RealOpt-CRC© User Manual

Table of Contents

RealOpt© Overview

RealOpt© is a software enterprise system developed by Dr. Eva Lee and her research team at the Center for Operations Research in Medicine and HealthCare, School of Industrial and Systems Engineering, Georgia Institute of Technology. RealOpt© consists of various decision support capabilities for modeling and optimizing the public health infrastructure for emergency response.

RealOpt-CRC©

RealOpt-CRC allows emergency planners to:

- Design customized and efficient community reception center process flows.
- Assess current resources and determine minimum needs to conduct population monitoring.
- Determine optimal labor and instrumentation resources, and provide the most-efficient placement of staff throughout the process.
- Determine the number of centers and number of shifts needed to complete the screening for the affected population.
- Determine the best operations performance under a given resource limitation (e.g., limited detection instruments, limited personnel).
- Conduct virtual drills and design emergency exercises with a variety of screening scenarios.

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System Requirements

1. Microsoft Windows operating system
2. About 100 MB of free disk space

RealOpt-CRC© is written in Java and can run on any computer platform and operating system. The instructions included in this manual are for Microsoft Windows Users.

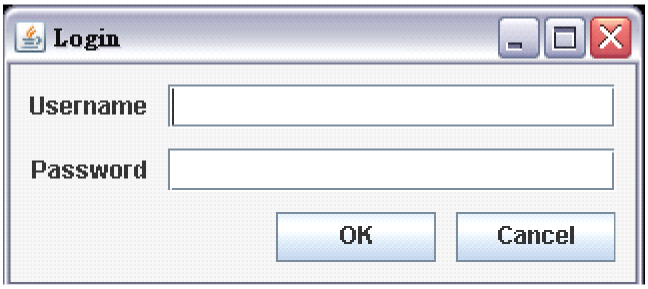
Installation

RealOpt-CRC© is currently available to users from federal, state, local, and tribal agencies. Please direct RealOpt-CRC© requests to Dr. Eva Lee eva.lee@isye.gatech.edu. Upon receiving the confirmation email, save the “RealOpt-CRC” folder to the desired location on your computer.

Requests for technical support, questions about installation or platform compatibility, and feedback regarding the software usage should be directed to RealOpt@isye.gatech.edu.

Launching the Application

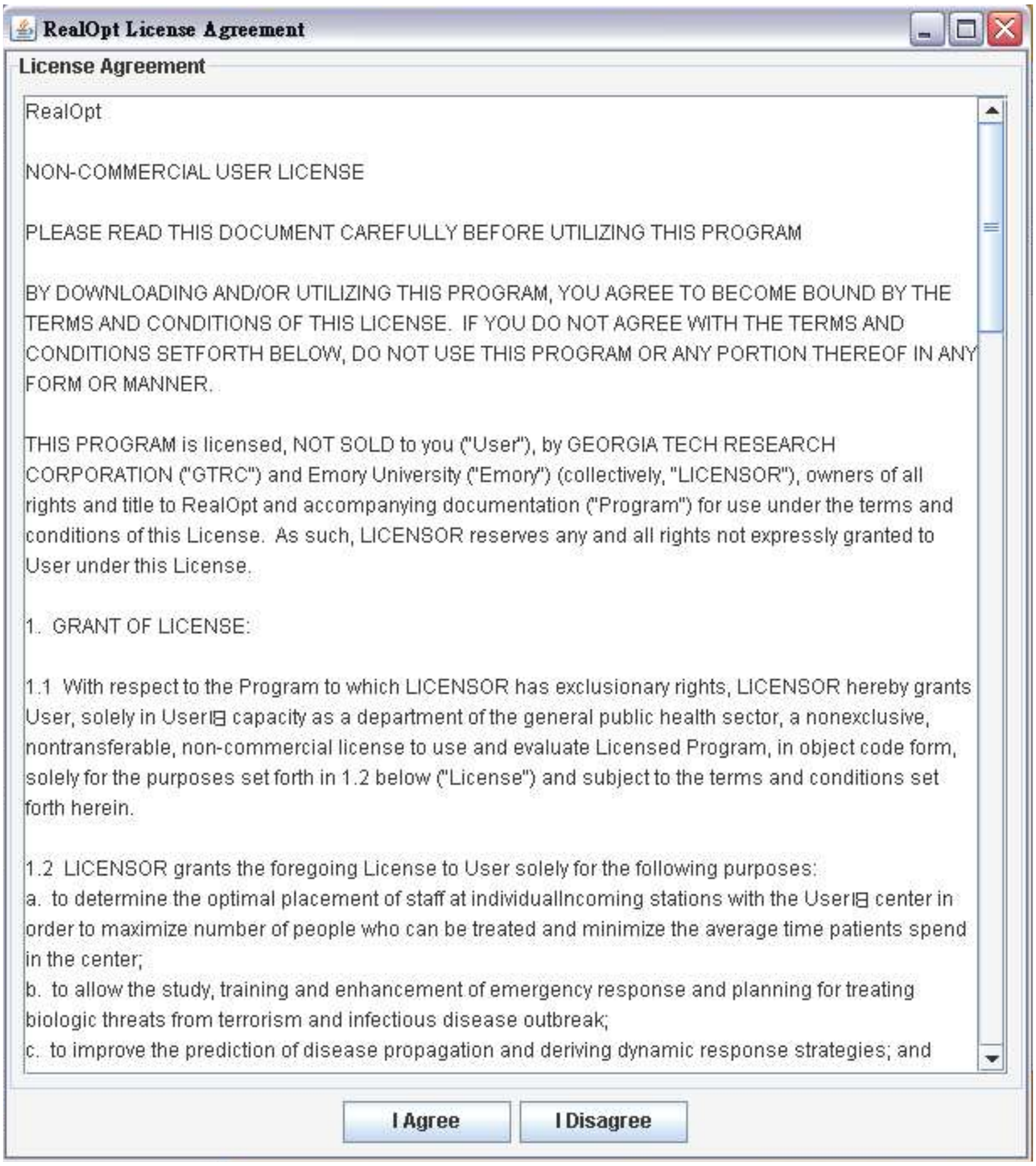
Double-click the batch file **RealOpt-CRC.bat**. A login window should show up:



Send an email to RealOpt@isye.gatech.edu with a subject line ”RealOpt-CRC Password Request,” and a username of your choice to obtain a password. There are no restrictions on the choice of a username.

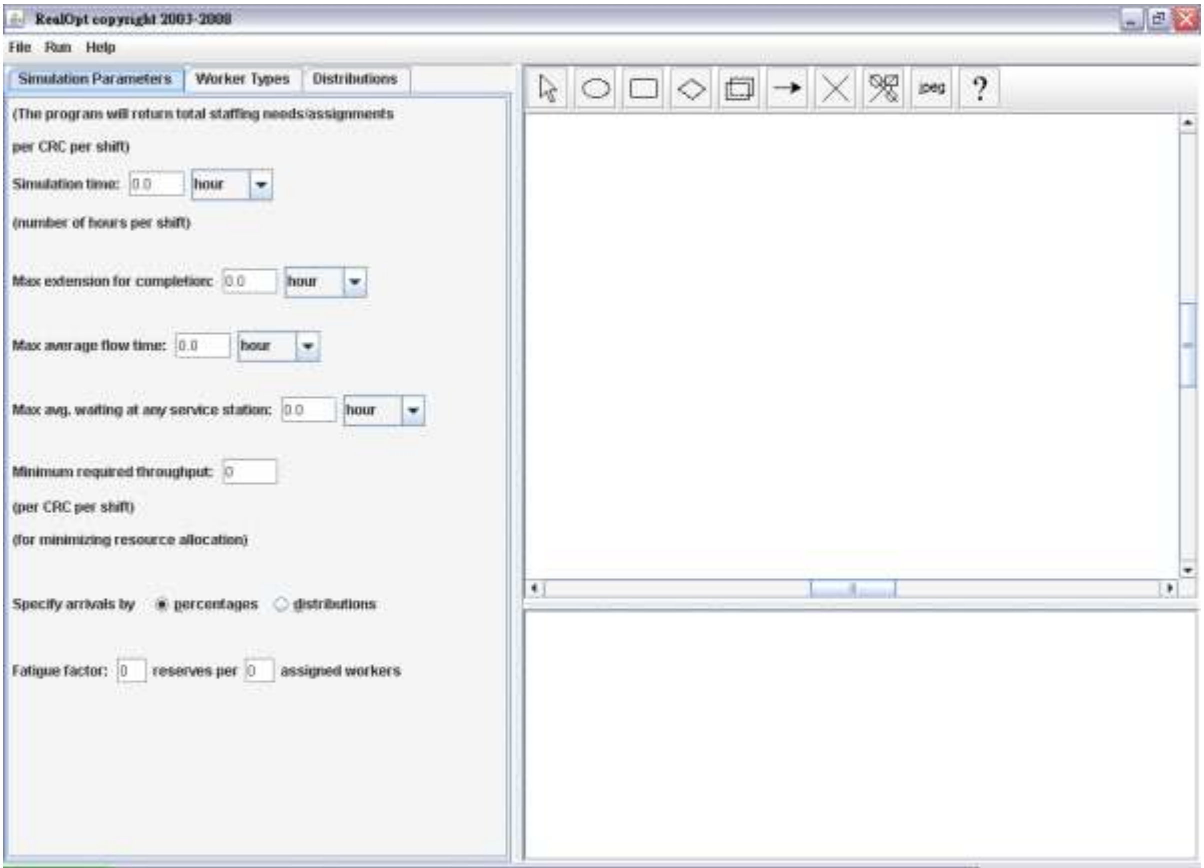
Enter your username and the password and click the **OK** button. You should see a license agreement window similar to the one on the next page.

The program will remember your valid username and password. You will not be asked for them next time you launch RealOpt©.



Please read the license agreement and understand the terms, before clicking the “I Agree” button to proceed.

You should then see the main window.

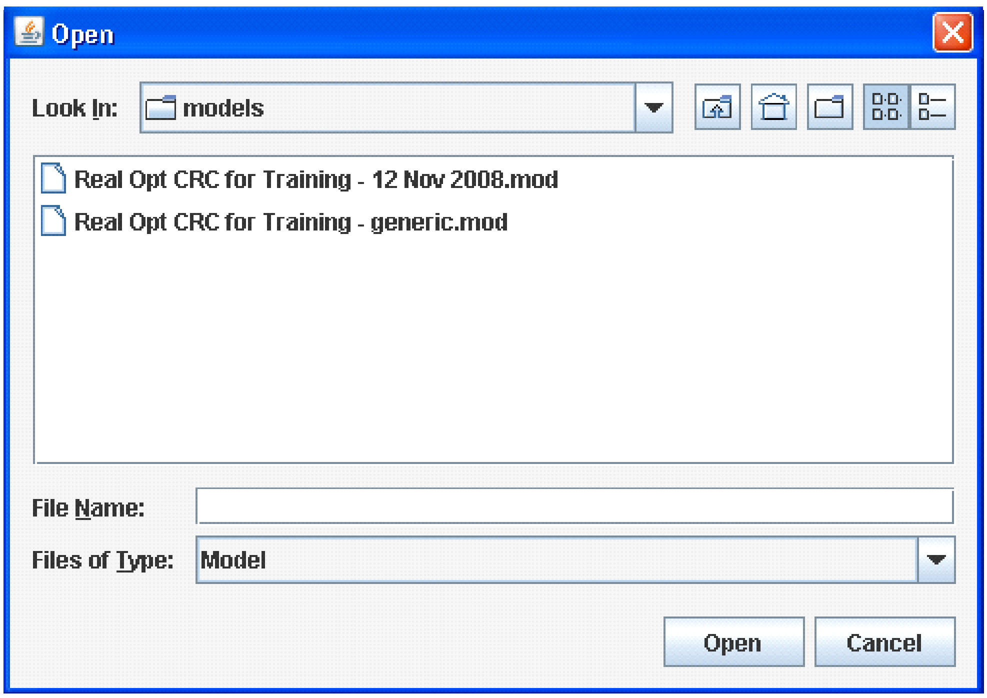


It consists of a menu bar, three tabbed panels on the left (Simulation Parameters, Worker Types, Distributions), a drawing area with a tool bar in the upper right, and a log window in the lower right.

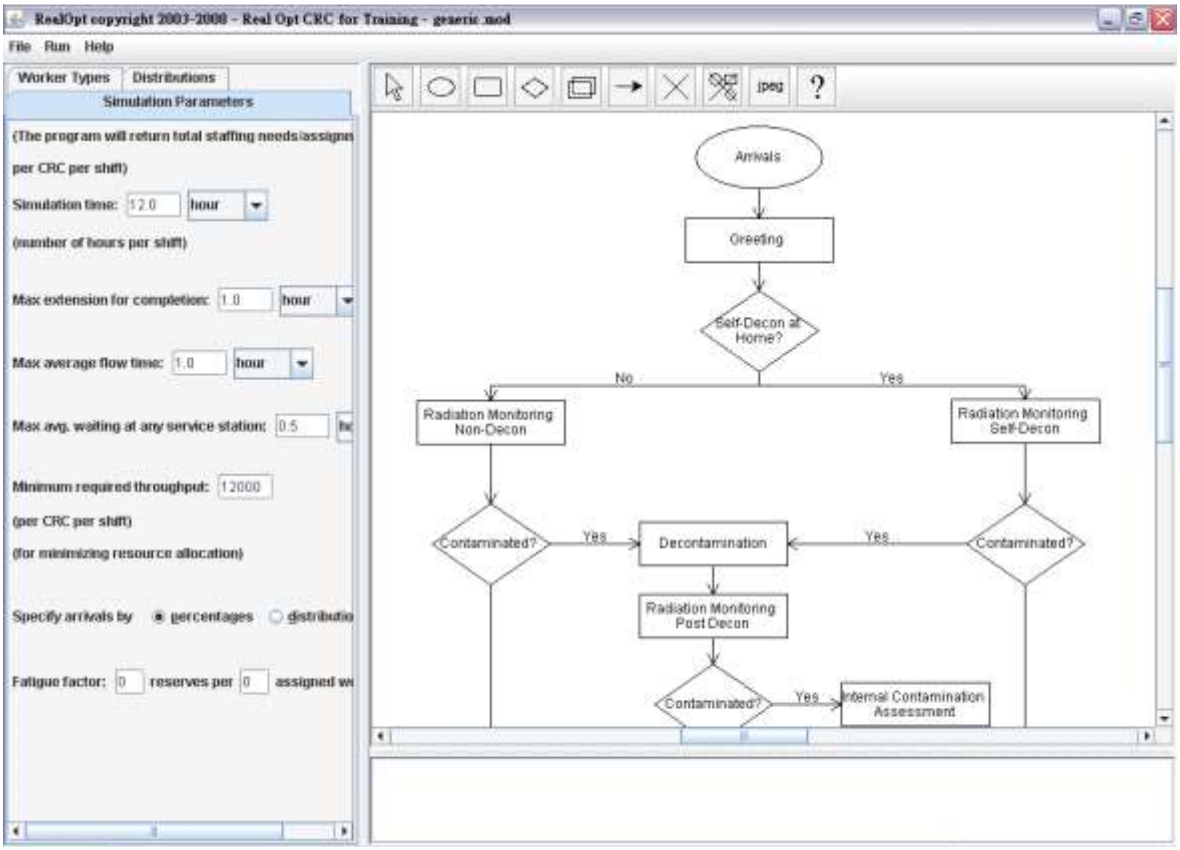
Selecting a Process Flow

Before any optimization/simulation can be performed, a facility model must be selected or drawn. To open a facility model, click the **File** menu and then click **Open …**

A dialog window will pop up, displaying a list of existing models.



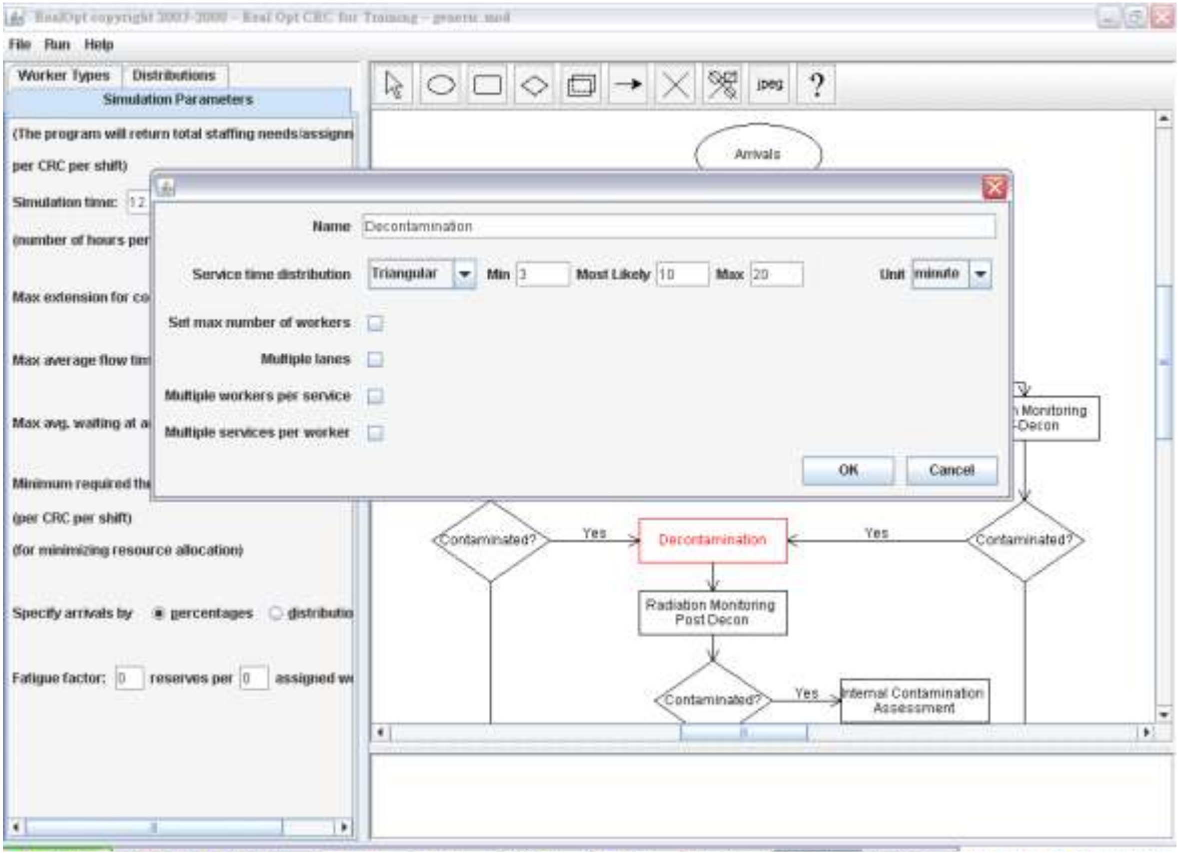
Choose **Real Opt CRC for Training - generic.mod** and click the **Open** button. You should see a window similar to the following one.


RealOpt copyright 2003-2008 - Real Opt CRC for Training - generic.mod
File Run Help
Worker Types
Distributions
Simulation Parameters
Simulation time:
hour
(number of hours per shift)
Max extension for completion:
Max average flow time:
Max avg. waiting at any service station:
Minimum required throughput:
(per CRC per shift)
(for minimizing resource allocation)
Specify arrivals by
percentages
Fatigue factor:
reserves per
Arrivals
Greeting
Self-Decon at Home?
No
Yes
Radiation Monitoring Non-Decon
Radiation Monitoring Self-Decon
Contaminated?
Decontamination
Radiation Monitoring Post Decon
Internal Contamination Assessment

Editing a Process Flow

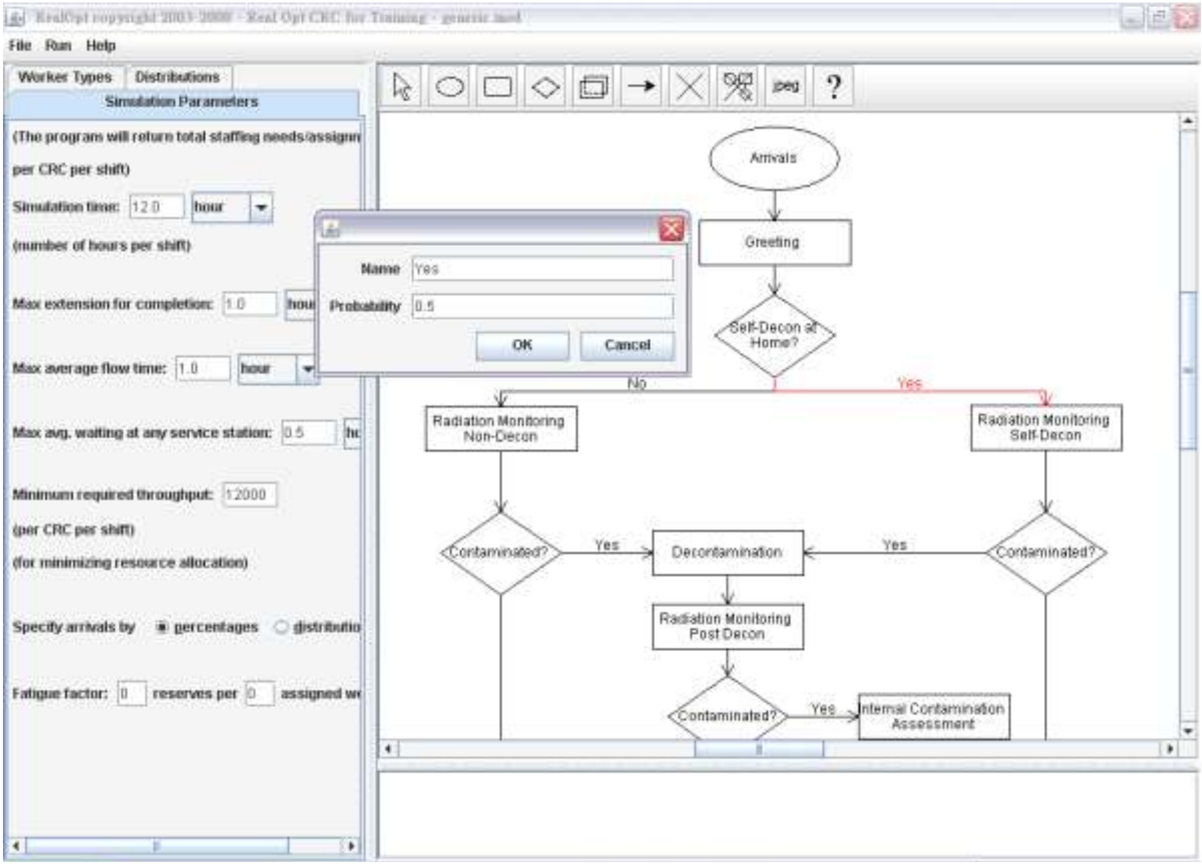
Various operations can be performed once a model is in place.

You can change block parameters by double-clicking the appropriate block. It will then be highlighted in red and a dialog window containing its parameters will pop up.



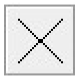
You can edit the appropriate parameter fields. To change a probability distribution, first select its type from the drop-down list, and then enter its parameters. Time unit is selected from the drop-down list on the right. Click the **OK** button to save your changes, or the **Cancel** button to discard them.

To change the probabilities regarding how the flow of people is split after a decision block, double-click the appropriate arrow. It will then be highlighted in red and a dialog window will pop up allowing you to enter a name and the probability.



Click the **OK** button to save the changes, or the **Cancel** button to discard them.

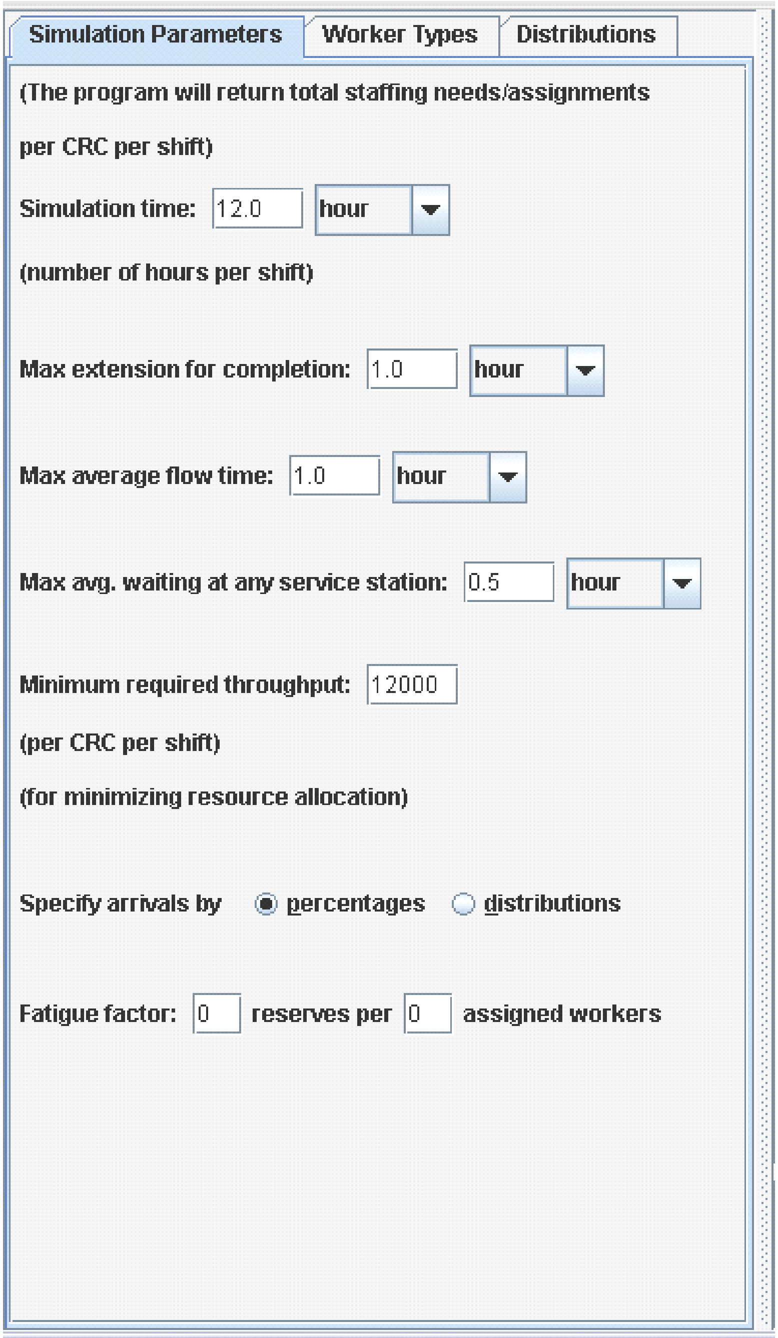
Blocks can be dragged around to their desired locations.

You can remove a block or an arrow by single-clicking it and then clicking the  button in the drawing tool bar.

Drawing blocks and arrows, as well as the use of other buttons, will be introduced in a later section of this user manual.

Simulation Parameters

You can change simulation parameters by editing the appropriate fields on the left. Time units are selected from a drop-down list.



Max extension for completion: This is an extended period of time after the specified simulation time, which allows all entities to finish service and exit the facility. It is to reflect that a facility may close at a certain time; however, it will still finish processing the individuals who remain inside.

Max average flow time: The average time that an individual spends in the system.

Max average waiting at any service station: The average waiting time in queue at any service station.

Minimum required throughput: Minimum total number of individuals going through the system.

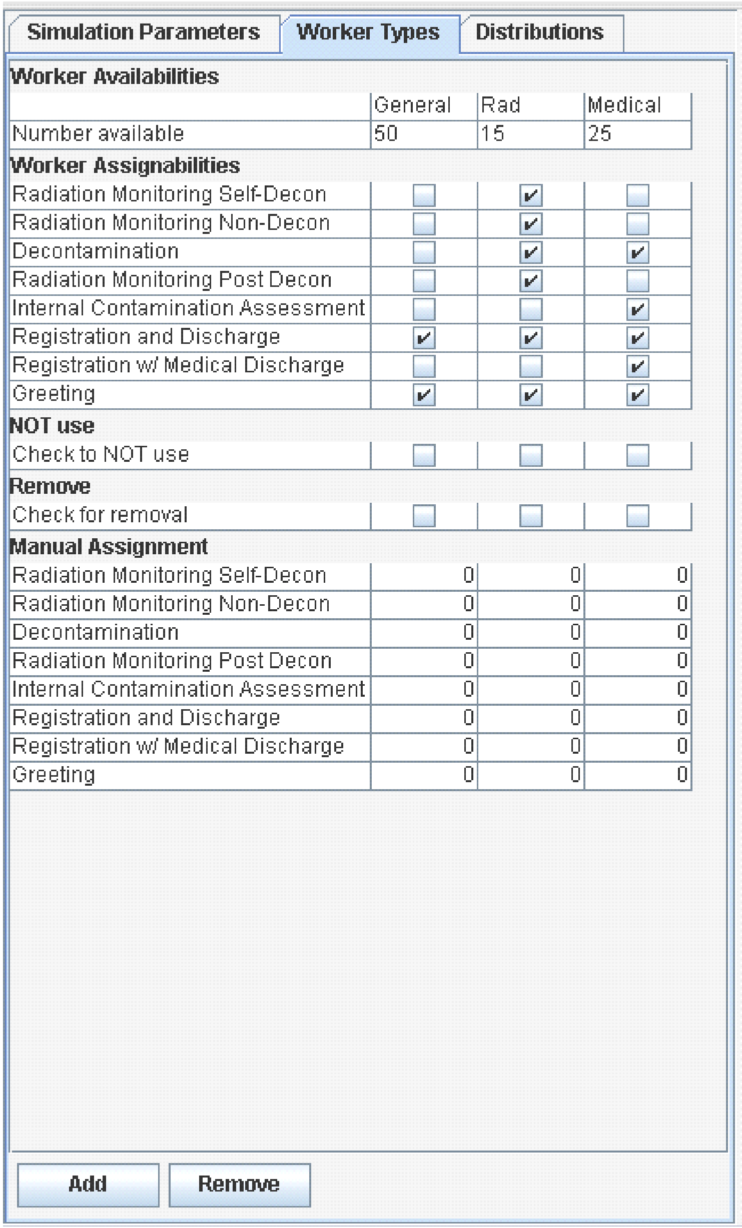
Tips for specifying minimum required throughput: Suppose you have a county population of 600,000 and you would like to screen the entire population within 3 days using 5 screening centers. In this case, your throughput per day will be 600,000/3 = 200,000. Assuming we distribute the load evenly among each center (it does not have to be), one can estimate that approximately 200,000/5 = 40,000 individuals should be processed per location per day. Using the CDC protocol, we assume the shift for workers is 12 hours (you can input the duration you prefer). In this case, for every 12 hours in a single location, we would like 20,000 individuals to be processed, and thus you can input the "minimum required throughout" as 20,000.

For each of the two remaining parameters, namely, **arrival specification** and **fatigue factor**, we will have a section dedicated to it. For now, let's keep them default.

Worker Types

You can edit/view worker types, number of available workers of each type, and whether a type of worker can be assigned to a process block by selecting the "Worker Types" tab.

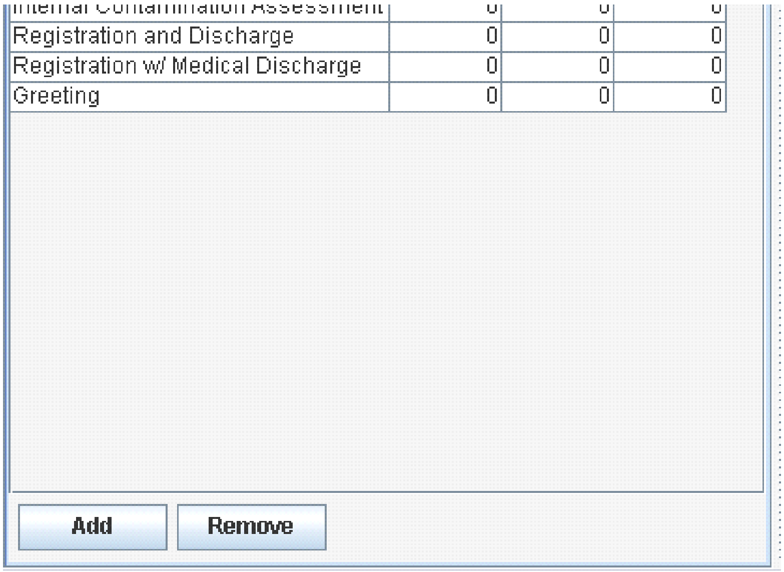
Open the model "Real Opt CRC for Training - 12 Nov 2008.mod" and switch to the Worker Types Panel. You should see a window similar to the following:



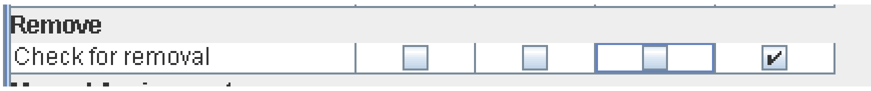
To make changes in the Worker Availabilities, edit the appropriate cells in the first two rows. **[Note that each time you edit a numerical value or edit text in a cell, you must press the Enter key for your change to be saved.]** Use the check boxes to specify worker assignments.

To temporarily disable the use of any worker types, simply check the appropriate boxes in the **NOT Use** row.

To add a worker type, click the **Add** button at the bottom of the worker information panel.

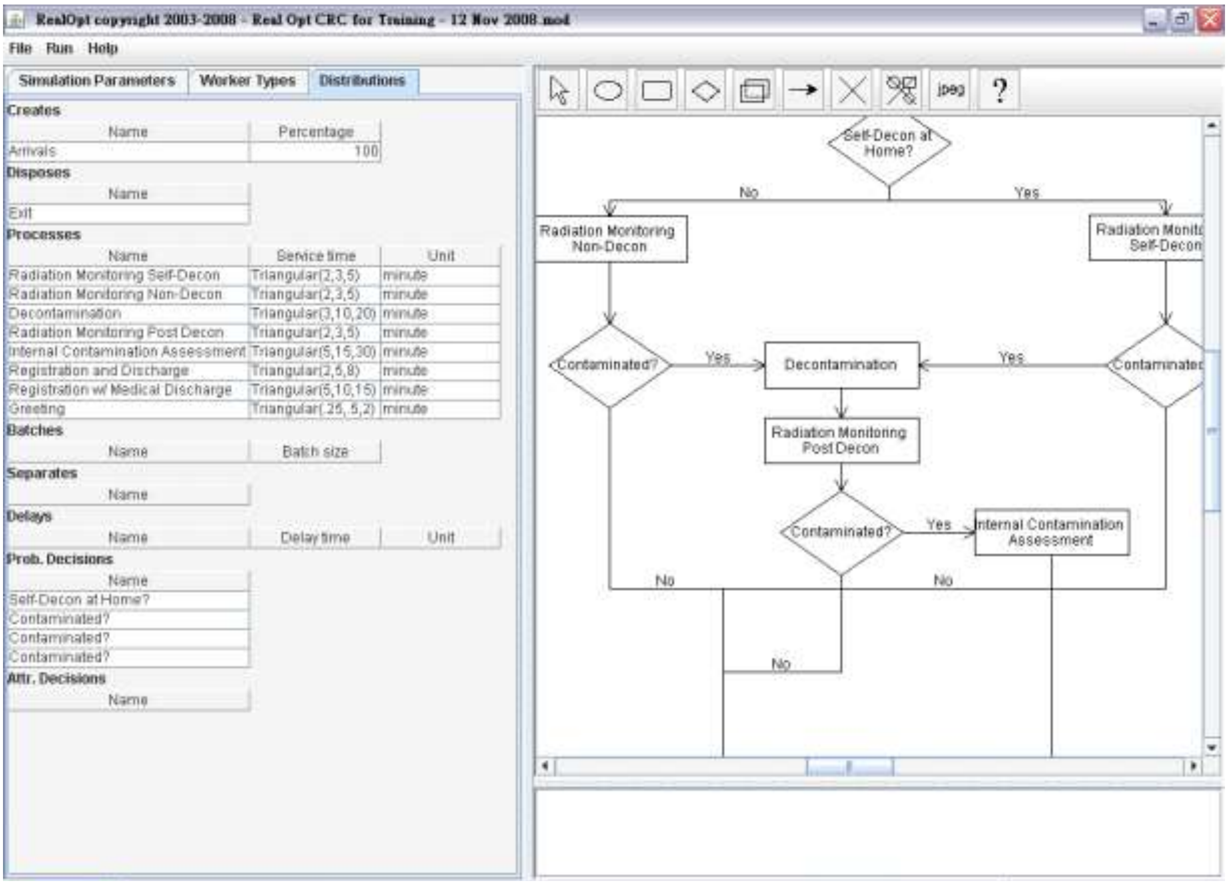


To remove an entire worker type column from the listing, first check the appropriate box in the **Remove** row, and then click the **Remove** button at the bottom. **[Note that the entire column will be removed.**

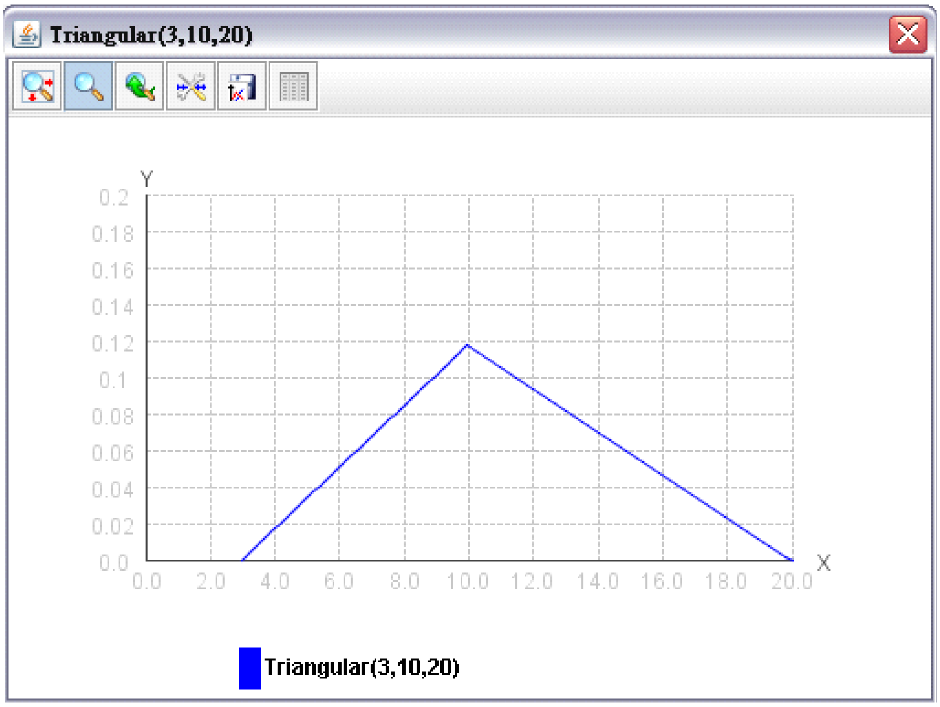


Probability Distributions

You can get a tabular view of the blocks' probability distributions and other parameters by selecting the **Distributions** tab.



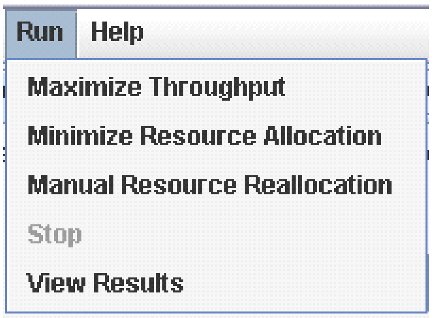
You can visualize a probability distribution by double-clicking the corresponding table cell. A dialog window will pop up, containing a graph of the probability density function.



Triangular(3,10,20)
Y
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
X
Triangular(3,10,20)

Running Optimization and Simulation

To launch the optimization and simulation, click the **Run** menu and then select either **Minimize Resource Allocation**, **Maximize Throughput**, or **Manual Resource Reallocation**.



Note that these operations can help you determine:

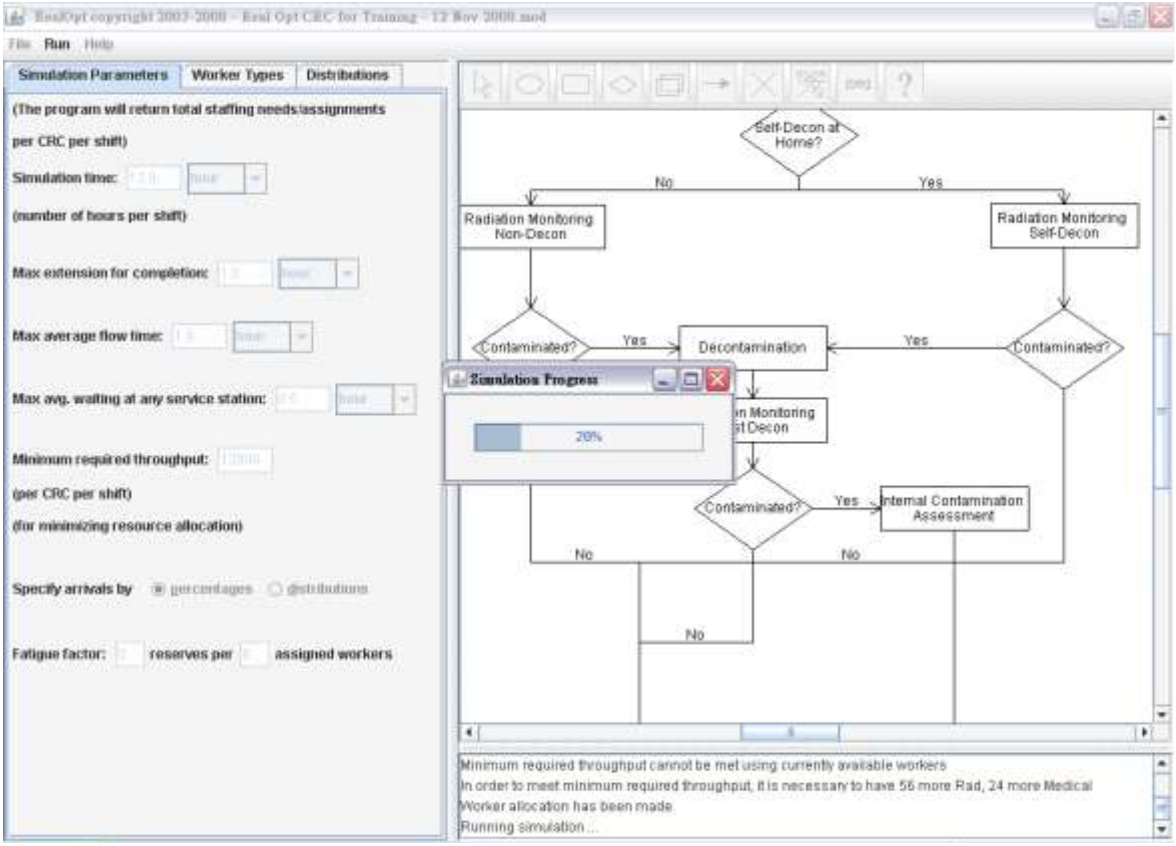
- The minimum number of workers needed to screen your regional population.
- The maximum number of individuals that you can screen.
- Additional resources needed.

Minimize Resource Allocation determines the least number of workers needed to meet the minimum required throughput (entered as one of the simulation parameters). In the case when the minimum required throughput cannot be met using currently available worker resources, the program will suggest the minimum number of additional workers needed in order to meet the minimum throughput requirement.

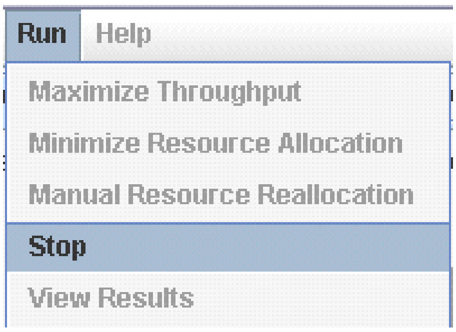
Maximize Throughput determines the maximum throughput that can be achieved using available worker resources.

Manual Resource Reallocation allows users to input a staffing assignment for resource allocation. It can also be used to modify an existing staffing assignment. Specifically, after running **Minimize Resource Allocation** or **Maximize Throughput** to obtain an optimal staffing for each station, users can adjust the staffing assignment manually (e.g., the user can assign extra workers for a station with high utilization or with a long queue length).

Once optimization is running, you can use the log window to monitor the progress of the optimization and simulation.

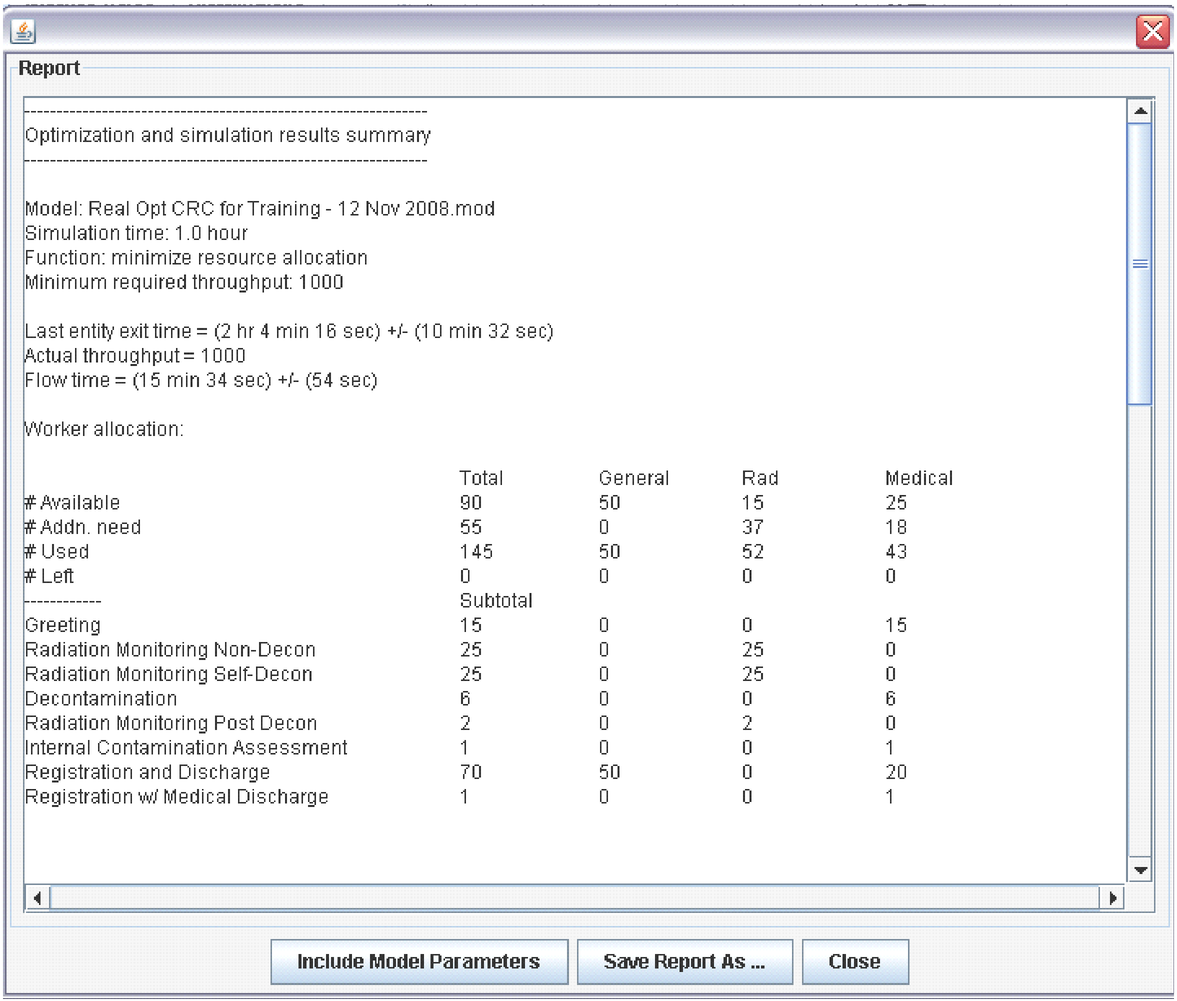


To stop the optimization midway, select **Stop** from the **Run** menu.



Viewing Results

When optimization and simulation run to completion, a result output window will automatically pop up as shown below.



Optimization and simulation results summary

Model: Real Opt CRC for Training - 12 Nov 2008.mod
Simulation time: 1.0 hour
Function: minimize resource allocation
Minimum required throughput: 1000

Last entity exit time = (2 hr 4 min 16 sec) +/- (10 min 32 sec)
Actual throughput = 1000
Flow time = (15 min 34 sec) +/- (54 sec)

Worker allocation:

	Total	General	Rad	Medical
# Available	90	50	15	25
# Addn. need	55	0	37	18
# Used	145	50	52	43
# Left	0	0	0	0
------------	Subtotal			
Greeting	15	0	0	15
Radiation Monitoring Non-Decon	25	0	25	0
Radiation Monitoring Self-Decon	25	0	25	0
Decontamination	6	0	0	6
Radiation Monitoring Post Decon	2	0	2	0
Internal Contamination Assessment	1	0	0	1
Registration and Discharge	70	50	0	20
Registration w/ Medical Discharge	1	0	0	1

The first few lines summarize the model being run, the optimization selection, and the simulation parameters.

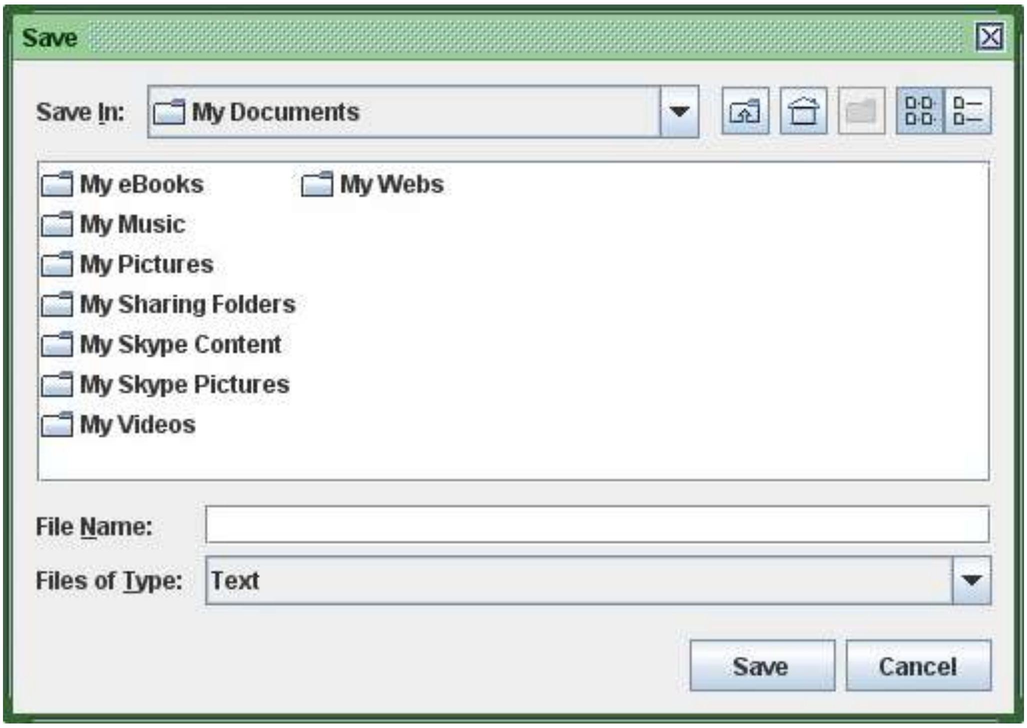
Following that are system statistics. Throughput is the total number of outgoing individuals. Flow time is the average time that an individual spends in the system.

Next is a summary of worker allocations. Each column represents a worker type. The first three rows (or four, with one more for additional requirements in some Minimize Resource Allocation cases) are the total number of available workers, the total number of workers being allocated, and the number of workers left after the allocation is being made, respectively. Each of the rest of the rows represents the worker allocation at an individual station.

The rest of the report lists detailed statistics for every process block and batch block. Queue length is the average length of the queue at the indicated station over the simulation time length. Waiting time is the average time that an individual spends waiting in queue at this station. Utilization is the average instant utilization (number of servers busy divided by the number of servers available) over the simulation time.

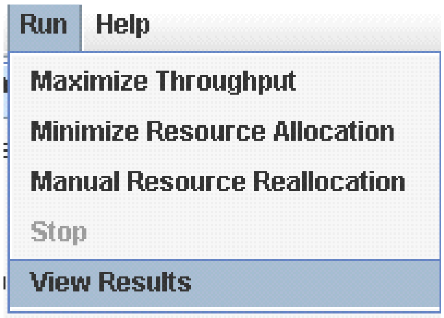
Selecting **Include Model Parameters** copies the parameters used in the associated simulation into the report.

You can either save the report or close it by clicking the corresponding button. If you choose to save it, another dialog window will pop up as shown below.



Select a location and a file name, then click the **Save** button.

If you close the result output window and want to view it again, select **View Results** from the **Run** menu.

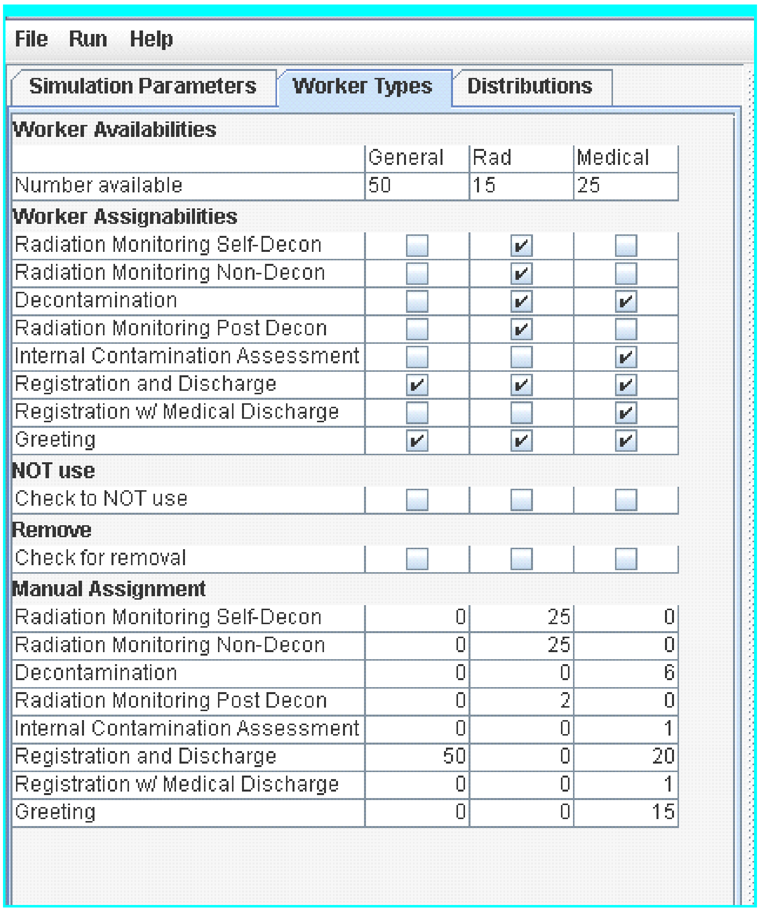


The report is saved in plain text format. You can use any text editor to review a previously saved report (e.g. Notepad, WordPad, Microsoft Word).

Manual Resource Reallocation

Since resource allocation is a difficult problem, it is advised that users first run **Minimize Resource Allocation** or **Maximize Throughput** to obtain a staffing assignment.

Manual Resource Reallocation can then be used to modify an existing staff assignment. Specifically, after running **Minimize Resource Allocation** or **Maximize Throughput** to obtain an optimal staffing for each station (the optimal assignment will appear in the **Worker Type** panel, under **Manual Assignment**), users can adjust the staffing assignment manually (e.g., the user can assign extra workers for a station with high utilization or with a long queue length).

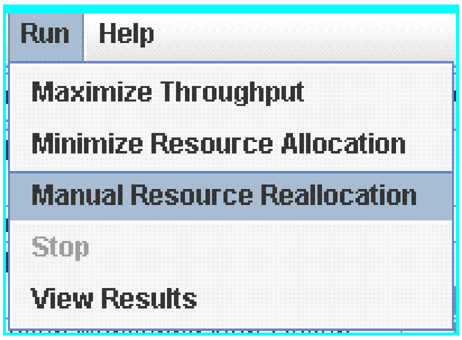

File Run Help

Simulation Parameters | Worker Types | Distributions

	General	Rad	Medical
Worker Availabilities			
Number available	50	15	25
Worker Assignabilities			
Radiation Monitoring Self-Decon	☐	☑	☐
Radiation Monitoring Non-Decon	☐	☑	☐
Decontamination	☐	☑	☑
Radiation Monitoring Post Decon	☐	☑	☐
Internal Contamination Assessment	☐	☐	☑
Registration and Discharge	☑	☑	☑
Registration w/ Medical Discharge	☐	☐	☑
Greeting	☑	☑	☑
NOT use			
Check to NOT use	☐	☐	☐
Remove			
Check for removal	☐	☐	☐
Manual Assignment			
Radiation Monitoring Self-Decon	0	25	0
Radiation Monitoring Non-Decon	0	25	0
Decontamination	0	0	6
Radiation Monitoring Post Decon	0	2	0
Internal Contamination Assessment	0	0	1
Registration and Discharge	50	0	20
Registration w/ Medical Discharge	0	0	1
Greeting	0	0	15

Users can choose to manually alter the entries here to modify the output. For example, a high utilization in a station can be reduced by addition of an extra worker. Note that by manually adjusting the worker assignment, output of other stations will also be affected. It is advised that users modify this incrementally to see the performance gain of one additional worker at a time.

Once the assignment is modified, click on the **Run** menu and select **Manual Resource Reallocation**.



We illustrate this effect by adding one extra worker to the Greeting station.

Original Results	After adding one extra worker to Radiation Monitoring Post-Decon station
Last entity exit time = (13 hr 9 min 51 sec) +/- (23 min 7 sec) Actual throughput = 12000 Flow time = (16 min 36 sec) +/- (1 min 27 sec)	Last entity exit time = (12 hr 42 min 2 sec) +/- (10 min 29 sec) Actual throughput = 12000 Flow time = (17 min 20 sec) +/- (1 min 41 sec)
Greeting ..Queue length = 11 +/- 2 ..Waiting time = (45 sec) +/- (8 sec) ..Num of workers = 16 ..Utilization = 87.9% +/- 2.5%	Greeting ..Queue length = 11 +/- 3 ..Waiting time = (44 sec) +/- (11 sec) ..Num of workers = 16 ..Utilization = 91.0% +/- 1.2%
Radiation Monitoring Non-Decon ..Queue length = 20 +/- 4 ..Waiting time = (2 min 46 sec) +/- (40 sec) ..Num of workers = 28 ..Utilization = 90.5% +/- 2.3%	Radiation Monitoring Non-Decon ..Queue length = 28 +/- 10 ..Waiting time = (3 min 37 sec) +/- (1 min 18 sec) ..Num of workers = 28 ..Utilization = 93.4% +/- 1.0%
Radiation Monitoring Self-Decon ..Queue length = 28 +/- 14 ..Waiting time = (3 min 44 sec) +/- (1 min 50 sec) ..Num of workers = 28 ..Utilization = 91.0% +/- 2.9%	Radiation Monitoring Self-Decon ..Queue length = 38 +/- 21 ..Waiting time = (4 min 48 sec) +/- (2 min 42 sec) ..Num of workers = 28 ..Utilization = 94.4% +/- 1.7%
Decontamination ..Queue length = 15 +/- 6 ..Waiting time = (18 min 11 sec) +/- (7 min 34 sec) ..Num of workers = 10 ..Utilization = 92.7% +/- 2.7%	Decontamination ..Queue length = 8 +/- 3 ..Waiting time = (9 min 52 sec) +/- (4 min 1 sec) ..Num of workers = 10 ..Utilization = 93.1% +/- 1.3%
Radiation Monitoring Post Decon ..Queue length = 5 +/- 2 ..Waiting time = (5 min 58 sec) +/- (2 min 42 sec) **..Num of workers = 3** **..Utilization = 93.6% +/- 2.3%**	Radiation Monitoring Post Decon ..Queue length = 0 +/- 0 ..Waiting time = (16 sec) +/- (1 sec) **..Num of workers = 4** **..Utilization = 70.6% +/- 1.0%**

Internal Contamination Assessment ..Queue length = 0 +/- 0 ..Waiting time = (55 sec) +/- (47 sec) ..Num of workers = 1 ..Utilization = 13.6% +/- 6.0%	Internal Contamination Assessment ..Queue length = 0 +/- 0 ..Waiting time = (42 sec) +/- (58 sec) ..Num of workers = 1 ..Utilization = 10.2% +/- 2.9%
Registration and Discharge ..Queue length = 17 +/- 7 ..Waiting time = (1 min 7 sec) +/- (30 sec) ..Num of workers = 83 ..Utilization = 91.7% +/- 2.5%	Registration and Discharge ..Queue length = 27 +/- 7 ..Waiting time = (1 min 45 sec) +/- (27 sec) ..Num of workers = 83 ..Utilization = 94.9% +/- 1.3%
Registration w/ Medical Discharge ..Queue length = 0 +/- 0 ..Waiting time = (1 sec) +/- (3 sec) ..Num of workers = 1 ..Utilization = 8.3% +/- 3.2%	Registration w/ Medical Discharge ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 1 ..Utilization = 6.4% +/- 1.7%

Inter-Arrival Specification

You can choose to specify arrivals either by percentages or distributions. This is done on the **Simulation Parameters** panel.

By percentages: The program will generate for each Create block a proper Poisson arrival process (i.e. exponentially distributed inter-arrival time) according to the system throughput and the percentage this Create block accounts for. The arrival rate is determined in such a way that the desired number of incoming entities can be generated during the given simulation time, and it takes just about this much time for all of them to arrive. This option is default and is recommended.

By distributions (for advanced users): Individuals will arrive according to each Create block's inter-arrival time distribution and number of entities per arrival, which are entered by the user. Be careful with this option as the following scenarios may happen:

1) The individuals enter the system so fast that the entire population pours in during the first few hours, and because of the flow time constraint, the system allocates the required workers, and becomes idle after a period of time, well before the end of the specified simulation time, resulting in early termination of simulation.

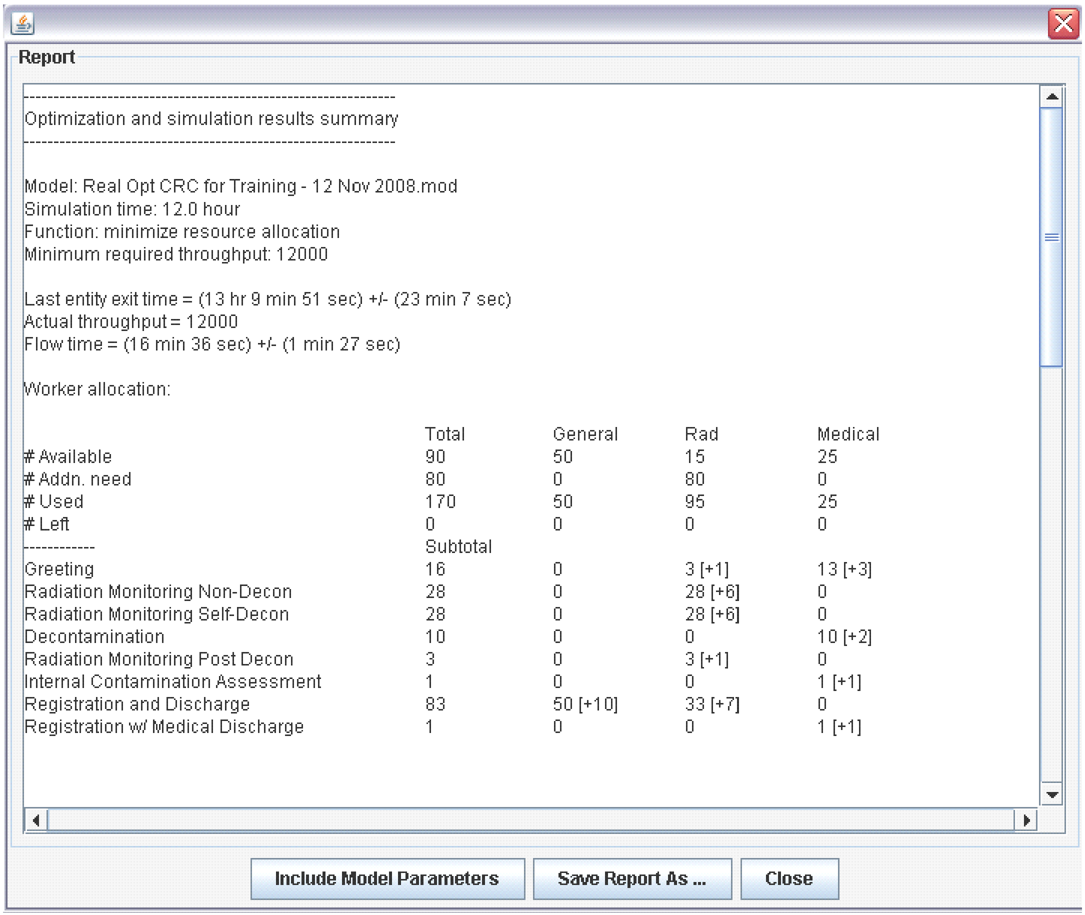
2) In the case of **Minimize Resource Allocation**, the number of entities created over the simulation time may be fewer than the minimum required throughput, and therefore optimization has to stop.

3) In the case of **Maximize Throughput**, the facility may be able to treat the maximum number of entities that can be created in the simulation time, and some workers may remain after allocation (because not sufficient individuals arrive into the system). If optimal worker usage is sought, the user should manually adjust (increase) the arrival rate.

Fatigue Factor

The fatigue factor can be set on the “Simulation Parameters” panel.

In this example, the user puts 1 reserve for each 5 front-line workers to take into account worker fatigue and breaks during a shift. Then launch the optimization and simulation again, you should see a result output window like below.



The numbers in the square brackets indicate the corresponding number of reserve workers.

Running Time

The table below summarizes the running times for a few scenarios. They were run on Intel Xeon E5430 processors (2.68GHz), using Redhat Enterprise Linux 5.2. We ran **Minimize Resource Allocation** on two facility models with minimum required throughput ranging from 12,000 to 240,000. Naturally, for the same model, the running time grows as the minimum required throughput increases.

model \ minimum required throughput	Real Opt CRC for Training - 12 Nov 2008	Real Opt CRC for Training – generic
12,000	6.73	6.7
24,000	7.18	7.23
36,000	10.67	10.62
48,000	14.02	14.04
60,000	17.38	17.32
72,000	20.88	20.85
84,000	24.29	23.98
96,000	27.84	27.67
108,000	30.88	31.13
120,000	34.54	34.79
132,000	38.46	38.29
144,000	41.46	41.84
156,000	45.46	45.59
168,000	49.23	49.88
180,000	52.84	52.17
192,000	56.04	55.67
204,000	60.03	60.28
216,000	64.51	63.93
228,000	67.33	67.42
240,000	71.12	70.75

Running times (seconds)

Please note that the running times also depend on your computer specification. This table should give you a rough idea how long to expect to wait.

Designing a Process Flow

To start a new model, select **New** from the **File** menu.

There are eight basic drawing elements:

Create: Creates entities that enter the simulation flow. Typically these are households or individuals that are streaming into the simulated facility.

Dispose: Represents an exit from the system.

Process: Represents a work station where entities (individuals, etc.) receive service. Examples include greeting stations, registration stations, decontamination stations, etc.

Batch: Sometimes entities need to form groups before they will proceed to a block service. For example, before a bus can leave for the next block service, individuals have to wait until the bus is filled up. This is done by placing a **Batch** that collects the incoming entities into batches of a specified size.

Separate: After a batch has been created and processed, we may need to break the batch back into individual entities. A Separate accomplishes that.

Delay: Represents a delay in the simulation flow. For example, a situation in which individuals require time to fill forms can be modeled as a Delay. Similarly, a bus ride can be modeled as a Delay.

Decision: Split the incoming stream of entities and direct them to two or more destinations. The decision is made probabilistically. A probability is assigned to each of its outgoing flows. These probabilities determine how the incoming stream of entities splits among various destinations (e.g., at Contaminated station some individuals are found to be contaminated, while others are not).

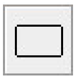
Arrow: Connect various blocks. An arrow going out of a Decision has a probability associated with it, as described in Decision.

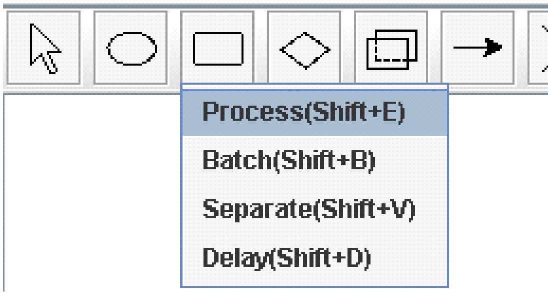
Creates and Disposes are represented by ellipsoids; Processes, Batches, Separates, Delays are represented by rectangles; Decisions are represented by rhombuses.

An Illustrative Example

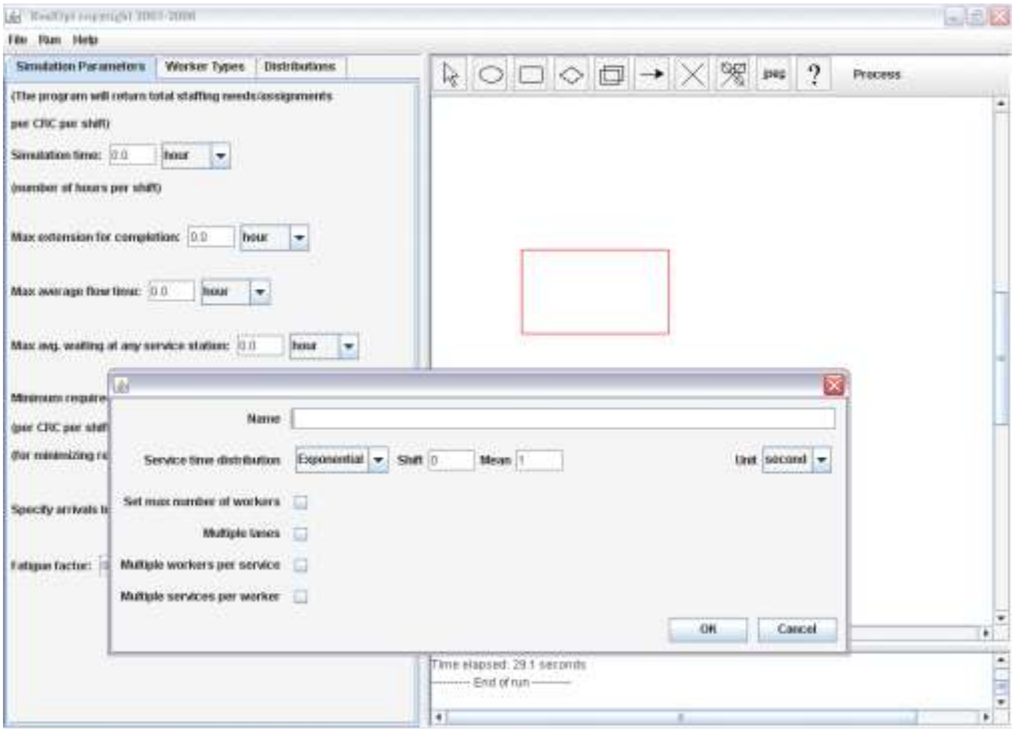
As an illustration, we will create a simple model consisting of a Create, a Process, and a Dispose.

To draw any block, first click the button in the drawing tool bar that represents its shape, and then select its type from the drop-down menu.

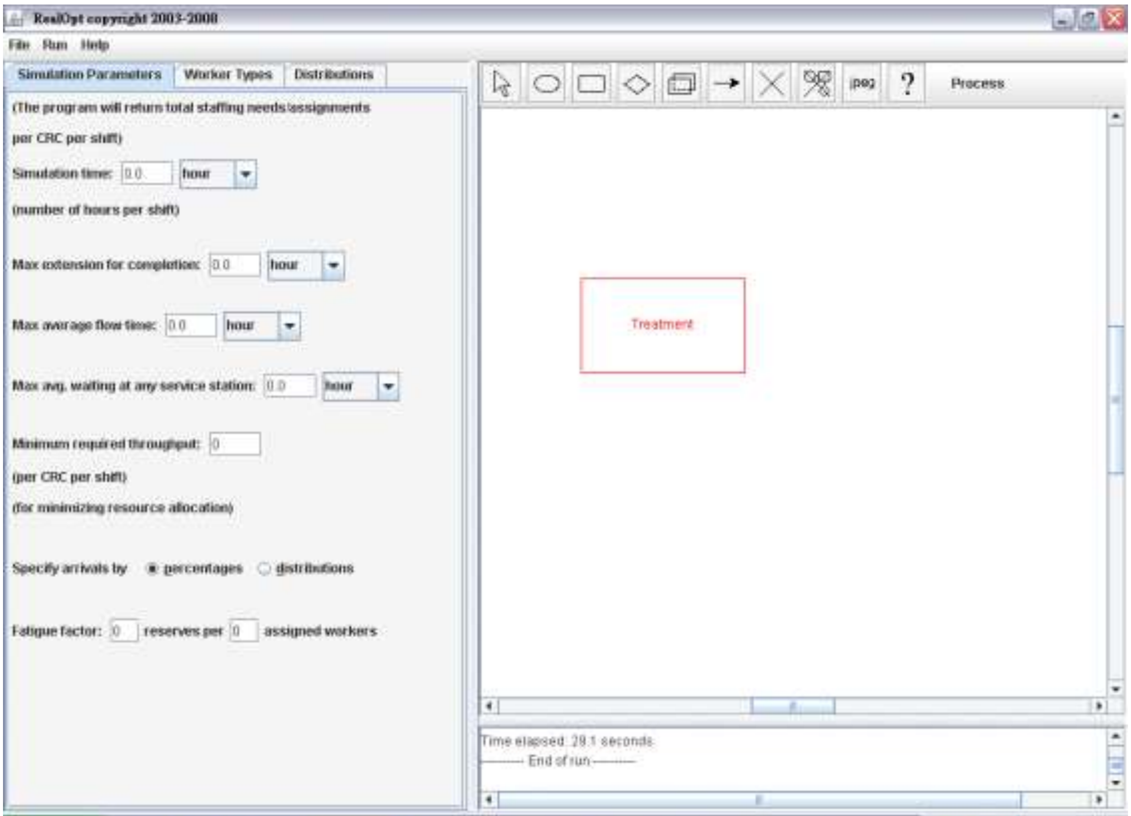
First we draw a Process. Click  and then select **Process**.



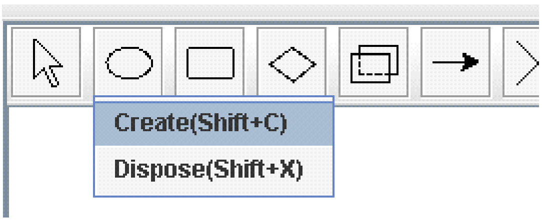
Next, press the mouse in the drawing area where you want the Process's upper left point to be, drag the mouse, and release it where you want its lower right point to be. As soon as it is drawn, a dialog window will pop up asking for its parameters.

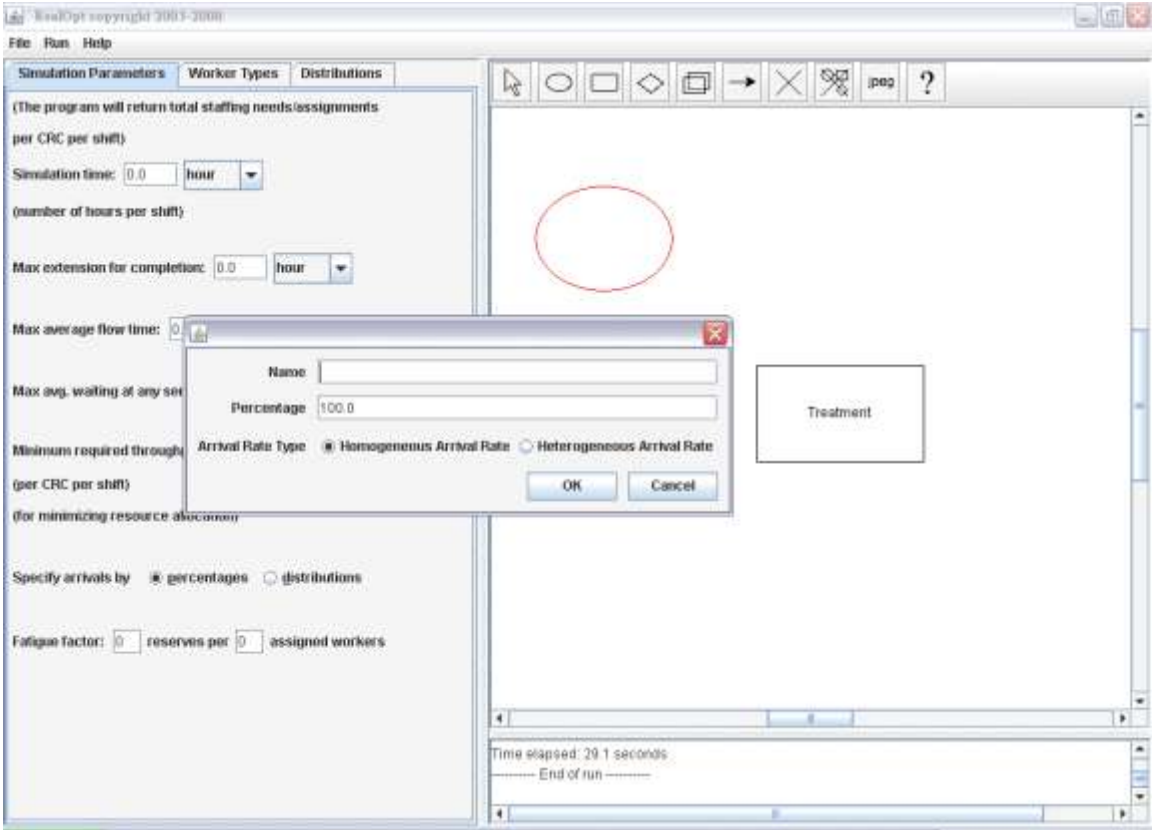


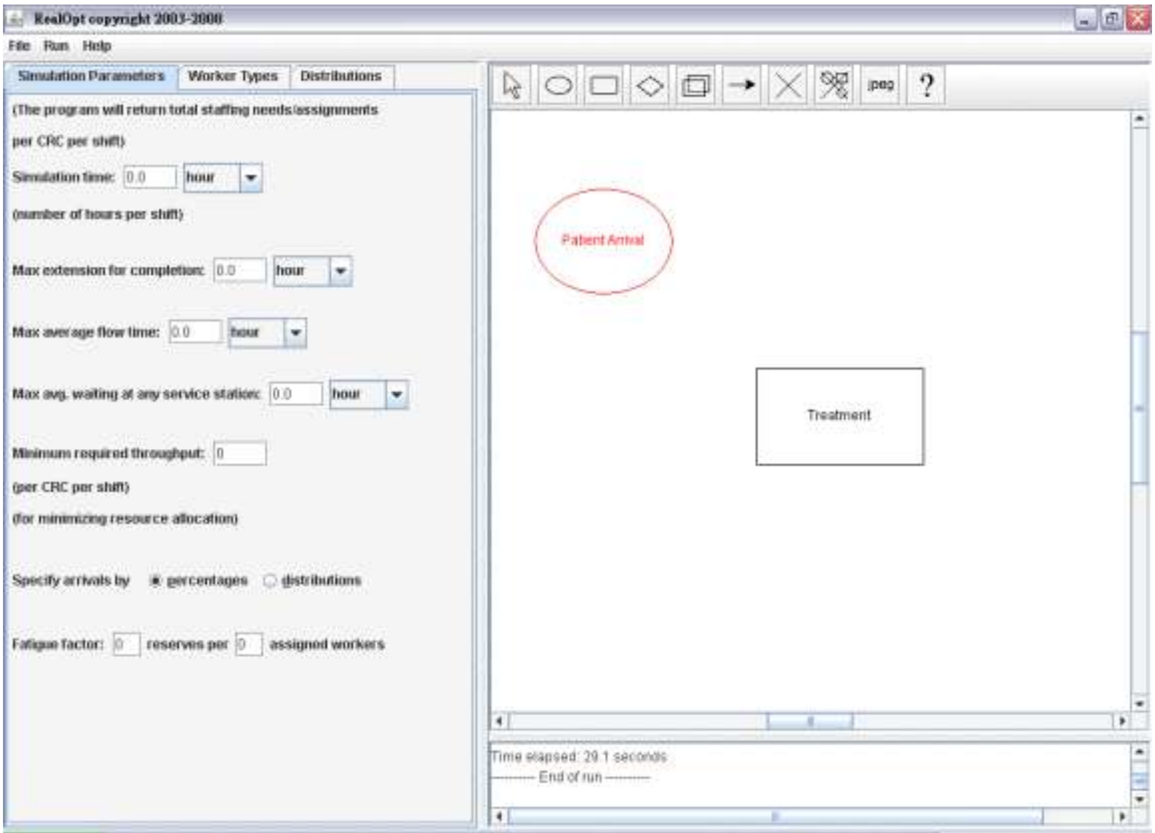
Enter appropriate parameters and click the **OK** button. The Process will appear with its name:



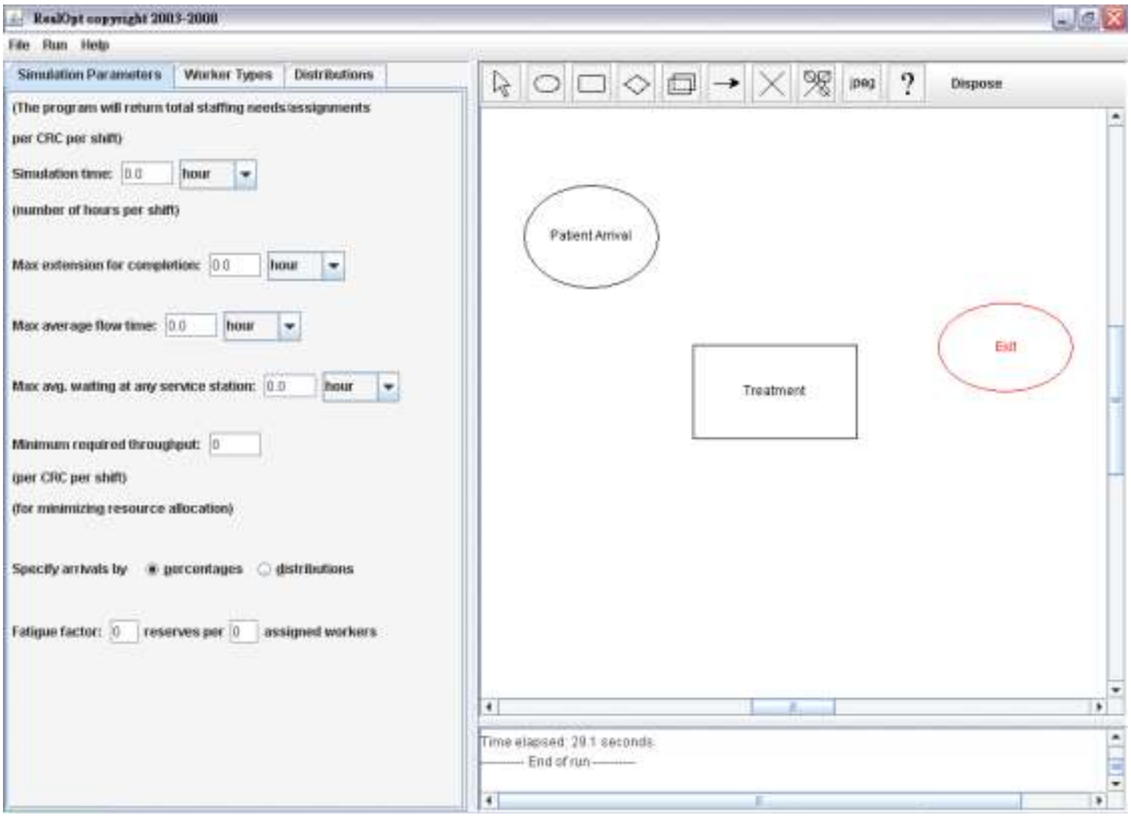
Similarly, we draw a Create (to represent entities entering into the system) as shown below:



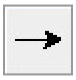

RealOpt copyright 2003-2008
File Run Help
Simulation Parameters
Worker Types
Distributions
(The program will return total staffing needs/assignments
per CRC per shift)
Simulation time: 0.0 hour
(number of hours per shift)
Max extension for completion: 0.0 hour
Max average flow time:
Name
Percentage 100.0
Arrival Rate Type
Homogeneous Arrival Rate
Heterogeneous Arrival Rate
OK
Cancel
Specify arrivals by percentages distributions
Fatigue factor: 0 reserves per 0 assigned workers
Treatment
Time elapsed: 29.1 seconds
---------- End of run ----------


RealOpt copyright 2003-2008
File Run Help
Simulation Parameters
Worker Types
Distributions
(The program will return total staffing needs/assignments
per CRC per shift)
Simulation time: 0.0 hour
(number of hours per shift)
Max extension for completion: 0.0 hour
Max average flow time: 0.0 hour
Max avg. waiting at any service station: 0.0 hour
Minimum required throughput: 0
(per CRC per shift)
(for minimizing resource allocation)
Specify arrivals by percentages distributions
Fatigue factor: 0 reserves per 0 assigned workers
Patient Arrival
Treatment
Time elapsed: 29.1 seconds
---------- End of run ----------

Next, we draw a Dispose representing the exit from the system:

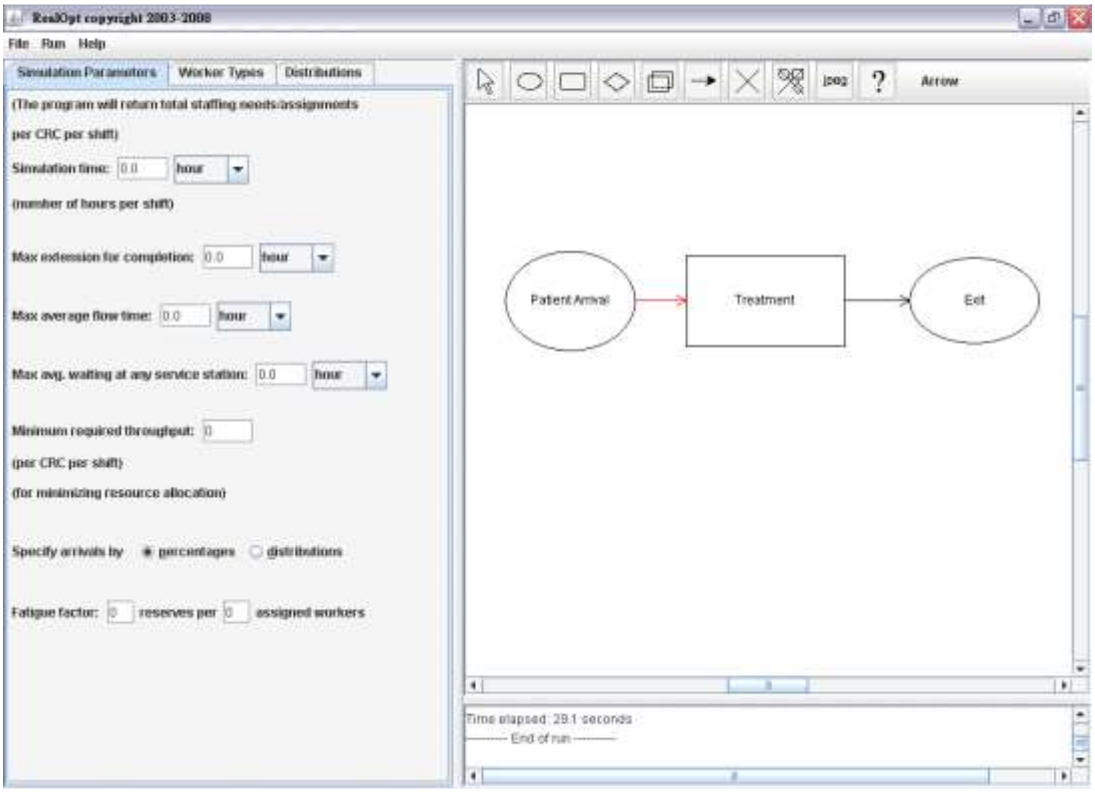


Finally, we connect these blocks with arrows.

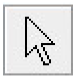
To do this, first click  in the drawing tool bar, then press the mouse anywhere in the origination block, drag the mouse pointer to anywhere in the destination block, and release it.

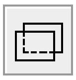
To add more arrows, repeat these steps.

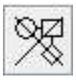
In our simple model, we connect “Individual Arrival” to “Treatment”, and “Treatment” to “Exit”. You should then see a window similar to the following one.



By now, we have introduced five of the eight buttons in the drawing tool bar. The other three are:

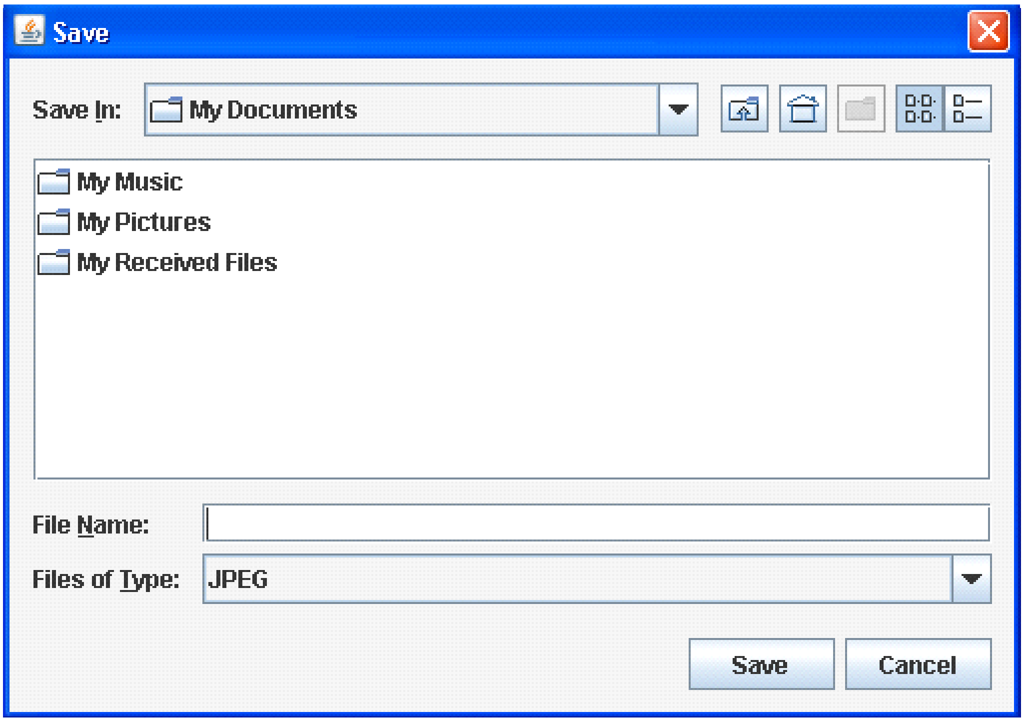
 Clicking this button takes you back to default mode (selecting and moving) when you click a drawing button and then change your mind.

 This button performs the duplication function. First select the target block, and then click this button.

 Clicking this erases the entire floor plan

 Clicking this button will pop up a list of help topics on floor plan design, which will then take you to the appropriate sections of the user manual

This allows you to save the current drawing area as a JPEG image. Once it is clicked, a dialog window will pop up like below:



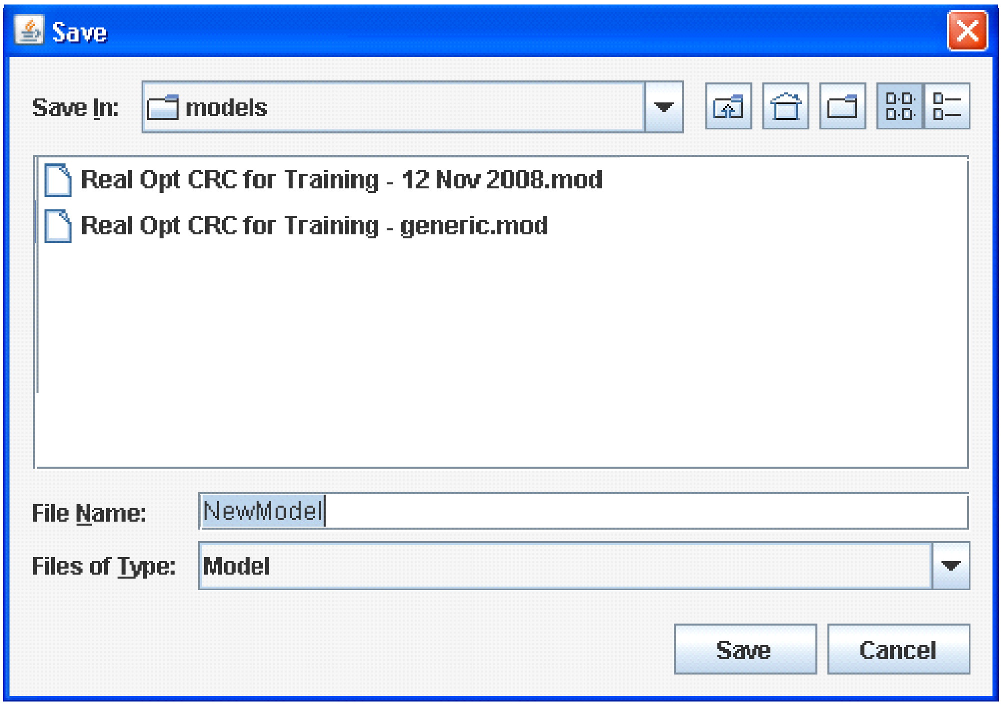
Select a location and a file name, then click the **Save** button.

The program will optimally crop the drawing area so that all elements of the floor plan will be saved, including those outside the current viewport, but not excessive blank areas.

Saving a Process Flow

To save a model, select **Save As …** from the **File** menu

A dialog window will pop up like below



Select a location and a file name, then click the **Save** button.

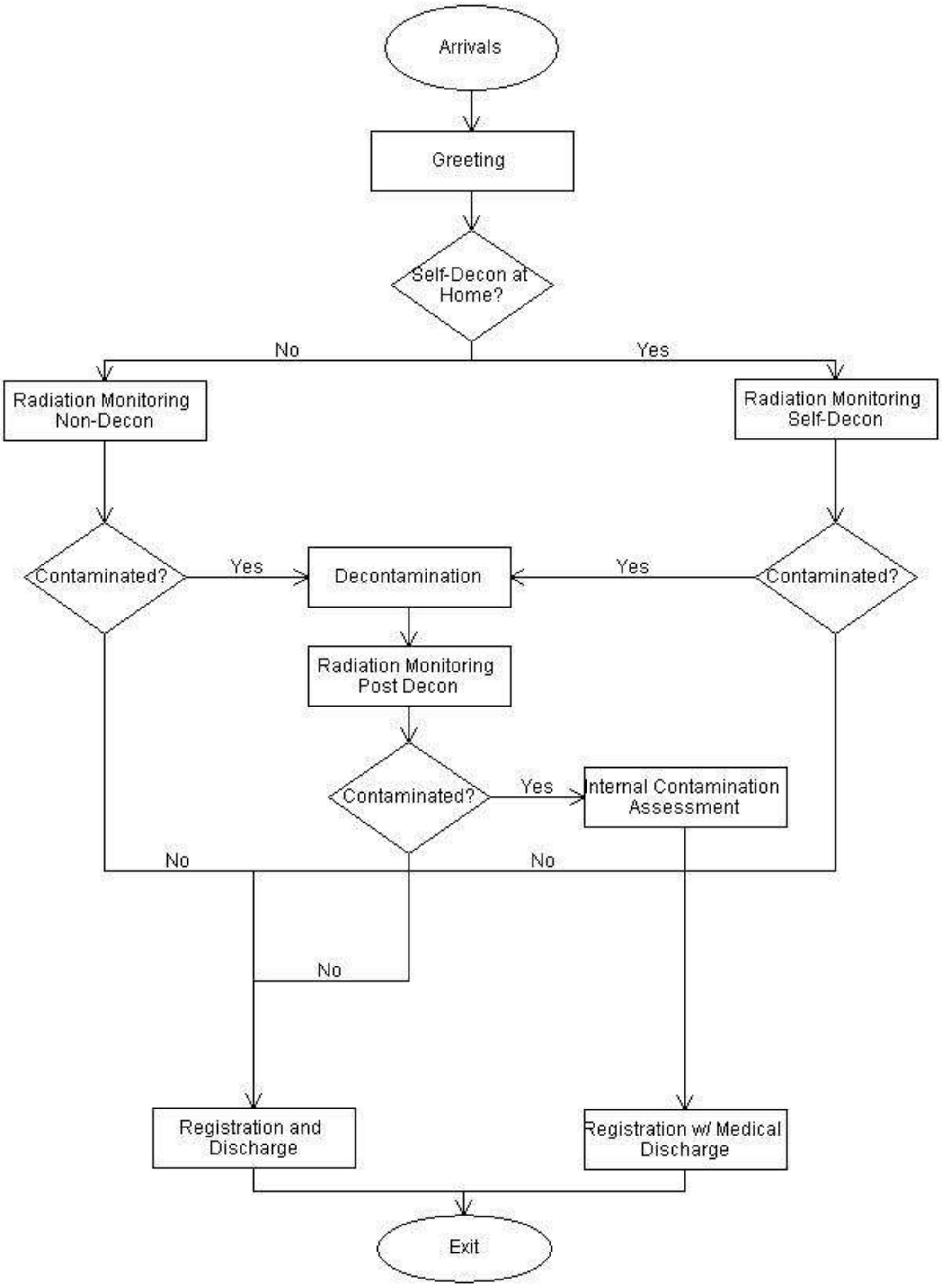
Resizing Blocks

All the blocks (create, dispose, process, delay, batch, separate, decision) can be resized by holding the Ctrl key and dragging the desired block.

Hotkeys for the Drawing Toolbar

Default	Shift+Q
Arrow	Shift+A
Create	Shift+C
Dispose	Shift+X
Process	Shift+E
Batch	Shift+B
Separate	Shift+V
Delay	Shift+D
Decision	Shift+S
Delete	Delete
Delete entire model	Ctrl+Delete
Duplicate	Ctrl+C
Save as JPEG	Ctrl+S

A Community Reception Center Process Flow



This software comes with two community reception center (CRC) models, Real Opt CRC for Training - generic.mod and Real Opt CRC for Training - 12 Nov 2008.mod. The process flow above is a basic CRC model and serves as the foundation for both files. Key tasks in this example include detection of radioactive contamination on the body or clothing, removal of the contamination (decontamination), detection of the intake of radioactive materials into the body, registration, and medical consultation.

Below, we illustrate the worker assignability. This shows the skills of workers who can perform the various tasks within the community reception center.

Real Opt CRC for Training - generic.mod	Real Opt CRC for Training - 12 Nov 2008.mod

Real Opt CRC for Training - generic.mod

Worker Availabilities

	Staff
Number available	500

Worker Assignabilities

Greeting	✓
Radiation Monitoring Non-Decon	✓
Radiation Monitoring Self-Decon	✓
Decontamination	✓
Radiation Monitoring Post Decon	✓
Internal Contamination Assessment	✓
Registration and Discharge	✓
Registration w/ Medical Discharge	✓

Real Opt CRC for Training - 12 Nov 2008.mod

Worker Availabilities

	General	Rad	Medical
Number available	50	15	25

Worker Assignabilities

Radiation Monitoring Self-Decon		✓	
Radiation Monitoring Non-Decon		✓	
Decontamination		✓	✓
Radiation Monitoring Post Decon		✓	
Internal Contamination Assessment			✓
Registration and Discharge	✓	✓	✓
Registration w/ Medical Discharge			✓
Greeting	✓	✓	✓

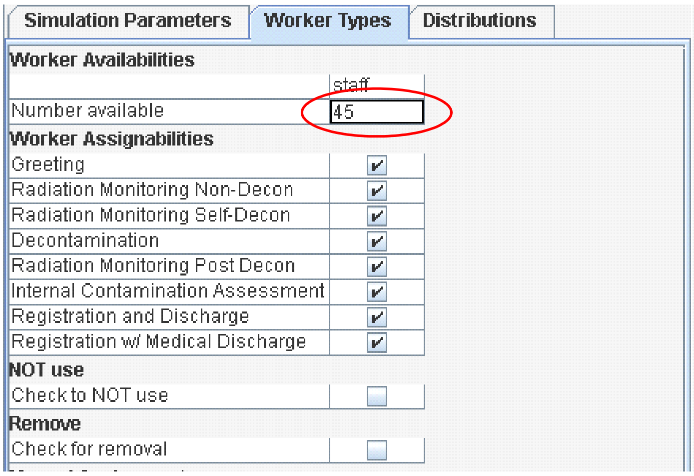
In Real Opt CRC for Training - generic.mod, all available workers are considered identical. Note that every checkbox in the Worker Assignabilities Table needs to be checked to ensure that every station will be manned.

In Real Opt CRC for Training - 12 Nov 2008.mod, on the other hand, each single column with checked checkboxes in the Worker Assignabilities Table represents the specific skills of the corresponding worker type. At least one checkbox in each row needs to be checked to ensure every station will be manned.

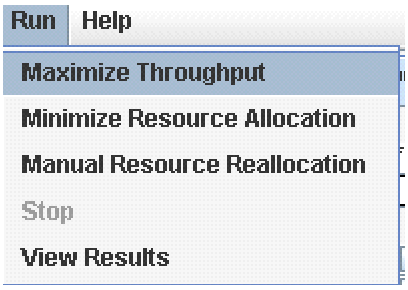
Practice Scenarios-Case Study 1:

"I have 45 staff members and 9 detection instruments at my disposal,. How can I maximize my throughput?" For illustrative purposes, we solve several variations of the stated problem. First, we consider the case where there is no limit on the number of detection instruments available. Next, we consider the case where the 9 detection instruments are to be split among the 3 radiation monitoring stations indicated in the floor plan. Finally, we consider a case in which some workers are able to perform multiple tasks.

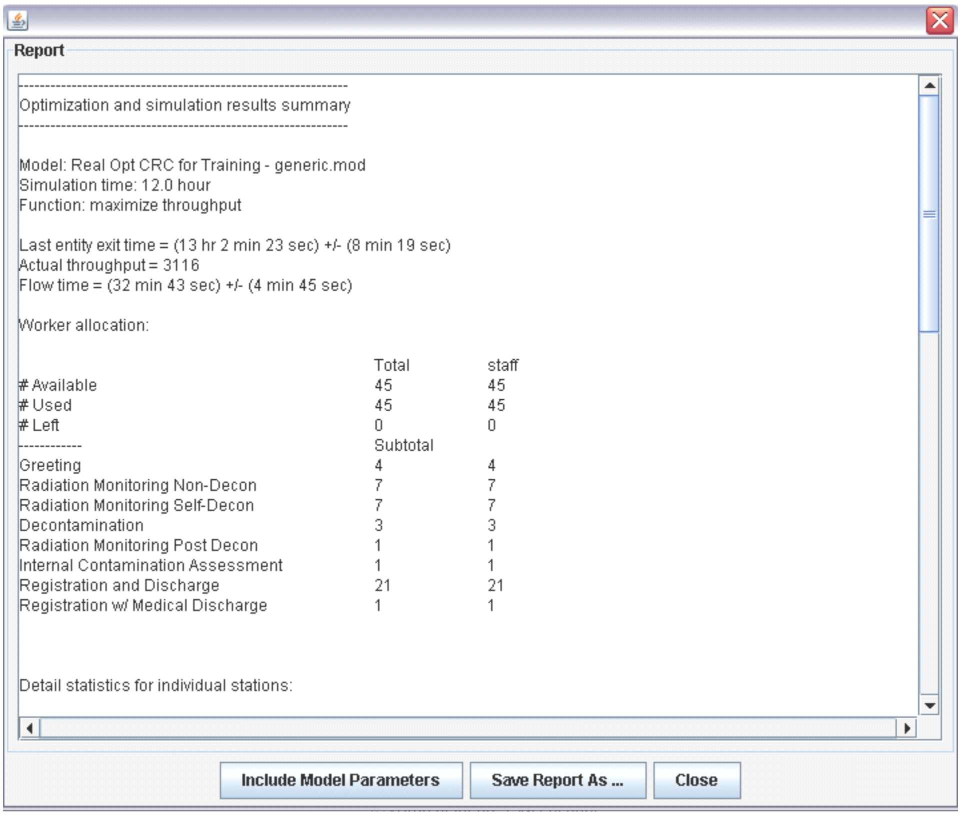
1.1. Base case (no limit on the number of available detection instruments)
Open the file Real Opt CRC for Training - generic.mod. To set up the available number of staff members, click on the **Worker Types** panel and type in the available number. In this example we assume there are 45 staff members available. Remember to press the **Enter key** after typing in the number.



The **Maximize Throughput** function can be found in the main toolbar. (Run→Maximize Throughput)



After running **Maximize Throughput**, an output window similar to the following will pop up automatically.



Details of this output are documented below:

--

Optimization and simulation results summary

--

Model: Real Opt CRC for Training - generic.mod
Simulation time: 12.0 hour
Function: maximize throughput

Last entity exit time = (13 hr 2 min 23 sec) +/- (8 min 19 sec)
Actual throughput = 3116
Flow time = (32 min 43 sec) +/- (4 min 45 sec)

Worker allocation: (Note that since there is only one type of staff in this example, the column labeled 'staff' is identical to the 'Total' column. If there were multiple staff types, there would be multiple columns to the right of 'Total', each column corresponding one staff type.)

	Total	*staff*
# Available	*45*	*45*

# Used	*45*	*45*
# Left	*0*	*0*
------------	*Subtotal*	
Greeting	*4*	*4*
Radiation Monitoring Non-Decon	*7*	*7*
Radiation Monitoring Self-Decon	*7*	*7*
Decontamination	*3*	*3*
Radiation Monitoring Post Decon	*1*	*1*
Internal Contamination Assessment	*1*	*1*
Registration and Discharge	*21*	*21*
Registration w/ Medical Discharge	*1*	*1*

Detail statistics for individual stations:

Greeting
..Queue length = 38 +/- 12
..Waiting time = (9 min 44 sec) +/- (3 min 5 sec)
..Num of workers = 4
..Utilization = 92.5% +/- 1.3%

Radiation Monitoring Non-Decon
..Queue length = 19 +/- 9
..Waiting time = (9 min 52 sec) +/- (4 min 40 sec)
..Num of workers = 7
..Utilization = 94.9% +/- 0.8%

Radiation Monitoring Self-Decon
..Queue length = 25 +/- 9
..Waiting time = (12 min 27 sec) +/- (4 min 28 sec)
..Num of workers = 7
..Utilization = 95.1% +/- 2.2%

Decontamination
..Queue length = 1 +/- 0
..Waiting time = (7 min 20 sec) +/- (2 min 53 sec)
..Num of workers = 3
..Utilization = 80.0% +/- 4.2%

Radiation Monitoring Post Decon
..Queue length = 0 +/- 0
..Waiting time = (1 min 46 sec) +/- (19 sec)
..Num of workers = 1
..Utilization = 71.7% +/- 4.0%

Internal Contamination Assessment
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 1
..Utilization = 4.0% +/- 2.1%

Registration and Discharge
..Queue length = 4 +/- 0
..Waiting time = (1 min 10 sec) +/- (12 sec)
..Num of workers = 21
..Utilization = 94.7% +/- 0.9%

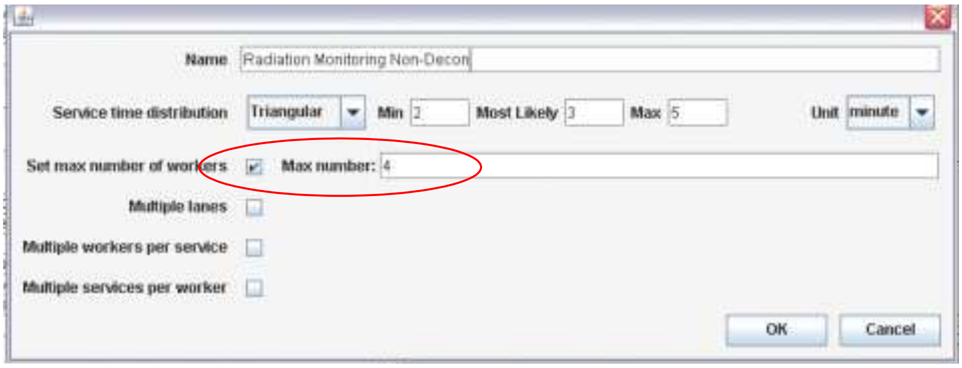
Registration w/ Medical Discharge
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 1
..Utilization = 2.4% +/- 1.1%

Note that Greeting, Radiation Monitoring Non-Decon, Radiation Monitoring Self-Decon, and Registration and Discharge all have utilization above 90%. Stations with highest utilization are usually considered as *bottlenecks*.

1.2. Limitation on number of workers assigned in some stations

Suppose there are only 9 detection instruments. We assume there are at most 4 in the Radiation Monitoring Non-Decon station, at most 4 in the Radiation Monitoring Self-Decon station, and at most 1 in the Radiation Monitoring Post Decon station (Users can choose any combination as along as the total sums up to 9). Use the **Set max number of workers** option in the process dialog to setup the max number. The following figure shows the process dialog of Radiation Monitoring Non-Decon station. By double-clicking the process block of Radiation Monitoring Self-Decon/Post Decon station, a similar dialog will pop up.

Remember to press **OK** to finish setting up this parameter.



After running the **Maximize Throughput** function, we obtain the following results:

Optimization and simulation results summary

Model: Real Opt CRC for Training - generic.mod

Simulation time: 12.0 hour

Function: maximize throughput

Last entity exit time = (13 hr 18 min 37 sec) +/- (8 min 21 sec)

Actual throughput = 1818

Flow time = (34 min 3 sec) +/- (4 min 45 sec)

Worker allocation:

	Total	*staff*
# Available	*45*	*45*
# Used	*28*	*28*
# Left	*17*	*17*
------------	*Subtotal*	
Greeting	*3*	*3*
Radiation Monitoring Non-Decon	*4*	*4*
Radiation Monitoring Self-Decon	*4*	*4*
Decontamination	*2*	*2*
Radiation Monitoring Post Decon	*1*	*1*
Internal Contamination Assessment	*1*	*1*
Registration and Discharge	*12*	*12*

Registration w/ Medical Discharge 1 1

Detail statistics for individual stations:

Greeting
..Queue length = 1 +/- 0
..Waiting time = (29 sec) +/- (5 sec)
..Num of workers = 3
..Utilization = 70.1% +/- 0.8%

Radiation Monitoring Non-Decon
..Queue length = 18 +/- 5
..Waiting time = (16 min 39 sec) +/- (4 min 54 sec)
..Num of workers = 4
..Utilization = 93.9% +/- 2.2%

Radiation Monitoring Self-Decon
..Queue length = 30 +/- 9
..Waiting time = (26 min 26 sec) +/- (7 min 57 sec)
..Num of workers = 4
..Utilization = 96.5% +/- 1.5%

Decontamination
..Queue length = 0 +/- 0
..Waiting time = (5 min 26 sec) +/- (2 min 42 sec)
..Num of workers = 2
..Utilization = 68.0% +/- 4.7%

Radiation Monitoring Post Decon
..Queue length = 0 +/- 0
..Waiting time = (27 sec) +/- (3 sec)
..Num of workers = 1
..Utilization = 41.8% +/- 2.5%

Internal Contamination Assessment
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 1

..Utilization = 2.0% +/- 1.2%

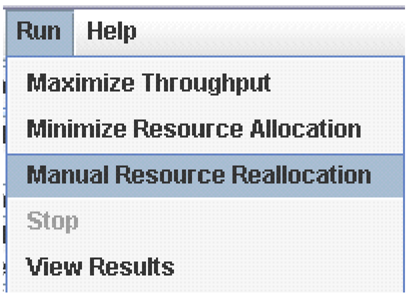
Registration and Discharge
..Queue length = 3 +/- 1
..Waiting time = (1 min 27 sec) +/- (29 sec)
..Num of workers = 12
..Utilization = 94.4% +/- 0.7%

Registration w/ Medical Discharge
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 1
..Utilization = 1.1% +/- 0.6%

Observe that the two services: Radiation Monitoring Self-Decon/Non-Decon with max number of workers as specified present high resource utilization (and thus are bottlenecks), whereas the Radiation Monitoring Post Decon has a low utilization, even though the maximum number of workers is set to 1. Registration and Discharge also has a high utilization rate. Further, in this example, Radiation Monitoring Non-Decon and Radiation Monitoring Self-Decon are the stations with *limiting resources,* because the assignment reaches the maximum number of workers allowed.

RealOpt-CRC© provides the **Manual Resource Reallocation** function to allow users to manually modify an existing optimal staffing assignment. For example, users can assign extra workers to a station with high utilization or with a long queue. The Manual Assignment table can be found in the **Worker Types** panel. Users can reallocate workers by changing the numbers in this table.

The **Manual Resource Reallocation** function can be found in the main toolbar. (Run→Manual Resource Reallocation)



Notice that by running the **Manual Resource Reallocation** function, RealOpt-CRC© only reallocates the original workload within each station to the new workforce. Hence, increasing the worker numbers can effectively lower the utilization, reduce the queue length, wait time, and flow time. In the following example, the number of workers assigned to Registration and Discharge station is increased from 12 to 16. Users can perform this increase because adding 4 workers still maintain the total worker usage to be within the 45 limit. Note also in this case, we cannot increase workers for Radiation Monitoring Non-Decon and Radiation Monitoring Self-Decon because the current maximum of 4 workers has been achieved for each of these stations.

Before manual reallocation		**After manual reallocation**	
Manual Assignment		**Manual Assignment**	
Greeting	3	Greeting	3
Radiation Monitoring Non-Decon	4	Radiation Monitoring Non-Decon	4
Radiation Monitoring Self-Decon	4	Radiation Monitoring Self-Decon	4
Decontamination	2	Decontamination	2
Radiation Monitoring Post Decon	1	Radiation Monitoring Post Decon	1
Internal Contamination Assessment	1	Internal Contamination Assessment	1
Registration and Discharge	12	Registration and Discharge	16
Registration w/ Medical Discharge	1	Registration w/ Medical Discharge	1

After running **Manual Resource Reallocation** function, users should see the following results:

--

Optimization and simulation results summary

--

Model: Real Opt CRC for Training - generic.mod
Simulation time: 12.0 hour
Function: maximize throughput

Last entity exit time = (13 hr 20 min 5 sec) +/- (10 min 29 sec)
Actual throughput = 1818
Flow time = (32 min 9 sec) +/- (5 min 27 sec)

Worker allocation:

Total staff

# Available	*45*	*45*
# Used	*32*	*32*
# Left	*13*	*13*
------------	*Subtotal*	
Greeting	*3*	*3*
Radiation Monitoring Non-Decon	*4*	*4*
Radiation Monitoring Self-Decon	*4*	*4*
Decontamination	*2*	*2*
Radiation Monitoring Post Decon	*1*	*1*
Internal Contamination Assessment	*1*	*1*
Registration and Discharge	*16*	*16*
Registration w/ Medical Discharge	*1*	*1*

Detail statistics for individual stations:

Greeting
..Queue length = 1 +/- 0
..Waiting time = (29 sec) +/- (4 sec)
..Num of workers = 3
..Utilization = 70.0% +/- 0.8%

Radiation Monitoring Non-Decon
..Queue length = 26 +/- 8
..Waiting time = (22 min 37 sec) +/- (7 min 31 sec)
..Num of workers = 4
..Utilization = 95.9% +/- 1.3%

Radiation Monitoring Self-Decon
..Queue length = 22 +/- 9
..Waiting time = (19 min 46 sec) +/- (7 min 39 sec)
..Num of workers = 4
..Utilization = 94.2% +/- 2.5%

Decontamination
..Queue length = 0 +/- 0
..Waiting time = (4 min 25 sec) +/- (1 min 9 sec)
..Num of workers = 2
..Utilization = 67.9% +/- 3.9%

Radiation Monitoring Post Decon
..Queue length = 0 +/- 0
..Waiting time = (28 sec) +/- (2 sec)
..Num of workers = 1
..Utilization = 41.6% +/- 2.5%

Internal Contamination Assessment
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 1
..Utilization = 1.6% +/- 1.0%

Registration and Discharge
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 16
..Utilization = 70.9% +/- 0.8%

Registration w/ Medical Discharge
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 1
..Utilization = 0.7% +/- 0.4%

The following comparison shows increasing the number of workers assigned to Registration and Discharge station effectively reduces the queue length, waiting time, and utilization in this station.

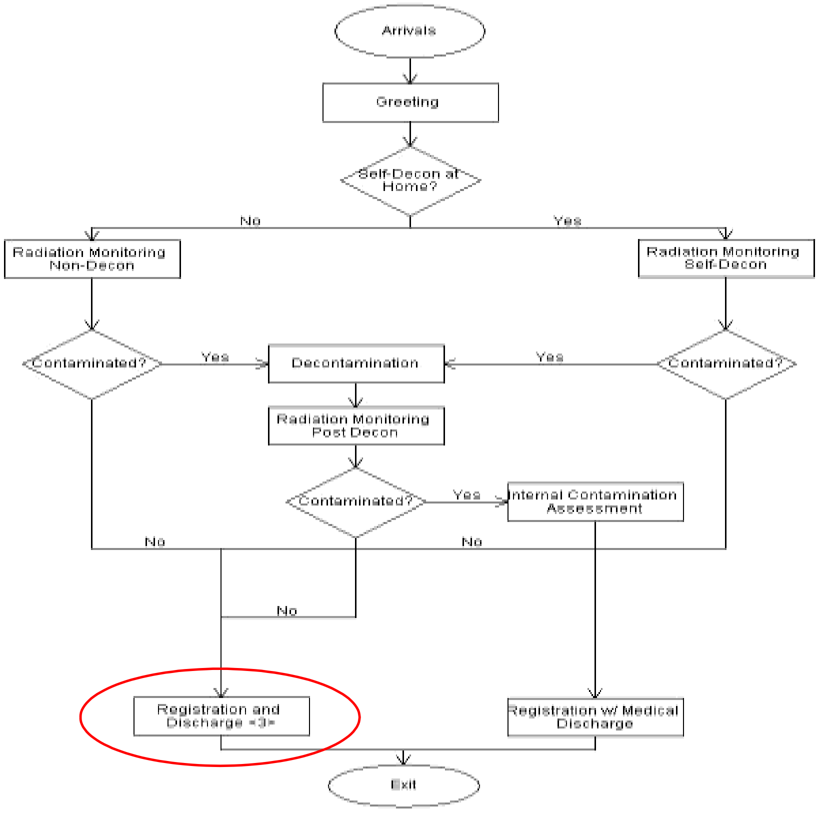
Before manual reallocation	**After manual reallocation**
Registration and Discharge ..Queue length = 3 +/- 1 ..Waiting time = (1 min 27 sec) +/- (29 sec) ..Num of workers = 12 ..Utilization = 94.4% +/- 0.7%	**Registration and Discharge** **..Queue length = 0 +/- 0** **..Waiting time = (0 sec) +/- (0 sec)** **..Num of workers = 16** **..Utilization = 70.9% +/- 0.8%**

Keep in mind that using **Manual Resource Reallocation *does not*** influence the achieved throughput. To calculate potential improved throughout by assigning additional workers, use the **Maximize Throughput** function.

1.3. Multiple services per worker

RealOpt-CRC© allows users to define **Multiple services per worker**. This parameter can be found in the Process dialog. Process dialog will pop up by double-clicking the process block in the model. In this example we set the registration service ratio as 3. In other words, each worker assigned to Registration and Discharge station can oversee three services simultaneously. We still assume the max number of workers on Radiation Monitoring Non-Decon station and Radiation Monitoring Self-Decon station is 4 for each, and at most 1 in the Radiation Monitoring Post Decon station.

Click **OK** to finish and go back to the model. Users will notice that the caption in the Registration and Discharge block is now appended with **"<3>"** to explicitly show this parameter.



After running the **Maximize Throughput** function, users should see the following results:

--

Optimization and simulation results summary

--

Model: Real Opt CRC for Training - generic.mod
Simulation time: 12.0 hour
Function: maximize throughput

Last entity exit time = (13 hr 18 min 37 sec) +/- (8 min 21 sec)
Actual throughput = 1818
Flow time = (34 min 3 sec) +/- (4 min 45 sec)

Worker allocation:

	Total	*staff*
# Available	*45*	*45*
# Used	*20*	*20*
# Left	*25*	*25*

------------	Subtotal	
Greeting	*3*	*3*
Radiation Monitoring Non-Decon	*4*	*4*
Radiation Monitoring Self-Decon	*4*	*4*
Decontamination	*2*	*2*
Radiation Monitoring Post Decon	*1*	*1*
Internal Contamination Assessment	*1*	*1*
Registration and Discharge<3>	***4***	***4***
Registration w/ Medical Discharge	*1*	*1*

Detail statistics for individual stations:

Greeting
..Queue length = 1 +/- 0
..Waiting time = (29 sec) +/- (5 sec)
..Num of workers = 3
..Utilization = 70.1% +/- 0.8%

Radiation Monitoring Non-Decon
..Queue length = 18 +/- 5
..Waiting time = (16 min 39 sec) +/- (4 min 54 sec)
..Num of workers = 4
..Utilization = 93.9% +/- 2.2%

Radiation Monitoring Self-Decon
..Queue length = 30 +/- 9
..Waiting time = (26 min 26 sec) +/- (7 min 57 sec)
..Num of workers = 4
..Utilization = 96.5% +/- 1.5%

Decontamination
..Queue length = 0 +/- 0
..Waiting time = (5 min 26 sec) +/- (2 min 42 sec)
..Num of workers = 2
..Utilization = 68.0% +/- 4.7%

Radiation Monitoring Post Decon
..Queue length = 0 +/- 0

..Waiting time = (27 sec) +/- (3 sec)
..Num of workers = 1
..Utilization = 41.8% +/- 2.5%

Internal Contamination Assessment
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 1
..Utilization = 2.0% +/- 1.2%

Registration and Discharge
..Queue length = 3 +/- 1
..Waiting time = (1 min 27 sec) +/- (29 sec)
..Num of workers = 4
..Utilization = 94.4% +/- 0.7%

Registration w/ Medical Discharge
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 1
..Utilization = 1.1% +/- 0.6%

Now the results show that only 20 workers are used, with 4 workers used in Registration and Discharge station.

Concluding remarks

By comparing the base case in which there is no limit on the number of available detection instruments, the case with limitation on the number of detection instruments and corresponding limits on the numbers of workers assigned to certain stations, and the case with multiple services per worker, we observe that the throughput in the base case is the highest. This case allows one to make use of all available workers (45) and achieves a maximum throughput of 3116. In the case with a limit on the availability of detection instruments, the availability can thus be considered as the limiting factor and the achievable throughput decreases from 3116 to 1818. Lastly, allowing multiple services per worker can effectively reduce the number of workers required without sacrificing the achievable throughput.

Summary of Results

Case	1.1 (base case)	1.2 (9 detection instruments)		1.3 (multiple services per worker)
		1.2.1. Before manual reallocation	1.2.2. After manual reallocation	
RealOpt-CRC function & parameters	Run Maximize Throughput on Real Opt CRC for Training - generic.mod.	Repeat Maximize Throughput, this time set number of detectors to 9	Use 1.2.1 solution, run Manual Resource Allocation by increasing 4 workers in the Registration and Discharge station	Run Maximize Throughput with 9 detectors, and Registration and Discharge station set to 3 services per worker
Last entity exit time	(13 hr 2 min 23 sec) +/- (8 min 19 sec)	(13 hr 18 min 37 sec) +/- (8 min 21 sec)	(13 hr 20 min 5 sec) +/- (10 min 29 sec)	(13 hr 18 min 37 sec) +/- (8 min 21 sec)
Actual throughput	3116	1818	1818	1818
Flow time	(32 min 43 sec) +/- (4 min 45 sec)	(34 min 3 sec) +/- (4 min 45 sec)	(32 min 9 sec) +/- (5 min 27 sec)	(34 min 3 sec) +/- (4 min 45 sec)
Worker used	45	28	32	20
Detail statistics	Greeting ..Queue length = 38 +/- 12 ..Waiting time = (9 min 44 sec) +/- (3 min 5 sec) ..Num of workers = 4 ..Utilization = 92.5% +/- 1.3%	Greeting ..Queue length = 1 +/- 0 ..Waiting time = (29 sec) +/- (5 sec) ..Num of workers = 3 ..Utilization = 70.1% +/- 0.8%	Greeting ..Queue length = 1 +/- 0 ..Waiting time = (29 sec) +/- (4 sec) ..Num of workers = 3 ..Utilization = 70.0% +/- 0.8%	Greeting ..Queue length = 1 +/- 0 ..Waiting time = (29 sec) +/- (5 sec) ..Num of workers = 3 ..Utilization = 70.1% +/- 0.8%
	Radiation Monitoring Non-Decon ..Queue length = 19 +/- 9 ..Waiting time = (9 min 52 sec) +/- (4 min 40 sec) ..Num of workers = 7 ..Utilization = 94.9% +/- 0.8%	Radiation Monitoring Non-Decon ..Queue length = 18 +/- 5 ..Waiting time = (16 min 39 sec) +/- (4 min 54 sec) ..Num of workers = 4 ..Utilization = 93.9% +/- 2.2%	Radiation Monitoring Non-Decon ..Queue length = 26 +/- 8 ..Waiting time = (22 min 37 sec) +/- (7 min 31 sec) ..Num of workers = 4 ..Utilization = 95.9% +/- 1.3%	Radiation Monitoring Non-Decon ..Queue length = 18 +/- 5 ..Waiting time = (16 min 39 sec) +/- (4 min 54 sec) ..Num of workers = 4 ..Utilization = 93.9% +/- 2.2%
	Radiation Monitoring Self-Decon ..Queue length = 25 +/- 9 ..Waiting time = (12 min 27 sec) +/- (4 min 28 sec) ..Num of workers = 7 ..Utilization = 95.1% +/- 2.2%	Radiation Monitoring Self-Decon ..Queue length = 30 +/- 9 ..Waiting time = (26 min 26 sec) +/- (7 min 57 sec) ..Num of workers = 4 ..Utilization = 96.5% +/- 1.5%	Radiation Monitoring Self-Decon ..Queue length = 22 +/- 9 ..Waiting time = (19 min 46 sec) +/- (7 min 39 sec) ..Num of workers = 4 ..Utilization = 94.2% +/- 2.5%	Radiation Monitoring Self-Decon ..Queue length = 30 +/- 9 ..Waiting time = (26 min 26 sec) +/- (7 min 57 sec) ..Num of workers = 4 ..Utilization = 96.5% +/- 1.5%
	Decontamination ..Queue length = 1 +/- 0 ..Waiting time = (7 min 20 sec) +/- (2 min 53 sec) ..Num of workers = 3 ..Utilization = 80.0% +/- 4.2%	Decontamination ..Queue length = 0 +/- 0 ..Waiting time = (5 min 26 sec) +/- (2 min 42 sec) ..Num of workers = 2 ..Utilization = 68.0% +/- 4.7%	Decontamination ..Queue length = 0 +/- 0 ..Waiting time = (4 min 25 sec) +/- (1 min 9 sec) ..Num of workers = 2 ..Utilization = 67.9% +/- 3.9%	Decontamination ..Queue length = 0 +/- 0 ..Waiting time = (5 min 26 sec) +/- (2 min 42 sec) ..Num of workers = 2 ..Utilization = 68.0% +/- 4.7%

	Radiation Monitoring Post Decon ..Queue length = 0 +/- 0 ..Waiting time = (1 min 46 sec) +/- (19 sec) ..Num of workers = 1 ..Utilization = 71.7% +/- 4.0%	Radiation Monitoring Post Decon ..Queue length = 0 +/- 0 ..Waiting time = (27 sec) +/- (3 sec) ..Num of workers = 1 ..Utilization = 41.8% +/- 2.5%	Radiation Monitoring Post Decon ..Queue length = 0 +/- 0 ..Waiting time = (28 sec) +/- (2 sec) ..Num of workers = 1 ..Utilization = 41.6% +/- 2.5%	Radiation Monitoring Post Decon ..Queue length = 0 +/- 0 ..Waiting time = (27 sec) +/- (3 sec) ..Num of workers = 1 ..Utilization = 41.8% +/- 2.5%
	Internal Contamination Assessment ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 1 ..Utilization = 4.0% +/- 2.1%	Internal Contamination Assessment ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 1 ..Utilization = 2.0% +/- 1.2%	Internal Contamination Assessment ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 1 ..Utilization = 1.6% +/- 1.0%	Internal Contamination Assessment ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 1 ..Utilization = 2.0% +/- 1.2%
	Registration and Discharge ..Queue length = 4 +/- 0 ..Waiting time = (1 min 10 sec) +/- (12 sec) ..Num of workers = 21 ..Utilization = 94.7% +/- 0.9%	Registration and Discharge ..Queue length = 3 +/- 1 ..Waiting time = (1 min 27 sec) +/- (29 sec) ..Num of workers = 12 ..Utilization = 94.4% +/- 0.7%	Registration and Discharge ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 16 ..Utilization = 70.9% +/- 0.8%	Registration and Discharge ..Queue length = 3 +/- 1 ..Waiting time = (1 min 27 sec) +/- (29 sec) ..Num of workers = 4 ..Utilization = 94.4% +/- 0.7%
	Registration w/ Medical Discharge ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 1 ..Utilization = 2.4% +/- 1.1%	Registration w/ Medical Discharge ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 1 ..Utilization = 1.1% +/- 0.6%	Registration w/ Medical Discharge ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 1 ..Utilization = 0.7% +/- 0.4%	Registration w/ Medical Discharge ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 1 ..Utilization = 1.1% +/- 0.6%

Practice Scenarios-Case Study 2:

"Now that I know what my current throughput is, how can I determine the best use for 5 additional workers who show up to assist?"

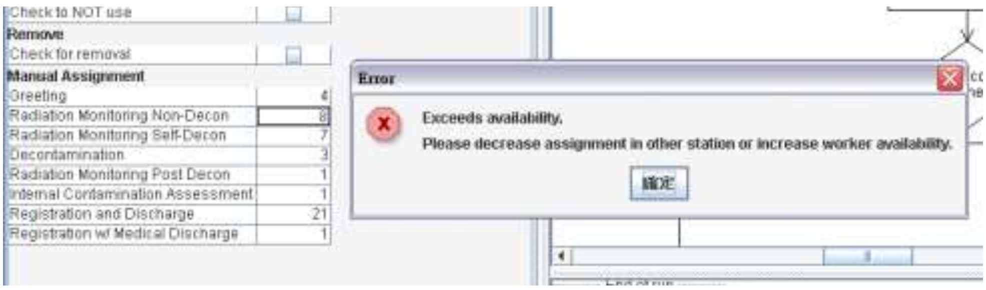
Identify bottlenecks

As mentioned in Case Study 1, stations with the highest utilization are usually considered as *bottlenecks*. In those examples with and without limitation on number of workers assigned to some stations in Case Study 1, we can easily identify that Radiation Monitoring Non-Decon station, Radiation Monitoring Self-Decon station, and Registration with Discharge station have the highest utilizations. These three stations can thus be considered as bottlenecks.

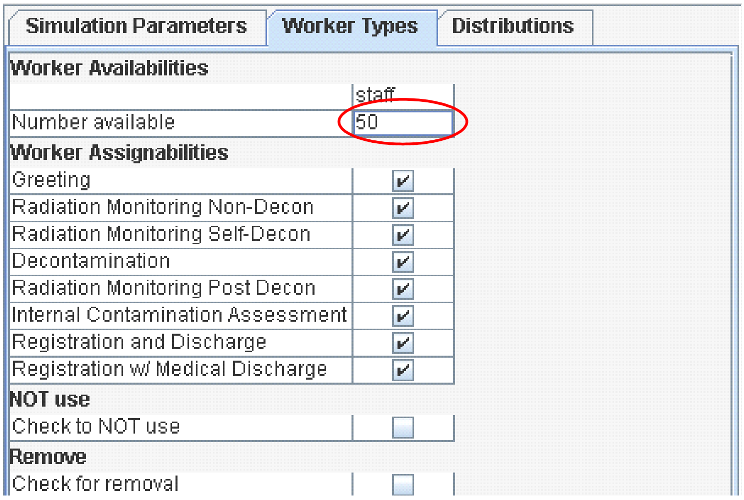
2.1. Adding extra workers to bottlenecks via the Manual Resource Reallocation function

In case 1.1 when all 45 workers were assigned, we identified that Radiation Monitoring Non-Decon station, Radiation Monitoring Self-Decon, and Registration and Discharge station present the highest utilizations. By adding more worker(s) to each of these stations and running **Manual Resource Reallocation** function, we can significantly improve the utilization, queue length, and waiting time of those three stations. In addition, the flow time and last entity exit time can also be reduced significantly. We will illustrate the steps to arrive at this result below.

Before adding more worker(s) to each of the three stations and running the **Manual Resource Reallocation** function, users must increase worker availability or decrease assignment in other station(s) first since the original 45 workers are completely assigned. Users should see the error message as illustrated below if they add workers to stations manually without increasing the worker availability or decrease assignment first.



To modify the available number of staff members, users should use the **Worker Types** panel and type in the available number. In this example originally there are 45 workers available. With 5 additional workers, the total number of staff becomes 50. Users should remember to press the **Enter key** after typing in the number.



We next increase the worker assignment in the manual panel of the three stations

Before manual reallocation		After manual reallocation	
Manual Assignment		**Manual Assignment**	
Greeting	4	Greeting	4
Radiation Monitoring Non-Decon	7	Radiation Monitoring Non-Decon	9
Radiation Monitoring Self-Decon	7	Radiation Monitoring Self-Decon	9
Decontamination	3	Decontamination	3
Radiation Monitoring Post Decon	1	Radiation Monitoring Post Decon	1
Internal Contamination Assessment	1	Internal Contamination Assessment	1
Registration and Discharge	21	Registration and Discharge	22
Registration w/ Medical Discharge	1	Registration w/ Medical Discharge	1

Note that this manual re-optimization is possible with the assumption that there are extra detection instruments that one can use (for the extra workers available). Otherwise, the 5 extra workers should be assigned to other stations.

We compare the output in the table below.

Before manual reallocation			After manual reallocation		
	Total	staff		Total	staff
# Available	45	45	# Available	50	50
# Used	**45**	**45**	**# Used**	**50**	**50**
# Left	0	0	# Left	0	0
Flow time = (32 min 43 sec) +/- (4 min 45 sec)			Flow time = (18 min 28 sec) +/- (3 min 52 sec)		

Last entity exit time = (13 hr 2 min 23 sec) +/- (8 min 19 sec)	Last entity exit time = (12 hr 38 min 3 sec) +/- (9 min 32 sec)
Radiation Monitoring Non-Decon ..Queue length = 19 +/- 9 ..Waiting time = (9 min 52 sec) +/- (4 min 40 sec) **..Num of workers = 7** ..Utilization = 94.9% +/- 0.8%	Radiation Monitoring Non-Decon ..Queue length = 0 +/- 0 ..Waiting time = (12 sec) +/- (1 sec) **..Num of workers = 9** ..Utilization = 76.7% +/- 1.2%
Radiation Monitoring Self-Decon ..Queue length = 25 +/- 9 ..Waiting time = (12 min 27 sec) +/- (4 min 28 sec) **..Num of workers = 7** ..Utilization = 95.1% +/- 2.2%	Radiation Monitoring Self-Decon ..Queue length = 0 +/- 0 ..Waiting time = (12 sec) +/- (2 sec) **..Num of workers = 9** ..Utilization = 75.9% +/- 1.3%
Registration and Discharge ..Queue length = 4 +/- 0 ..Waiting time = (1 min 10 sec) +/- (12 sec) **..Num of workers = 21** ..Utilization = 94.7% +/- 0.9%	Registration and Discharge ..Queue length = 3 +/- 0 ..Waiting time = (51 sec) +/- (12 sec) **..Num of workers = 22** ..Utilization = 93.6% +/- 1.1%

A similar improvement can also be observed for Case 1.2, in which limited detection instruments are available. In this example the throughput can achieve as high as 1818 per 12 hours when 9 detection instruments are available. We can improve the various bottlenecks if some of these 5 extra workers come along with the detection devices, then we can add some of these workers to Radiation Monitoring Non-Decon station, some to Radiation Monitoring Self-Decon station, and the remaining worker without devices to Registration and Discharge station. Assume among the 5 extra workers, 4 come with the detection device. As a result, we can reassign the workers as follows:

Before manual reallocation		**After manual reallocation**	
Manual Assignment		**Manual Assignment**	
Greeting	3	Greeting	3
Radiation Monitoring Non-Decon	4	Radiation Monitoring Non-Decon	6
Radiation Monitoring Self-Decon	4	Radiation Monitoring Self-Decon	6
Decontamination	2	Decontamination	2
Radiation Monitoring Post Decon	1	Radiation Monitoring Post Decon	1
Internal Contamination Assessment	1	Internal Contamination Assessment	1
Registration and Discharge	12	Registration and Discharge	13
Registration w/ Medical Discharge	1	Registration w/ Medical Discharge	1

The result is contrasted as follows:

Before manual reallocation			**After manual reallocation**		
	Total	staff		Total	staff
# Available	45	45	# Available	50	50
# Used	**28**	**28**	**# Used**	**33**	**33**
# Left	17	17	# Left	12	12
Flow time = (34 min 3 sec) +/- (4 min 45 sec)			Flow time = (14 min 46 sec) +/- (1 min 17 sec)		

Last entity exit time = (13 hr 18 min 37 sec) +/- (8 min 21 sec)	Last entity exit time = (12 hr 35 min 57 sec) +/- (18 min 11 sec)
Radiation Monitoring Non-Decon ..Queue length = 18 +/- 5 ..Waiting time = (16 min 39 sec) +/- (4 min 54 sec) **..Num of workers = 4** ..Utilization = 93.9% +/- 2.2%	Radiation Monitoring Non-Decon ..Queue length = 0 +/- 0 ..Waiting time = (15 sec) +/- (3 sec) **..Num of workers = 6** ..Utilization = 67.2% +/- 2.3%
Radiation Monitoring Self-Decon ..Queue length = 30 +/- 9 ..Waiting time = (26 min 26 sec) +/- (7 min 57 sec) **..Num of workers = 4** ..Utilization = 96.5% +/- 1.5%	Radiation Monitoring Self-Decon ..Queue length = 0 +/- 0 ..Waiting time = (14 sec) +/- (2 sec) **..Num of workers = 6** ..Utilization = 66.8% +/- 1.7%
Registration and Discharge ..Queue length = 3 +/- 1 ..Waiting time = (1 min 27 sec) +/- (29 sec) **..Num of workers = 12** ..Utilization = 94.4% +/- 0.7%	Registration and Discharge ..Queue length = 8 +/- 3 ..Waiting time = (3 min 36 sec) +/- (1 min 17 sec) **..Num of workers = 13** ..Utilization = 92.6% +/- 2.0%

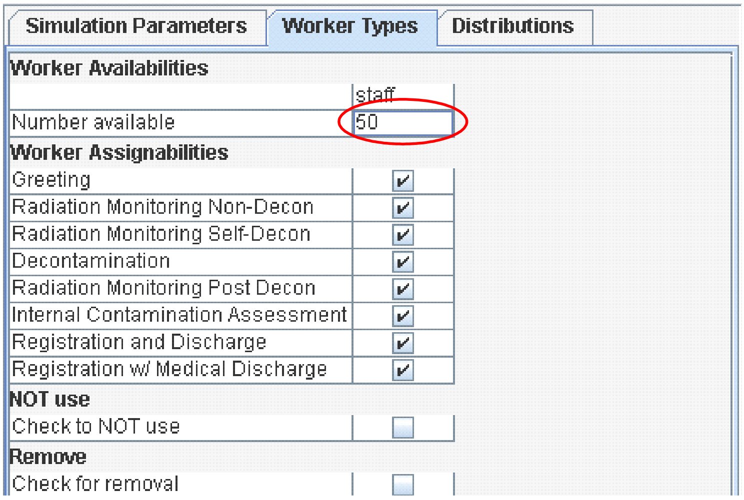
This illustrates that even though we have extra workers, some bottleneck processes still remain since there is a limitation on the availability of instruments. Note that Registration and Discharge utilization still remains high and waiting time at this station increases. Freeing the Radiation Monitoring bottleneck enables people to reach Registration and Discharge more rapidly, therefore creating a slight back up at Registration and Discharge. As resources become available, it would be advantageous to add a few more workers to this station.

As a reminder, **Manual Resource Reallocation *does not*** influence the achieved throughput. Rather, it improves the service received by improving utilization, queue length, wait time, and flow time. For users who desire to improve throughput with the additional labor resources, the **Maximize Throughput** function should be used.

2.2. Maximize throughput by using the extra 5 workers (without limitation on detection instruments)

To assign the extra 5 workers in an *optimal fashion*, use the **Maximize Throughput** function instead of the **Manual Resource Reallocation** function.

To modify the available number of staff members, use the **Worker Types** panel and type in the available number. In this example we assume there are originally 45 staff available. After adding 5 extra workers there are now 50 staff available. Remember to press the **Enter key** after typing in the number.



If there is no limit on the availability of detection instruments, after running the **Maximize Throughput** function, we obtain the following results:

Optimization and simulation results summary

Model: Real Opt CRC for Training - generic.mod
Simulation time: 12.0 hour
Function: maximize throughput

Last entity exit time = (13 hr 11 min 8 sec) +/- (6 min 59 sec)
Actual throughput = 3543
Flow time = (42 min 5 sec) +/- (2 min 54 sec)

Worker allocation:

	Total	*staff*
# Available	*50*	*50*
# Used	*50*	*50*
# Left	*0*	*0*
------------	*Subtotal*	
Greeting	*5*	*5*
Radiation Monitoring Non-Decon	*8*	*8*
Radiation Monitoring Self-Decon	*8*	*8*
Decontamination	*3*	*3*
Radiation Monitoring Post Decon	*1*	*1*

Internal Contamination Assessment	*1*	*1*
Registration and Discharge	*23*	*23*
Registration w/ Medical Discharge	*1*	*1*

Detail statistics for individual stations:

Greeting
..Queue length = 4 +/- 0
..Waiting time = (57 sec) +/- (11 sec)
..Num of workers = 5
..Utilization = 82.5% +/- 0.8%

Radiation Monitoring Non-Decon
..Queue length = 36 +/- 10
..Waiting time = (16 min 8 sec) +/- (4 min 26 sec)
..Num of workers = 8
..Utilization = 92.9% +/- 1.1%

Radiation Monitoring Self-Decon
..Queue length = 44 +/- 11
..Waiting time = (19 min 52 sec) +/- (4 min 47 sec)
..Num of workers = 8
..Utilization = 94.1% +/- 1.4%

Decontamination
..Queue length = 2 +/- 1
..Waiting time = (11 min 33 sec) +/- (4 min 48 sec)
..Num of workers = 3
..Utilization = 87.1% +/- 4.4%

Radiation Monitoring Post Decon
..Queue length = 0 +/- 0
..Waiting time = (2 min 13 sec) +/- (21 sec)
..Num of workers = 1
..Utilization = 79.2% +/- 3.7%

Internal Contamination Assessment
..Queue length = 0 +/- 0

..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 1
..Utilization = 4.8% +/- 3.2%

Registration and Discharge
..Queue length = 55 +/- 9
..Waiting time = (12 min 17 sec) +/- (2 min 6 sec)
..Num of workers = 23
..Utilization = 97.2% +/- 0.9%

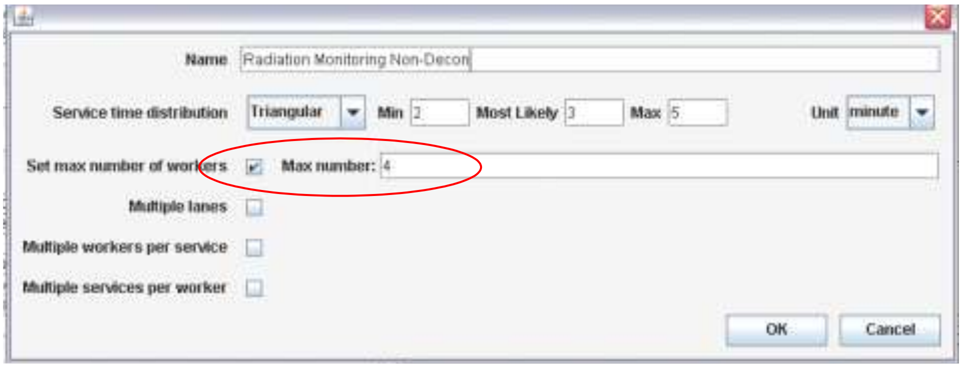
Registration w/ Medical Discharge
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 1
..Utilization = 2.6% +/- 1.5%

Comparing the results with case 1.1, the throughput increases from 3116 to 3543 after assigning 5 extra workers. RealOpt-CRC © ensures the extra 5 workers are assigned optimally.

2.3. Maximize throughput by using the extra 5 workers (with limitation on detection instruments)

2.3.1 Original limitation on detection instruments

By applying the same procedure as in 2.2, in this section we will show how the throughput can be improved by using extra 5 workers when there is limitation on the number of detection instruments. Suppose there remain 9 detection instruments. We again assume there are at most 4 in the Radiation Monitoring Non-Decon station, at most 4 in the Radiation Monitoring Self-Decon station, and at most 1 in the Radiation Monitoring Post-Decon station as in case 1.2. As described before, use the **Set max number of workers** option in the process dialog to setup the max number. The following figure shows the process dialog of Radiation Monitoring Non-Decon station. The same figure can be found in case 1.2.



After running the **Maximize Throughput** function, the following results are obtained:

Optimization and simulation results summary

Model: Real Opt CRC for Training - generic.mod
Simulation time: 12.0 hour
Function: maximize throughput

Last entity exit time = (13 hr 18 min 37 sec) +/- (8 min 21 sec)
Actual throughput = 1818
Flow time = (34 min 3 sec) +/- (4 min 45 sec)

Worker allocation:

	Total	*staff*
# Available	*50*	*50*
# Used	*28*	*28*
# Left	*22*	*22*
------------	*Subtotal*	
Greeting	*3*	*3*
Radiation Monitoring Non-Decon	*4*	*4*
Radiation Monitoring Self-Decon	*4*	*4*
Decontamination	*2*	*2*
Radiation Monitoring Post Decon	*1*	*1*
Internal Contamination Assessment	*1*	*1*
Registration and Discharge	*12*	*12*
Registration w/ Medical Discharge	*1*	*1*

Detail statistics for individual stations:

Greeting
..Queue length = 1 +/- 0
..Waiting time = (29 sec) +/- (5 sec)
..Num of workers = 3
..Utilization = 70.1% +/- 0.8%

Radiation Monitoring Non-Decon
..Queue length = 18 +/- 5
..Waiting time = (16 min 39 sec) +/- (4 min 54 sec)
..Num of workers = 4
..Utilization = 93.9% +/- 2.2%

Radiation Monitoring Self-Decon
..Queue length = 30 +/- 9
..Waiting time = (26 min 26 sec) +/- (7 min 57 sec)
..Num of workers = 4
..Utilization = 96.5% +/- 1.5%

Decontamination
..Queue length = 0 +/- 0
..Waiting time = (5 min 26 sec) +/- (2 min 42 sec)
..Num of workers = 2
..Utilization = 68.0% +/- 4.7%

Radiation Monitoring Post Decon
..Queue length = 0 +/- 0
..Waiting time = (27 sec) +/- (3 sec)
..Num of workers = 1
..Utilization = 41.8% +/- 2.5%

Internal Contamination Assessment
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 1
..Utilization = 2.0% +/- 1.2%

Registration and Discharge
..Queue length = 3 +/- 1
..Waiting time = (1 min 27 sec) +/- (29 sec)
..Num of workers = 12
..Utilization = 94.4% +/- 0.7%

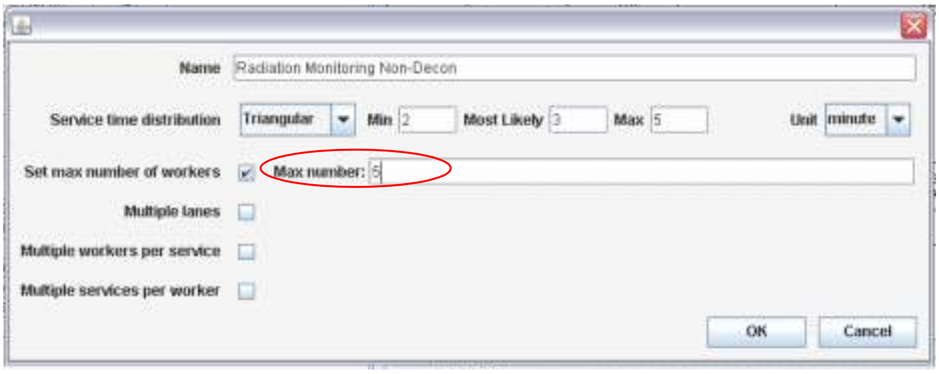
Registration w/ Medical Discharge
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 1
..Utilization = 1.1% +/- 0.6%

Contrary to what was desired, the throughput does not improve after adding 5 extra workers. Actually, this could have been anticipated from the results in Case 1.2, since the original 45 workers were not used up. Consequently, the extra 5 workers are redundant in terms of improving throughput.

This example shows that detection instruments are the critical resource if improved throughput is to be achieved.

2.3.2. Partly relaxed limitation on detection instruments

We will illustrate how throughput will change when the limitation on detection instruments is relaxed. Suppose in addition to 5 extra workers, there is also an increase in detection instruments. In this case, for example, we can modify the maximum number in the Radiation Monitoring Non-Decon station. Double-click the process block in the model and modify the corresponding parameter in the process dialog. The following figure shows that the number of detection instruments available for use in the Radiation Monitoring Non-Decon station has been set to 5 (an increase from the previous value of 4). Remember to press **OK** to finish setting up this parameter.



Configuring the Radiation Monitoring Self-Decon station and Radiation Monitoring Post-Decon station can be done in an identical way.

The table below illustrates several scenarios involving adjustments in available workers, and assignment of available detection instruments to the three monitoring stations. The computed throughput and the number of workers used are reported for each scenario.

Num. of workers available	Max. number of workers*	Actual Throughput (run Maximize Throughput)	Workers used
45	No limit	3116	45
	4-4-1	1818	28
	5-5-2	2309	33
	6-6-2	2617	40
50	No limit	3543	50
	4-4-1	1818	28
	5-5-2	2309	33
	6-6-2	2617	40

*Max. number of workers on Radiation Monitoring Non-Decon station, Radiation Monitoring Self-Decon station, and Radiation Monitoring Post Decon station, respectively.

This table illustrates the significance of detection instruments in increasing throughput. For the case considered, adding an extra 5 workers is helpful to improve throughput only when there is also an increase in detection instruments.

It is possible that extra detection instruments will eventually become redundant and extra workers will become critical in terms of improving throughput if we keep relaxing the limitation on detection instruments.

Concluding remarks

In this section we first illustrated how to identify bottlenecks and to assign extra workers manually to improve the utilization, queue length, and waiting time at bottleneck stations. Specifically, by assigning an additional 5 workers split among three stations (Radiation Monitoring Non-Decon, Radiation Monitoring Self-Decon, and Registration and Discharge), the flow time was reduced from over 30 minutes to about 18 minutes. A similar improvement was observed in the case when we increased the number of detectors from 9 to 14.

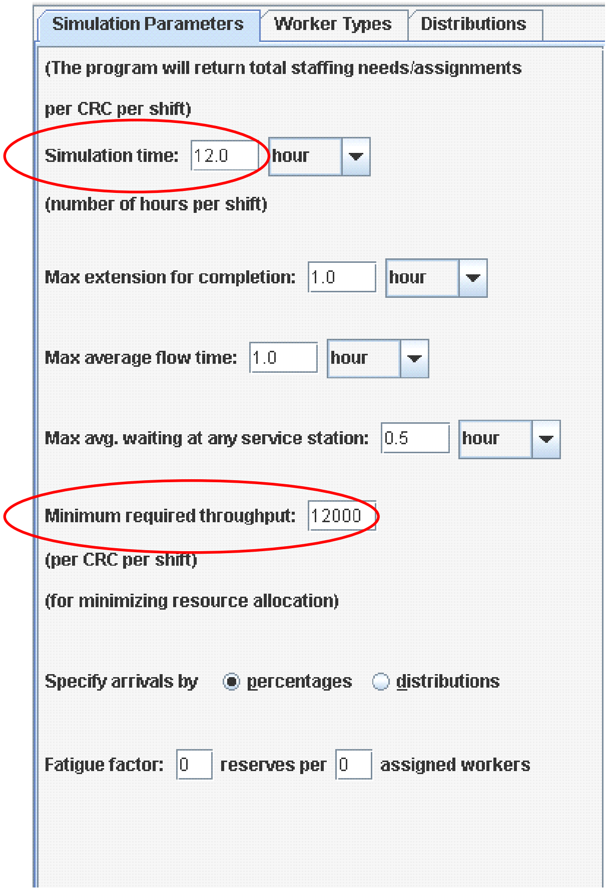
Next, we demonstrated some examples to optimally assign 5 extra workers to **Maximize Throughput** when there was no limitation on detection instruments. We showed that, by optimally assigning 5 extra workers, achievable throughput increased from 3116 to 3543 (in particular, 4 more detectors were needed, because 4 of the extra workers were assigned to the radiation monitoring stations). However, when number of detection instruments was limited to the original 9, the extra 5 workers were redundant in terms of improving throughput. On the other hand, by gradually relaxing the limitation on detection instruments, the achievable throughput was improved from 1818 to 2309 if 3 out of the 5 extra workers were equipped with detection devices, and improved from 1818 to 2617 if all 5 extra workers were equipped. We thus concluded that detection instruments are the critical resource if improved throughput is to be achieved.

Practice Scenarios-Case Study 3:

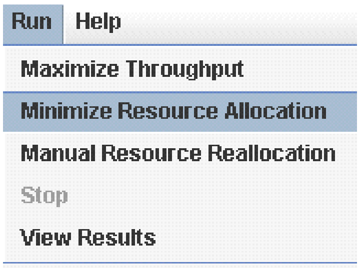
"My goal is to process 1000 people per hour. What staffing resources will I need to meet this goal in a 12 hour shift?"

3.1. Base case

Use the **Minimize Resource Allocation** function to determine the optimal resources needed to satisfy a minimum required throughput. The parameters (simulation time of 12 hours, and minimum required throughput of 12000) can be input via the **Simulation Parameters** panel.



The **Minimize Resource Allocation** function can be found in the main toolbar. (Run→Minimize Resource Allocation)



After running **Minimize Resource Allocation**, the following results are obtained:

Optimization and simulation results summary

Model: Real Opt CRC for Training - generic.mod
Simulation time: 12.0 hour
Function: minimize resource allocation
Minimum required throughput: 12000

Last entity exit time = (13 hr 9 min 51 sec) +/- (23 min 7 sec)
Actual throughput = 12000
Flow time = (16 min 36 sec) +/- (1 min 27 sec)

Worker allocation:

	Total	*staff*
# Available	*45*	*45*
# Addn. need	*125*	*125*
# Used	*170*	*170*
# Left	*0*	*0*
------------	*Subtotal*	
Greeting	*16*	*16*
Radiation Monitoring Non-Decon	*28*	*28*
Radiation Monitoring Self-Decon	*28*	*28*
Decontamination	*10*	*10*
Radiation Monitoring Post Decon	*3*	*3*
Internal Contamination Assessment	*1*	*1*
Registration and Discharge	*83*	*83*
Registration w/ Medical Discharge	*1*	*1*

Detail statistics for individual stations:

Greeting
..Queue length = 11 +/- 2
..Waiting time = (45 sec) +/- (8 sec)
..Num of workers = 16
..Utilization = 87.9% +/- 2.5%

Radiation Monitoring Non-Decon
..Queue length = 20 +/- 4
..Waiting time = (2 min 46 sec) +/- (40 sec)
..Num of workers = 28
..Utilization = 90.5% +/- 2.3%

Radiation Monitoring Self-Decon
..Queue length = 28 +/- 14
..Waiting time = (3 min 44 sec) +/- (1 min 50 sec)
..Num of workers = 28
..Utilization = 91.0% +/- 2.9%

Decontamination
..Queue length = 15 +/- 6
..Waiting time = (18 min 11 sec) +/- (7 min 34 sec)
..Num of workers = 10
..Utilization = 92.7% +/- 2.7%

Radiation Monitoring Post Decon
..Queue length = 5 +/- 2
..Waiting time = (5 min 58 sec) +/- (2 min 42 sec)
..Num of workers = 3
..Utilization = 93.6% +/- 2.3%

Internal Contamination Assessment
..Queue length = 0 +/- 0
..Waiting time = (55 sec) +/- (47 sec)
..Num of workers = 1
..Utilization = 13.6% +/- 6.0%

Registration and Discharge

..Queue length = 17 +/- 7
..Waiting time = (1 min 7 sec) +/- (30 sec)
..Num of workers = 83
..Utilization = 91.7% +/- 2.5%

Registration w/ Medical Discharge
..Queue length = 0 +/- 0
..Waiting time = (1 sec) +/- (3 sec)
..Num of workers = 1
..Utilization = 8.3% +/- 3.2%

Observe that in order to achieve the required throughput, 170 workers must be used. Since the number of workers available was set to only 45, the system indicates (in the line labeled **# Addn. need**) that 125 additional workers are needed in order to meet the minimum required throughput. Also observe that the number of detection instruments needed is 59, corresponding to the number of workers assigned to the three monitoring stations.

3.2. What if we have only 9 detection instruments, how long will it take to finish screening of 12,000 people?

We will take the results from 3.1 above, increase the available workers to at least 170, and then perform **Manual Resource Reallocation** by assigning workers appropriately. In this case, we assign 4 workers to the Radiation Monitoring Non-Decon station, 4 to the Radiation Monitoring Self-Decon station, and 1 to the Radiation Monitoring Post Decon station (users can choose any combination as along as the total sums up to 9), as shown in the screenshot below:

Before manual reallocation		**After manual reallocation**	
Manual Assignment		**Manual Assignment**	
Greeting	16	Greeting	16
Radiation Monitoring Non-Decon	28	Radiation Monitoring Non-Decon	4
Radiation Monitoring Self-Decon	28	Radiation Monitoring Self-Decon	4
Decontamination	10	Decontamination	10
Radiation Monitoring Post Decon	3	Radiation Monitoring Post Decon	1
Internal Contamination Assessment	1	Internal Contamination Assessment	1
Registration and Discharge	83	Registration and Discharge	83
Registration w/ Medical Discharge	1	Registration w/ Medical Discharge	1

Running **Manual Resource Reallocation** we obtain the following result, which clearly has undesirable characteristics in terms of flow time, queue lengths and wait times. *Although the solution itself is not practical, it is included here for pedagogical reasons to illustrate potential pitfalls, and how to overcome them.*

--

Optimization and simulation results summary

--

Model: Real Opt CRC for Training - generic.mod
Simulation time: 12.0 hour
Function: minimize resource allocation

Last entity exit time = (3 day 12 hr 29 min 45 sec) +/- (21 min 11 sec)
Actual throughput = 12000
Flow time = (1 day 11 hr 56 min 9 sec) +/- (4 min 20 sec)

Worker allocation:

	Total	*staff*
# Available	*200*	*200*
# Used	*120*	*120*
# Left	*80*	*80*
------------	*Subtotal*	
Greeting	*16*	*16*
Radiation Monitoring Non-Decon	***4***	***4***
Radiation Monitoring Self-Decon	***4***	***4***
Decontamination	*10*	*10*
Radiation Monitoring Post Decon	***1***	***1***
Internal Contamination Assessment	*1*	*1*
Registration and Discharge	*83*	*83*
Registration w/ Medical Discharge	*1*	*1*

Detail statistics for individual stations:

Greeting
..Queue length = 1 +/- 0

..Waiting time = (43 sec) +/- (10 sec)
..Num of workers = 16
..Utilization = 13.6% +/- 0.0%

Radiation Monitoring Non-Decon
..Queue length = 2548 +/- 40
..Waiting time = (1 day 11 hr 48 min 35 sec) +/- (18 min 32 sec)
..Num of workers = 4
..Utilization = 98.9% +/- 0.7%

Radiation Monitoring Self-Decon
..Queue length = 2529 +/- 41
..Waiting time = (1 day 11 hr 41 min 30 sec) +/- (16 min 22 sec)
..Num of workers = 4
..Utilization = 98.7% +/- 0.8%

Decontamination
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 10
..Utilization = 14.5% +/- 0.3%

Radiation Monitoring Post Decon
..Queue length = 0 +/- 0
..Waiting time = (1 min 18 sec) +/- (8 sec)
..Num of workers = 1
..Utilization = 44.2% +/- 1.0%

Internal Contamination Assessment
..Queue length = 0 +/- 0
..Waiting time = (19 sec) +/- (25 sec)
..Num of workers = 1
..Utilization = 2.4% +/- 0.6%

Registration and Discharge
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 83

..Utilization = 14.2% +/- 0.0%

Registration w/ Medical Discharge
..Queue length = 0 +/- 0
..Waiting time = (1 sec) +/- (2 sec)
..Num of workers = 1
..Utilization = 1.4% +/- 0.3%

Observe that it takes 3 days and 12 hours to screen all 12,000 individuals. If only one reception center is open, then, we can roughly say that it will take about seven 12-hour shifts to finish.

To determine the minimum resources needed (per shift) to screen 12,000 individuals with only 9 detectors available, we perform the following steps:

- Determine using the **Maximize Throughput** function the best throughput one can achieve when we have limited detectors. *From Case 1.2, with 9 detection instruments, we see that 28 workers are needed, and it can process 1818 individuals in 12 hours.*
- Dividing 12,000 by this throughput gives the number of shifts needed, 7.
- If we assume workers work for 12 hours, and then rest for 12 hours, then the total number of workers needed is 56.
- We emphasize that the result from **Manual Resource Reallocation** is not appropriate for determining the labor resource needs per shift. Specifically, the **Manual Resource Reallocation** results indicate a total of 120 workers needed, all working through the entire period of 36 hours. Whereas, the **Maximize Throughput** allows one to determine the best throughput that can be achieved in 12 hours under the limited resource restriction (of 9 detectors), providing an optimal screening operation.

Concluding remarks

In this section we provided the base case analysis to illustrate usage of the **Minimize Resource Allocation** function to satisfy a pre-set throughput. We illustrated how **Manual Resource Reallocation** could be performed on the resulting solution due to a change of the availability of detection instruments. Based on the observed long completion time (*Last entity exit time = (3 day 12 hr 29 min 45 sec) +/- (21 min 11 sec)*), we demonstrated the proper use of the **Maximize Throughput** function and the associated steps to determine the minimum resources needed per shift to screen 12,000 individuals when only 9 detectors were available.

Summary of Results

Case	3.1	3.2 (9 detectors only)
RealOpt-CRC function & parameters	Run Minimize Resource Allocation on Real Opt CRC for Training - generic.mod	Using 3.1 solution, set limits on detectors, and run Manual Resource Allocation
Last entity exit time	(13 hr 9 min 51 sec) +/- (23 min 7 sec)	(3 day 12 hr 29 min 45 sec) +/- (21 min 11 sec)
Actual throughput	12000	12000
Flow time	(16 min 36 sec) +/- (1 min 27 sec)	(1 day 11 hr 56 min 9 sec) +/- (4 min 20 sec)
Worker used	170	120
Detail statistics	Greeting ..Queue length = 11 +/- 2 ..Waiting time = (45 sec) +/- (8 sec) ..Num of workers = 16 ..Utilization = 87.9% +/- 2.5%	Greeting ..Queue length = 1 +/- 0 ..Waiting time = (43 sec) +/- (10 sec) ..Num of workers = 16 ..Utilization = 13.6% +/- 0.0%
	Radiation Monitoring Non-Decon ..Queue length = 20 +/- 4 ..Waiting time = (2 min 46 sec) +/- (40 sec) ..Num of workers = 28 ..Utilization = 90.5% +/- 2.3%	Radiation Monitoring Non-Decon ..Queue length = 2548 +/- 40 ..Waiting time = (1 day 11 hr 48 min 35 sec) +/- (18 min 32 sec) ..Num of workers = 4 ..Utilization = 98.9% +/- 0.7%
	Radiation Monitoring Self-Decon ..Queue length = 28 +/- 14 ..Waiting time = (3 min 44 sec) +/- (1 min 50 sec) ..Num of workers = 28 ..Utilization = 91.0% +/- 2.9%	Radiation Monitoring Self-Decon ..Queue length = 2529 +/- 41 ..Waiting time = (1 day 11 hr 41 min 30 sec) +/- (16 min 22 sec) ..Num of workers = 4 ..Utilization = 98.7% +/- 0.8%
	Decontamination ..Queue length = 15 +/- 6 ..Waiting time = (18 min 11 sec) +/- (7 min 34 sec) ..Num of workers = 10 ..Utilization = 92.7% +/- 2.7%	Decontamination ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 10 ..Utilization = 14.5% +/- 0.3%
	Radiation Monitoring Post Decon ..Queue length = 5 +/- 2 ..Waiting time = (5 min 58 sec) +/- (2 min 42 sec)	Radiation Monitoring Post Decon ..Queue length = 0 +/- 0 ..Waiting time = (1 min 18 sec) +/- (8 sec)

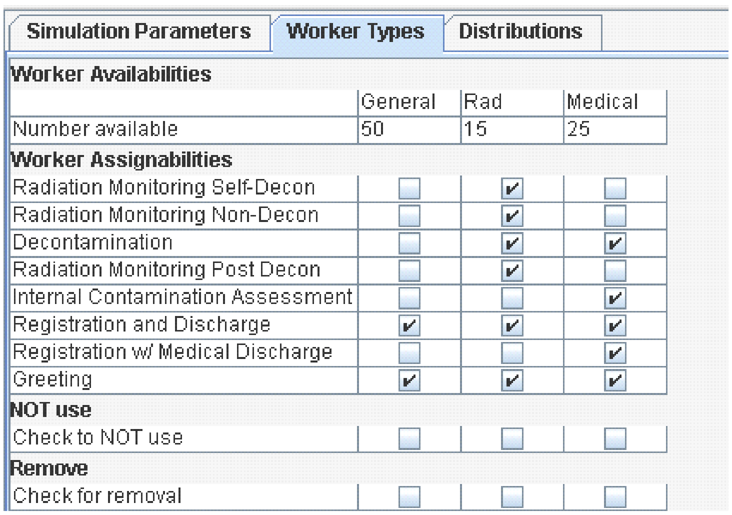
	..Num of workers = 3 ..Utilization = 93.6% +/- 2.3%	..Num of workers = 1 ..Utilization = 44.2% +/- 1.0%
	Internal Contamination Assessment ..Queue length = 0 +/- 0 ..Waiting time = (55 sec) +/- (47 sec) ..Num of workers = 1 ..Utilization = 13.6% +/- 6.0%	Internal Contamination Assessment ..Queue length = 0 +/- 0 ..Waiting time = (19 sec) +/- (25 sec) ..Num of workers = 1 ..Utilization = 2.4% +/- 0.6%
	Registration and Discharge ..Queue length = 17 +/- 7 ..Waiting time = (1 min 7 sec) +/- (30 sec) ..Num of workers = 83 ..Utilization = 91.7% +/- 2.5%	Registration and Discharge ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 83 ..Utilization = 14.2% +/- 0.0%
	Registration w/ Medical Discharge ..Queue length = 0 +/- 0 ..Waiting time = (1 sec) +/- (3 sec) ..Num of workers = 1 ..Utilization = 8.3% +/- 3.2%	Registration w/ Medical Discharge ..Queue length = 0 +/- 0 ..Waiting time = (1 sec) +/- (2 sec) ..Num of workers = 1 ..Utilization = 1.4% +/- 0.3%

Practice Scenarios-Case Study 4: Multiple worker types

4.1. Minimum resource allocation

RealOpt-CRC© allows users to define multiple worker types into the model. Each worker type can have different abilities to work at different stations. Open the file Real Opt CRC for Training - 12 Nov 2008.mod, which describes a scenario involving three different types of workers: General, Rad, and Medical. General workers can only be assigned to the Registration and Discharge station or the Greeting station. On the other hand, Medical workers can be assigned to stations that require professional skills, such as the Decontamination station or the Internal Contamination Assessment station, and Rad workers can handle detection instruments, decontamination, and any duties that General workers can perform.

The assignabilities can be modified in the **Worker Assignabilities Table** in the **Worker Types** panel.



Worker Availabilities	General	Rad	Medical
Number available	50	15	25
Worker Assignabilities			
Radiation Monitoring Self-Decon	☐	☑	☐
Radiation Monitoring Non-Decon	☐	☑	☐
Decontamination	☐	☑	☑
Radiation Monitoring Post Decon	☐	☑	☐
Internal Contamination Assessment	☐	☐	☑
Registration and Discharge	☑	☑	☑
Registration w/ Medical Discharge	☐	☐	☑
Greeting	☑	☑	☑
NOT use			
Check to NOT use	☐	☐	☐
Remove			
Check for removal	☐	☐	☐

To determine the resources needed (stratified by workertype) to process 12,000 individuals in a 12-hour shift, we run the **Minimum Resource Allocation** function, and obtain the following result:

Optimization and simulation results summary

Model: Real Opt CRC for Training - 12 Nov 2008.mod
Simulation time: 12.0 hour
Function: minimize resource allocation
Minimum required throughput: 12000

Last entity exit time = (13 hr 9 min 51 sec) +/- (23 min 7 sec)
Actual throughput = 12000
Flow time = (16 min 36 sec) +/- (1 min 27 sec)

Worker allocation:

	Total	General	Rad	Medical
# Available	90	50	15	25
# Addn. need	80	0	78	2
# Used	170	50	93	27
# Left	0	0	0	0
------------	Subtotal			
Greeting	16	0	16	0
Radiation Monitoring Non-Decon	28	0	28	0
Radiation Monitoring Self-Decon	28	0	28	0
Decontamination	10	0	10	0
Radiation Monitoring Post Decon	3	0	3	0
Internal Contamination Assessment	1	0	0	1
Registration and Discharge	83	50	8	25
Registration w/ Medical Discharge	1	0	0	1

Detail statistics for individual stations:

Greeting
..Queue length = 11 +/- 2
..Waiting time = (45 sec) +/- (8 sec)
..Num of workers = 16
..Utilization = 87.9% +/- 2.5%

Radiation Monitoring Non-Decon
..Queue length = 20 +/- 4
..Waiting time = (2 min 46 sec) +/- (40 sec)
..Num of workers = 28
..Utilization = 90.5% +/- 2.3%

Radiation Monitoring Self-Decon
..Queue length = 28 +/- 14
..Waiting time = (3 min 44 sec) +/- (1 min 50 sec)
..Num of workers = 28
..Utilization = 91.0% +/- 2.9%

Decontamination
..Queue length = 15 +/- 6
..Waiting time = (18 min 11 sec) +/- (7 min 34 sec)
..Num of workers = 10
..Utilization = 92.7% +/- 2.7%
Radiation Monitoring Post Decon

..Queue length = 5 +/- 2
..Waiting time = (5 min 58 sec) +/- (2 min 42 sec)
..Num of workers = 3
..Utilization = 93.6% +/- 2.3%

Internal Contamination Assessment
..Queue length = 0 +/- 0
..Waiting time = (55 sec) +/- (47 sec)
..Num of workers = 1
..Utilization = 13.6% +/- 6.0%

Registration and Discharge
..Queue length = 17 +/- 7
..Waiting time = (1 min 7 sec) +/- (30 sec)
..Num of workers = 83
..Utilization = 91.7% +/- 2.5%

Registration w/ Medical Discharge
..Queue length = 0 +/- 0
..Waiting time = (1 sec) +/- (3 sec)
..Num of workers = 1
..Utilization = 8.3% +/- 3.2%

It should not be surprising that the results of this optimization are the same as when only one worker type is used in Case 3.1.

4.2. Maximize throughput

By running the **Maximize Throughput** function on the Real Opt CRC for Training - 12 Nov 2008.mod model, we obtain the following results:

--
Optimization and simulation results summary
--

Model: Real Opt CRC for Training - 12 Nov 2008.mod
Simulation time: 12.0 hour
Function: maximize throughput

Last entity exit time = (13 hr 2 min 23 sec) +/- (8 min 19 sec)
Actual throughput = 3116
Flow time = (32 min 43 sec) +/- (4 min 45 sec)

Worker allocation:

	Total	General	Rad	Medical
# Available	90	50	15	25
# Used	45	5	15	25
# Left	45	45	0	0
------------	Subtotal			
Greeting	4	0	0	4
Radiation Monitoring Non-Decon	7	0	7	0
Radiation Monitoring Self-Decon	7	0	7	0
Decontamination	3	0	0	3
Radiation Monitoring Post Decon	1	0	1	0
Internal Contamination Assessment	1	0	0	1
Registration and Discharge	21	5	0	16
Registration w/ Medical Discharge	1	0	0	1

Detail statistics for individual stations:

Greeting
..Queue length = 38 +/- 12
..Waiting time = (9 min 44 sec) +/- (3 min 5 sec)
..Num of workers = 4
..Utilization = 92.5% +/- 1.3%

Radiation Monitoring Non-Decon
..Queue length = 19 +/- 9
..Waiting time = (9 min 52 sec) +/- (4 min 40 sec)
..Num of workers = 7
..Utilization = 94.9% +/- 0.8%

Radiation Monitoring Self-Decon
..Queue length = 25 +/- 9
..Waiting time = (12 min 27 sec) +/- (4 min 28 sec)
..Num of workers = 7
..Utilization = 95.1% +/- 2.2%

Decontamination
..Queue length = 1 +/- 0
..Waiting time = (7 min 20 sec) +/- (2 min 53 sec)
..Num of workers = 3
..Utilization = 80.0% +/- 4.2%

Radiation Monitoring Post Decon
..Queue length = 0 +/- 0
..Waiting time = (1 min 46 sec) +/- (19 sec)
..Num of workers = 1

..Utilization = 71.7% +/- 4.0%

Internal Contamination Assessment
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 1
..Utilization = 4.0% +/- 2.1%

Registration and Discharge
..Queue length = 4 +/- 0
..Waiting time = (1 min 10 sec) +/- (12 sec)
..Num of workers = 21
..Utilization = 94.7% +/- 0.9%

Registration w/ Medical Discharge
..Queue length = 0 +/- 0
..Waiting time = (0 sec) +/- (0 sec)
..Num of workers = 1
..Utilization = 2.4% +/- 1.1%

It should not be surprising that the total number of workers assigned to each station is equal to the number of assigned to each station when only one worker type is used in Case 1.1.

In this example the limiting resources are Rad workers and Medical workers because they are completely exhausted. We can increase the resulting throughput ***only if*** we increase the availabilities of limiting resources. More specifically, the throughput can be increased by increasing the number of Rad workers. On the other hand, increasing the General workers will not influence the current throughput because there are 45 un-used General workers.

It is worth noticing that increasing the availabilities of limiting factors ***does not*** necessarily increase the maximized throughput. In this example, increasing the number of Medical workers alone will ***NOT*** increase the maximized throughput even though it is a limiting factor.

Concluding remarks
This section illustrated the use of **Minimize Resource Allocation** and **Maximize Throughput** functions when the model consisted of multiple worker types.

Summary of Results

Case	3.1	4.1
RealOpt-CRC function & parameters	Run Minimize Resource Allocation on Real Opt CRC for Training - generic.mod	Run Minimize Resource Allocation on Real Opt CRC for Training - 12 Nov 2008.mod
Last entity exit time	(13 hr 9 min 51 sec) +/- (23 min 7 sec)	(13 hr 9 min 51 sec) +/- (23 min 7 sec)
Actual throughput	12000	12000
Flow time	(16 min 36 sec) +/- (1 min 27 sec)	(16 min 36 sec) +/- (1 min 27 sec)
Worker used	170	170
Detail statistics	Greeting ..Queue length = 11 +/- 2 ..Waiting time = (45 sec) +/- (8 sec) ..Num of workers = 16 ..Utilization = 87.9% +/- 2.5%	Greeting ..Queue length = 11 +/- 2 ..Waiting time = (45 sec) +/- (8 sec) ..Num of workers = 16 ..Utilization = 87.9% +/- 2.5%
	Radiation Monitoring Non-Decon ..Queue length = 20 +/- 4 ..Waiting time = (2 min 46 sec) +/- (40 sec) ..Num of workers = 28 ..Utilization = 90.5% +/- 2.3%	Radiation Monitoring Non-Decon ..Queue length = 20 +/- 4 ..Waiting time = (2 min 46 sec) +/- (40 sec) ..Num of workers = 28 ..Utilization = 90.5% +/- 2.3%
	Radiation Monitoring Self-Decon ..Queue length = 28 +/- 14 ..Waiting time = (3 min 44 sec) +/- (1 min 50 sec) ..Num of workers = 28 ..Utilization = 91.0% +/- 2.9%	Radiation Monitoring Self-Decon ..Queue length = 28 +/- 14 ..Waiting time = (3 min 44 sec) +/- (1 min 50 sec) ..Num of workers = 28 ..Utilization = 91.0% +/- 2.9%
	Decontamination ..Queue length = 15 +/- 6 ..Waiting time = (18 min 11 sec) +/- (7 min 34 sec) ..Num of workers = 10 ..Utilization = 92.7% +/- 2.7%	Decontamination ..Queue length = 15 +/- 6 ..Waiting time = (18 min 11 sec) +/- (7 min 34 sec) ..Num of workers = 10 ..Utilization = 92.7% +/- 2.7%
	Radiation Monitoring Post Decon ..Queue length = 5 +/- 2 ..Waiting time = (5 min 58 sec) +/- (2 min 42 sec) ..Num of workers = 3 ..Utilization = 93.6% +/- 2.3%	Radiation Monitoring Post Decon ..Queue length = 5 +/- 2 ..Waiting time = (5 min 58 sec) +/- (2 min 42 sec) ..Num of workers = 3 ..Utilization = 93.6% +/- 2.3%
	Internal Contamination Assessment ..Queue length = 0 +/- 0 ..Waiting time = (55 sec) +/- (47 sec)	Internal Contamination Assessment ..Queue length = 0 +/- 0 ..Waiting time = (55 sec) +/- (47 sec)

	..Num of workers = 1 ..Utilization = 13.6% +/- 6.0%	..Num of workers = 1 ..Utilization = 13.6% +/- 6.0%
	Registration and Discharge ..Queue length = 17 +/- 7 ..Waiting time = (1 min 7 sec) +/- (30 sec) ..Num of workers = 83 ..Utilization = 91.7% +/- 2.5%	Registration and Discharge ..Queue length = 17 +/- 7 ..Waiting time = (1 min 7 sec) +/- (30 sec) ..Num of workers = 83 ..Utilization = 91.7% +/- 2.5%
	Registration w/ Medical Discharge ..Queue length = 0 +/- 0 ..Waiting time = (1 sec) +/- (3 sec) ..Num of workers = 1 ..Utilization = 8.3% +/- 3.2%	Registration w/ Medical Discharge ..Queue length = 0 +/- 0 ..Waiting time = (1 sec) +/- (3 sec) ..Num of workers = 1 ..Utilization = 8.3% +/- 3.2%

Summary of Results (Continued)

Case	1.1	4.2
RealOpt-CRC function & parameters	Run Maximize Throughput on Real Opt CRC for Training - generic.mod.	Run Maximize Throughput on Real Opt CRC for Training - 12 Nov 2008.mod
Last entity exit time	(13 hr 2 min 23 sec) +/- (8 min 19 sec)	(13 hr 2 min 23 sec) +/- (8 min 19 sec)
Actual throughput	3116	3116
Flow time	(32 min 43 sec) +/- (4 min 45 sec)	(32 min 43 sec) +/- (4 min 45 sec)
Worker used	45	45
Detail statistics	Greeting ..Queue length = 38 +/- 12 ..Waiting time = (9 min 44 sec) +/- (3 min 5 sec) ..Num of workers = 4 ..Utilization = 92.5% +/- 1.3%	Greeting ..Queue length = 38 +/- 12 ..Waiting time = (9 min 44 sec) +/- (3 min 5 sec) ..Num of workers = 4 ..Utilization = 92.5% +/- 1.3%
	Radiation Monitoring Non-Decon ..Queue length = 19 +/- 9 ..Waiting time = (9 min 52 sec) +/- (4 min 40 sec) ..Num of workers = 7 ..Utilization = 94.9% +/- 0.8%	Radiation Monitoring Non-Decon ..Queue length = 19 +/- 9 ..Waiting time = (9 min 52 sec) +/- (4 min 40 sec) ..Num of workers = 7 ..Utilization = 94.9% +/- 0.8%
	Radiation Monitoring Self-Decon ..Queue length = 25 +/- 9 ..Waiting time = (12 min 27 sec) +/- (4 min 28 sec) ..Num of workers = 7 ..Utilization = 95.1% +/- 2.2%	Radiation Monitoring Self-Decon ..Queue length = 25 +/- 9 ..Waiting time = (12 min 27 sec) +/- (4 min 28 sec) ..Num of workers = 7 ..Utilization = 95.1% +/- 2.2%
	Decontamination ..Queue length = 1 +/- 0 ..Waiting time = (7 min 20 sec) +/- (2 min 53 sec) ..Num of workers = 3 ..Utilization = 80.0% +/- 4.2%	Decontamination ..Queue length = 1 +/- 0 ..Waiting time = (7 min 20 sec) +/- (2 min 53 sec) ..Num of workers = 3 ..Utilization = 80.0% +/- 4.2%
	Radiation Monitoring Post Decon ..Queue length = 0 +/- 0 ..Waiting time = (1 min 46 sec) +/- (19 sec) ..Num of workers = 1 ..Utilization = 71.7% +/- 4.0%	Radiation Monitoring Post Decon ..Queue length = 0 +/- 0 ..Waiting time = (1 min 46 sec) +/- (19 sec) ..Num of workers = 1 ..Utilization = 71.7% +/- 4.0%

	Internal Contamination Assessment ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 1 ..Utilization = 4.0% +/- 2.1%	Internal Contamination Assessment ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 1 ..Utilization = 4.0% +/- 2.1%
	Registration and Discharge ..Queue length = 4 +/- 0 ..Waiting time = (1 min 10 sec) +/- (12 sec) ..Num of workers = 21 ..Utilization = 94.7% +/- 0.9%	Registration and Discharge ..Queue length = 4 +/- 0 ..Waiting time = (1 min 10 sec) +/- (12 sec) ..Num of workers = 21 ..Utilization = 94.7% +/- 0.9%
	Registration w/ Medical Discharge ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 1 ..Utilization = 2.4% +/- 1.1%	Registration w/ Medical Discharge ..Queue length = 0 +/- 0 ..Waiting time = (0 sec) +/- (0 sec) ..Num of workers = 1 ..Utilization = 2.4% +/- 1.1%

Appendix: Probability Distributions

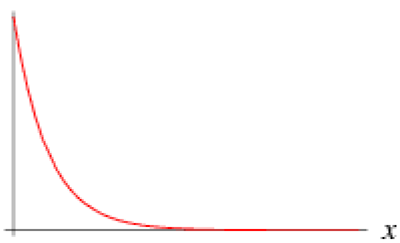
Exponential Distribution:

A type of probability distribution that is often used to model the time between events that happen at a constant average rate, e.g. interarrival times. Its mean value is the average time.

Probability density function:

$$f(x) = \begin{cases} \frac{1}{\beta} e^{-\frac{x}{\beta}} & \text{if } x \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

β : mean



Weisstein, Eric W. "Exponential Distribution." From *MathWorld*--A Wolfram Web Resource. http://mathworld.wolfram.com/ExponentialDistribution.html

Triangular Distribution:

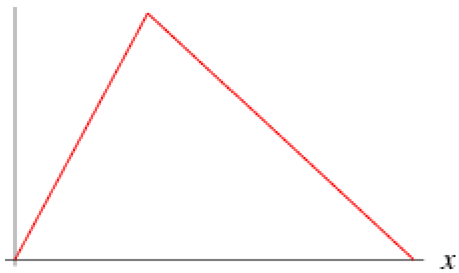
A type of probability distribution with a lower limit, a mode, and an upper limit. It admits values within the limits and is most likely to take the mode value. Triagular distribution is often useful for modeling service times

Probability density function:

$$f(x) = \begin{cases} \frac{2(x-a)}{(b-a)(c-a)} & \text{if } a \leq x \leq c \\ \frac{2(b-x)}{(b-a)(c-a)} & \text{if } c < x \leq b \\ 0 & \text{otherwise} \end{cases}$$

a: lower limit

b: upper limit
c: most likely (mode) value



Weisstein, Eric W. "Triangular Distribution." From *MathWorld*--A Wolfram Web Resource. http://mathworld.wolfram.com/TriangularDistribution.html

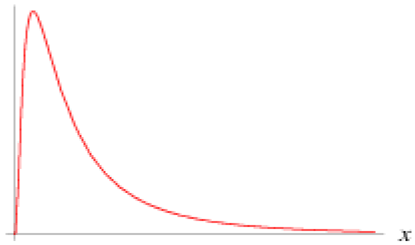
Lognormal Distribution:

A distribution of a random variable whose natural logarithm is normally distributed. A log normal distribution is skewed so that a higher proportion of observations exceed the expected value, versus falling short of the expected value.

Probability density function:

$$f(x) = \begin{cases} \frac{1}{x\sigma\sqrt{2\pi}} \exp \frac{-(\ln x - \mu)^2}{2\sigma^2} & \text{if } \quad x > 0 \\ 0 & \text{otherwise} \end{cases}$$

σ: shape parameter
μ: scale parameter



Weisstein, Eric W. "Log Normal Distribution." From *MathWorld*--A Wolfram Web Resource. http://mathworld.wolfram.com/LogNormalDistribution.html

Glossary

Arrow	Arc that connects two blocks
Batch	Point where groups are formed before proceeding
Batch size	Number of entities needed to form a batch
Create	Point where incoming entities are created
Decision	Split point of the simulation flow
Delay	Point where a delay takes place
Dispose	Exit from the system
Exponential distribution	A type of probability distribution that is often used to model the time between events that happen at a constant average rate, e.g. interarrival times. Its mean value is the average time
Extension	An extended period of time after the specified simulation time, which allows all entities to finish service and exit the facility. It is to reflect that a facility may close at a certain time; however, it will still finish processing the individuals who remain inside.
Flow time	Time that an entity spends in the system
Instant utilization	Ratio of the number of busy servers to the number of available servers at a time point
Interarrival time	Time between two consecutive arrivals
Lognormal distribution	A distribution of a random variable whose natural logarithm is normally distributed. A log normal distribution is skewed so that a higher proportion of observations exceed the expected value, versus falling short of the expected value.
Probability distribution	A mathematical description of a random variable that associates a probability with any interval
Process	Work station where entities receive service
Queue length	Number of entities in queue at a station

Separate	Point where batches are broken back into individuals
Service time	Time that an entity spends in service
Throughput	Total number of entities that go through the system
Triangular distribution	A type of probability distribution with a lower limit, a mode, and an upper limit. It admits values within the limits and is most likely to take the mode value. Triangular distribution is often useful for modeling service times
Utilization	Average instant utilization over the simulation time length
Waiting time	Time that an entity spends waiting in queue at a station

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Dependency on other libraries

RealOpt-CRC© utilizes JMathPlot, which is a part of JMathTools, to visualize probability distributions.

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