing service at an operation.

You must identify the data type for each characteristic, from the choices provided. Finally, the value of the characteristics is tracked by customer, and reported as results on the Simulate screen. The Example 4.ssd model uses one characteristic (or attribute), the “InspectionCount,” which will take integer values, as shown in the screen shot in Exhibit 3.

Locations screen



“Locations” Screen

“Locations” are the places at which work is performed, in this case, “Stations.” A queue can form in connection with each location, and *ServiceSimulator* allows you to set a limit on the size of the queue. If a customer arrives to a full queue, the action that occurs depends on whether it is a newly arriving customer or one already in the system. If a newly arrived customer comes when the queue is full, he or she does not join the queue and so is turned away (i.e., he or she becomes a lost customer). If a customer that is already in the system would be moving to a queue that is full, the customer cannot move and so the operation where the

customer currently is located becomes “blocked” and cannot serve any more customers until the customer can move to the queue.

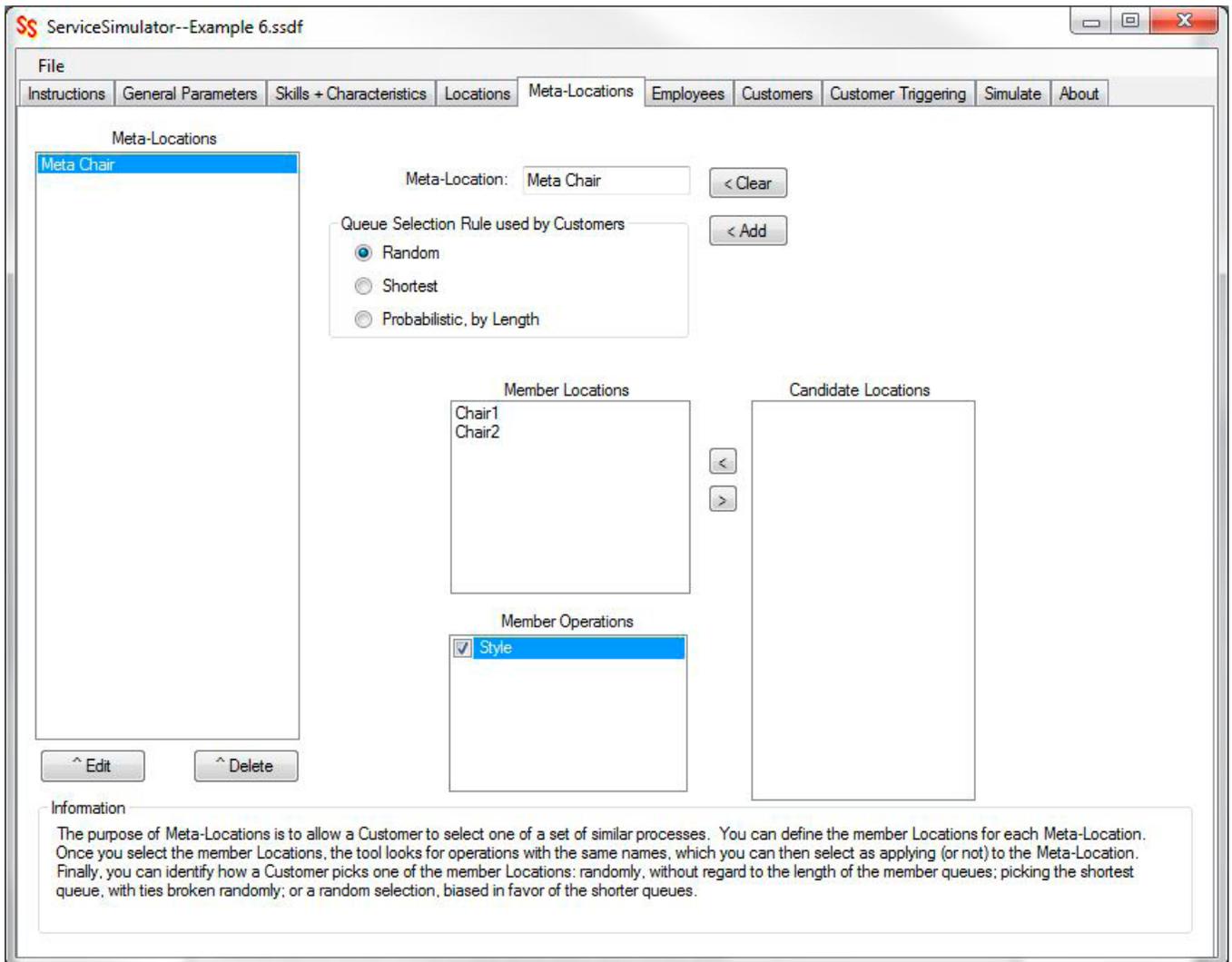
An “Operation” is a specific task at a location. Each location can have an unlimited number of different operations. Each operation has a minimum and maximum batch size, a priority, and a set of required capabilities. In the screen shot in Exhibit 4, again from the Example 4.ssd hair salon model, the Inspection operation has a priority of 2, is performed in a batch size of 1 (i.e., between the minimum and maximum batch sizes of 1), and requires 1 person with the Inspection capability.

The “Go-To Rules” indicate where a customer will go after leaving a particular location or operation. In the Example 4.ssd model, there are two Go-To rules that apply to the Inspection Station and Inspection Operation panels. The first rule applies when the customer’s InspectionCount equals zero (meaning they have not yet had a cut). It directs a customer to the Trainee A Chair location (Cut operation), with a probability of 0.6, and to the Trainee B Chair location (Cut operation), with a probability of 0.4. In both cases, there is no travel time (i.e., transit time is set to a constant value of zero minutes). The second Go-To rule applies for customers whose InspectionCount equals or exceeds 1 (meaning that they are returning to the Inspection location after having received a cut). Rule 2 indicates that customers exit the system, with a probability of 0.80 (if the cut is not satisfactory), return to the Trainee A Chair location (Recut operation), with a probability of 0.12, or return to the Trainee B Chair location (Recut operation), with a probability of 0.08. All these possibilities have zero travel times. Note that a Go-To rule may be defined based on more than one characteristic.

The “Arrival/Departure Actions” panel allows you to specify how the value of characteristics will change when a customer arrives at or leaves a location or operation. If the “applies on arrival” option is selected, the action is applied on arrival; otherwise it applies on departure. In the Example 4.ssd model, a customer’s InspectionCount characteristic is increased by 1, every time he or she departs the Inspection location.

The “Queue Rules” identify the priority for removing customers from the location’s queue. The queue rules in this example show that customers should be removed from the Inspection queue based on highest operation priority as the primary criterion, with ties broken by highest total waiting time. Since the Reinspection operation is assigned a priority of 1, and the Inspection is assigned a priority of 2, a customer waiting for reinspection will have precedence over any customer waiting for the initial inspection. A pre-emptive queue rule means that a higher priority customer arriving at the queue would preempt, or interrupt, the service for any lower priority customer.

Meta-locations screen



“Meta-Locations” Screen

The purpose of the Meta-Locations panel is to allow a customer to select one of a set of similar processes. You can define the member locations for each Meta-Location. In the case shown in Exhibit 5, the meta-locations are the two hair cutting stations from Example 6, which models customer waits in a salon (but does not involve training as in Example 4). Once you select the member locations, *ServiceSimulator* looks for operations with the same names, which you

can then select as applying (or not) to the Meta-Location. Finally, you can identify how a customer picks one of the member locations: randomly, without regard to the length of the member queues; picking the shortest queue (with ties broken randomly); or a random selection, biased in favor of the shorter queues. Example 6 describes a situation where three types of customer randomly select one of two lines for service, as modeled in the Exhibit 5 screenshot.

Resources screen

“Resources” Screen

Resources specify what (or who) actually performs the work. In the screen capture in Exhibit 6, the resources are employees, as shown in the screen taken from the Example 4.ssdff file. For each resource type you must identify the minimum and maximum number of units of the resource that are available (which may be the same number), and, if desired, the cost per hour of each resource unit. If the “interrupt work at the end of availability” option is selected, then when the resource is going off-shift, any customers being served by that resource are placed back in the queue, where service will be continued by some other resource. If this option is not selected (as in the exhibit), the resource will finish serving a customer before ending the shift.

The “Place work on hold while on break” determines how work is handled when a resource is on a break of 1 hour or shorter. If the option is selected, any work the resource is performing while on break is held until the resource returns

from break, when it resumes. If the option is not selected (as in the exhibit), the resource will hand off work at the start of the break, or continue working, depending on the “Interrupt work” option.

You must also identify the locations and operations that can be covered by the resource. This includes setting a priority on each operation, and identifying the time required (in minutes) for the resource to perform the task. In the example shown in Exhibit 6, Inspection (cut) has a lower priority (i.e., a higher number) than Reinspection (recut), meaning that if this resource becomes available, the inspector would serve a customer waiting for Reinspection before serving a customer waiting for Inspection. If desired, the processing times can be based on the value of characteristics, though a “default rule” processing time (in minutes) must always be defined.

Finally, on this screen you will need to set the availability of the resource, by specifying the work hours each day.

Customers screen

File

Instructions | General Parameters | Skills + Attributes | Stations | Meta-Stations | Employees | **Clients** | Client Triggering | Simulate | About

Clients

Client

< Edit
< Delete
< Copy
< Paste

Name: Client
Transaction Contribution: < Clear
Arives at Station: Inspection
Variable Cost: < Add
Arives at Operation: Inspection
Cost of a denied:
Inventory-Type Item Can Renege
Hold at Station: Cost a renege:
Hold at Operation: Renege Time:

Wait-Time--Transaction Relationship

Ignore Initial Wait Total Wait

< Edit
< Delete
Wait Time (mins): < Add
Net Transactions:

Actions on Arrival

InspectionCount (Initialize to 0) < Edit
< Delete
Specific Action on Arrival
InspectionCount < Clear
 Initialize to... 0 < Add
 Initialize to current (simulated) time
 Randomize

Arrivals

Day	Start	Finish	Distribution
Sun	08:00	16:00	Exponential(20)
Mon	08:00	16:00	Exponential(20)
Tue	08:00	16:00	Exponential(20)
Wed	08:00	16:00	Exponential(20)
Thu	08:00	16:00	Exponential(20)
Fri	08:00	16:00	Exponential(20)
Sat	08:00	16:00	Exponential(20)

< Edit
< Delete
< Copy
< Paste

Information

'Customers' are who (or what) is being served. For each type of Customer, you must specify where they arrive (Location and Operation).

You can also specify how any relevant Characteristics can be initialized when the Customer arrives.

Finally, you can specify the timing of arrivals, by day (or, if desired, day-part).

Arrival on Sun Start Finish
08:00 16:00
Arrival Distribution (minutes): Exponential(20)
When Net Stock On-Hand...
falls below:
Maximum Hold Time (in minutes):
^ Clear ^ Add

“Customers” Screen

“Customers” or clients are who (or what) is being served. For each type of customer, you must specify where they arrive (location and operation), as illustrated in the screen capture in Exhibit 7, drawn again from Example 4.ssd file. You can specify the contribution value of a completed service transaction, and the cost of denying service to a customer (i.e., the cost of them being turned away because the arrival queue is at capacity). You can specify whether customers renege (i.e., leave by choice before being served). If they renege, you also have the option of specifying the renege time distribution and the cost of a renege customer.

An “Inventory-Type Item” is an item that is produced and held in inventory (as in the case of the Fries in Example 5). For an inventory-type item (which could include customers), you can identify where the inventory will be held (the location and operation). You also define the production rules in the “Arrivals” panel: the quantity of items released for production (via the Arrival Distribution), the stock level to trigger a release of items for production, and the maximum amount of time (in minutes) the item can sit at the hold location or operation before it must be discarded. Inventory-type items can be best thought of as a component of the service delivery (again, as in the case of the French Fries in Example 5).

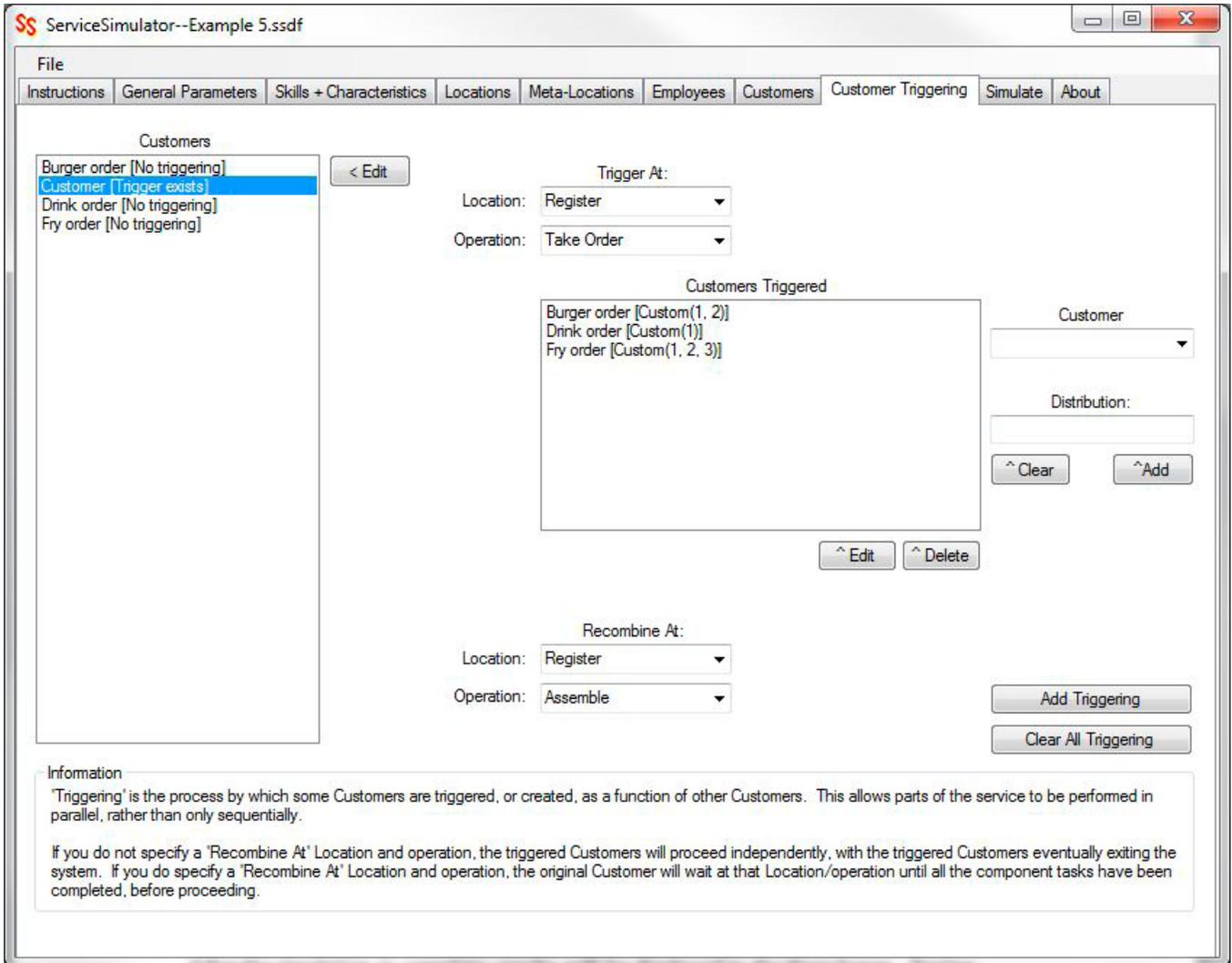
If desired, you can specify a functional relationship between future transactions and the wait time the customer experiences (either in the initial queue, or in total across all queues). For example, let's say you specified the following outcome values in connection with wait-time per transaction: 0.2 minutes, +1; 2 minutes, 0; and 5 minutes, -1. *ServiceSimulator* would interpret this as follows: any customer whose appropriate waiting time was under 0.2 minutes would yield one additional net future transaction; any customer whose appropriate wait time was over 5 minutes would yield a net loss of one transaction. If the wait time was between 0.2 and 2 minutes, the net transactions

are linearly distributed between +1 and 0; while if the wait time was between 2 and 5 minutes, the net transactions are linearly distributed between 0 and -1 (so that, for example, a wait time of 4 minutes would result in $-2/3$ transactions). Example 7, which involves telephone calls coming into a call center, shows a setting that uses this information.

If you have defined characteristics, then you can specify how they should be initialized when a customer arrives.

Finally, you can specify the timing of arrivals, by day. The arrival rates and distributions can differ both within and across days.

Customers Triggered screen



“Customers-Triggered” Screen

“Triggering” is the process by which some “customers” are triggered, or created, as a function of other customers. Consider, for example, a customer arriving at a quick service restaurant as described in Example 5. A customer placing an order triggers the components of the service to be started, such as grilling a burger, getting drinks, and dropping the fries. Depending on the number of staff present and their capabilities, those tasks could be done in parallel. Once those component tasks are finished, the customer’s order can be assembled. The screen shot in Exhibit 8, taken from the Example 5.ssd file, shows the customer triggering panels.

This screen shows that a customer triggers the Burger Order, Drink Order, and Fry Order after the customer completes service at the Register location, where the Take Order operation occurs. The service comes together, or recombines, at the Register location, with the Assemble operation. A customer’s order will not be assembled until all the components are ready and have arrived at that location for the appropriate operation.

If you do not specify a “Recombine At” location and operation, the triggered customers will proceed independently, with the triggered customers eventually exiting the system.

Simulation (and results) screen

The screenshot shows the ServiceSimulator software interface with the following components:

- File Menu:** Instructions, General Parameters, Skills + Attributes, Stations, Meta-Stations, Employees, Clients, Client Triggering, Simulate, About.
- Run the Simulator! Button:** A button to start the simulation.
- Now Simulating...:** A status area showing 'n/a' for three different metrics.
- Cancel Simulation Button:** A button to stop the simulation.
- Information:** A text box providing instructions on how to run the simulation, save results, and export them to Excel.
- Export Results to Excel Button:** A button to export simulation results to an Excel file.
- Excel Sheet Name:** A text input field for naming the Excel sheet.
- Summary Metrics:**
 - Selected Employee Combination:** 0.00 [Alternative 1]
 - Current Total Net Value:** 0.00
 - Best Total Net Value:** 0.00
 - Employee Numbers and Utilization:**

Inspector [1]	[22.28 0.00 78.47]	[7.70]
Instructor [1]	[72.96 0.00 27.05]	[93.82]
Trainee A [1]	[39.62 0.00 60.39]	[43.09]
Trainee B [1]	[33.34 0.00 66.66]	[50.73]
- Queue Details:**
 - Inspection [7 | 0.04 | 2.20]
 - Trainee A's Chair [8 | 0.46 | 16.41]
 - Trainee B's Chair [10 | 0.53 | 29.23]
- Summary for Clients:**
 - Client [37.44 | 19.40 | 18.04 | 0.00] [16264] [0.00 | 0.00 | 0.00] [0.00] [0.00]
 - InspectionCount [8.00 | 2.24]
- Showing [time in: system | service | queue | transit] [# served] [% denied | % renege | % discarded] [# interruptions][# preemptions] [Showing, for Attributes: max value on exit | avg value on exit]**

“Simulate” Screen

Having set your specifications based on the operation in question, the Simulate screen (shown in Exhibit 9) is where you run the simulation and see the results. Clicking the “Run the Simulator” button will perform the simulation. The software will first check for any obvious data problems, which you will need to correct before the simulation will run. After the simulation is complete, results will be displayed in the three boxes. Saving your file after running the simulation will also save these results, which you may find helpful when comparing alternative configurations of the service.

If you have specified different values for the minimum and maximum number of units of each resource (for example, staffing levels), *ServiceSimulator* will calculate the number of different combinations of Resources that could be

used. If this number does not exceed 100, then all combinations will be evaluated. If the number of combinations exceeds 100, then an intelligent, randomized search process is used to investigate up to 1,000 combinations (based on the limit set on the “General Parameters” screen). Regardless of the number of combinations evaluated, they are listed in declining order of total net economic value (the value of customers served, plus the value of any net future transaction increases, less the costs of labor, denied customers, renege customers, and any net future transaction losses).

After selecting a particular combination, the results include information on resources, queues, and customers, as illustrated in the screen capture, which is again from Example 4.ssd file. For each resource type, the results report the number of units used; the percentage of time the re-

source was busy, blocked, and idle; and the number of extra minutes worked beyond the available period. Once again, “blocked” is when an resource cannot move a customer along to the next operation, because the necessary operation is busy and the pre-operation queue is full.

The “Queue Detail” results report the maximum size of the queue, the average number of customers in the queue, and the average time a customer spends in the queue. The average time includes only those customers who actually have to wait in the queue.

The “Summary for Customers” box reports, for each customer type, the average time spent in the system; the average time spent being served; the average time spent in queues; the average time spent in transit from one location to another; the total number of customers served; the percentage of arriving customers who were denied service (i.e., turned away because the arrival queue was full when they arrived) and who reneged (because they reached their designated wait limit without being served); the average number of service interruptions (which occur when service is interrupted when a resource goes off-shift); and the average number of service preemptions (which occur when service is preempted by a higher-priority customer).

You also have the option of exporting results to Excel® from the Simulation screen. The alternatives are exported based on their ranked ordered.

Notable Model Limitation

In its current form, *ServiceSimulator*: Does not allow for different ways of accomplishing the same work (independent versus shared, for example).

ServiceSimulator Sample Problems

Hair Salon with a Single Stylist

Example 1. Walk-in customers arrive at a hair salon at the rate of 3 per hour (with the time between arrivals having a negative exponential distribution). The single stylist can serve a customer in 15 minutes, on average (with service times following a normal distribution with a standard deviation of 3 minutes). Develop a model to simulate the operation of this salon over a 10-hour period, for 100 days. How many customers were served? What was the average wait time for the customers? What proportion of customers had to wait for service? What was the utilization of the stylist, measured from opening time until the last customer was completed?

Hair Salon with a Single Stylist and Preferred Customers

Example 2. The hair salon described earlier has regular (preferred) customers (about 35% of the total) and walk-ins, or irregular customers. If preferred customers take precedence in the queue, find the average wait, by customer class.

Hair Salon with Two Trainees and an Inspector

Example 3. A hair-cutting teaching facility takes walk-in customers, who arrive at the rate of 3 per hour (with the time between arrivals having a negative exponential distribution). Each customer first goes to a receptionist-inspector, who then routes the customer to either Trainee A (60% of customers) or Trainee B (40% of customers). Following the completion of the cut, each customer returns to the receptionist-inspector. Approximately 80 percent of the customers returning to the receptionist-inspector are allowed to depart; the other 20 percent are routed back to one of the trainees. The times for the actions are listed in the table in Exhibit 10. What is the average number of times a customer spends in the system? Does the receptionist?

Hair Salon with Two Trainees and an Itinerant Inspector

Example 4. This example is identical to Example 3, with the following addition: An instructor travels between Trainee A and Trainee B, giving them suggestions and feedback on the cuts. The instructor spends the entire duration of a customer’s haircut with the appropriate trainee and customer. What is the average number of times a customer spends in the system? Does the receptionist? What is the average utilization of the instructor?

EXHIBIT 10

Specifications for Example 3

Function	Distribution	Parameters
Inter-arrival time	Exponential	20
Reception	Normal	2, 0.5
Trainee A cut	Normal	12, 2
Trainee B cut	Normal	16, 2.5
Inspection	Normal	2, 0.3
Trainee A re-cut	Normal	5, 1
Trainee B re-cut	Normal	7, 1.5

EXHIBIT 11

Specifications for Example 5

Item Ordered	# (Probability)	Time Per Single Item
Burgers	1 (0.8), 2 (0.2)	Normal (2, 0.4)
Fries	1 (0.5), 2 (0.3), 3 (0.2)	Normal (3.5, 0.1)*
Drinks	1 (0.6), 2 (0.4)	Normal (1, 0.1)

* Note: Time for a batch of fries

EXHIBIT 12

Data for Example 7

Queue Time (minutes):	0	0.1	0.5	1	2	5	10
Net Future Transactions	2	1	0	-0.2	-0.4	-1	-3

Food Waste at a Quick-Service Restaurant Counter

Example 5. Customers arrive at a quick-service restaurant with the time between arrivals exponentially distributed (mean of 10 minutes). Customers place their orders at the register. An order comprises a variable number of burgers, fries, and drinks, the details of which are provided in the table in Exhibit 11. The time required to place the order is normally distributed with a mean of 2 minutes and a standard deviation of 0.4 minutes. Once all the component items are ready, assembling the order, which is done by the register person, takes an average of 1 minute with a standard deviation of 0.1 minutes (normally distributed). Burgers and drinks are produced to order, but fries are produced in batches of 5; an order for a batch is released anytime the net stock on hand (=on-hand + in process - committed to customers) falls below one item. Fries can be held for up to 10 minutes before being discarded. Using the specifications shown in Exhibit 11, if one person is working at each of the four stations, what is the average time a customer is in the system? What percentage of fries is discarded?

Hair Salon with Two Stylists and Priority Customers

Example 6. A hair styling salon has two employees and three types of walk-in customers. The customers are regular, high priority, and very high priority. A high priority customer will always preempt the service for a regular customer, while a very high priority customer will preempt the service for both regular and high-priority customers. Regular customers arrive at the rate of 2 per hour, high priority customers at the rate of 1 every 45 minutes, and very high priority customers at the rate of 1 per hour. The time

between arrivals is exponentially distributed for all customer types. Regardless of the type of customer being served, or the stylist performing the service, the service duration is normally distributed with a 15-minute average and a 3-minute standard deviation. An arriving customer typically has a preference for a particular stylist, so the customer joins the queue of the stylist he or she desires, without regard to the number of customers already waiting for that stylist (or the number of people waiting for the other stylist). You can assume that the facility operates 8 hours per day, five days per week (Wednesday–Sunday). What is the average amount of time each type of customer spends in the system?

Call Center Queue Analysis

Example 7. Calls come in to the toll-free reservations telephone center for your hotel at the rate of 25 calls per hour, at peak times (you can assume that the time between calls is exponentially distributed). It takes a reservations agent an average of 3.5 minutes to serve a customer (i.e., excluding any time the customer waits on the phone before being served). This time is log normally distributed, with a standard deviation of 0.9 minutes. Reservation agents are paid \$10 per hour, including benefits. The average length of stay at the hotel is 2.7 nights, and the ADR (average daily rate) is \$165.00. Variable costs represent about 20 percent of the revenue. Historically, 72 percent of the calls have resulted in a booking being made. The company has tracked the call relationship between queue time and the effect on future business, as shown in Exhibit 12.

What staffing level would you recommend? ■

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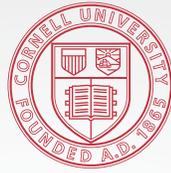
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