



Universidade de São Paulo
Brasil

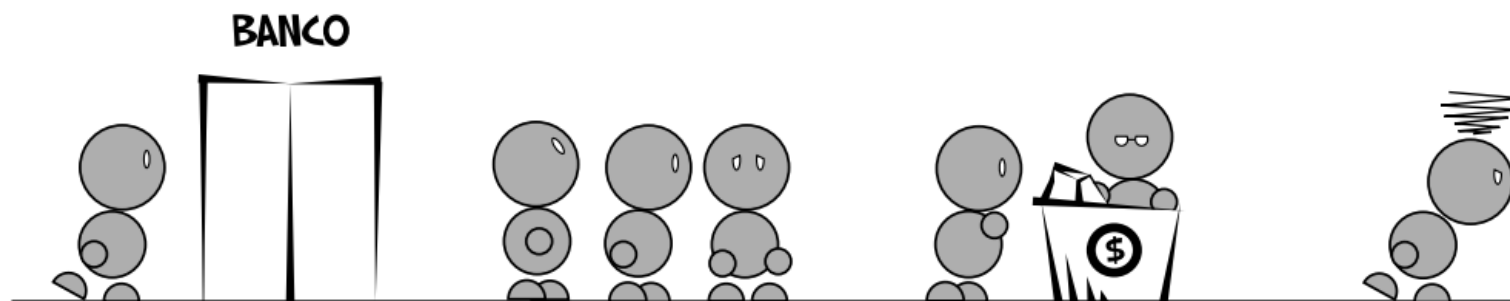
Modelagem e Simulação de Sistemas

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Departamento de Engenharia Química
Escola de Engenharia de Lorena – EEL

Teoria das Filas

Descrição do sistema

Funcionamento diário de 6 horas



Tempo médio de chegada = 10 min

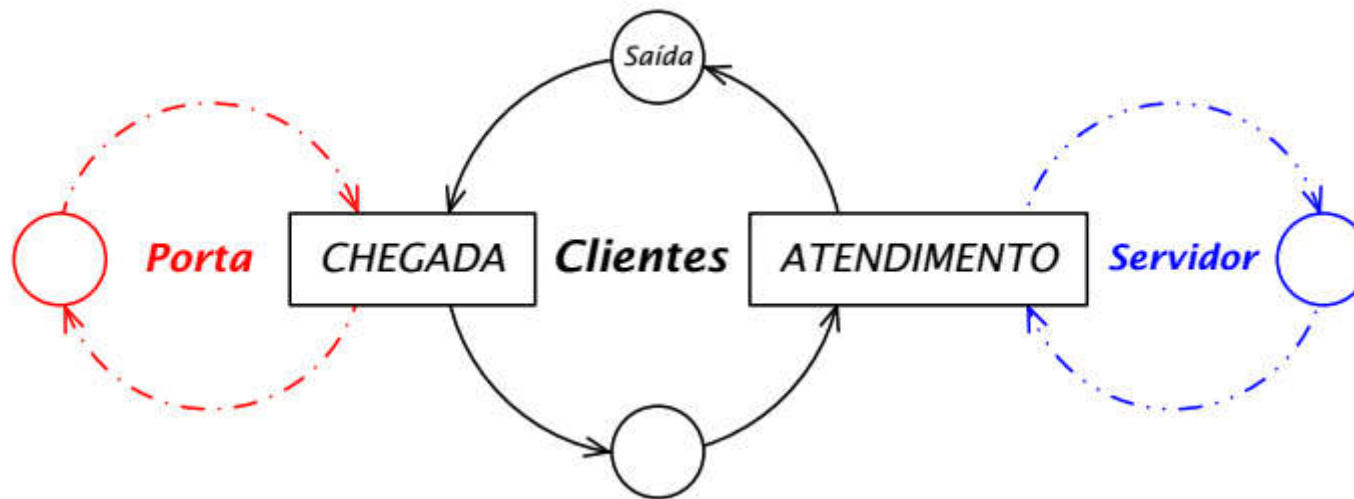
FIFO

Tempo médio de atendimento = 6 min



Escola de Engenharia de Lorena

Teoria das Filas



o posto bancário pode ser modelado como um sistema de fila M/M/1, com $\lambda = 6$ e $\mu = 10$ (valores em clientes/h)



Introdução ao Simul8

The screenshot shows the Simul8 2013 Professional (Exclusive EDUCATIONAL TUTOR ONLY - NOT FOR USE BY STUDENTS Edition) interface. The main window is titled 'SIMUL8 Educational Site License' and displays a simulation environment with a clock showing 'AM Mon' and 'October 21'. The interface includes a menu bar, a toolbar, a left-hand panel with 'Building Blocks', and a right-hand panel with a 'Getting started' guide. Red boxes and arrows highlight specific features: the menu bar, the toolbar, the clock, the building blocks panel, and the right-hand panel. A blue box highlights the central simulation window, and a purple dashed box highlights a specific instruction in the right-hand panel.

Menu de comandos

Botões de acesso rápido

Relógio da simulação

Painel de blocos construtores

Janela de simulação

Clique nesta faixa para fechar o painel de dicas

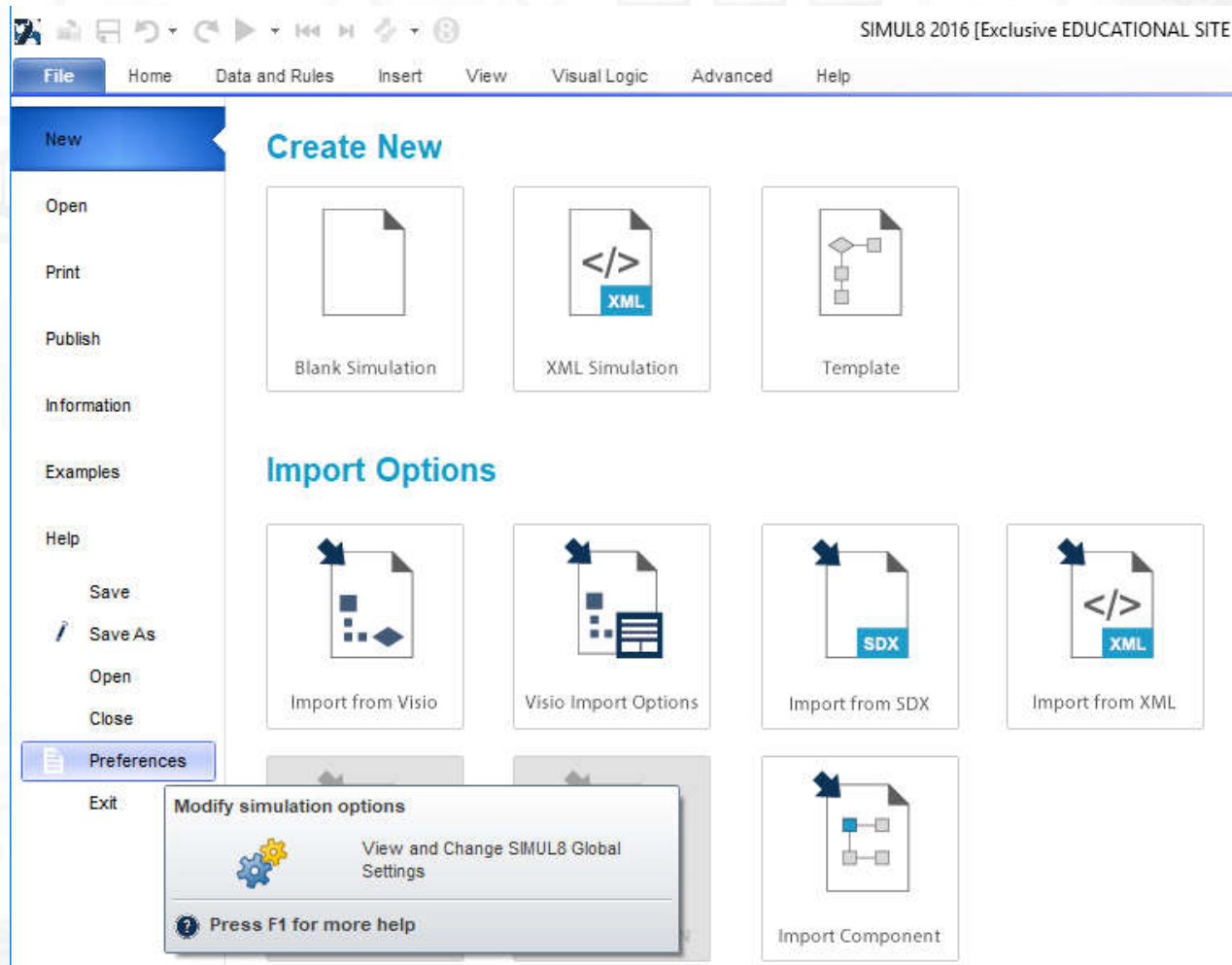
- To create a simulation to improve a process:
 - Drag simulation objects into the simulation window. Connect them with arrows to draw the process flow.
 - Add resources (e.g. people) and say where they are required.
 - Set settings and other parameters at the simulation objects.
 - Run the simulation and watch the behavior - review results screens. Add important results to the KPI Summary.
 - Only include enough detail to get the accuracy needed.
 - Run a Trial to get statistically accurate results.
 - Change the flow, resource levels and other parameters in above steps. See the best ideas to create a great process.
 - Show to co-workers to get their acceptance (and try their ideas) (implement in the real process)

Go to help.simul8.com/tutorials



Introdução ao Simul8

Configurações Básicas do Simul8



Introdução ao Simul8

Configurações Básicas do Simul8

Preferences

Finance | Continuous | Compatibility | Check | Options | Visual Logic
Undo | Distance | Files | Results | Speed | Automation | Display

Distance Measure

Feet Custom
 Meters Metres

Travel Times

Automatically set up on new Route Arrows
 Automatically adjust as Route Arrows change

Travel Speed Defaults

Speed: meters per minute
Scale: Pixels per meter

Resources

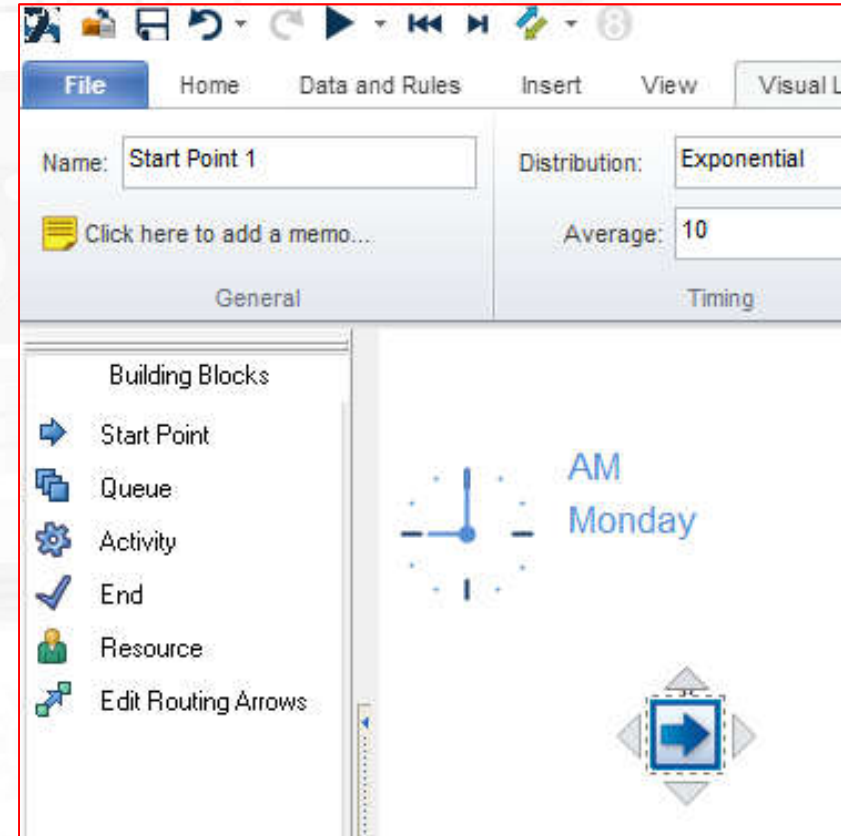
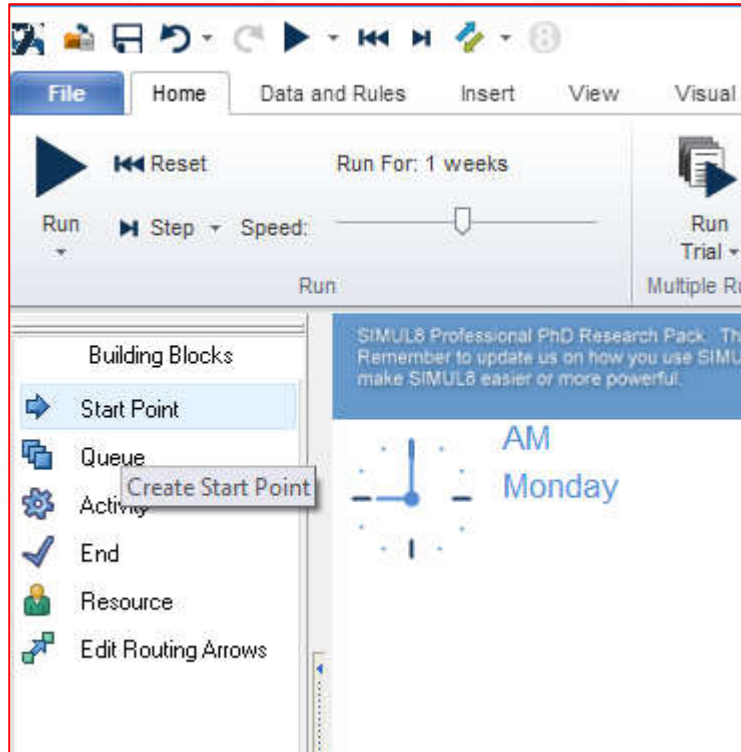
1: Resources are shared logically between Activities but do not spend time traveling between Activities. They cannot travel with work items between Activities. (Faster and uses less memory).
 2: In addition to above, Resources can spend time traveling between the Activities where they are used, and can stay attached to Work Items through more than one Activity.

Clicar



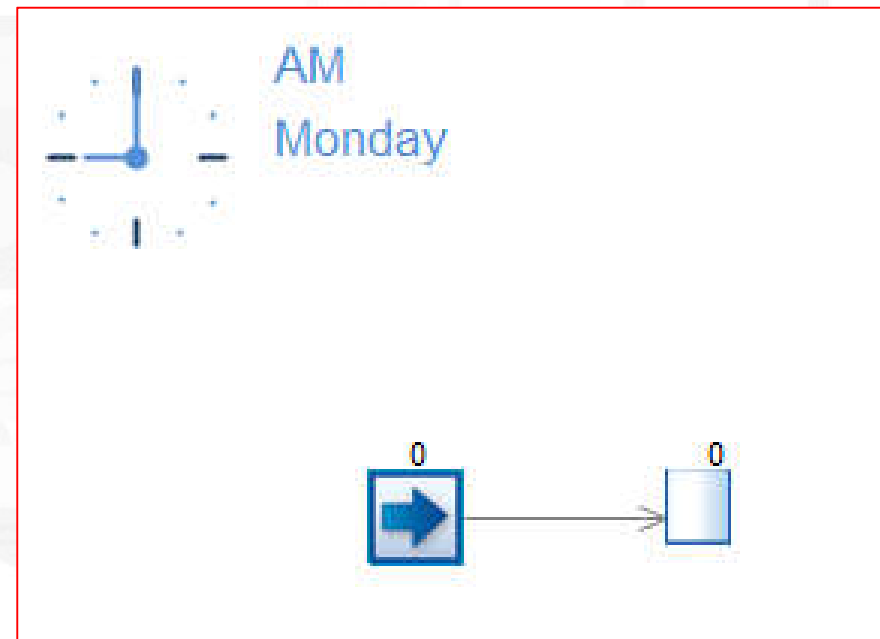
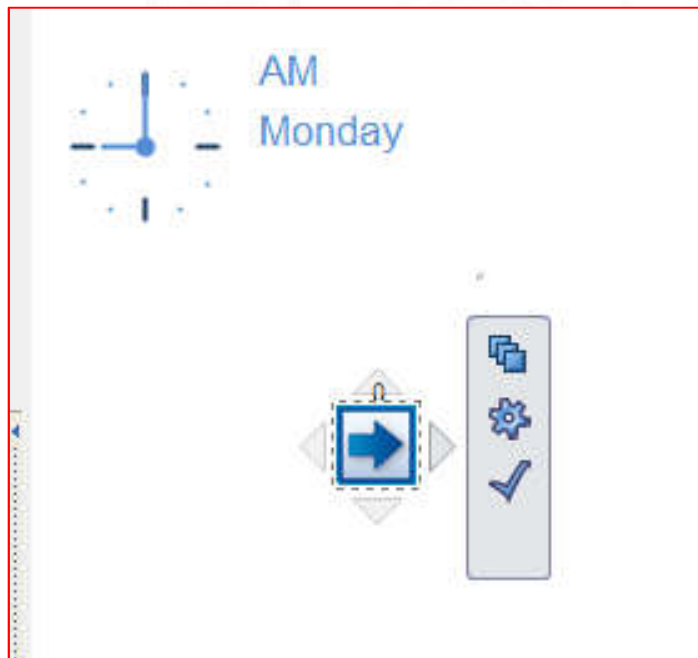
Introdução ao Simul8

Criando um ambiente de simulação



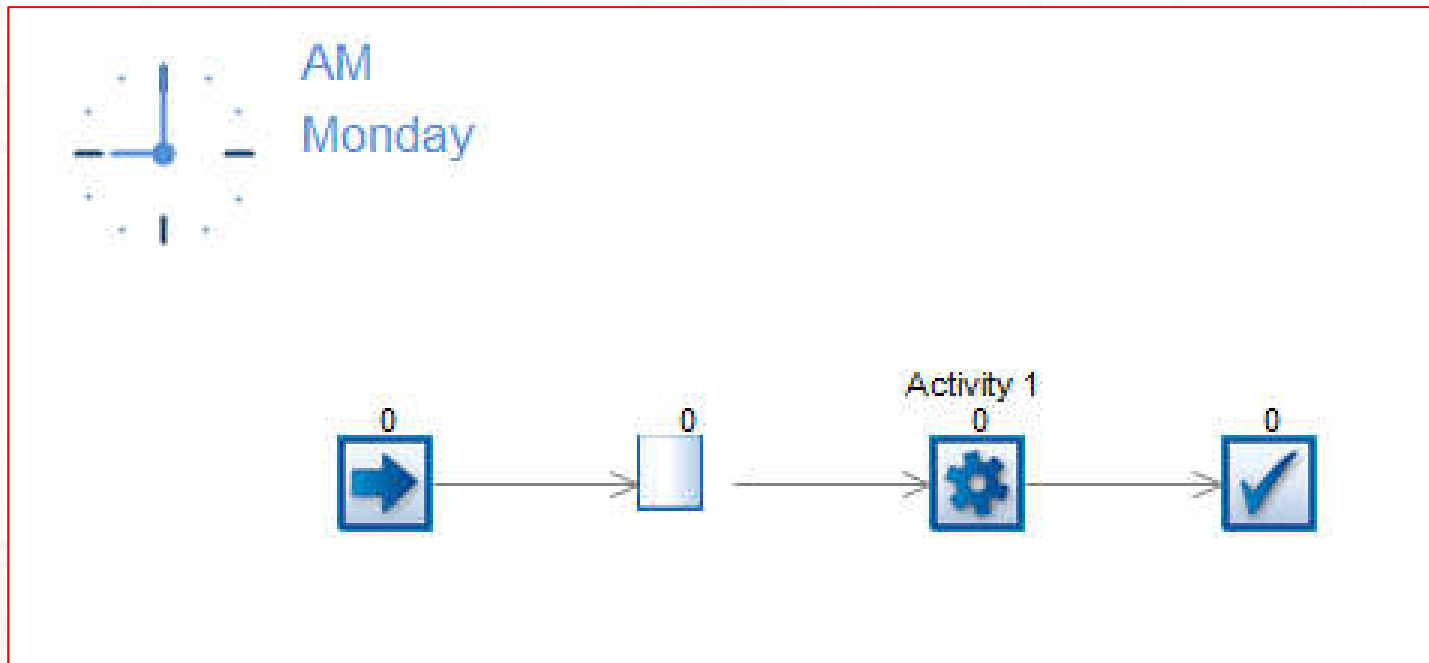
Introdução ao Simul8

Criando um ambiente de simulação



Introdução ao Simul8

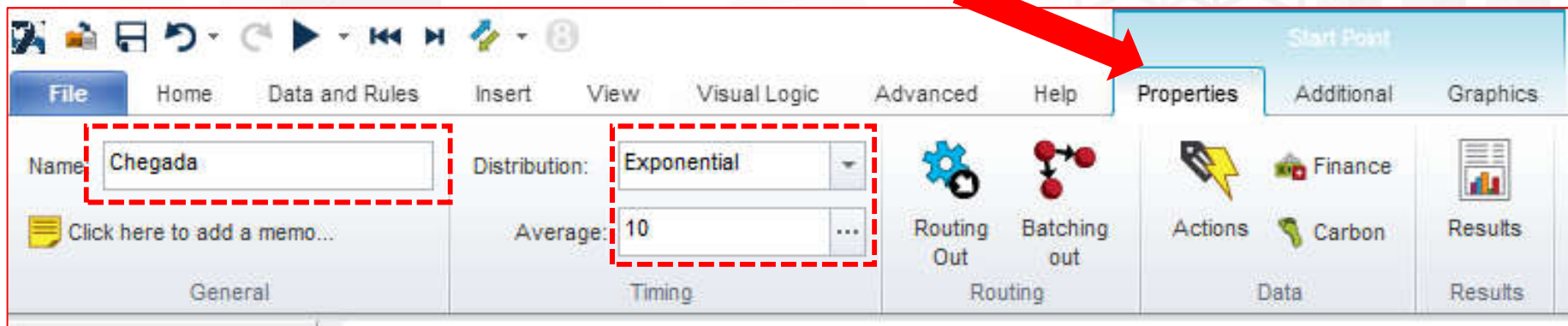
Criando um ambiente de simulação



Introdução ao Simul8

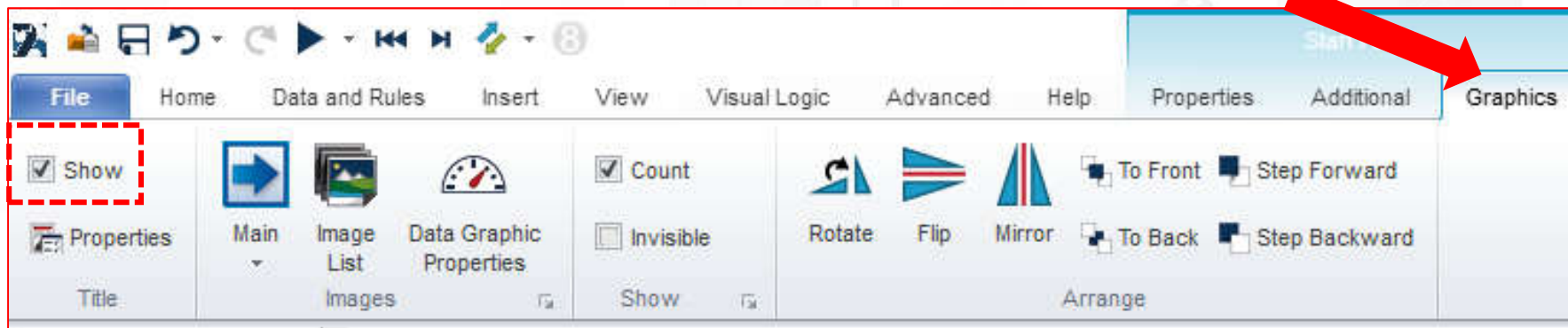
Clique sobre o objeto Start Point

Abra a aba de propriedades do **ponto de chegada de clientes** (Work Entry Point). Altere o título do objeto de Work Entry Point 1 para **Chegada** e ajuste o intervalo médio entre chegadas para **10 minutos**, com distribuição **exponencial**



Introdução ao Simul8

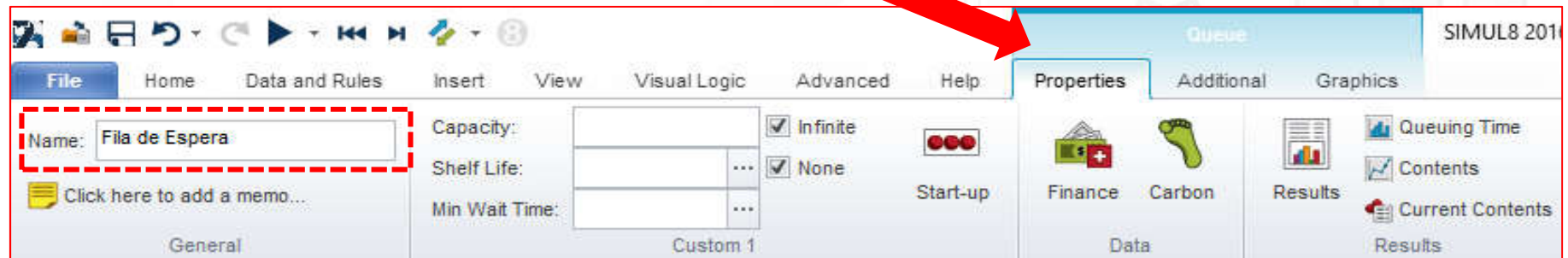
Abra a aba de gráficos do ponto de chegada de clientes **Chegada** e clique na opção **show** para que o nome atribuído apareça na tela.



Introdução ao Simul8

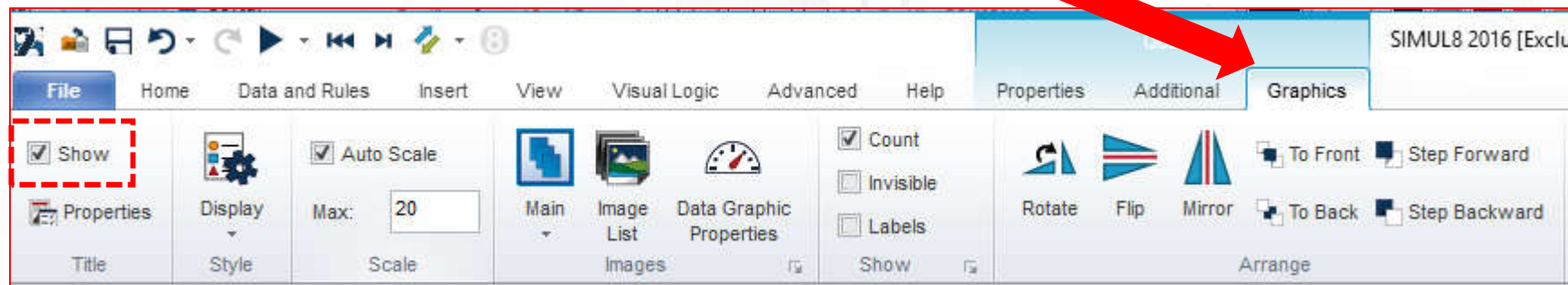
Clique sobre o objeto Queue

Clique na abade **Properties** da fila de espera e altere seu nome de Storage Area 1 para **Fila de Espera**.



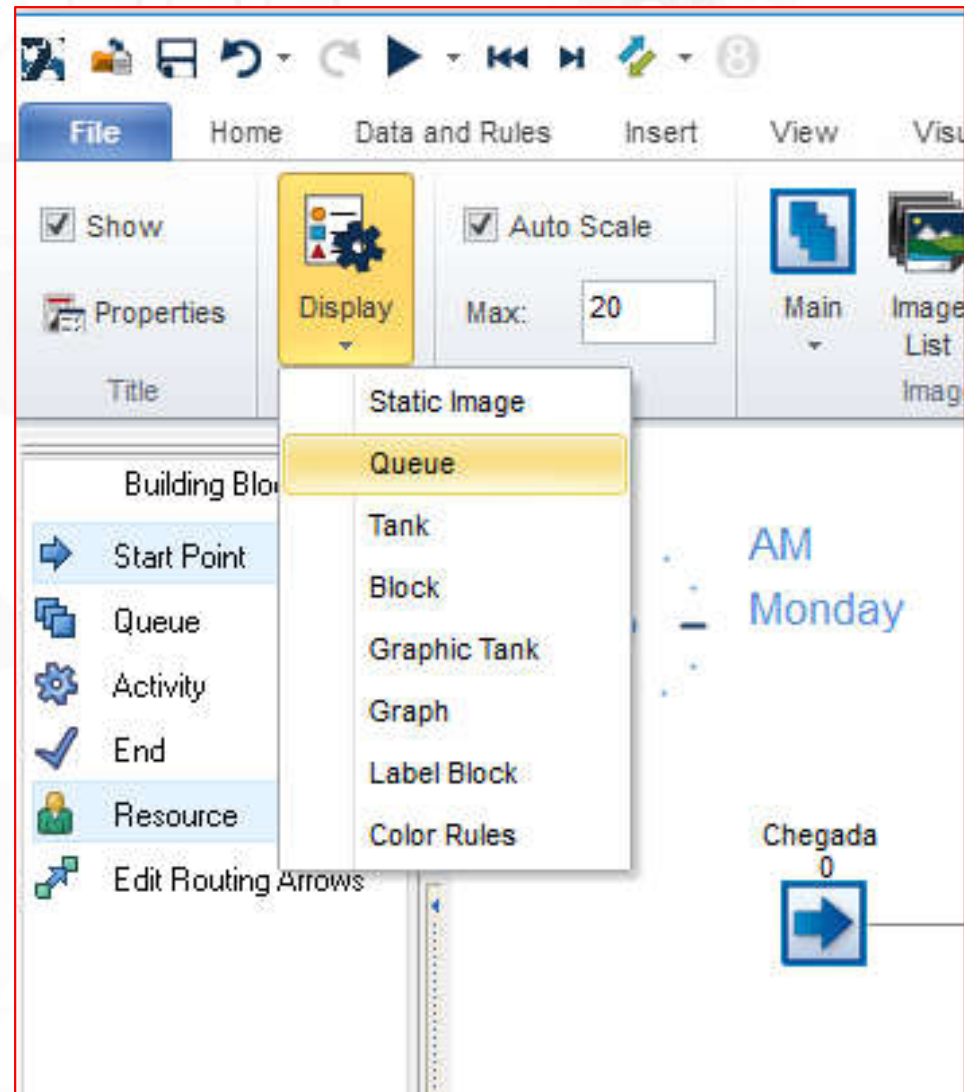
Introdução ao Simul8

Abra a aba de **Graphics** da fila de espera e clique na opção **show** para que o nome atribuído apareça na tela.



Introdução ao Simul8

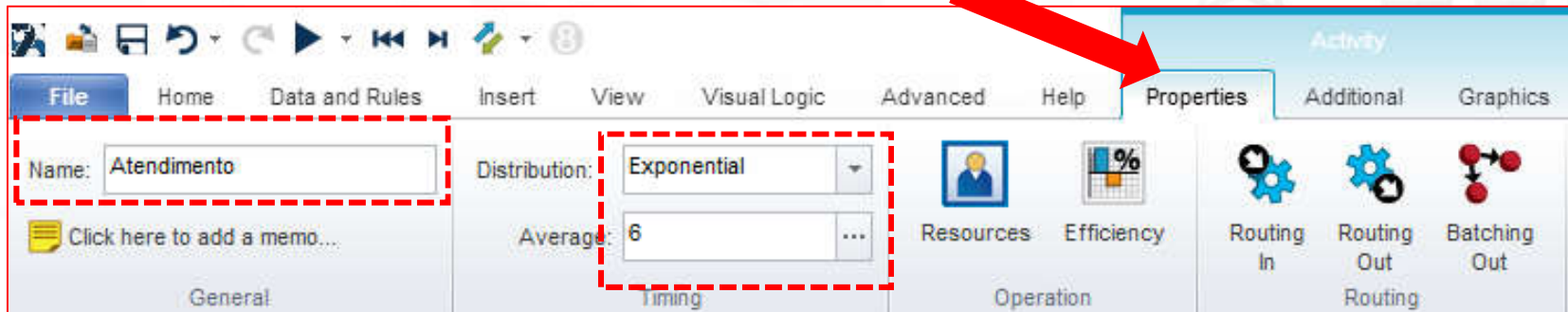
Nesta mesma aba selecione a opção de exibição **Queue** para que o SIMUL8 mostre uma fila **indiana** de clientes durante a simulação (a opção padrão é **Graphic Tank**, que mostra um tanque estilizado se enchendo ou se esvaziando, dependendo do tamanho da fila).



Introdução ao Simul8

Clique sobre o objeto Activity

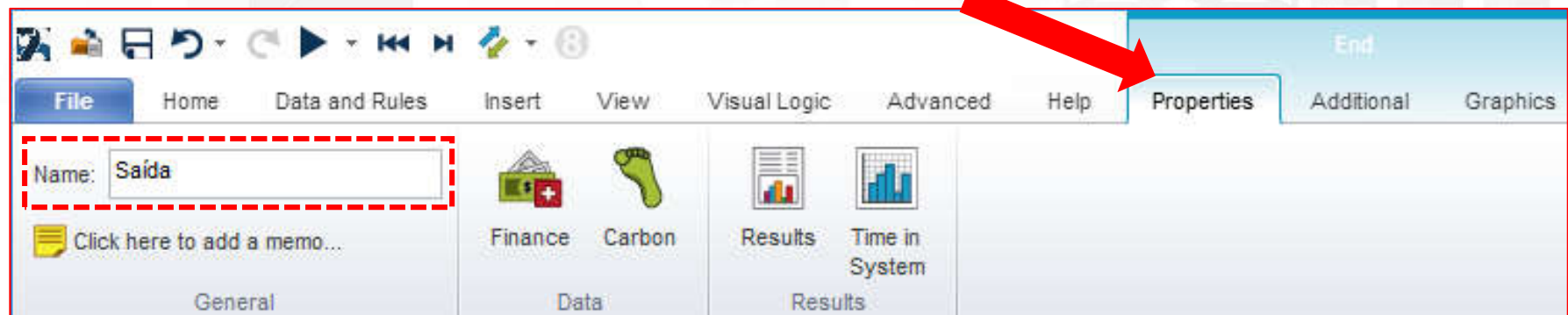
Abra a aba de propriedades do **activity** (Work Center). Altere o título do objeto de Work Center 1 para **Atendimento**. Ajuste também os parâmetros do processo: distribuição **exponencial**, com média de **6 minutos**



Introdução ao Simul8

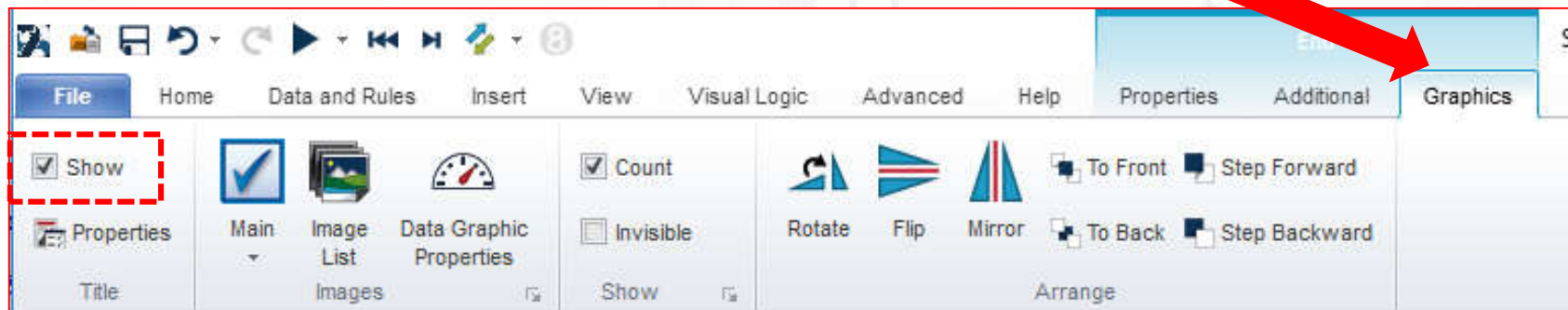
Clique sobre o objeto End

Clique na abade **Properties** do Work Complete e altere seu nome de End para **Saída**.



Introdução ao Simul8

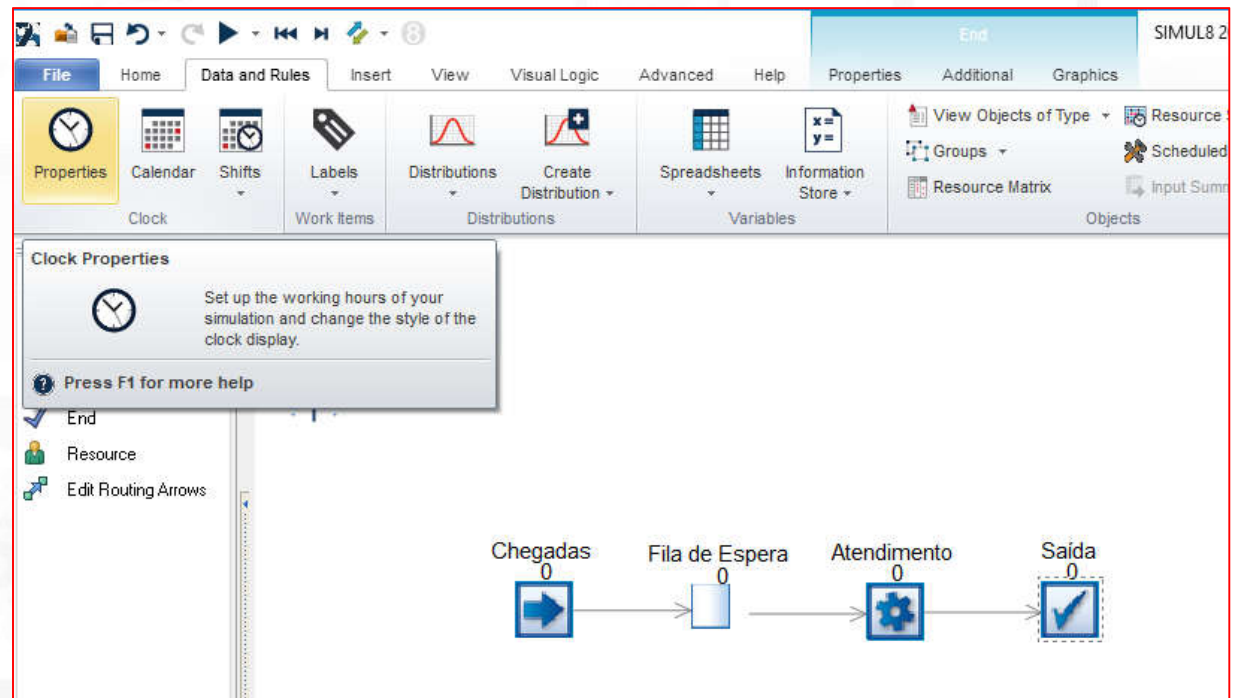
Abra a aba de **Graphics** da fila de espera e clique na opção **show** para que o nome atribuído apareça na tela.



Introdução ao Simul8

Ajustando a unidade de tempo

Todos os objetos de um modelo de simulação no SIMUL8 utilizam uma mesma unidade de tempo. No caso do nosso modelo, a unidade mais adequada é o minuto, que (por acaso) é a unidade padrão do SIMUL8: clique em **Data and Rules | Properties** ou dê um duplo-clique no relógio de simulação para comprovar isso



Introdução ao Simul8

Ajustando a unidade de tempo

Clock Properties

Time Units
 Seconds Minutes Hours Days

For units smaller than seconds use decimals of units e.g. 0.001 = 1 millisecond

Time format
 Simple unit count from zero Percent Time only
Decimals: Time Day
Description:

Digital Clock Face

HH:MM HH:MM.000 HH:MM:SS HH:MM:SS.000

Days
 Day Date Mon, Tues, Wed... Days per week:
 Day, Week

Running Time
Start time each day (HH:MM):
Duration of day (HH:MM):


The simulation will run for the total of Warm Up Period + Results Collection Period



Introdução ao Simul8

Ajustando a unidade de tempo

Clicar



Clock Properties

Time Units
 Seconds Minutes Hours Days

For units smaller than seconds use decimals of units e.g. 0.001 = 1 millisecond

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Description:

Digital Clock Face

HH:MM HH:MM.000 HH:MM:SS HH:MM:SS.000

Days
 Day Date Mon, Tues, Wed... Days per week:
 Day, Week

Running Time
Start time each day (HH:MM):
Duration of day (HH:MM):

The simulation will run for the total of Warm Up Period + Results Collection Period

Warm Up Period

Start results collection after this number of minutes:

Include in displayed clock time



Introdução ao Simul8

Ajustando a unidade de tempo

Clock Properties

Time Units
 Seconds Minutes Hours Days
For units smaller than seconds use decimals of units e.g. 0.001 = 1 millisecond

Time format
 Simple unit count from zero Percent Time only
Decimals: Time Day
Description:

Digital Clock Face

Days
 Day Date Mon, Tues, Wed... Days per week:
 Day, Week

Running Time
Start time each day (HH:MM):
Duration of day (HH:MM):

Warm Up Period Results Collection Period

The simulation will run for the total of Warm Up Period + Results Collection Period

Results Collection Period

Collect results for this amount of time for each simulation run:

Beep on Complete

OK
 Cancel

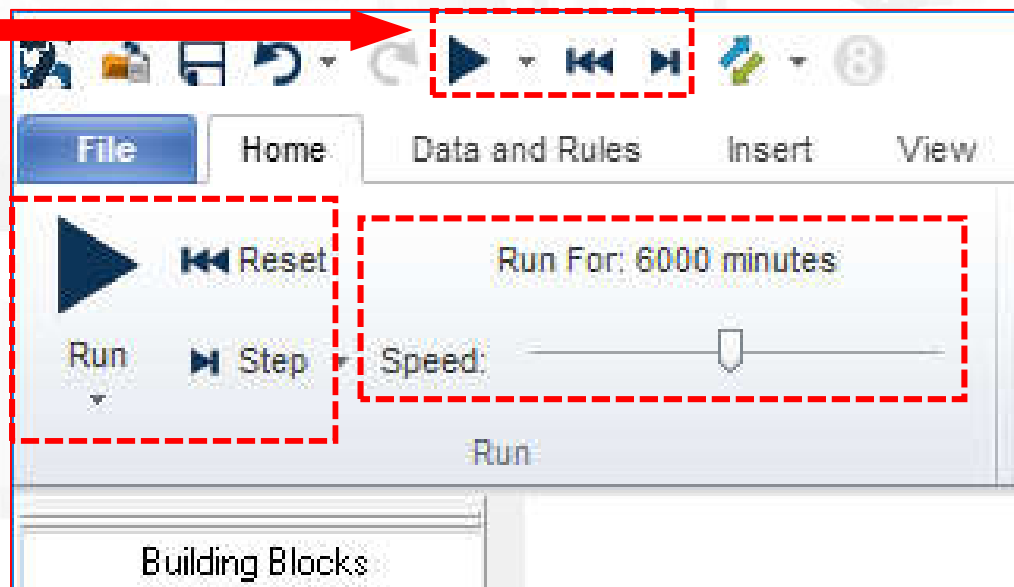
Clicar



Introdução ao Simul8

Executando uma Simulação

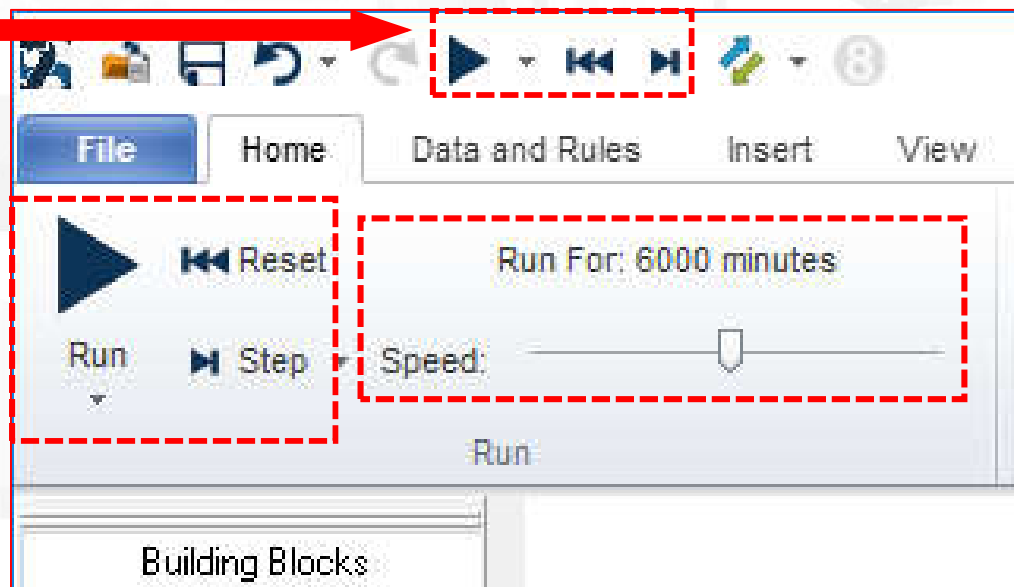
Controles
da
Simulação



Introdução ao Simul8

Executando uma Simulação

Controles
da
Simulação



Introdução ao Simul8

Executando uma Simulação



Introdução ao Simul8

Coletando resultados da Chegada

Para consultar os resultados obtidos após a simulação basta dar um duplo-clique em algum objeto do modelo e clicar no botão **Results** (os resultados dependerão do objeto).

Start Point Properties

Chegadas

Input Work Item Type:

Main Work Item Type

Inter-arrival times (minutes)

Average: 10

Distribution: Exponential

Buttons: OK, Cancel, Help, Memo, Results, Batching, Routing Out, Actions, Graphics, Carbon, Constraints

Options: First at start time, Unlimited arrivals, None, File, Schedule Sheet, From WI State Chart, Day Planner

Finance, Erase, Ignore hints about lost Work Items

Start Results

Chegadas	OK
Number of work items entered this entry point:	565
Number of work items lost:	0
Number of work items entered remainder of simulation:	565



Introdução ao Simul8

Coletando resultados da Fila

Queue Properties

Properties Visual Logic

Fila de Espera OK

Capacity: Infinite Cancel

Shelf Life: None Help

Min Wait Time: ... (minutes)

Prioritize LIFO High Volume Assemble Segregate Results

Queue Results

Fila de Espera OK

Number of work items in this storage:

Currently: 0
Minimum: 0.00
Average: 0.84
Maximum: 8.00
Total Entered: 565

Graph

Sync with other results
 Plot every change

Queuing Time:

	All	Non-Zeros
Minimum:	0.00	0.00
Average:	9.01	15.62
Maximum:	62.35	
Standard Deviation:	13.06	
Number of non zero queuing times:		326

Queuing Time within limit:

Time limit: minutes

Percentage within limit: 69%



Introdução ao Simul8

Coletando resultados da Fila

Queue Results

Fila de Espera OK

Number of work items in this storage:

Currently:	0	
Minimum:	0.00	
Average:	0.84	
Maximum:	8.00	
Total Entered:	565	

Graph

Sync with other results
 Plot every change

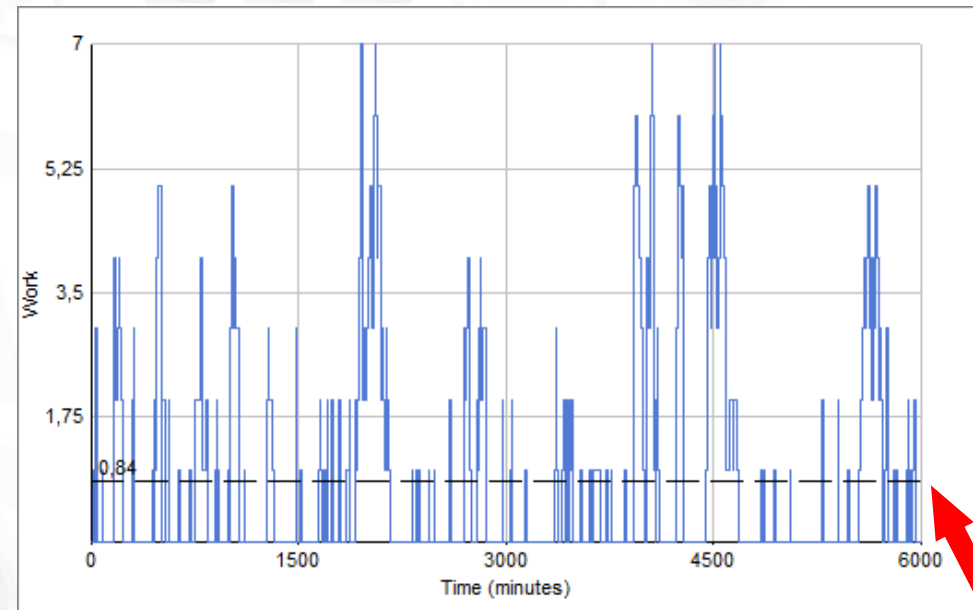
Queuing Time:

	All	Non-Zeros
Minimum:	0.00	0.00
Average:	9.01	15.62
Maximum:	62.35	
Standard Deviation:	13.06	
Number of non zero queuing times:		326

Queuing Time within limit:

Time limit: minutes Graph

Percentage within limit: 69%



Introdução ao Simul8

Coletando resultados da Fila

Queue Results

Fila de Espera ✔ OK

Number of work items in this storage:

Currently:	0	
Minimum:	0.00	
Average:	0.84	
Maximum:	8.00	
Total Entered:	565	

Graph

Sync with other results
 Plot every change

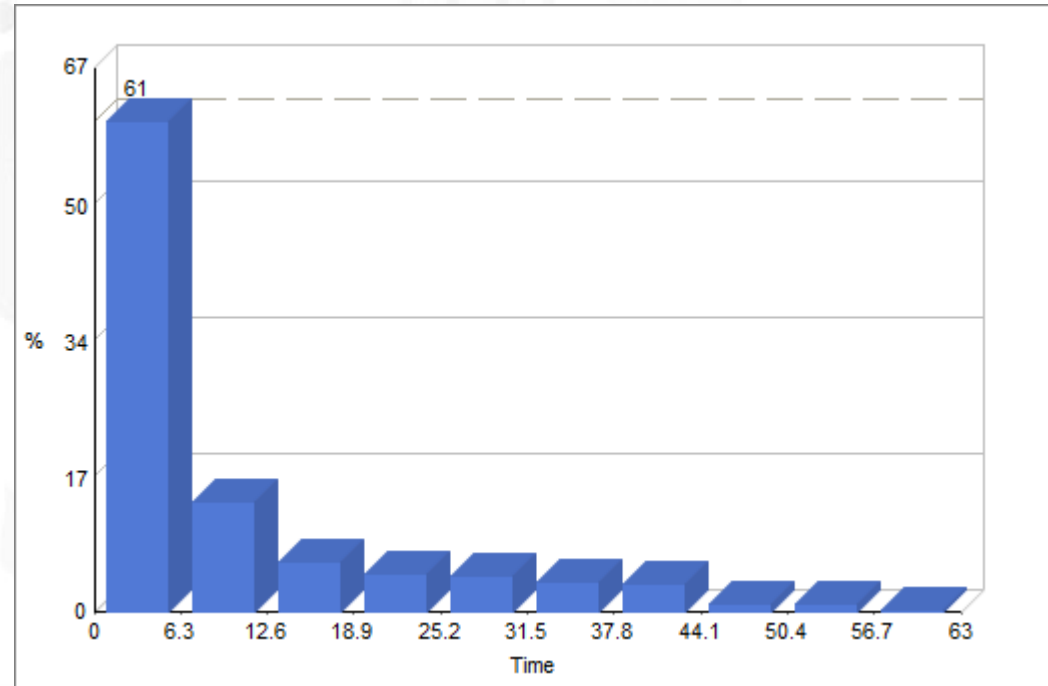
Queuing Time:

	All	Non-Zeros
Minimum:	0.00	0.00
Average:	9.01	15.62
Maximum:	62.35	
Standard Deviation:	13.06	
Number of non zero queuing times:		326

Queuing Time within limit:

Time limit: minutes

Percentage within limit: 69% 📊



Histograma dos tempos de espera




Introdução ao Simul8


Coletando resultados do Atendimento

Activity Properties

Atendimento


Timing (minutes) 

Average: 6

Distribution: Exponential 

New Detail


High Volume

Finance Erase Carbon 

IF On State Change

OK
 Cancel
 Help
Memo
Results
Resources
Efficiency
Routing In Out
Actions
Priority
Replicate = 1
Contents
Graphics
Shifts

Activity Results

Atendimento  OK

Number of work items:



Currently in Activity:	0
Minimum:	0.00
Average:	0.57
Maximum:	1.00
Completed Jobs:	565

Graph

Sync with other results
 Plot every change

Percent of time:

Awaiting Work:	43.26
Working:	56.74
Blocked:	0.00
Stopped:	0.00
Change Over:	0.00
Off Shift:	0.00
Resource Starved:	0.00
Scheduled Maintenance:	0.00



Introdução ao Simul8

Coletando resultados do Atendimento

Activity Results

Atendimento OK

Number of work items:

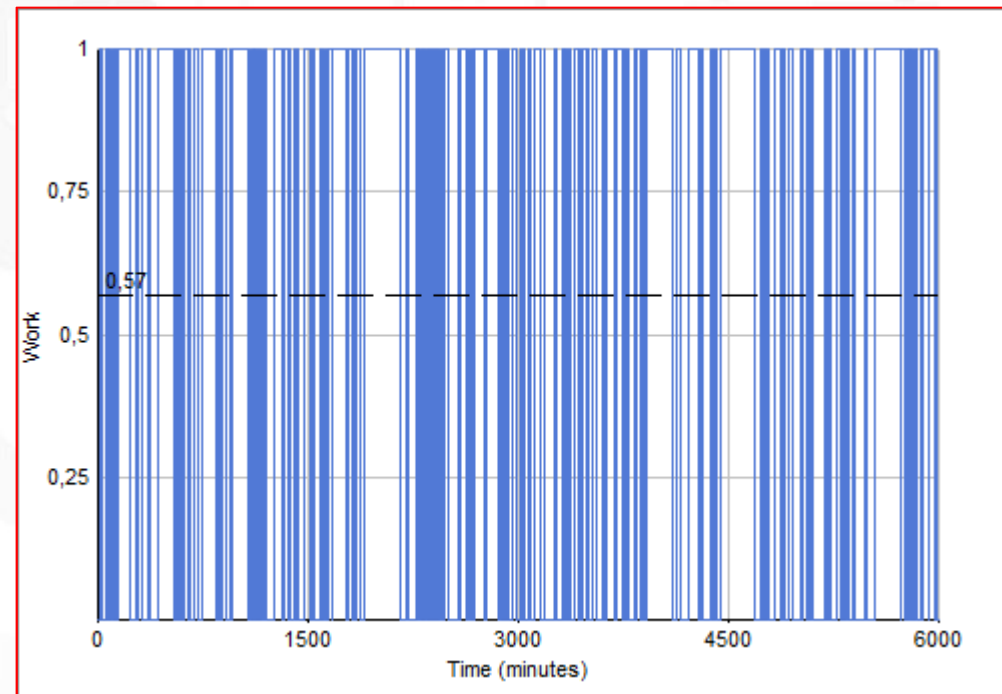
Currently in Activity:	0
Minimum:	0.00
Average:	0.57
Maximum:	1.00
Completed Jobs:	565

Graph

Sync with other results
 Plot every change

Percent of time:

Awaiting Work:	43.26
Working:	56.74
Blocked:	0.00
Stopped:	0.00
Change Over:	0.00
Off Shift:	0.00
Resource Starved:	0.00
Scheduled Maintenance:	0.00



Introdução ao Simul8

Coletando resultados do Atendimento

Activity Results

Atendimento ✔ OK

Number of work items:

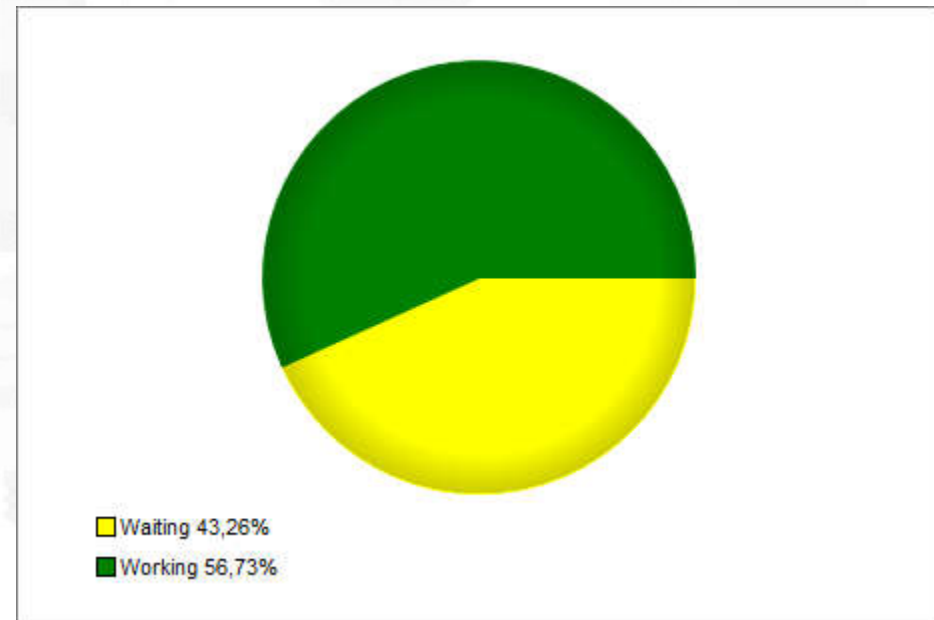

Currently in Activity:	0
Minimum:	0.00
Average:	0.57
Maximum:	1.00
Completed Jobs:	565

Graph

Sync with other results
 Plot every change

Percent of time:

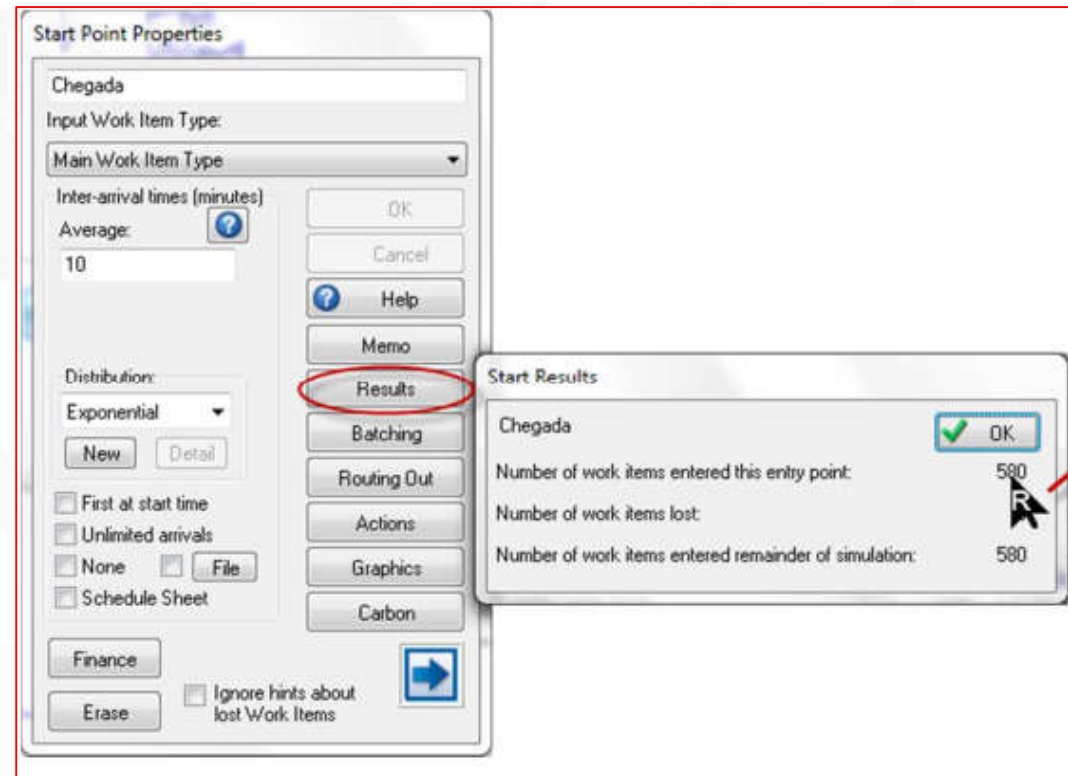
Awaiting Work:	43.26
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Blocked:	0.00
Stopped:	0.00
Change Over:	0.00
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Resource Starved:	0.00
Scheduled Maintenance:	0.00



Introdução ao Simul8

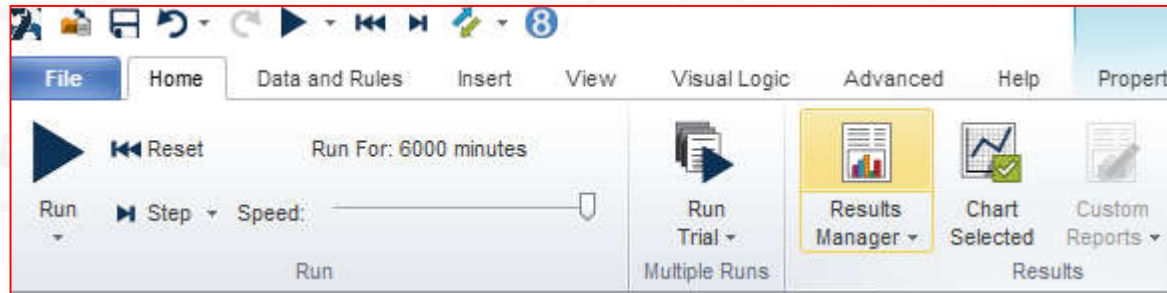
Gerando relatório de resultados

O SIMUL8 permite a criação de um resumo de resultados personalizado, que pode ser consultado após o final da simulação por meio do botão **Results Manager** da aba principal do programa (aba *Home*). Para configurar os resultados que serão exibidos no resumo é preciso clicar com o botão direito do *mouse* sobre os valores desejados nas janelas de resultados correspondentes (o cursor mudará de cor e de formato ao ser posicionado sobre algum resultado numérico. Para remover algum resultado do resumo, o procedimento é o mesmo.



Introdução ao Simul8

Gerando relatório de resultados



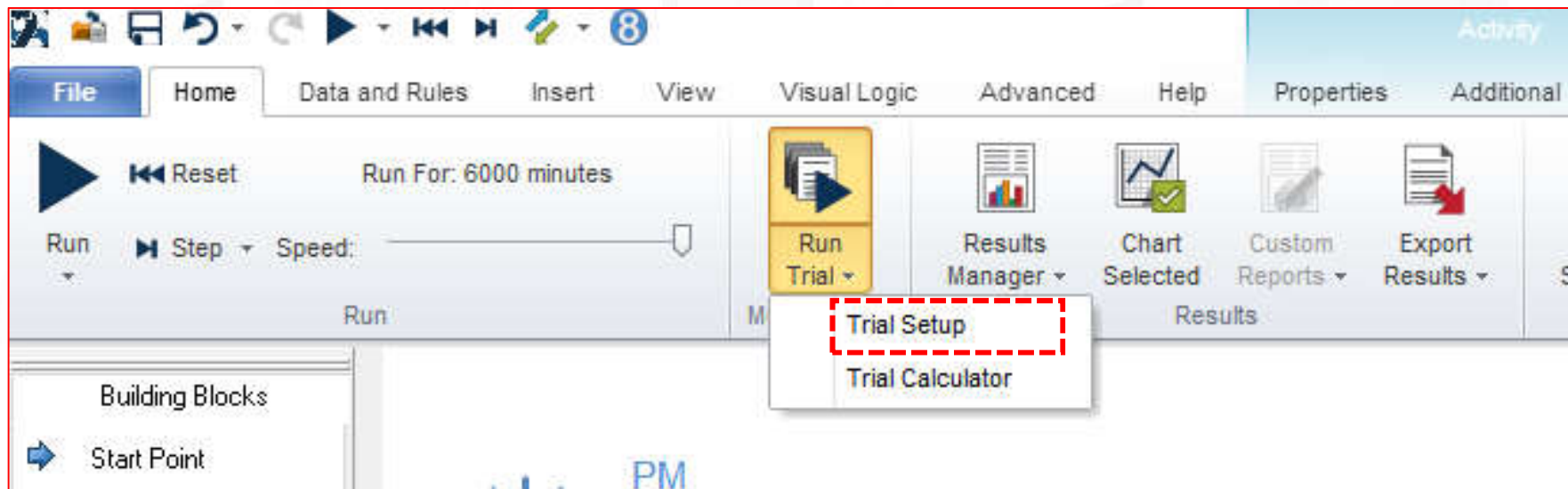
The screenshot shows the SIMUL8 Results Manager window. The window title is 'SIMUL8 Results Manager'. The 'KPIs' tab is selected. The table displays performance metrics for various components of the simulation.

from most recent run only.		Result	Click "Multiple Runs" button to get ranges.
Chegadas	Number Entered	565.00	
Fila de Espera	Average Queue Size	0.85	
	Average Queuing Time	9.01	
Atendimento	Average Use	0.57	
Saída	Maximum Time in System	78.98	
	Average Time in System	16.01	
Atendimento	Waiting %	43.26	
	Working %	56.74	



Introdução ao Simul8

Executando uma rodada de simulações



Introdução ao Simul8

Executando uma rodada de simulações

Alterar

Clicar

Conduct Trial

Number of runs in trial: **Run Trial** **Apply**

Calculate Required Number of Runs **Extend** **Cancel**

Base Random Number Set: **Help**

Name of trial:

Auto Display Results Summary at end of last run

Display ranges (%): **What is V.I.S.A.?**

Add Results to V.I.S.A. **Preselect V.I.S.A. model**

Use Parallel Processors for fast results (spare cores on this PC or others on LAN)
[\[Set up in File/Preferences/Results\]](#)

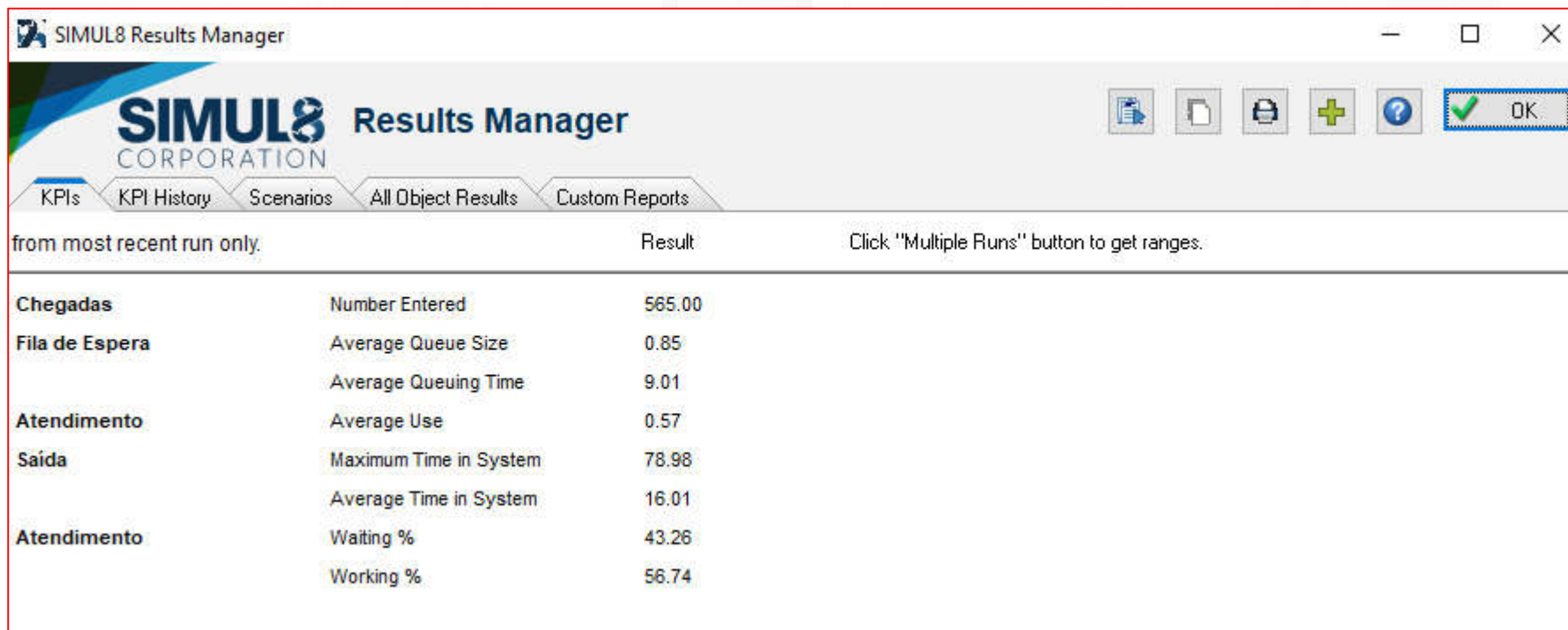
Use Antithetic runs for variance reduction (Professional Only)

Auto Display Dashboard at end of last run



Introdução ao Simul8

Gerando relatório de resultados



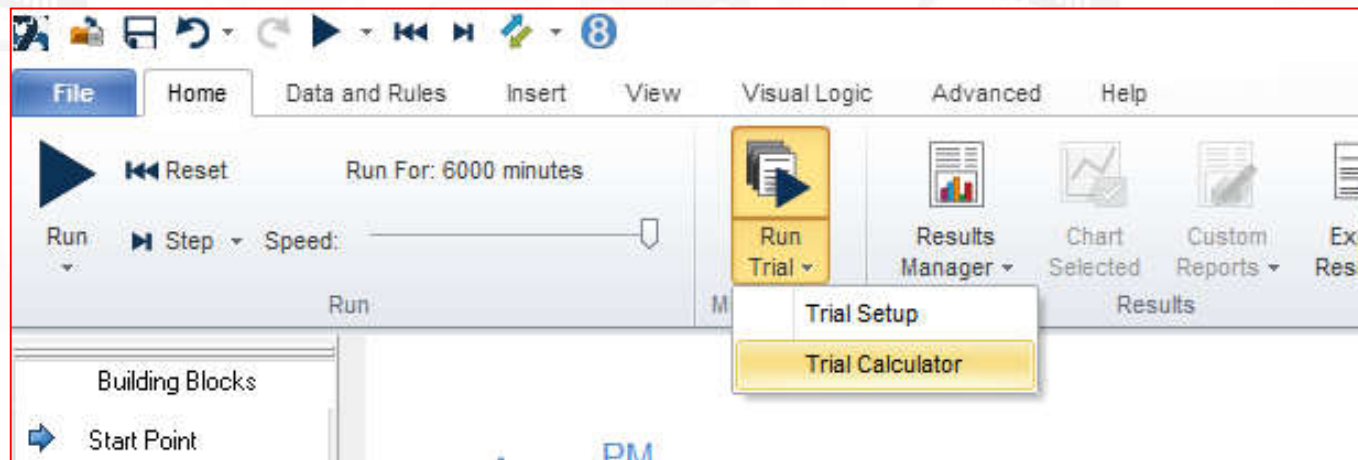
The screenshot shows the SIMUL8 Results Manager application window. The title bar reads "SIMUL8 Results Manager". The interface includes a logo for SIMUL8 CORPORATION, a navigation menu with tabs for "KPIs", "KPI History", "Scenarios", "All Object Results", and "Custom Reports", and a toolbar with icons for file operations and a green checkmark button labeled "OK". Below the navigation menu, there is a table of results. The table has three columns: a category, a metric name, and a numerical result. A note above the table says "from most recent run only." and "Click 'Multiple Runs' button to get ranges." The table contains the following data:

		Result
Chegadas	Number Entered	565.00
Fila de Espera	Average Queue Size	0.85
	Average Queuing Time	9.01
Atendimento	Average Use	0.57
Saida	Maximum Time in System	78.98
	Average Time in System	16.01
Atendimento	Waiting %	43.26
	Working %	56.74



Introdução ao Simul8

Dimensionando o número de Replicatas



Introdução ao Simul8

Dimensionando o número de Replicatas

Trial Calculator

The Trials Calculator recommends a number of runs to use for trials.
The recommendation is based on your required precision of the confidence limits around the estimate of the mean for your simulation results (KPIs)

Required precision: % of the mean. Your selected (95%) confidence limits will each be within this % of the estimate of the mean.

How to use: Add to the right hand box (below) all the KPIs you want to meet the required precision.

All KPIs

- Chegadas: Number Entered
- Fila de Espera: Average Queue Size
- Fila de Espera: Average Queuing Time
- Atendimento: Average Use
- Saída: Maximum Time in System
- Saída: Average Time in System**
- Atendimento: Waiting %
- Atendimento: Working %

KPIs to meet required precision

- Fila de Espera: Average Queue Size
- Saída: Average Time in System

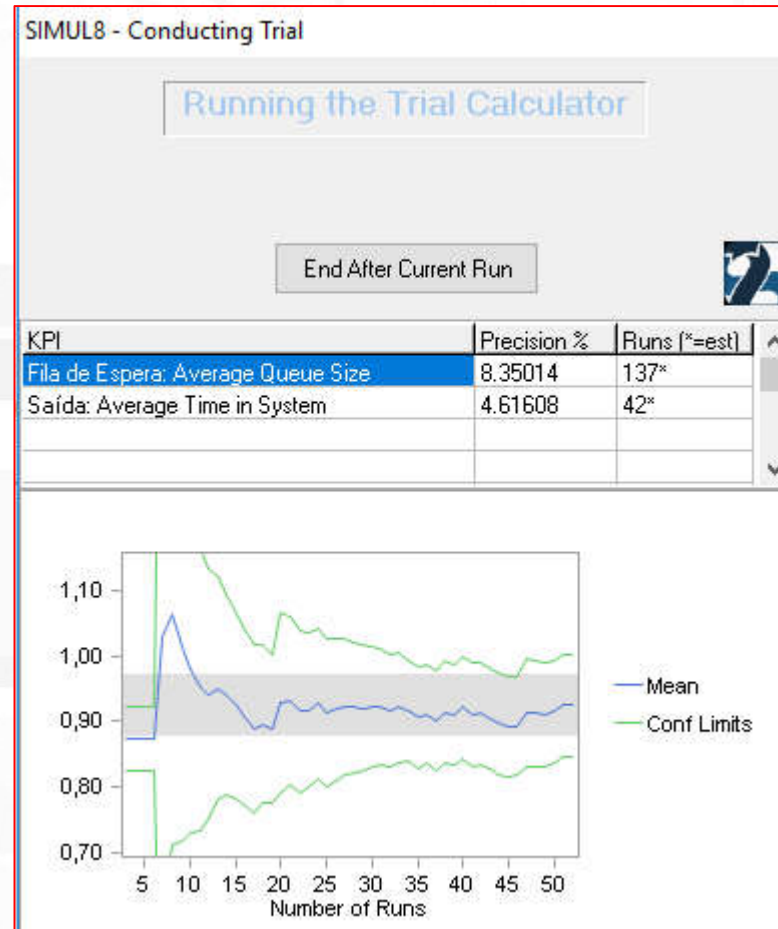
Highlight the KPI you want graphed first during the calculation

For information on how the Trial Calculator works, and information on other related research see <http://www.wbs.ac.uk/qo/autosimooa>



Introdução ao Simul8

Dimensionando o número de Replicatas



Introdução ao Simul8

Dimensionando o número de Replicatas

The screenshot displays the SIMUL8 Results Manager interface. The main window shows a table of KPIs with columns for Low 95% Range, Average Result, High 95% Range, and Risk. A 'Trials Calculator - Recommendations' dialog box is open in the foreground, showing recommended runs for specific KPIs.

		Low 95% Range	Average Result	High 95% Range	Risk
Chegadas	Number Entered	593.78	597.87	601.97	
Fila de Espera	Average Queue Size	0.88	0.93	0.97	
	Average Queuing Time	8.82	9.25	9.68	
Atendimento	Average Use	0.59	0.60	0.61	
Saída	Maximum Time in System	77.39	80.95	84.51	
	Average Time in System	15.80	16.26	16.71	
Atendimento	Waiting %	39.41	40.01	40.62	
	Working %	59.38	59.99	60.59	

KPI	Recommended Runs
(Recommended runs for 5% precision)	
Fila de Espera: Average Queue Size	142
Saída: Average Time in System	45

