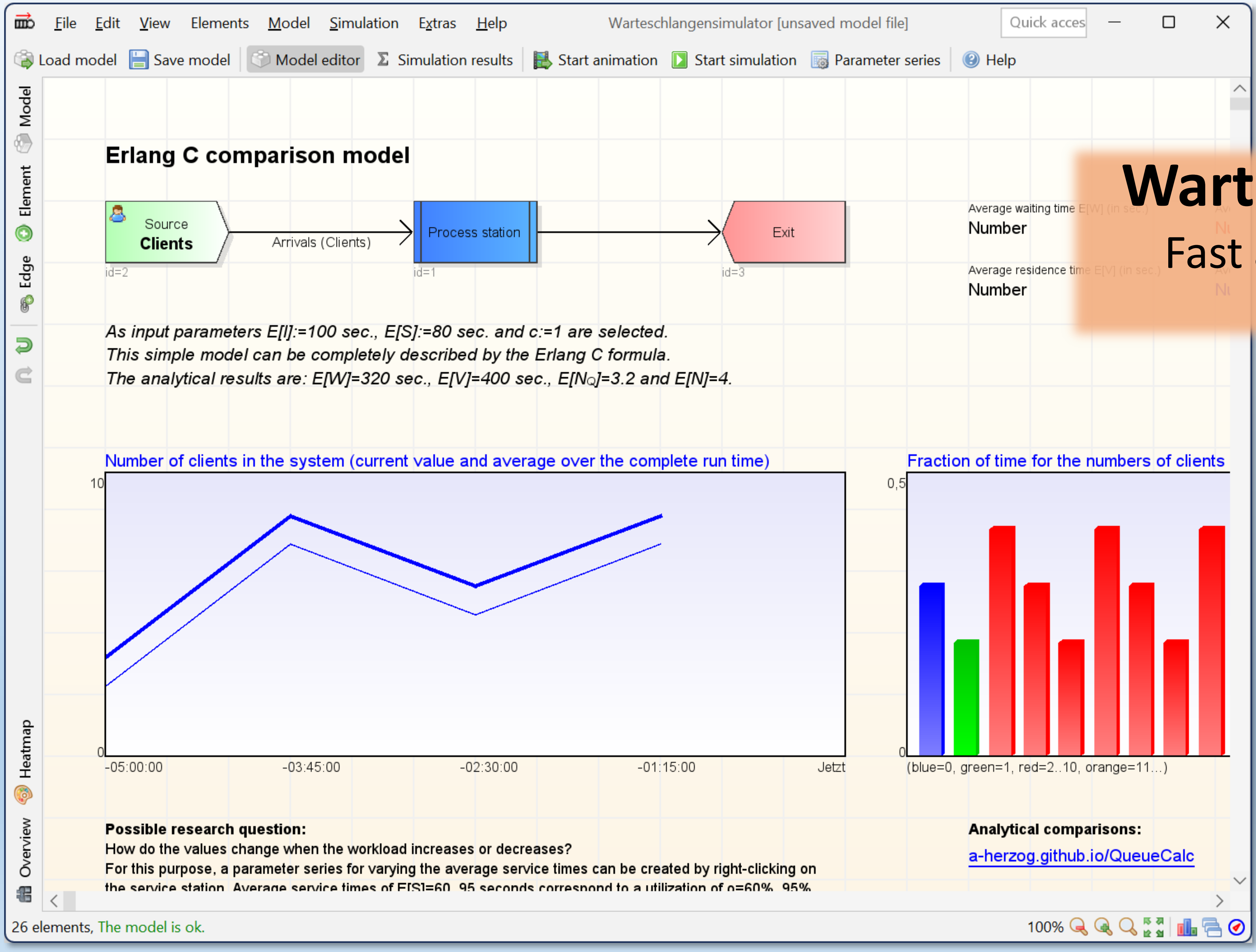
Warteschlangensimulator – Event-driven stochastic simulation   a-herzog.github.io/Warteschlangensimulator



Erlang C comparison model

As input parameters E[I]:=100 sec., E[S]:=80 sec. and c:=1 are selected.
This simple model can be completely described by the Erlang C formula.
The analytical results are: E[W]=320 sec., E[V]=400 sec., E[N_Q]=3.2 and E[N]=4.

Number of clients in the system (current value and average over the complete run time)

Fraction of time for the numbers of clients

(blue=0, green=1, red=2..10, orange=11...)

Possible research question:
How do the values change when the workload increases or decreases?
For this purpose, a parameter series for varying the average service times can be created by right-clicking on
the service station. Average service times of E[S]=60, 95 seconds correspond to a utilization of ρ=60%, 95%

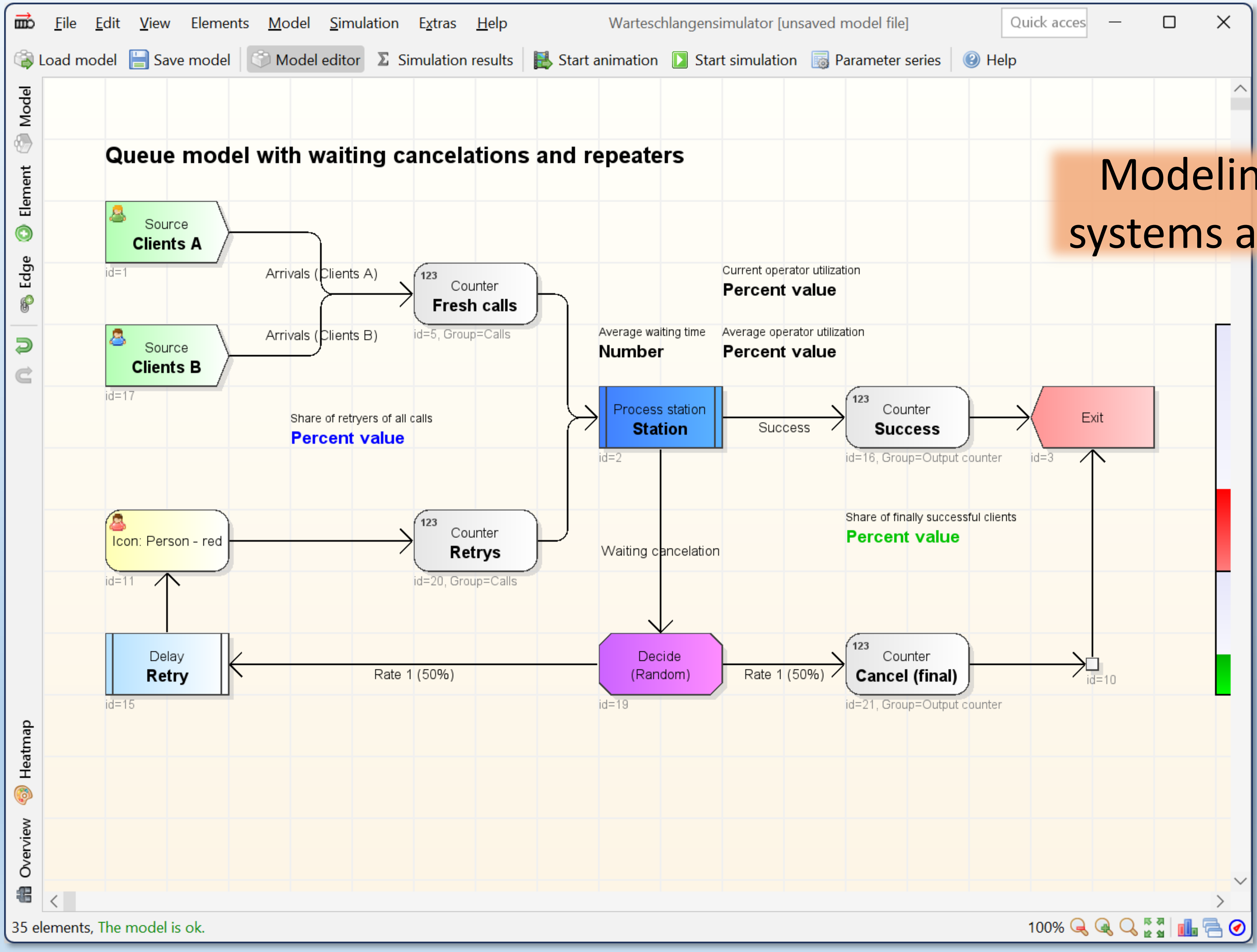
Analytical comparisons:
a-herzog.github.io/QueueCalc

26 elements, The model is ok.

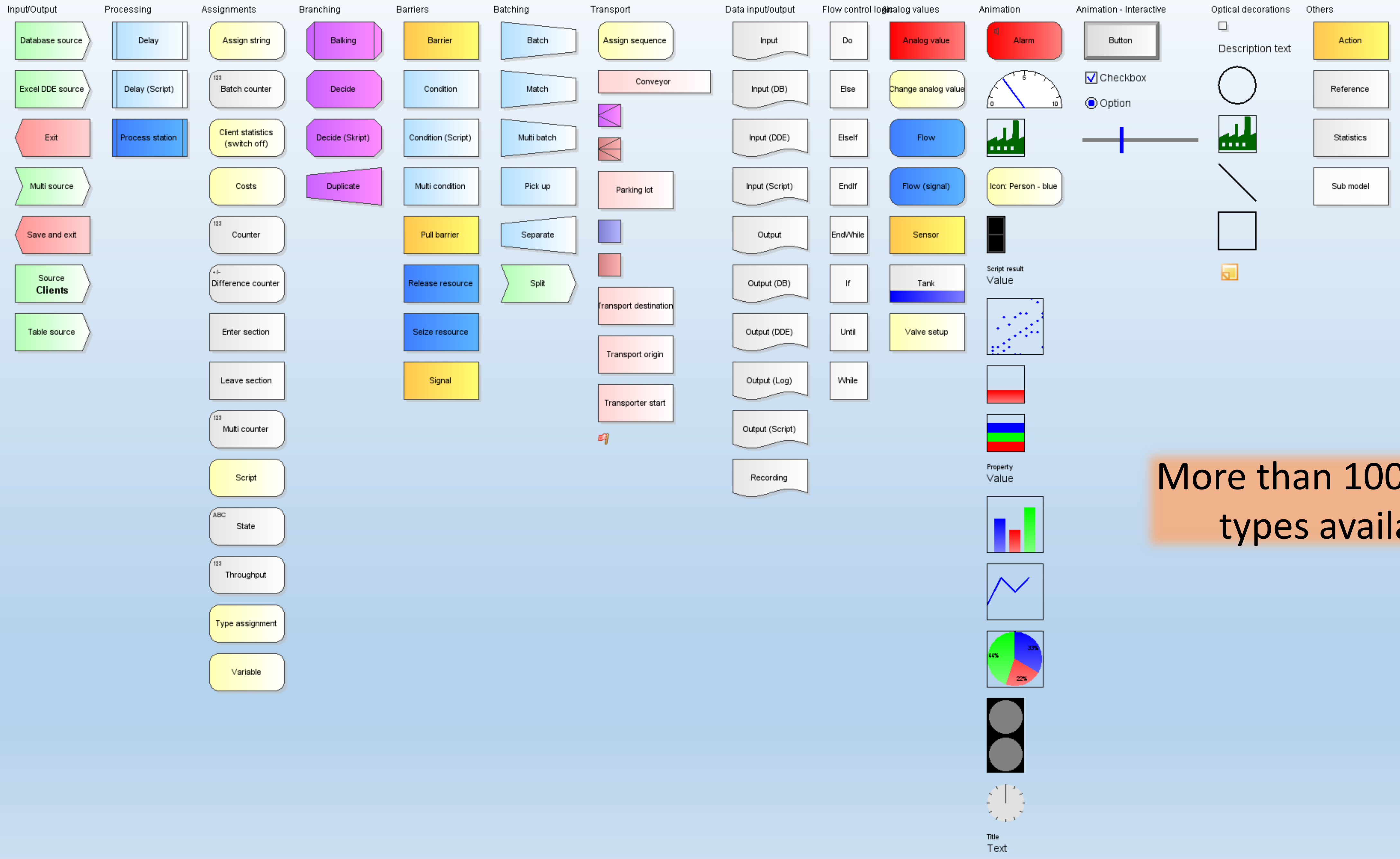
Warteschlangensimulator

Fast and versatile event-driven stochastic simulator

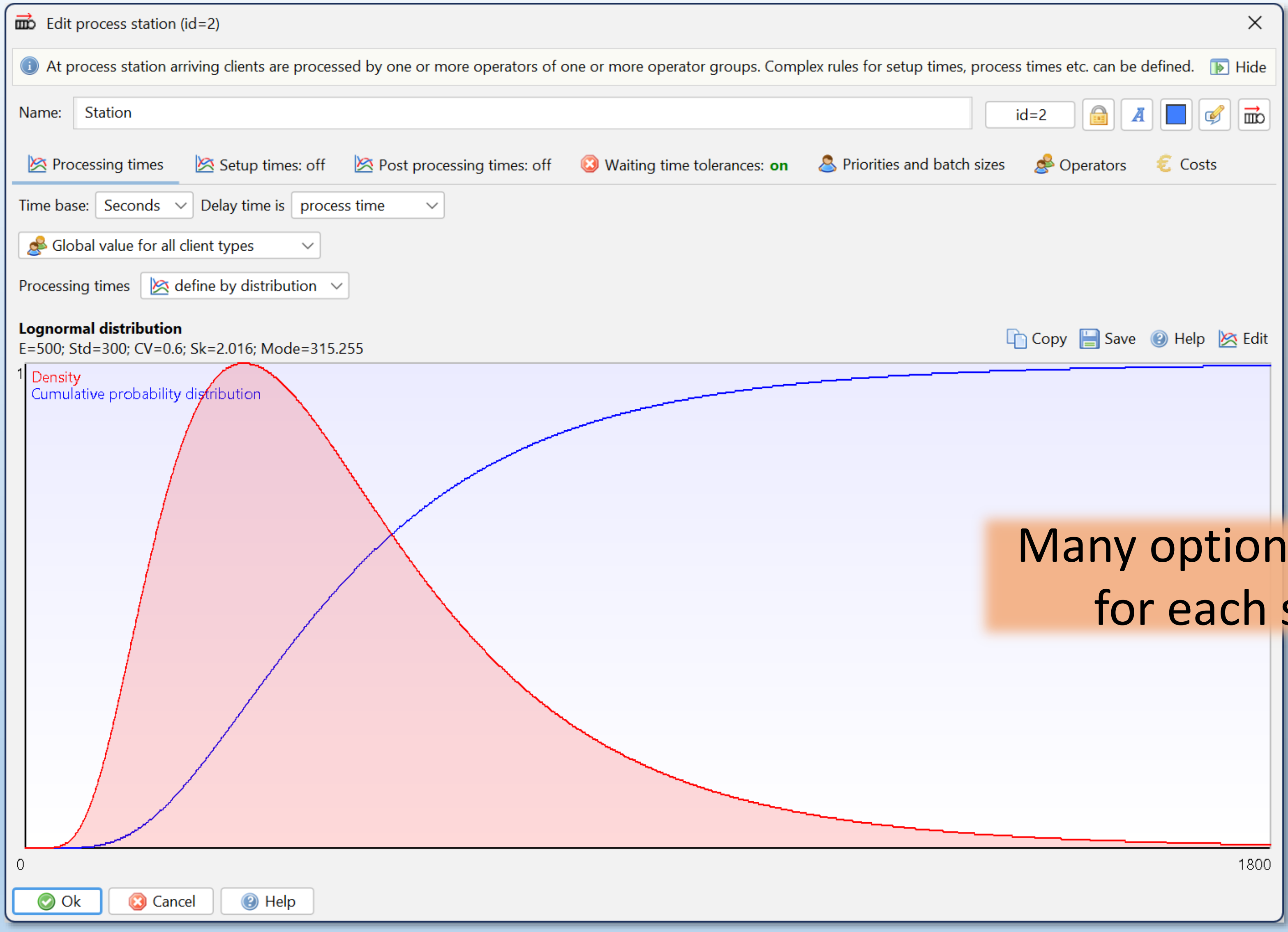
Modeling queueing systems as **flow charts**



Warteschlangensimulator – Event-driven stochastic simulation a-herzog.github.io/Warteschlangensimulator



More than 100 station types available


Edit process station (id=2)

At process station arriving clients are processed by one or more operators of one or more operator groups. Complex rules for setup times, process times etc. can be defined.

Name: Station

id=2

Processing times | Setup times: off | Post processing times: off | Waiting time tolerances: on | Priorities and batch sizes | Operators | Costs

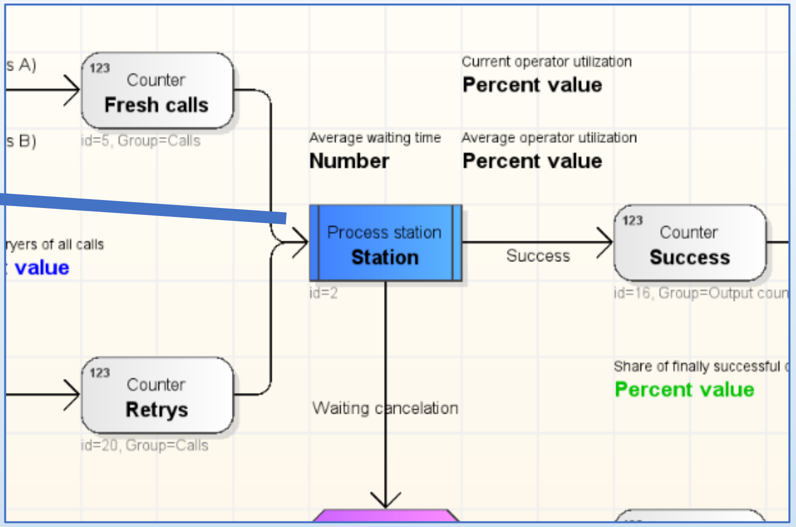
Time base: Seconds

Delay time is process time

Global value for all client types

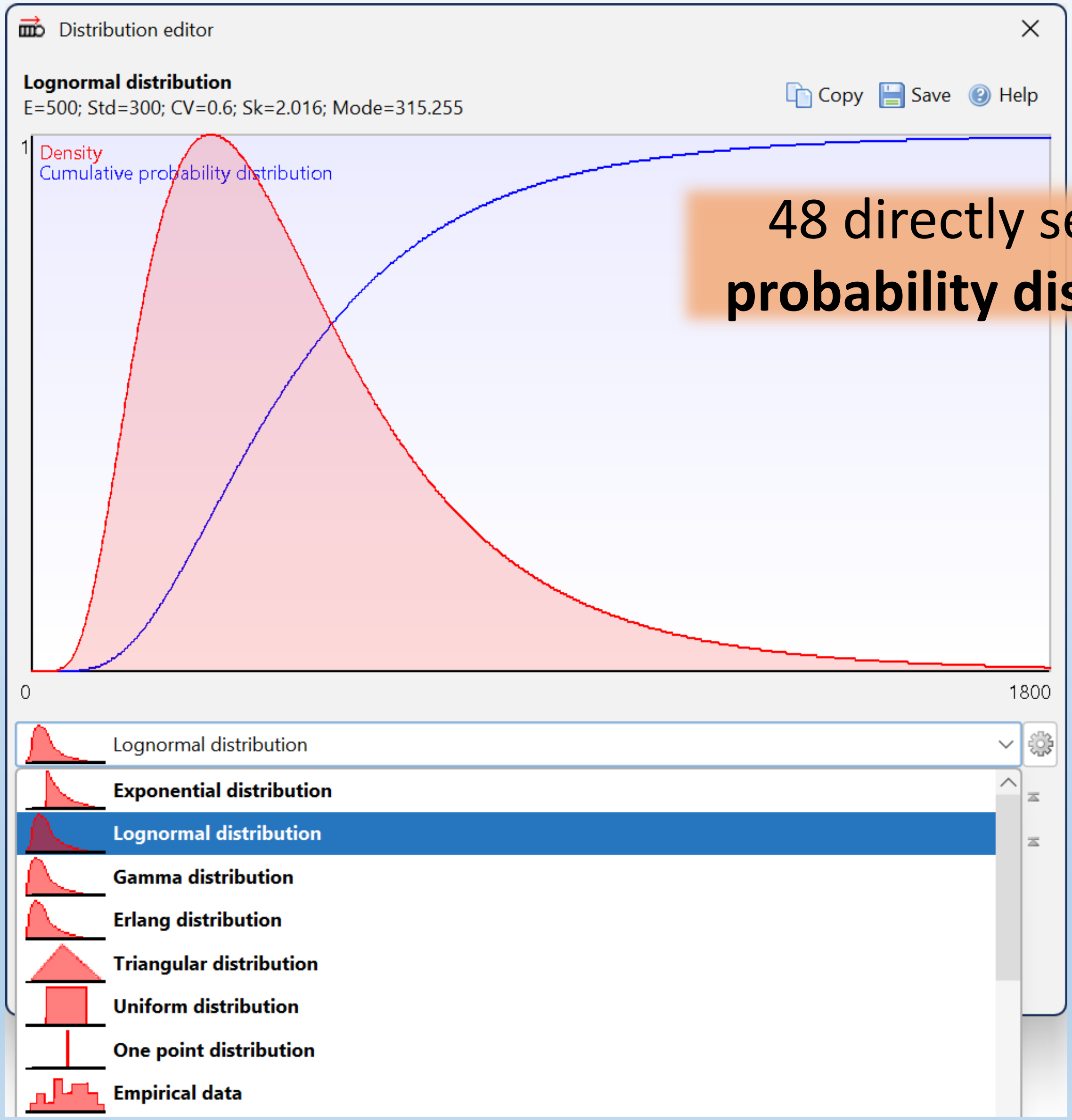
Processing times: define by distribution

Lognormal distribution
E=500; Std=300; CV=0.6; Sk=2.016; Mode=315.255



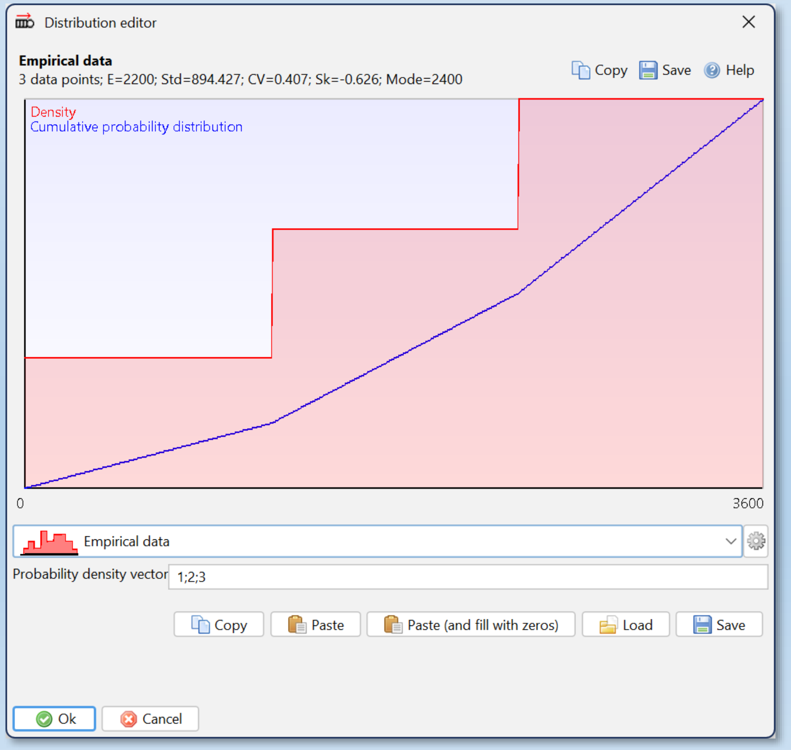
Many optional settings for each station

48 directly selectable **probability distributions**


Distribution editor

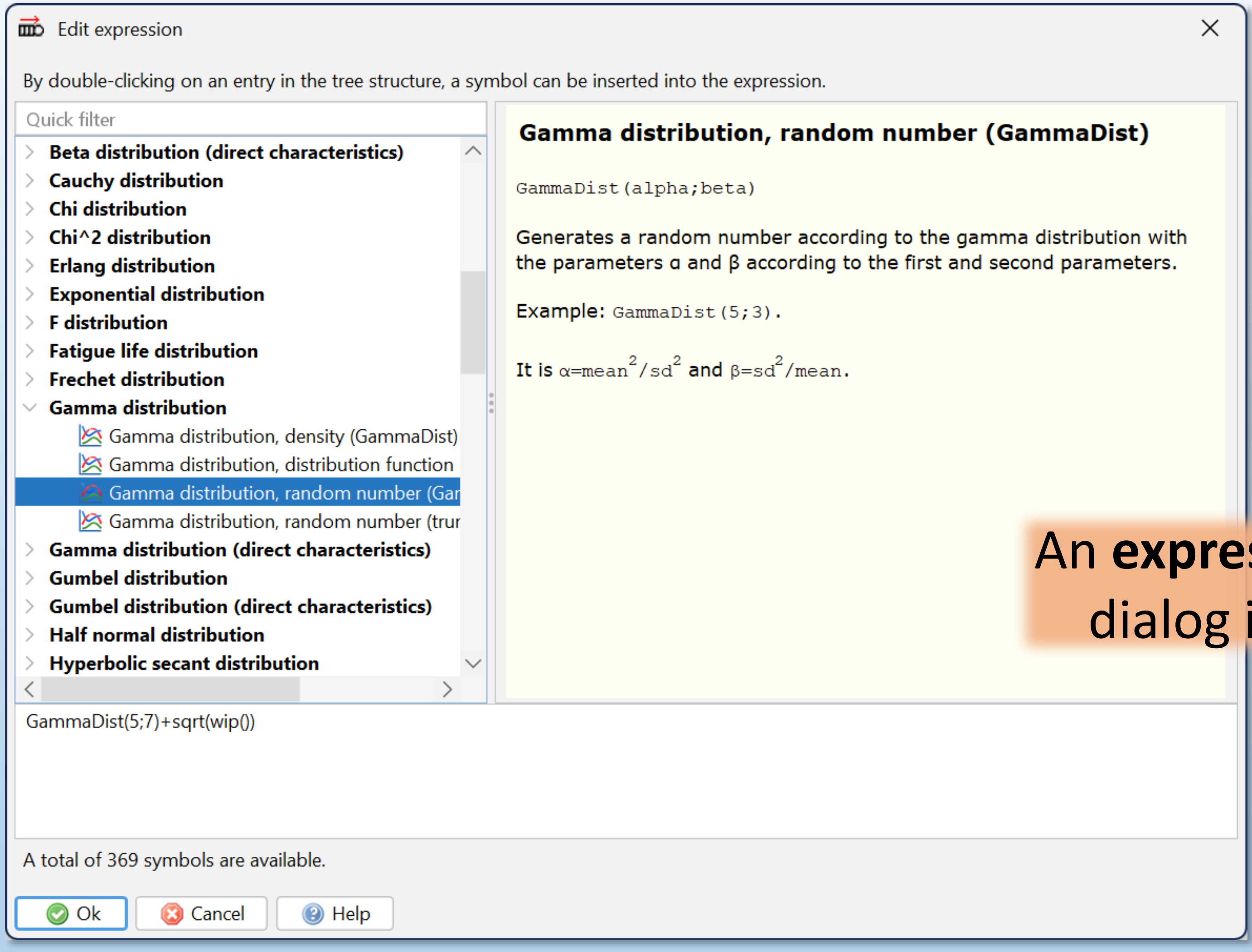
Lognormal distribution
E=500; Std=300; CV=0.6; Sk=2.016; Mode=315.255

... including the option to use **loaded empirical data**


Distribution editor

Empirical data
3 data points; E=2200; Std=894.427; CV=0.407; Sk=-0.626; Mode=2400

Probability density vector: 1;2;3


Edit expression

By double-clicking on an entry in the tree structure, a symbol can be inserted into the expression.

Quick filter
Beta distribution (direct characteristics)
Cauchy distribution
Chi distribution
Chi^2 distribution
Erlang distribution
Exponential distribution
F distribution
Fatigue life distribution
Frechet distribution
Gamma distribution
Gamma distribution, density (GammaDist)
Gamma distribution, distribution function
Gamma distribution, random number (Gar
Gamma distribution, random number (trur
Gamma distribution (direct characteristics)
Gumbel distribution
Gumbel distribution (direct characteristics)
Half normal distribution
Hyperbolic secant distribution

Gamma distribution, random number (GammaDist)

`GammaDist(alpha;beta)`

Generates a random number according to the gamma distribution with the parameters α and β according to the first and second parameters.

Example: `GammaDist(5;3)`.

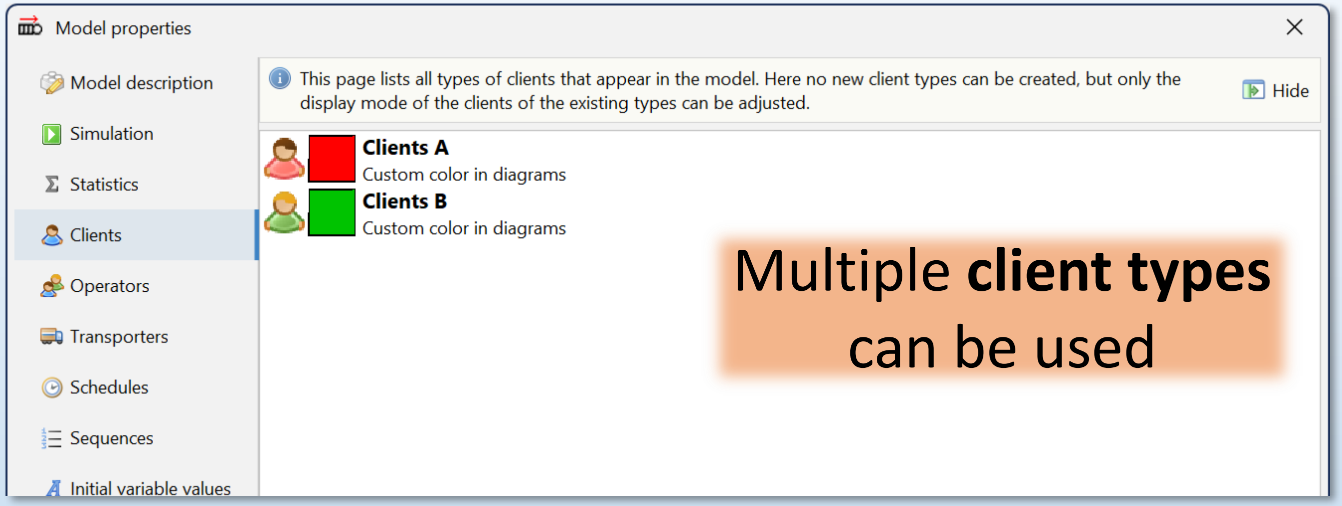
It is α=mean^2/sd^2 and β=sd^2/mean.

```
GammaDist(5;7)+sqrt(wip())
```

A total of 369 symbols are available.

Calculation expressions can also be used

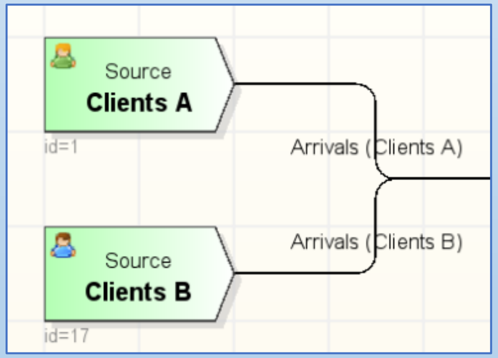
An **expression builder** dialog is available



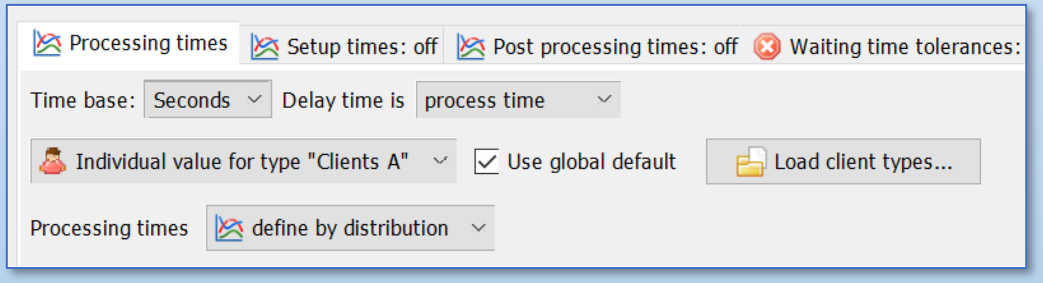
This page lists all types of clients that appear in the model. Here no new client types can be created, but only the display mode of the clients of the existing types can be adjusted.

🟥	**Clients A** Custom color in diagrams
🟩	**Clients B** Custom color in diagrams

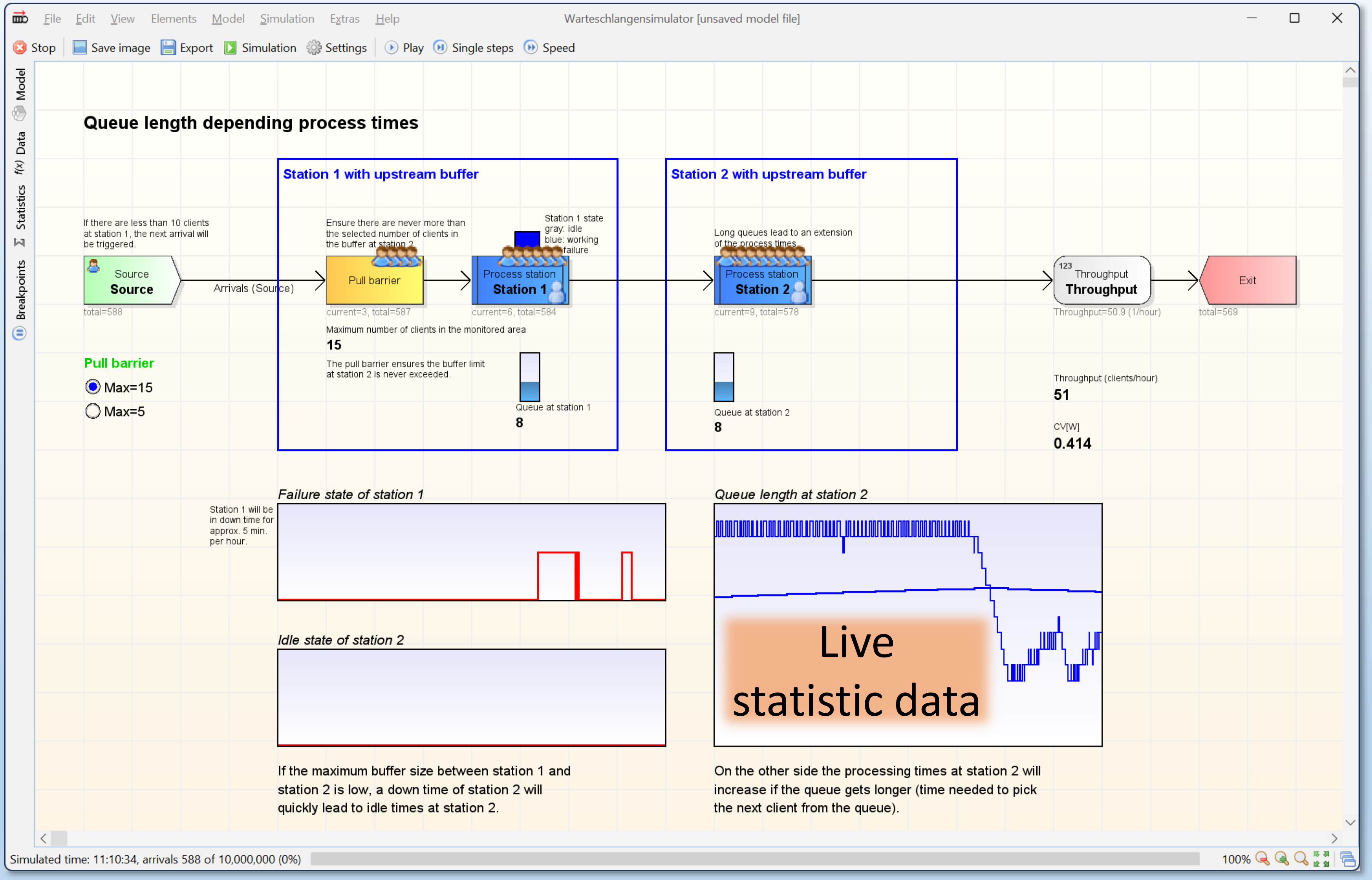
Multiple **client types** can be used



Each type can have an individual parameters



Time base: Seconds
Delay time is process time
Individual value for type "Clients A"
✓ Use global default
Processing times: define by distribution


File Edit View Elements Model Simulation Extras Help
Warteschlangensimulator [unsaved model file]
Stop Save image Export Simulation Settings Play Single steps Speed
Model Data f(x) Statistics Breakpoints
Station 1 with upstream buffer
Station 2 with upstream buffer
Source Source
Arrivals (Source)
Pull barrier
Process station Station 1
Process station Station 2
Throughput Throughput
Exit
total=588
current=3, total=587
current=6, total=584
current=9, total=578
Throughput=50.9 (1/hour)
total=569
Station 1 state gray: idle blue: working red: failure
Pull barrier
Max=15
Max=5
Maximum number of clients in the monitored area
15
Queue at station 1
8
Queue at station 2
8
Throughput (clients/hour)
51
CV[W]
0.414
Failure state of station 1
Idle state of station 2
Queue length at station 2
100%

Queue length depending process times

If there are less than 10 clients at station 1, the next arrival will be triggered.

Ensure there are never more than the selected number of clients in the buffer at station 2

Long queues lead to an extension of the process times

The pull barrier ensures the buffer limit at station 2 is never exceeded.

Station 1 will be in down time for approx. 5 min. per hour.

If the maximum buffer size between station 1 and station 2 is low, a down time of station 2 will quickly lead to idle times at station 2.

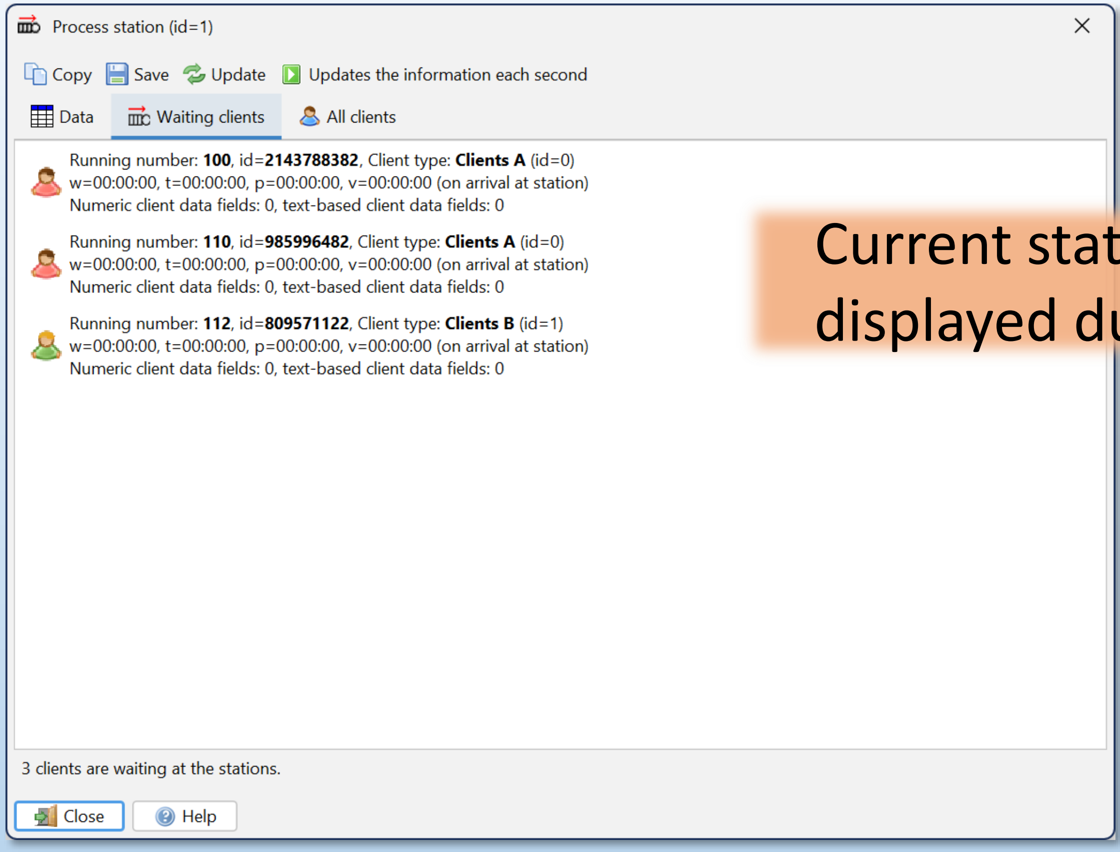
On the other side the processing times at station 2 will increase if the queue gets longer (time needed to pick the next client from the queue).

Simulated time: 11:10:34, arrivals 588 of 10,000,000 (0%)

Live statistic data

Animation of models

… which can be recorded as videos



Running number: **100**, id=**2143788382**, Client type: **Clients A** (id=0)
w=00:00:00, t=00:00:00, p=00:00:00, v=00:00:00 (on arrival at station)
Numeric client data fields: 0, text-based client data fields: 0

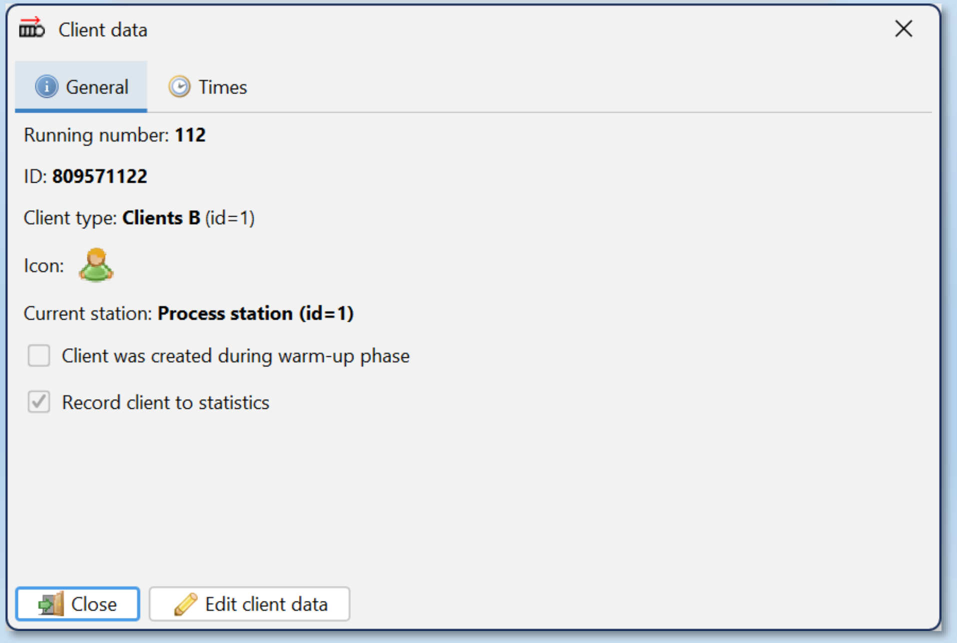
Running number: **110**, id=**985996482**, Client type: **Clients A** (id=0)
w=00:00:00, t=00:00:00, p=00:00:00, v=00:00:00 (on arrival at station)
Numeric client data fields: 0, text-based client data fields: 0

Running number: **112**, id=**809571122**, Client type: **Clients B** (id=1)
w=00:00:00, t=00:00:00, p=00:00:00, v=00:00:00 (on arrival at station)
Numeric client data fields: 0, text-based client data fields: 0

3 clients are waiting at the stations.

Current station data can be displayed during animation

… and also changed while animation is running



Running number: **112**

ID: **809571122**

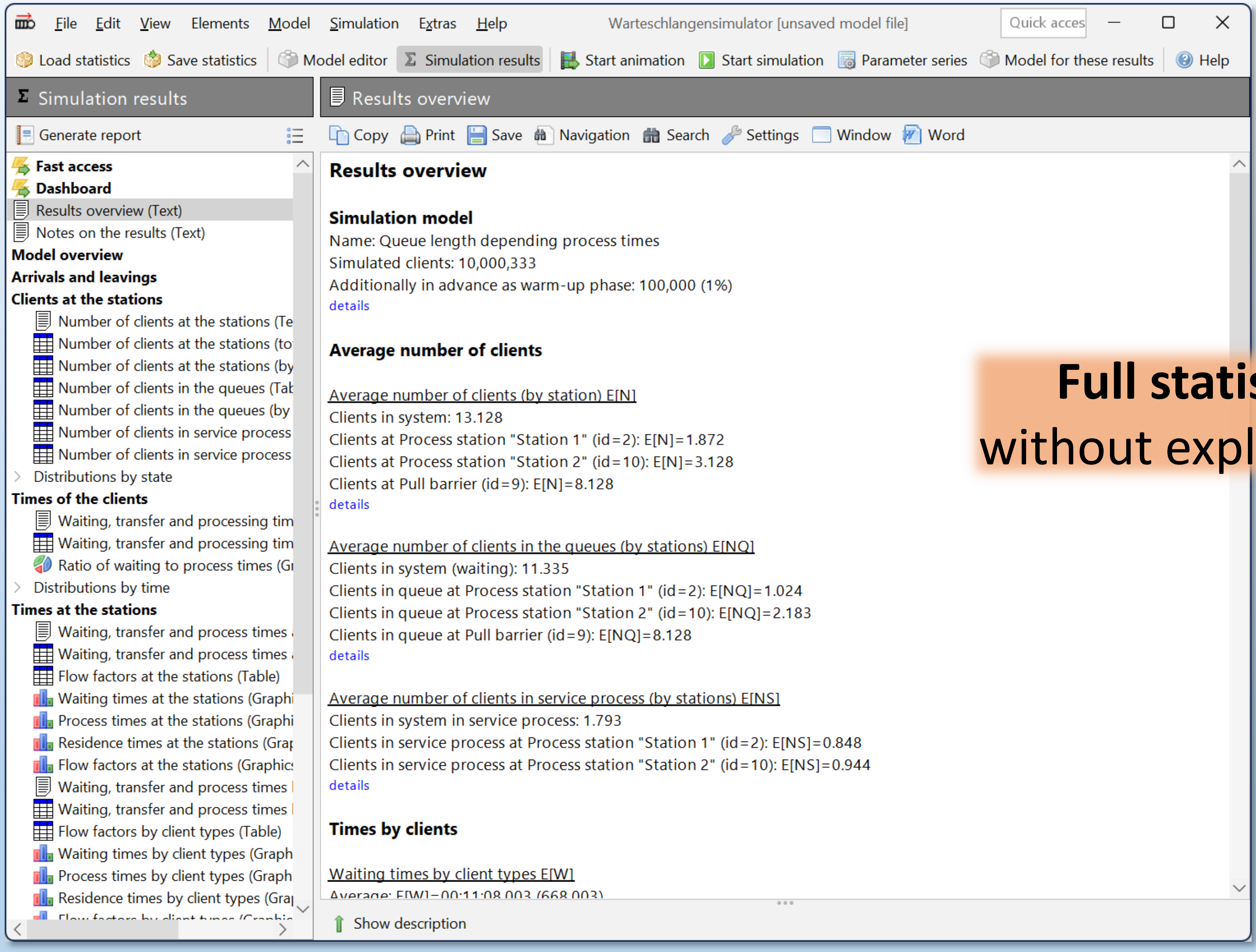
Client type: **Clients B** (id=1)

Icon:

Current station: **Process station (id=1)**

☐ Client was created during warm-up phase

☑ Record client to statistics


File
Edit
View
Elements
Model
Simulation
Extras
Help
Warteschlangensimulator [unsaved model file]
Quick acces
Load statistics
Save statistics
Model editor
Simulation results
Start animation
Start simulation
Parameter series
Model for these results
Help
Simulation results
Results overview
Generate report
Copy
Print
Save
Navigation
Search
Settings
Window
Word
Fast access
Dashboard
Results overview (Text)
Notes on the results (Text)
Model overview
Arrivals and leavings
Clients at the stations
Number of clients at the stations (Te
Number of clients at the stations (to
Number of clients at the stations (by
Number of clients in the queues (Tab
Number of clients in the queues (by
Number of clients in service process
Number of clients in service process
Distributions by state
Times of the clients
Waiting, transfer and processing tim
Waiting, transfer and processing tim
Ratio of waiting to process times (Gr
Distributions by time
Times at the stations
Waiting, transfer and process times
Waiting, transfer and process times
Flow factors at the stations (Table)
Waiting times at the stations (Graphi
Process times at the stations (Graphi
Residence times at the stations (Gra
Flow factors at the stations (Graphic
Waiting, transfer and process times
Waiting, transfer and process times
Flow factors by client types (Table)
Waiting times by client types (Graph
Process times by client types (Graph
Residence times by client types (Gra
Show description

Results overview

Simulation model
Name: Queue length depending process times
Simulated clients: 10,000,333
Additionally in advance as warm-up phase: 100,000 (1%)
details

Average number of clients

Average number of clients (by station) E[N]
Clients in system: 13.128
Clients at Process station "Station 1" (id=2): E[N]=1.872
Clients at Process station "Station 2" (id=10): E[N]=3.128
Clients at Pull barrier (id=9): E[N]=8.128
details

Average number of clients in the queues (by stations) E[NQ]
Clients in system (waiting): 11.335
Clients in queue at Process station "Station 1" (id=2): E[NQ]=1.024
Clients in queue at Process station "Station 2" (id=10): E[NQ]=2.183
Clients in queue at Pull barrier (id=9): E[NQ]=8.128
details

Average number of clients in service process (by stations) E[NS]
Clients in system in service process: 1.793
Clients in service process at Process station "Station 1" (id=2): E[NS]=0.848
Clients in service process at Process station "Station 2" (id=10): E[NS]=0.944
details

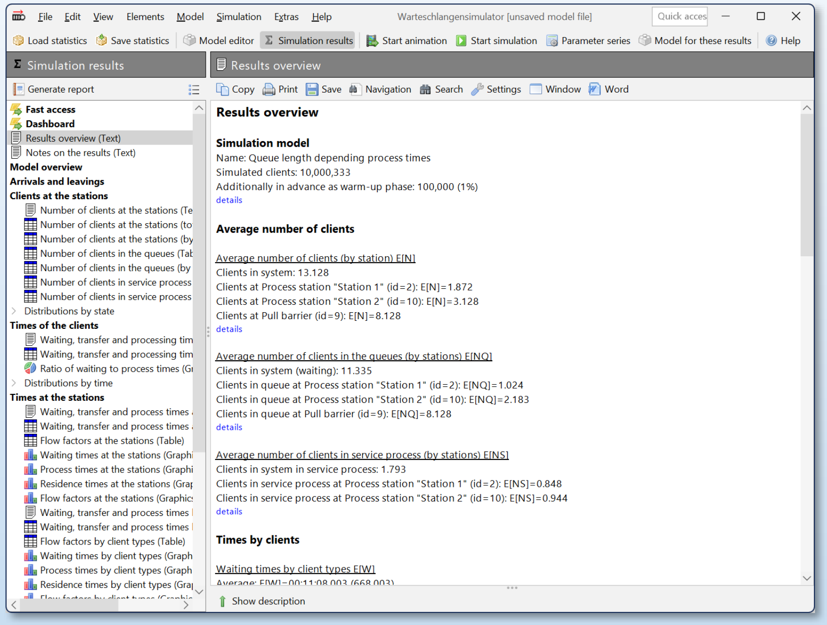
Times by clients

Waiting times by client types E[W]
Average: E[W]=00:11:08.003 (668.003)

Full statistic recording
without explicit configuration

Warteschlangensimulator – Event-driven stochastic simulation

a-herzog.github.io/Warteschlangensimulator



Results overview

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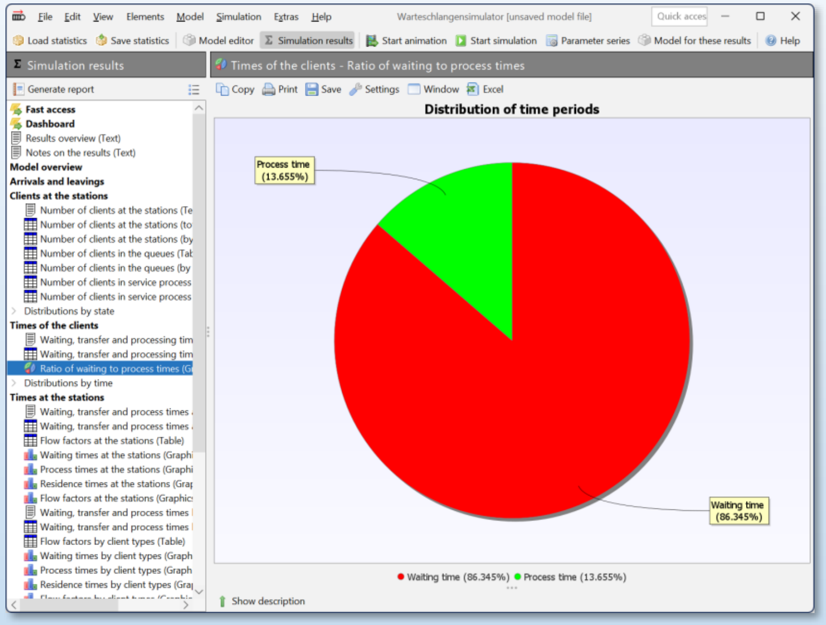
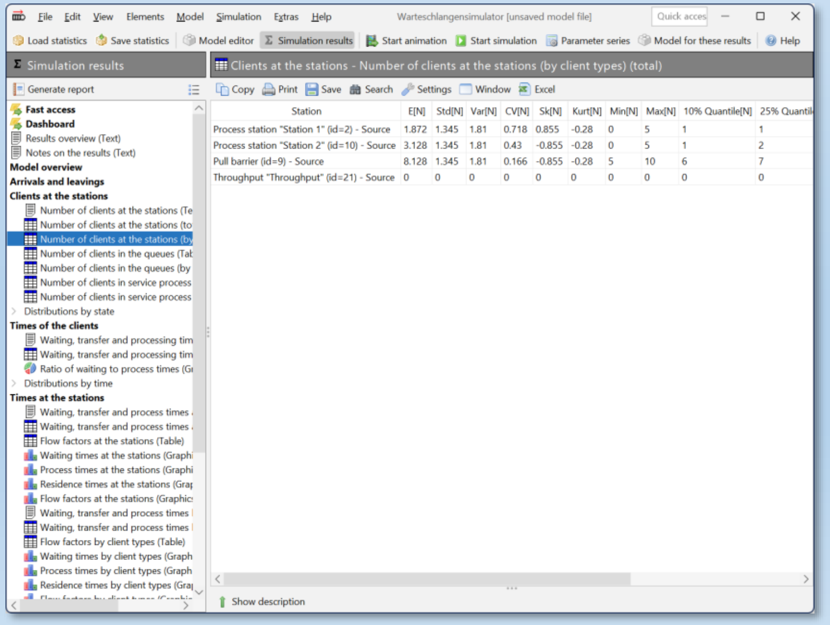
details

Times by clients

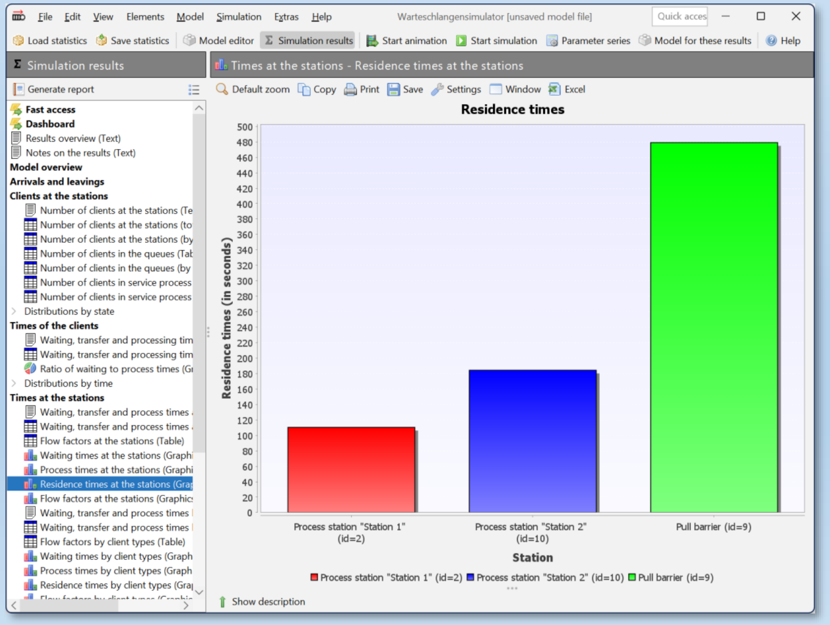
Waiting times by client types E[W]
Average: E[W]=00:11:08.003 (668.003)


Times of the clients - Ratio of waiting to process times
Distribution of time periods
Process time (13.655%)
Waiting time (86.345%)
● Waiting time (86.345%) ● Process time (13.655%)
Show description

Results available as texts, tables and charts

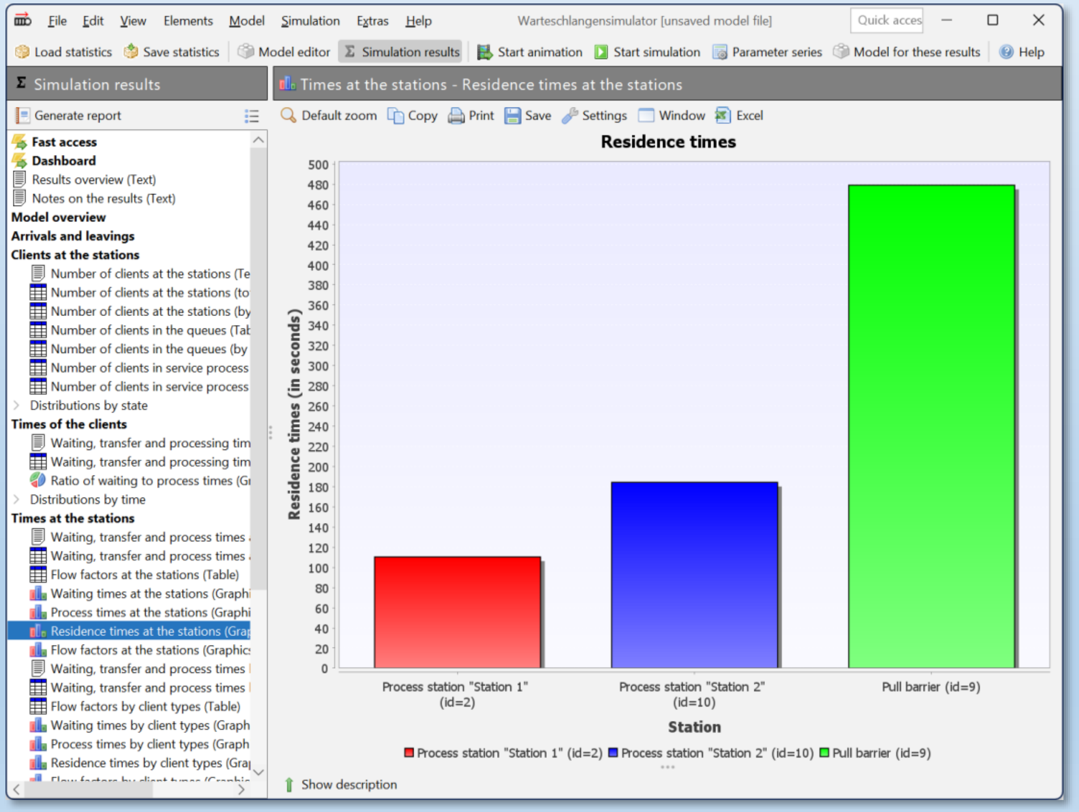

Clients at the stations - Number of clients at the stations (by client types) (total)
Copy
Print
Save
Search
Settings
Window
Excel
Show description

Station	E[N]	Std[N]	Var[N]	CV[N]	Sk[N]	Kurt[N]	Min[N]	Max[N]	10% Quantile[N]	25% Quantil
Process station "Station 1" (id=2) - Source	1.872	1.345	1.81	0.718	0.855	-0.28	0	5	1	1
Process station "Station 2" (id=10) - Source	3.128	1.345	1.81	0.43	-0.855	-0.28	0	5	1	2
Pull barrier (id=9) - Source	8.128	1.345	1.81	0.166	-0.855	-0.28	5	10	6	7
Throughput "Throughput" (id=21) - Source	0	0	0	0	0	0	0	0	0	0


Times at the stations - Residence times at the stations
Residence times
Residence times (in seconds)
Station
Process station "Station 1" (id=2)
Process station "Station 2" (id=10)
Pull barrier (id=9)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
Show description

Warteschlangensimulator – Event-driven stochastic simulation

a-herzog.github.io/Warteschlangensimulator


File
Edit
View
Elements
Model
Simulation
Extras
Help
Warteschlangensimulator [unsaved model file]
Quick access
Load statistics
Save statistics
Model editor
Simulation results
Start animation
Start simulation
Parameter series
Model for these results
Help
Simulation results
Times at the stations - Residence times at the stations
Generate report
Default zoom
Copy
Print
Save
Settings
Window
Excel
Fast access
Dashboard
Results overview (Text)
Notes on the results (Text)
Model overview
Arrivals and leavings
Clients at the stations
Number of clients at the stations (Te
Number of clients at the stations (to
Number of clients at the stations (by
Number of clients in the queues (Tab
Number of clients in the queues (by
Number of clients in service process
Number of clients in service process
Distributions by state
Times of the clients
Waiting, transfer and processing tim
Waiting, transfer and processing tim
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Flow factors at the stations (Table)
Waiting times at the stations (Graphi
Process times at the stations (Graphi
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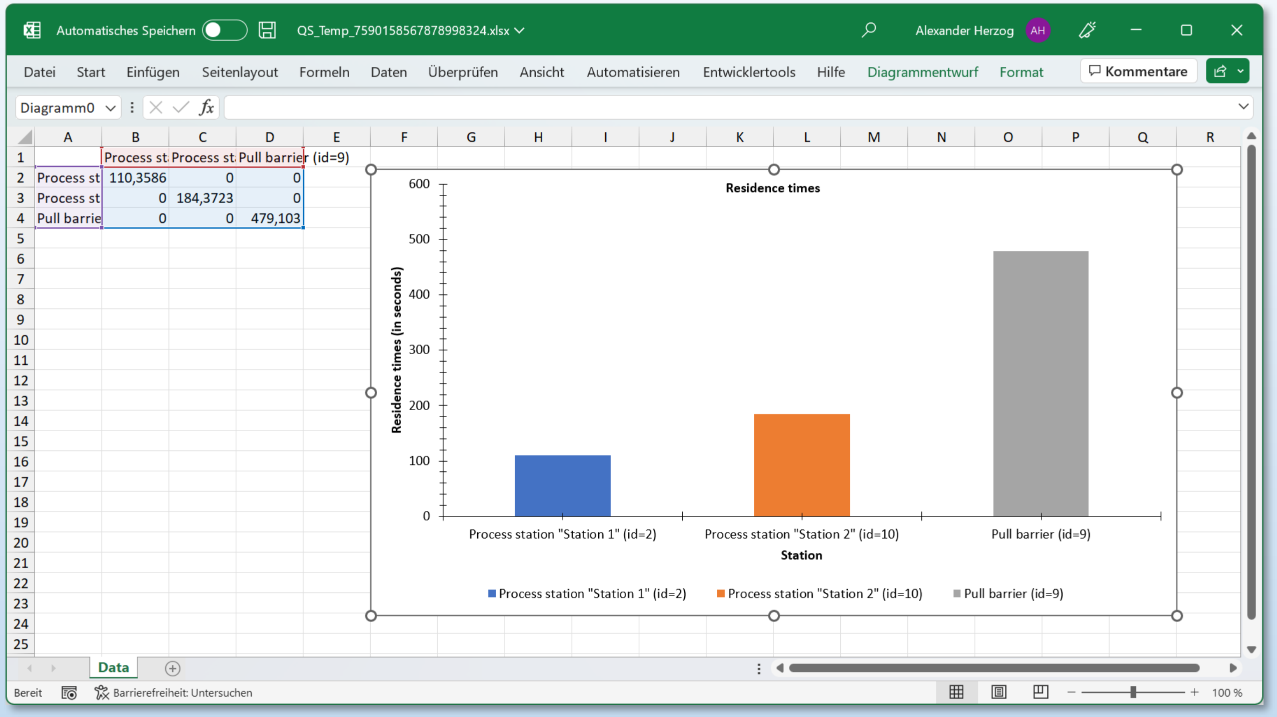
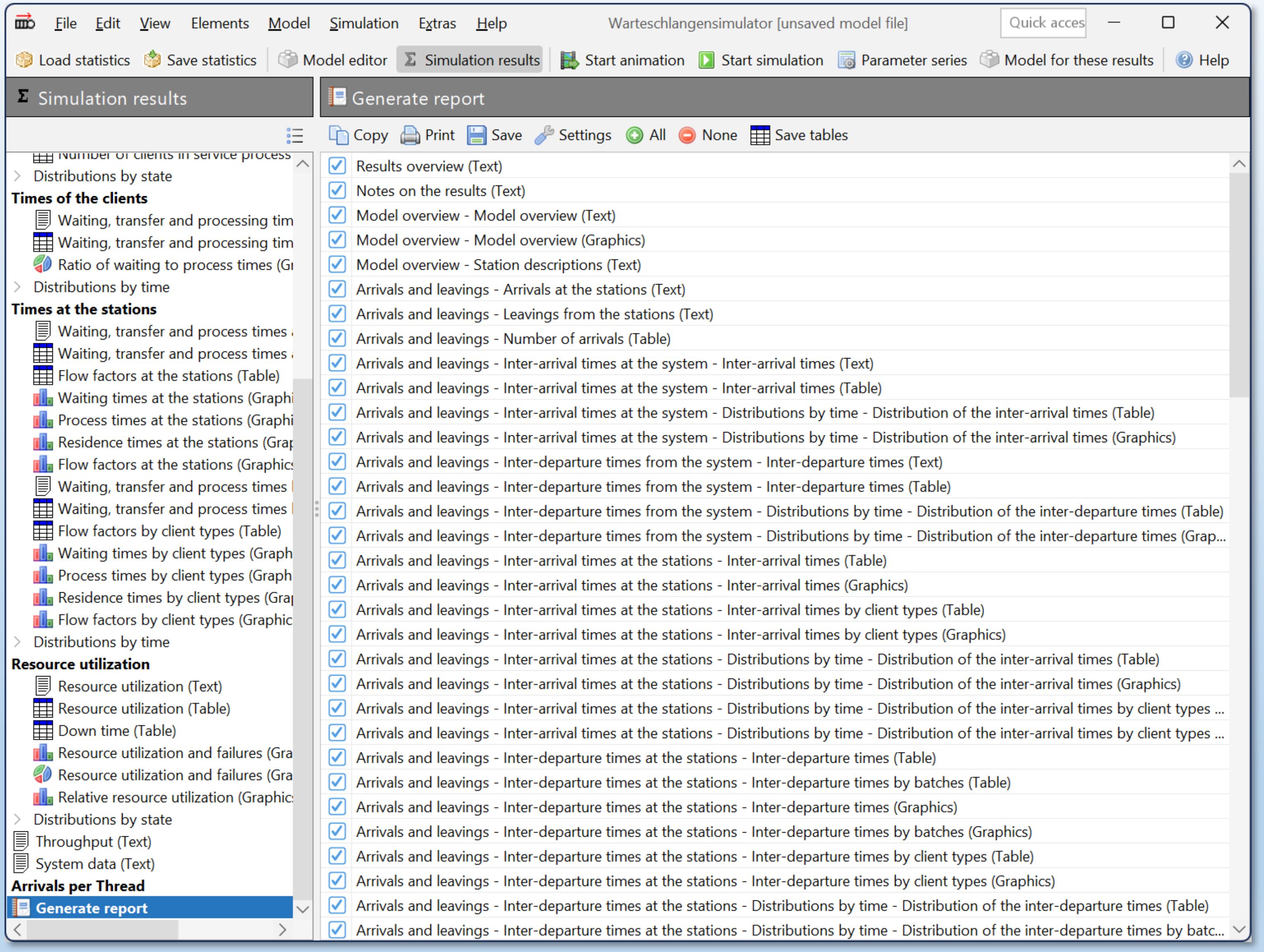
Waiting, transfer and process times
Waiting, transfer and process times
Flow factors by client types (Table)
Waiting times by client types (Graph
Process times by client types (Graph
Residence times by client types (Gra
Residence times
Residence times (in seconds)
Process station "Station 1" (id=2)
Process station "Station 2" (id=10)
Pull barrier (id=9)
Station
🟥 Process station "Station 1" (id=2) 🟦 Process station "Station 2" (id=10) 🟩 Pull barrier (id=9)
Show description


Automatisches Speichern
QS_Temp_7590158567878998324.xlsx
Alexander Herzog
Datei
Start
Einfügen
Seitenlayout
Formeln
Daten
Überprüfen
Ansicht
Automatisieren
Entwicklertools
Hilfe
Diagrammentwurf
Format
Kommentare
Diagramm0
Residence times
Residence times (in seconds)
Process station "Station 1" (id=2)
Process station "Station 2" (id=10)
Pull barrier (id=9)
Station
🟦 Process station "Station 1" (id=2) 🟧 Process station "Station 2" (id=10) ⬜ Pull barrier (id=9)
Data
Bereit
Barrierefreiheit: Untersuchen
100 %

	A	B	C	D
1		Process st	Process st	Pull barrier (id=9)
2	Process st	110,3586	0	0
3	Process st	0	184,3723	0
4	Pull barrie	0	0	479,103

Excel export of tables and charts available

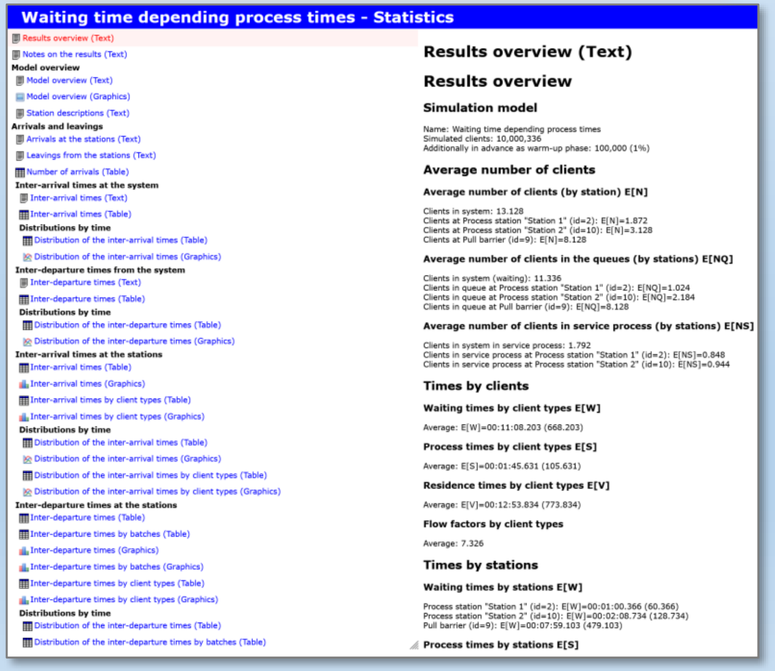


Number of clients in service process
Distributions by state
Times of the clients
Waiting, transfer and processing tim
Waiting, transfer and processing tim
Ratio of waiting to process times (Gr
Distributions by time
Times at the stations
Waiting, transfer and process times
Waiting, transfer and process times
Flow factors at the stations (Table)
Waiting times at the stations (Graphi
Process times at the stations (Graphi
Residence times at the stations (Grap
Flow factors at the stations (Graphic
Waiting, transfer and process times
Waiting, transfer and process times
Flow factors by client types (Table)
Waiting times by client types (Graph
Process times by client types (Graph
Residence times by client types (Gra
Flow factors by client types (Graphic
Distributions by time
Resource utilization
Resource utilization (Text)
Resource utilization (Table)
Down time (Table)
Resource utilization and failures (Gra
Resource utilization and failures (Gra
Relative resource utilization (Graphic
Distributions by state
Throughput (Text)
System data (Text)
Arrivals per Thread
Generate report

- [x] Results overview (Text)
- [x] Notes on the results (Text)
- [x] Model overview - Model overview (Text)
- [x] Model overview - Model overview (Graphics)
- [x] Model overview - Station descriptions (Text)
- [x] Arrivals and leavings - Arrivals at the stations (Text)
- [x] Arrivals and leavings - Leavings from the stations (Text)
- [x] Arrivals and leavings - Number of arrivals (Table)
- [x] Arrivals and leavings - Inter-arrival times at the system - Inter-arrival times (Text)
- [x] Arrivals and leavings - Inter-arrival times at the system - Inter-arrival times (Table)
- [x] Arrivals and leavings - Inter-arrival times at the system - Distributions by time - Distribution of the inter-arrival times (Table)
- [x] Arrivals and leavings - Inter-arrival times at the system - Distributions by time - Distribution of the inter-arrival times (Graphics)
- [x] Arrivals and leavings - Inter-departure times from the system - Inter-departure times (Text)
- [x] Arrivals and leavings - Inter-departure times from the system - Inter-departure times (Table)
- [x] Arrivals and leavings - Inter-departure times from the system - Distributions by time - Distribution of the inter-departure times (Table)
- [x] Arrivals and leavings - Inter-departure times from the system - Distributions by time - Distribution of the inter-departure times (Grap...
- [x] Arrivals and leavings - Inter-arrival times at the stations - Inter-arrival times (Table)
- [x] Arrivals and leavings - Inter-arrival times at the stations - Inter-arrival times (Graphics)
- [x] Arrivals and leavings - Inter-arrival times at the stations - Inter-arrival times by client types (Table)
- [x] Arrivals and leavings - Inter-arrival times at the stations - Inter-arrival times by client types (Graphics)
- [x] Arrivals and leavings - Inter-arrival times at the stations - Distributions by time - Distribution of the inter-arrival times (Table)
- [x] Arrivals and leavings - Inter-arrival times at the stations - Distributions by time - Distribution of the inter-arrival times (Graphics)
- [x] Arrivals and leavings - Inter-arrival times at the stations - Distributions by time - Distribution of the inter-arrival times by client types ...
- [x] Arrivals and leavings - Inter-arrival times at the stations - Distributions by time - Distribution of the inter-arrival times by client types ...
- [x] Arrivals and leavings - Inter-departure times at the stations - Inter-departure times (Table)
- [x] Arrivals and leavings - Inter-departure times at the stations - Inter-departure times by batches (Table)
- [x] Arrivals and leavings - Inter-departure times at the stations - Inter-departure times (Graphics)
- [x] Arrivals and leavings - Inter-departure times at the stations - Inter-departure times by batches (Graphics)
- [x] Arrivals and leavings - Inter-departure times at the stations - Inter-departure times by client types (Table)
- [x] Arrivals and leavings - Inter-departure times at the stations - Inter-departure times by client types (Graphics)
- [x] Arrivals and leavings - Inter-departure times at the stations - Distributions by time - Distribution of the inter-departure times (Table)
- [x] Arrivals and leavings - Inter-departure times at the stations - Distributions by time - Distribution of the inter-departure times by batc...

Report generator supporting docx, pdf, tex and html

html Reports can be saved as **interactive web viewers**



Waiting time depending process times - Statistics

Results overview (Text)
Notes on the results (Text)
Model overview
Model overview (Text)
Model overview (Graphics)
Station descriptions (Text)
Arrivals and leavings
Arrivals at the stations (Text)
Leavings from the stations (Text)
Number of arrivals (Table)
Inter-arrival times at the system
Inter-arrival times (Text)
Inter-arrival times (Table)
Distributions by time
Distribution of the inter-arrival times (Table)
Distribution of the inter-arrival times (Graphics)
Inter-departure times from the system
Inter-departure times (Text)
Inter-departure times (Table)
Distributions by time
Distribution of the inter-departure times (Table)
Distribution of the inter-departure times (Graphics)
Inter-arrival times at the stations
Inter-arrival times (Table)
Inter-arrival times (Graphics)
Inter-arrival times by client types (Table)
Inter-arrival times by client types (Graphics)
Distributions by time
Distribution of the inter-arrival times (Table)
Distribution of the inter-arrival times (Graphics)
Distribution of the inter-arrival times by client types (Table)
Distribution of the inter-arrival times by client types (Graphics)
Inter-departure times at the stations
Inter-departure times (Table)
Inter-departure times by batches (Table)
Inter-departure times (Graphics)
Inter-departure times by batches (Graphics)
Inter-departure times by client types (Table)
Inter-departure times by client types (Graphics)
Distributions by time
Distribution of the inter-departure times (Table)
Distribution of the inter-departure times by batches (Table)

Results overview (Text)

Results overview

Simulation model

Name: Waiting time depending process times
Simulated clients: 10,000,336
Additionally in advance as warm-up phase: 100,000 (1%)

Average number of clients

Average number of clients (by station) E[N]

Clients in system: 13.128
Clients at Process station "Station 1" (id=2): E[N]=1.872
Clients at Process station "Station 2" (id=10): E[N]=3.128
Clients at Pull barrier (id=9): E[N]=8.128

Average number of clients in the queues (by stations) E[NQ]

Clients in system (waiting): 11.336
Clients in queue at Process station "Station 1" (id=2): E[NQ]=1.024
Clients in queue at Process station "Station 2" (id=10): E[NQ]=2.184
Clients in queue at Pull barrier (id=9): E[NQ]=8.128

Average number of clients in service process (by stations) E[NS]

Clients in system in service process: 1.792
Clients in service process at Process station "Station 1" (id=2): E[NS]=0.848
Clients in service process at Process station "Station 2" (id=10): E[NS]=0.944

Times by clients

Waiting times by client types E[W]

Average: E[W]=00:11:08.203 (668.203)

Process times by client types E[S]

Average: E[S]=00:01:45.631 (105.631)

Residence times by client types E[V]

Average: E[V]=00:12:53.834 (773.834)

Flow factors by client types

Average: 7.326

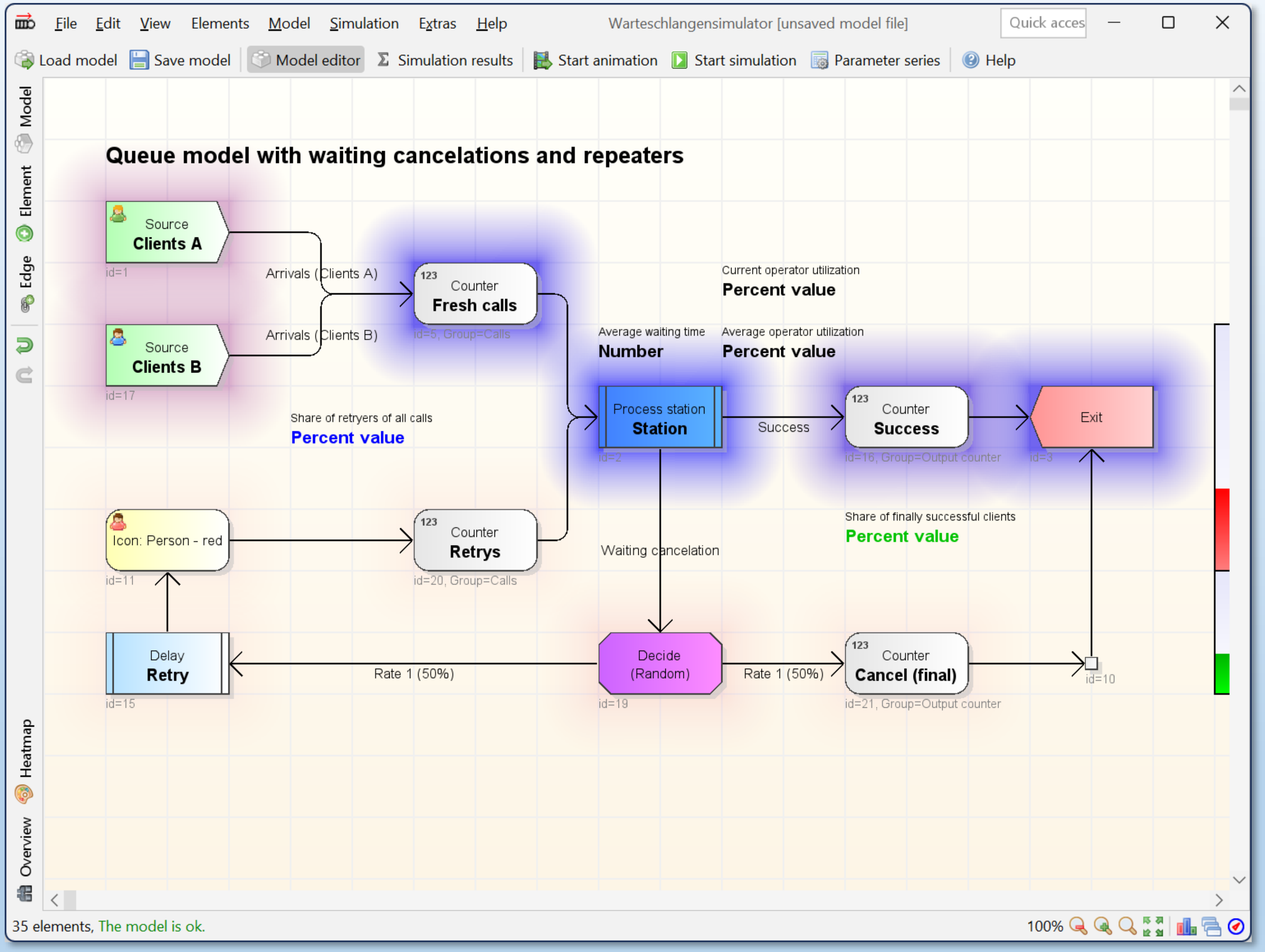
Times by stations

Waiting times by stations E[W]

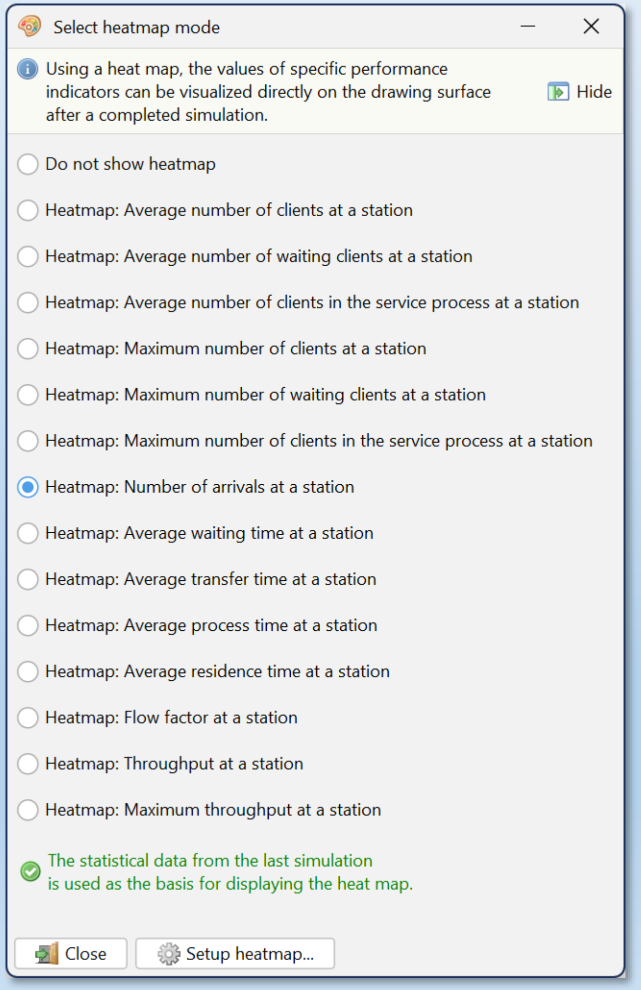
Process station "Station 1" (id=2): E[W]=00:01:00.366 (60.366)
Process station "Station 2" (id=10): E[W]=00:02:08.734 (128.734)
Pull barrier (id=9): E[W]=00:07:59.103 (479.103)

Process times by stations E[S]

Visualizing simulation results as **heatmaps**



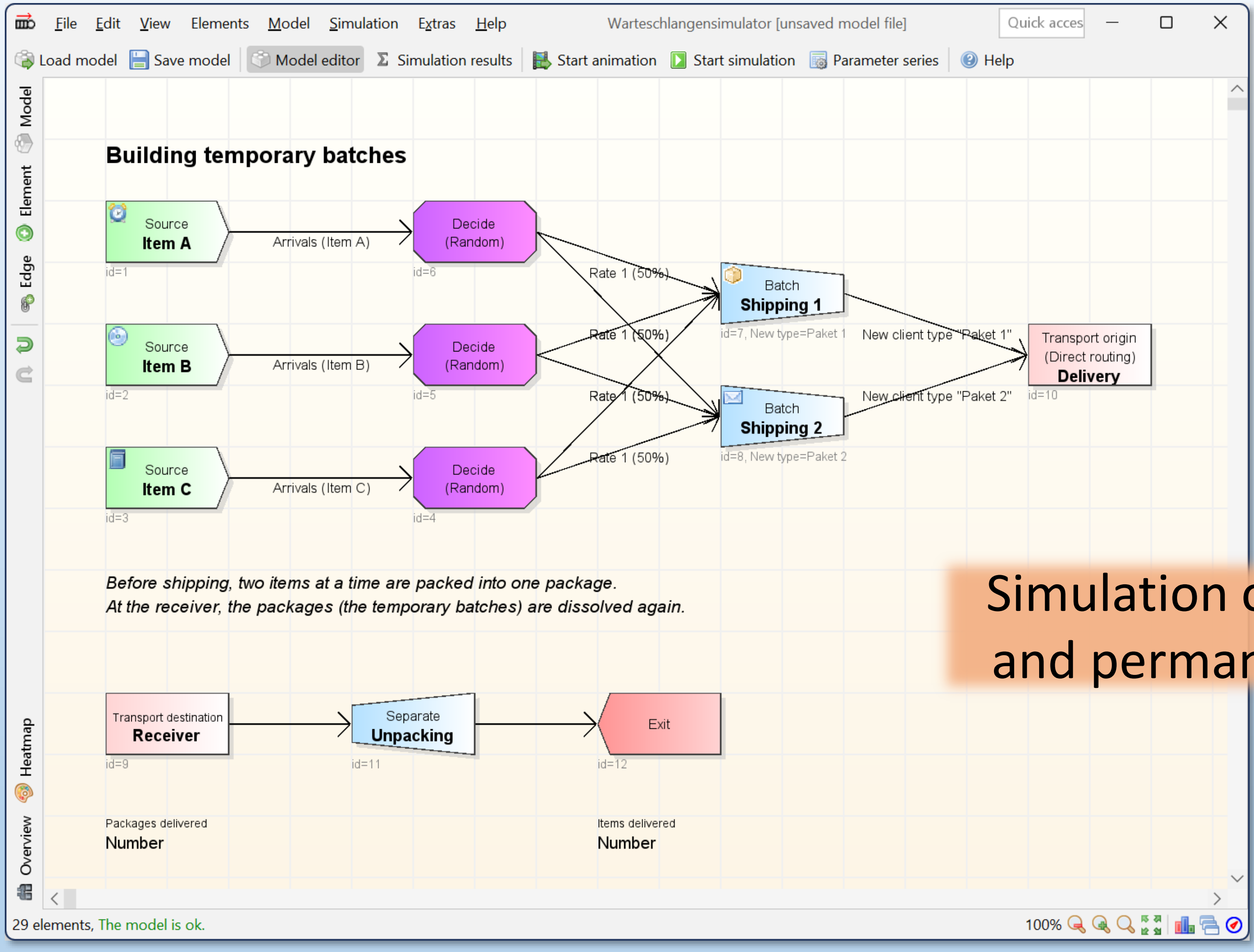
35 elements, The model is ok.



Using a heat map, the values of specific performance indicators can be visualized directly on the drawing surface after a completed simulation.

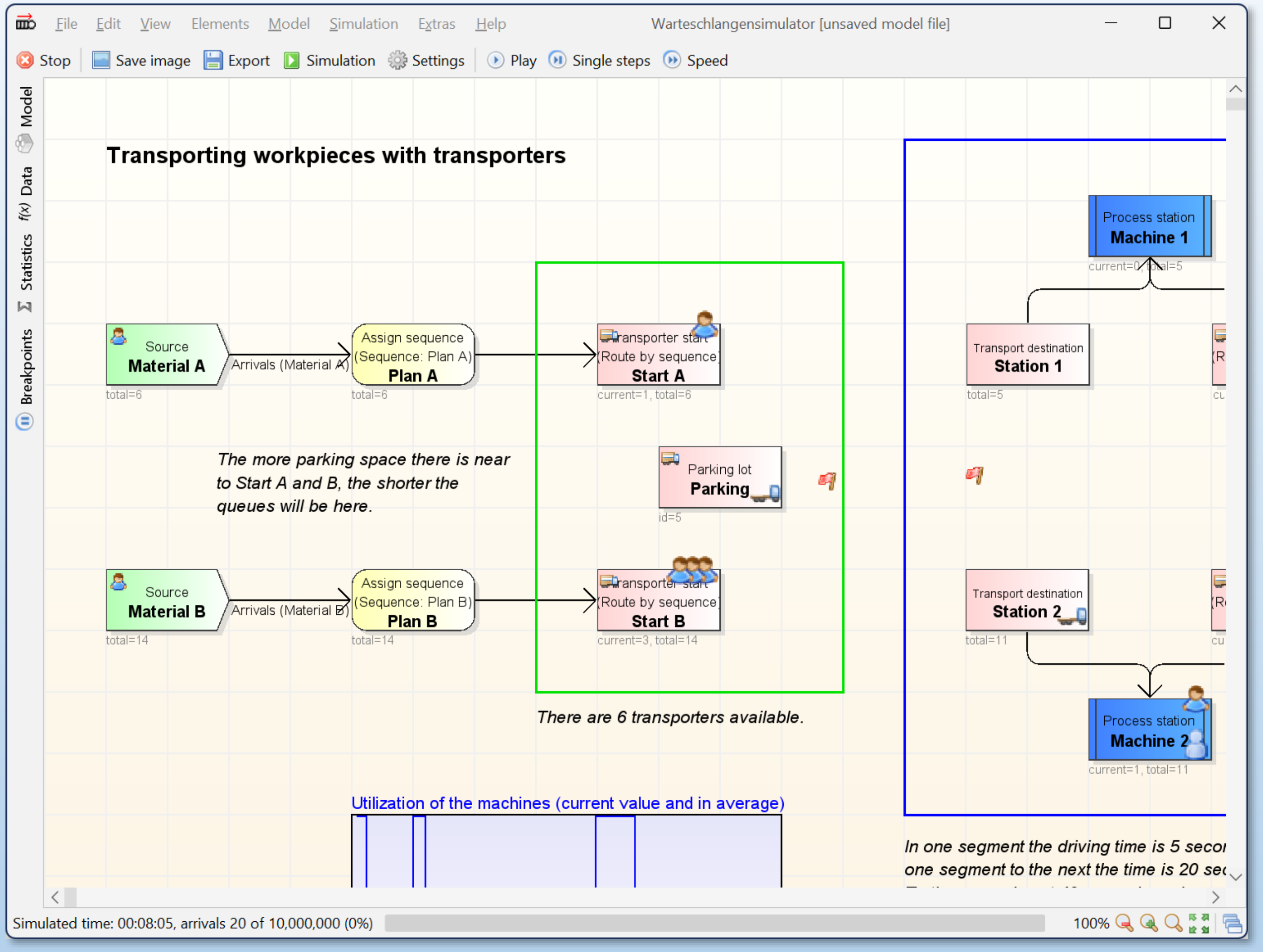
- Do not show heatmap
- Heatmap: Average number of clients at a station
- Heatmap: Average number of waiting clients at a station
- Heatmap: Average number of clients in the service process at a station
- Heatmap: Maximum number of clients at a station
- Heatmap: Maximum number of waiting clients at a station
- Heatmap: Maximum number of clients in the service process at a station
- [✓ Heatmap: Number of arrivals at a station]
- Heatmap: Average waiting time at a station
- Heatmap: Average transfer time at a station
- Heatmap: Average process time at a station
- Heatmap: Average residence time at a station
- Heatmap: Flow factor at a station
- Heatmap: Throughput at a station
- Heatmap: Maximum throughput at a station

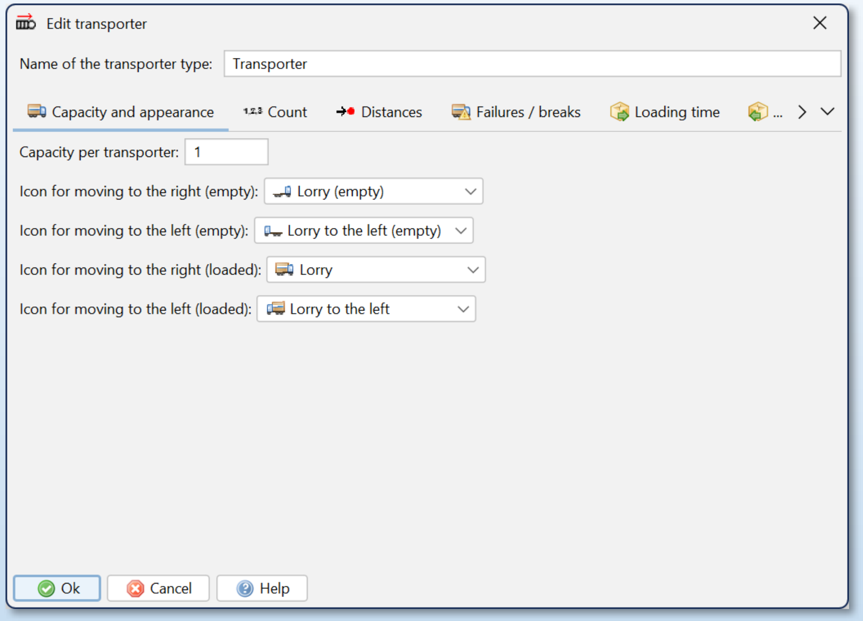
The statistical data from the last simulation is used as the basis for displaying the heat map.



Before shipping, two items at a time are packed into one package.
At the receiver, the packages (the temporary batches) are dissolved again.

Simulation of temporary and permanent **batches**


File Edit View Elements Model Simulation Extras Help
Warteschlangensimulator [unsaved model file]
Stop
Save image
Export
Simulation
Settings
Play
Single steps
Speed
Model
Data
Statistics
Breakpoints
Transporting workpieces with transporters
Source
Material A
total=6
Arrivals (Material A)
Assign sequence (Sequence: Plan A)
Plan A
total=6
Transporter start (Route by sequence)
Start A
current=1, total=6
Parking lot
Parking
id=5
The more parking space there is near to Start A and B, the shorter the queues will be here.
Source
Material B
total=14
Arrivals (Material B)
Assign sequence (Sequence: Plan B)
Plan B
total=14
Transporter start (Route by sequence)
Start B
current=3, total=14
There are 6 transporters available.
Process station
Machine 1
current=0, total=5
Transport destination
Station 1
total=5
Transport destination
Station 2
total=11
Process station
Machine 2
current=1, total=11
Utilization of the machines (current value and in average)
In one segment the driving time is 5 secon
one segment to the next the time is 20 sec
Simulated time: 00:08:05, arrivals 20 of 10,000,000 (0%)
100%


Edit transporter

Name of the transporter type: Transporter

Capacity per transporter: 1

Icon for moving to the right (empty): Lorry (empty)

Icon for moving to the left (empty): Lorry to the left (empty)

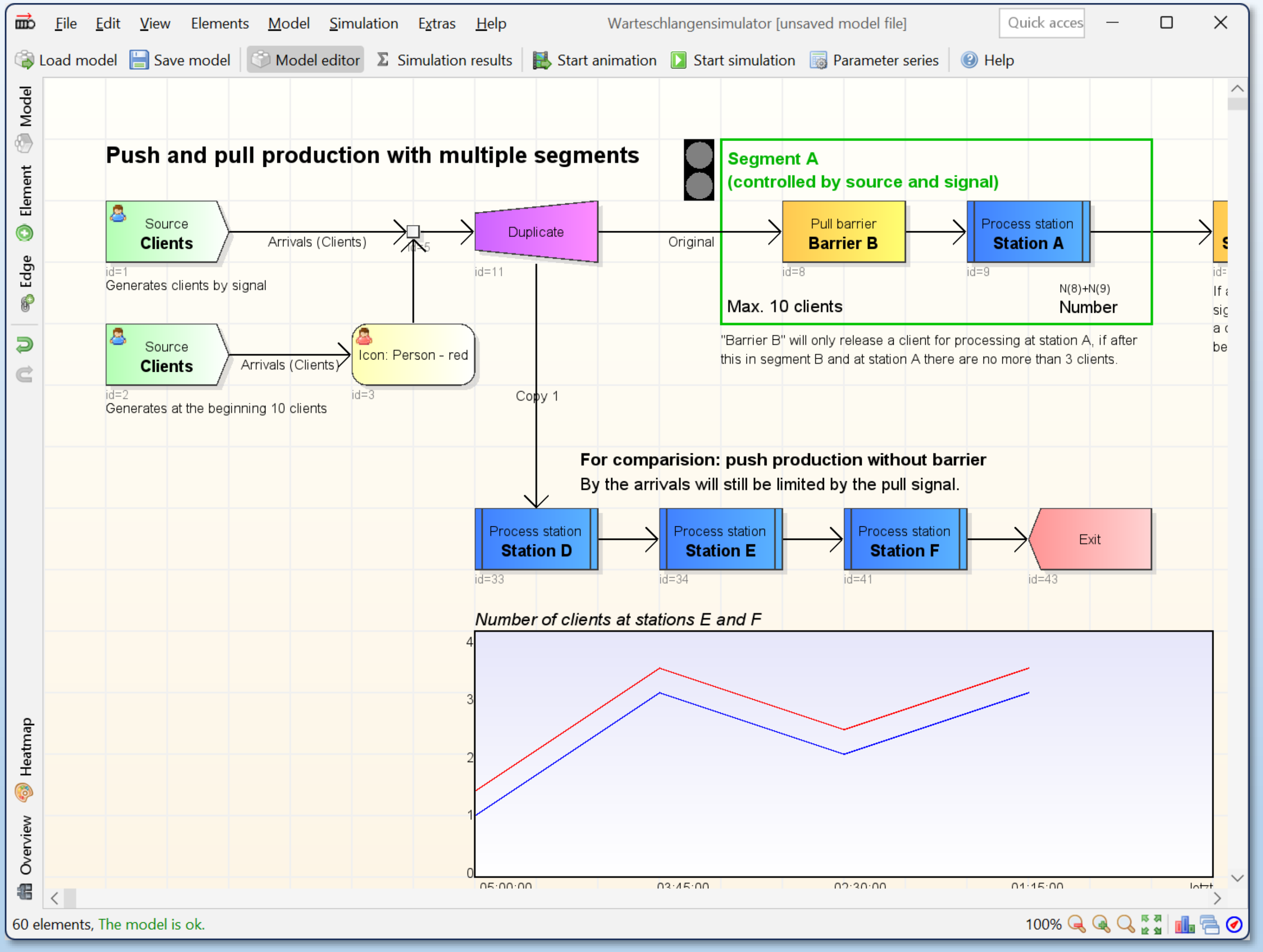
Icon for moving to the right (loaded): Lorry

Icon for moving to the left (loaded): Lorry to the left

Simulation of transport processes using **transporters**

Warteschlangensimulator – Event-driven stochastic simulation

a-herzog.github.io/Warteschlangensimulator



Push and pull production with multiple segments

Segment A
(controlled by source and signal)

Max. 10 clients

Generates clients by signal

Generates at the beginning 10 clients

"Barrier B" will only release a client for processing at station A, if after this in segment B and at station A there are no more than 3 clients.

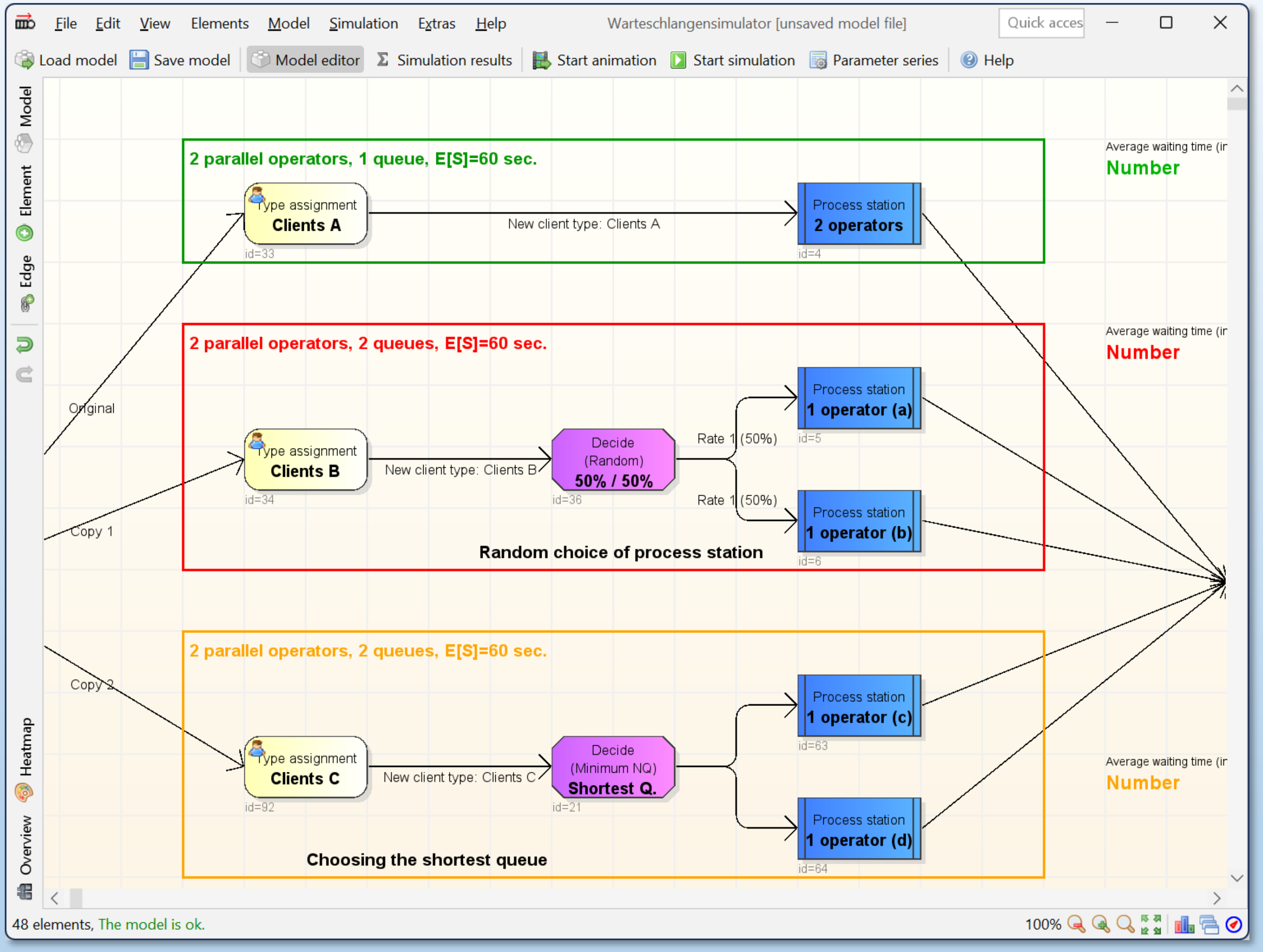
For comparision: push production without barrier
By the arrivals will still be limited by the pull signal.

Number of clients at stations E and F

60 elements, The model is ok.

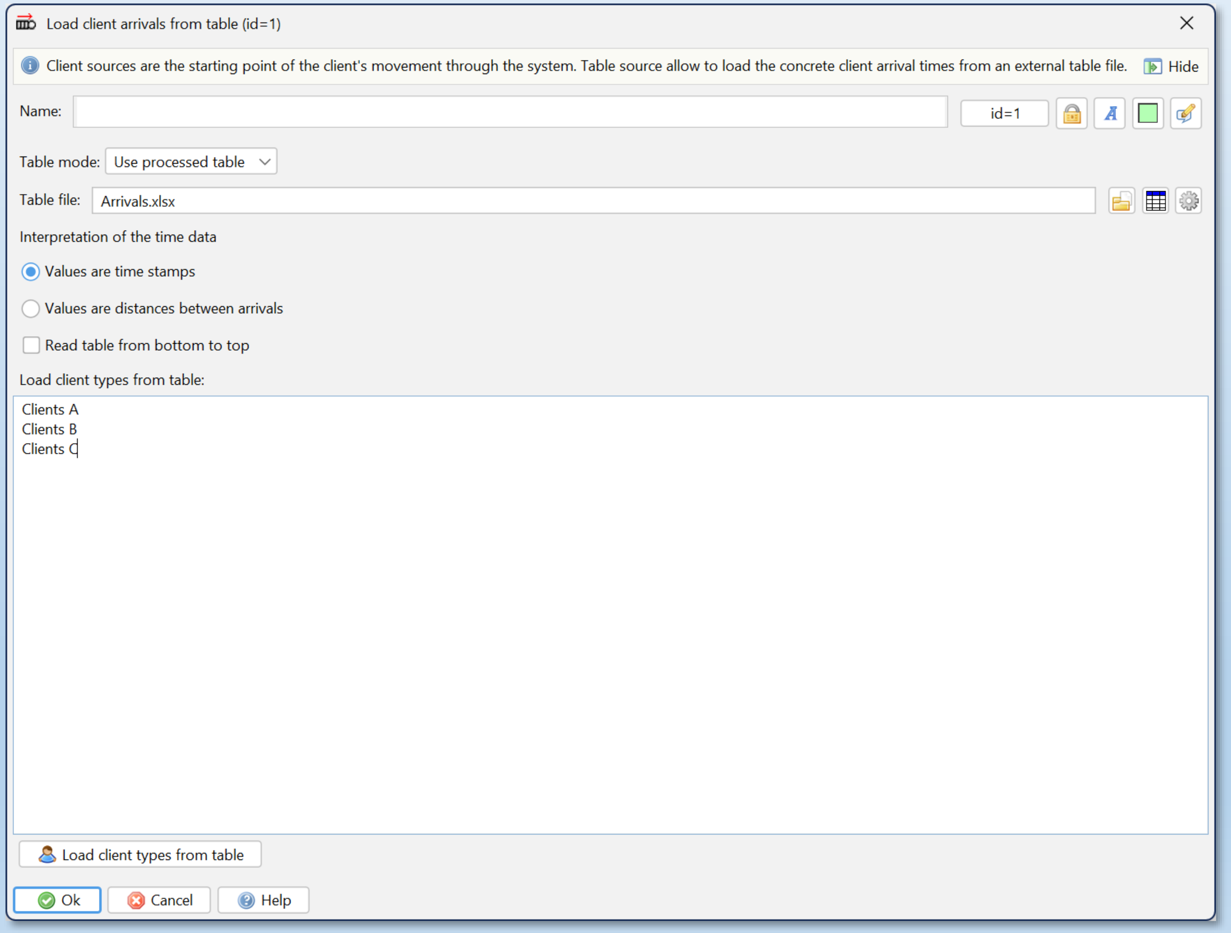
Push/pull production – and any other kind of condition-based barriers, signals etc.

Warteschlangensimulator – Event-driven stochastic simulation



Branching clients by conditions, by chance, script-based, etc.

Using **external data** for client arrivals and parameters in simulation process



Load client arrivals from table (id=1)

Client sources are the starting point of the client's movement through the system. Table source allow to load the concrete client arrival times from an external table file. Hide

Name: id=1

Table mode: Use processed table

Table file: Arrivals.xlsx

Interpretation of the time data

(●) Values are time stamps

( ) Values are distances between arrivals

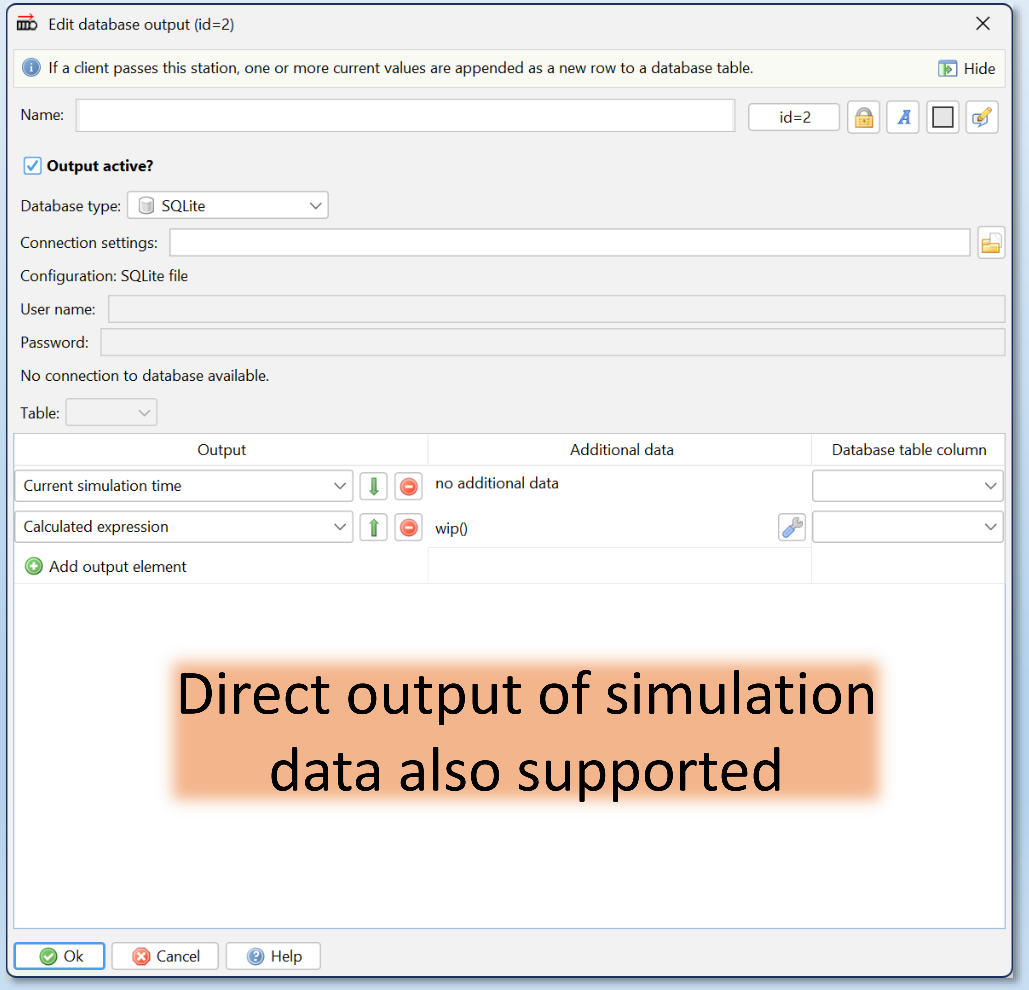
[ ] Read table from bottom to top

Load client types from table:

Clients A
Clients B
Clients C

Load client types from table

Ok Cancel Help



Edit database output (id=2)

If a client passes this station, one or more current values are appended as a new row to a database table. Hide

Name: id=2

[✓] **Output active?**

Database type: SQLite

Connection settings:

Configuration: SQLite file

User name:

Password:

No connection to database available.

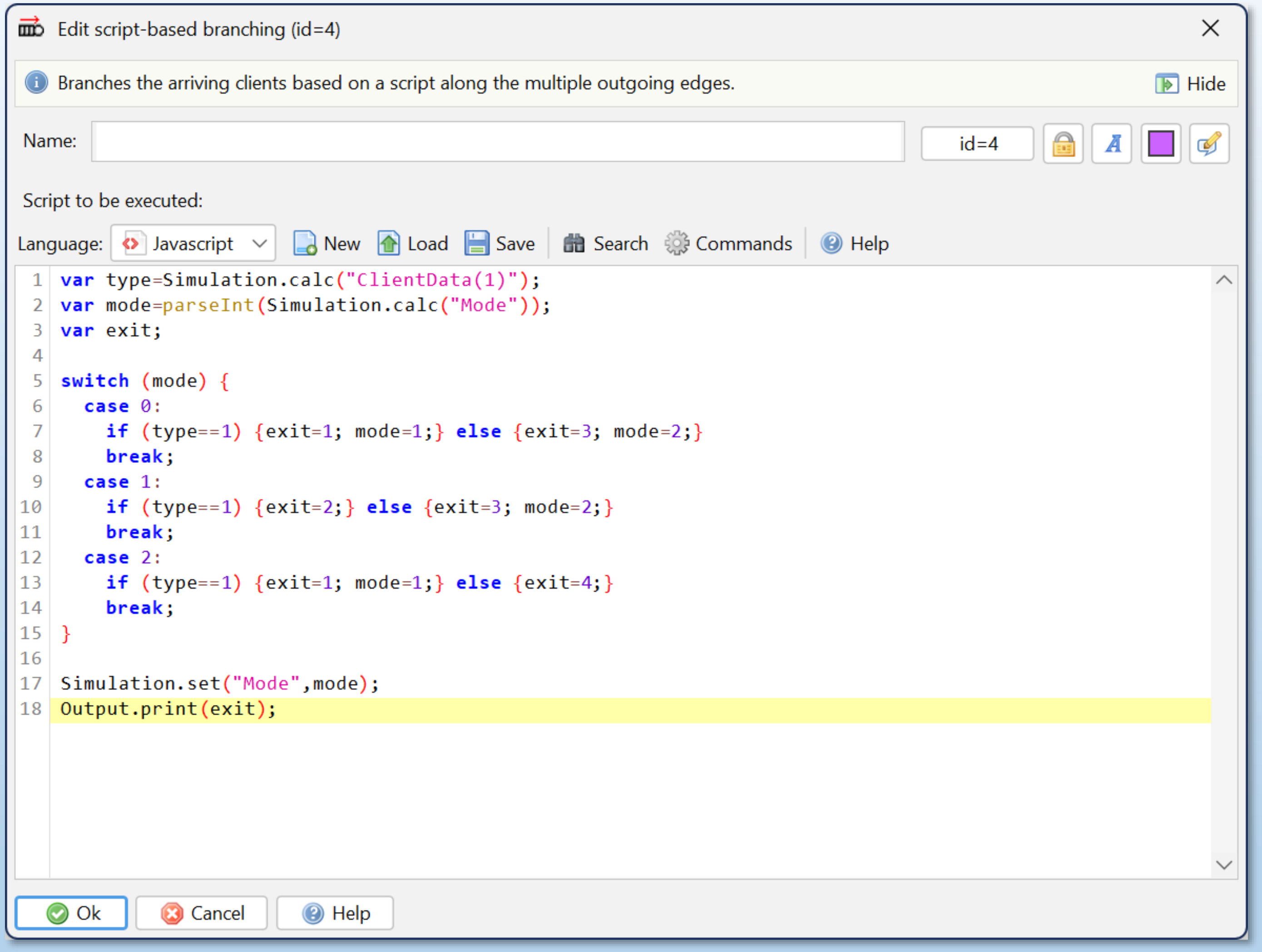
Table:

Output	Additional data	Database table column
Current simulation time	no additional data	
Calculated expression	wip()	

Add output element

Direct output of simulation data also supported

Ok Cancel Help



Branches the arriving clients based on a script along the multiple outgoing edges.

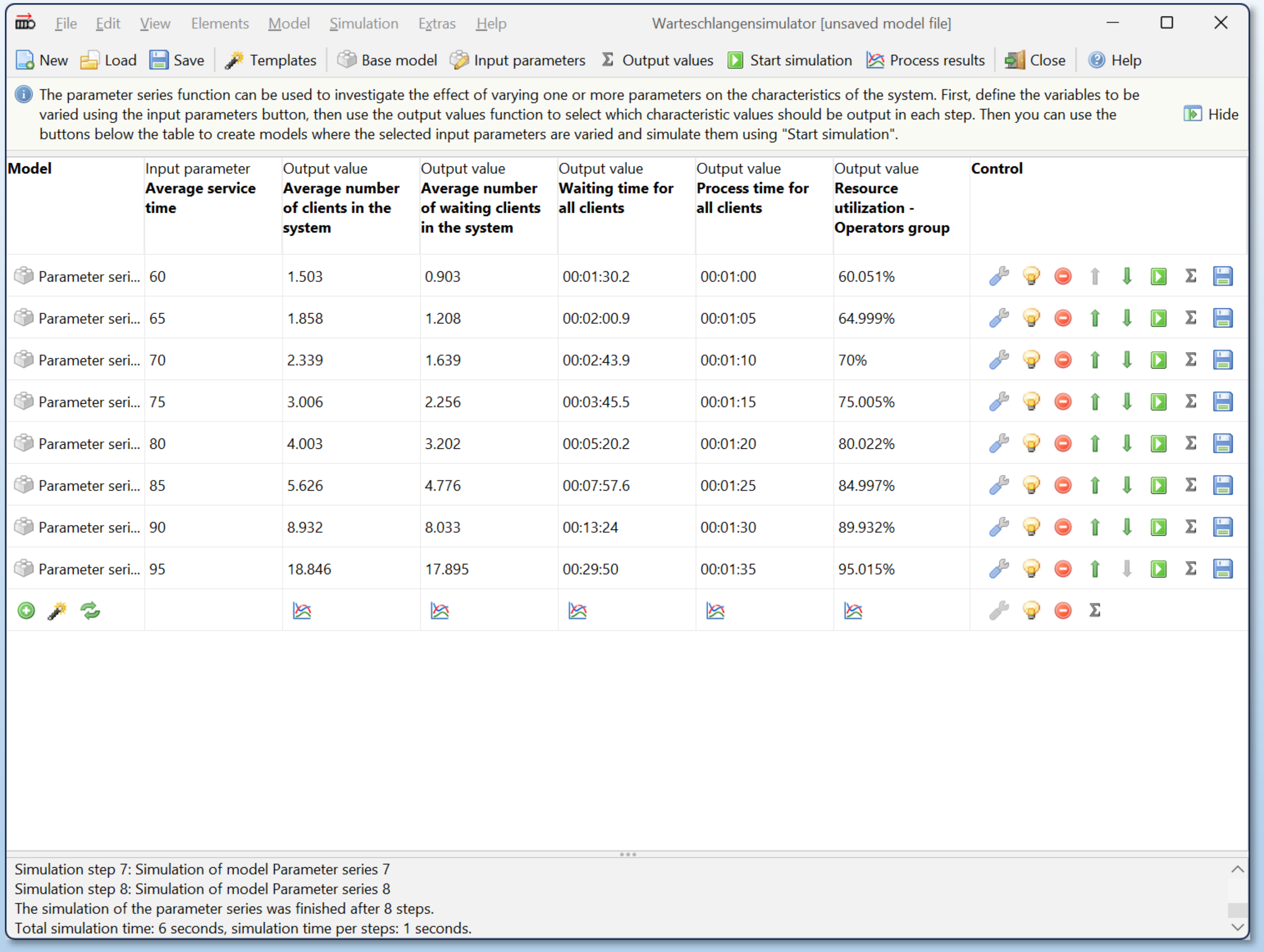
Script to be executed:

```
var type=Simulation.calc("ClientData(1)");
var mode=parseInt(Simulation.calc("Mode"));
var exit;

switch (mode) {
  case 0:
    if (type==1) {exit=1; mode=1;} else {exit=3; mode=2;}
    break;
  case 1:
    if (type==1) {exit=2;} else {exit=3; mode=2;}
    break;
  case 2:
    if (type==1) {exit=1; mode=1;} else {exit=4;}
    break;
}

Simulation.set("Mode",mode);
Output.print(exit);
```

Scripts can be used for modelling complex control strategies

Supported languages: Javascript and Java

Warteschlangensimulator – Event-driven stochastic simulation

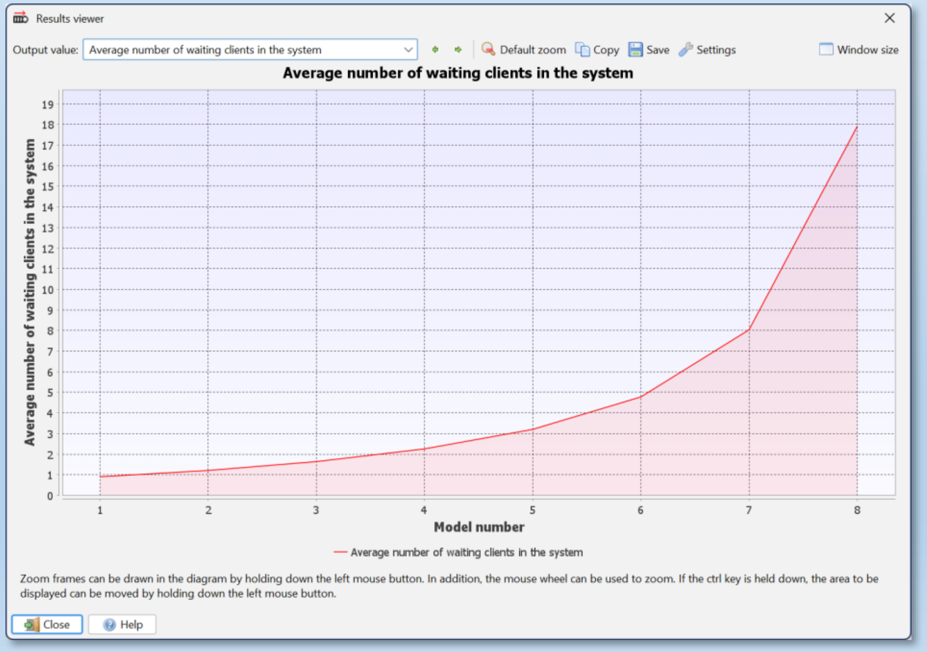


The parameter series function can be used to investigate the effect of varying one or more parameters on the characteristics of the system. First, define the variables to be varied using the input parameters button, then use the output values function to select which characteristic values should be output in each step. Then you can use the buttons below the table to create models where the selected input parameters are varied and simulate them using "Start simulation".

Model	Input parameter **Average service time**	Output value **Average number of clients in the system**	Output value **Average number of waiting clients in the system**	Output value **Waiting time for all clients**	Output value **Process time for all clients**	Output value **Resource utilization - Operators group**	**Control**
Parameter seri...	60	1.503	0.903	00:01:30.2	00:01:00	60.051%	
Parameter seri...	65	1.858	1.208	00:02:00.9	00:01:05	64.999%	
Parameter seri...	70	2.339	1.639	00:02:43.9	00:01:10	70%	
Parameter seri...	75	3.006	2.256	00:03:45.5	00:01:15	75.005%	
Parameter seri...	80	4.003	3.202	00:05:20.2	00:01:20	80.022%	
Parameter seri...	85	5.626	4.776	00:07:57.6	00:01:25	84.997%	
Parameter seri...	90	8.932	8.033	00:13:24	00:01:30	89.932%	
Parameter seri...	95	18.846	17.895	00:29:50	00:01:35	95.015%	

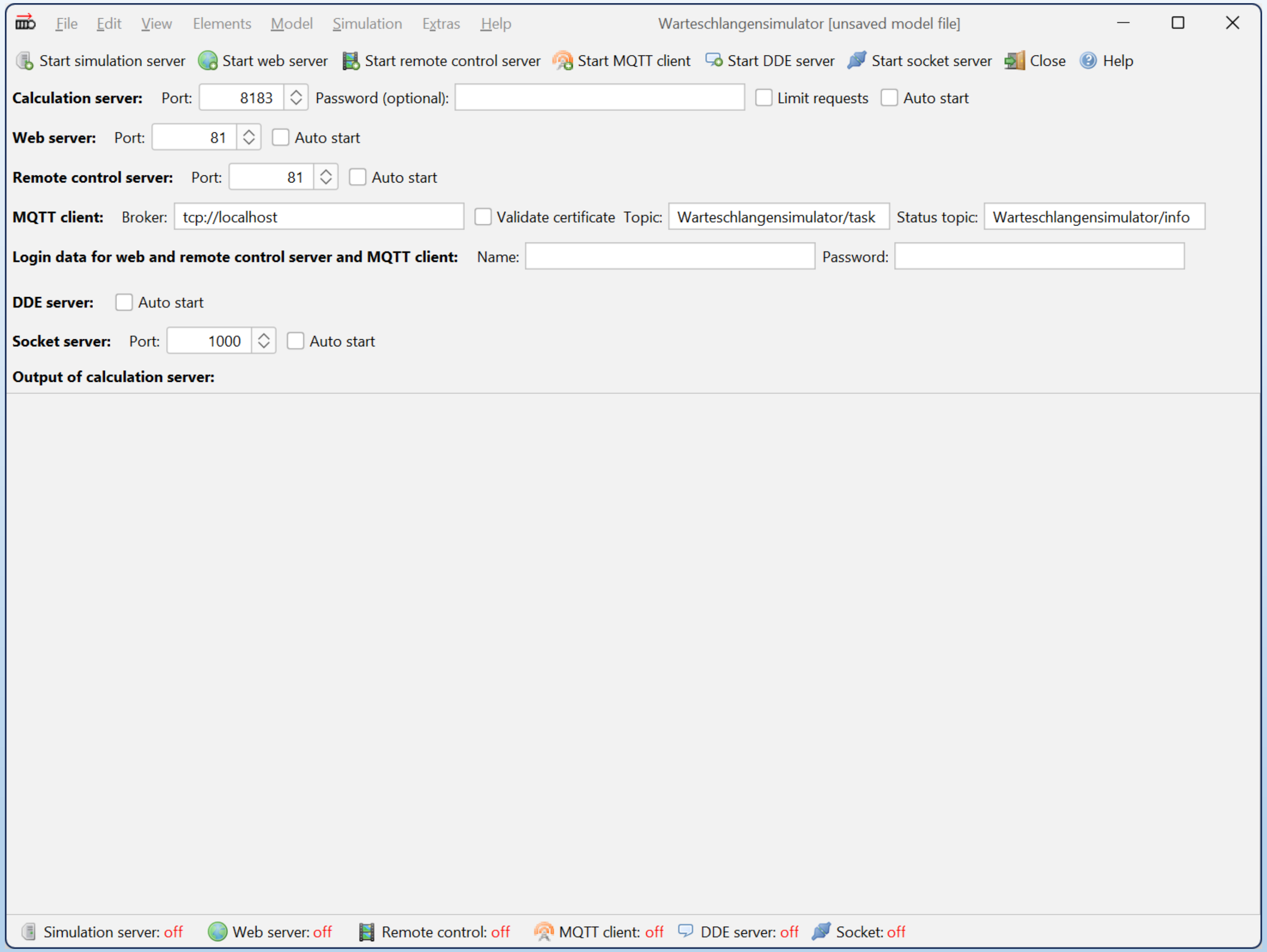
```
Simulation step 7: Simulation of model Parameter series 7
Simulation step 8: Simulation of model Parameter series 8
The simulation of the parameter series was finished after 8 steps.
Total simulation time: 6 seconds, simulation time per steps: 1 seconds.
```

Fast and easy creation of **parameter studies**



Zoom frames can be drawn in the diagram by holding down the left mouse button. In addition, the mouse wheel can be used to zoom. If the ctrl key is held down, the area to be displayed can be moved by holding down the left mouse button.

Optimizer also built-in



Calculation server: Port: 8183 Password (optional): ☐ Limit requests ☐ Auto start

Web server: Port: 81 ☐ Auto start

Remote control server: Port: 81 ☐ Auto start

MQTT client: Broker: tcp://localhost ☐ Validate certificate Topic: Warteschlangensimulator/task Status topic: Warteschlangensimulator/info

Login data for web and remote control server and MQTT client: Name: Password:

DDE server: ☐ Auto start

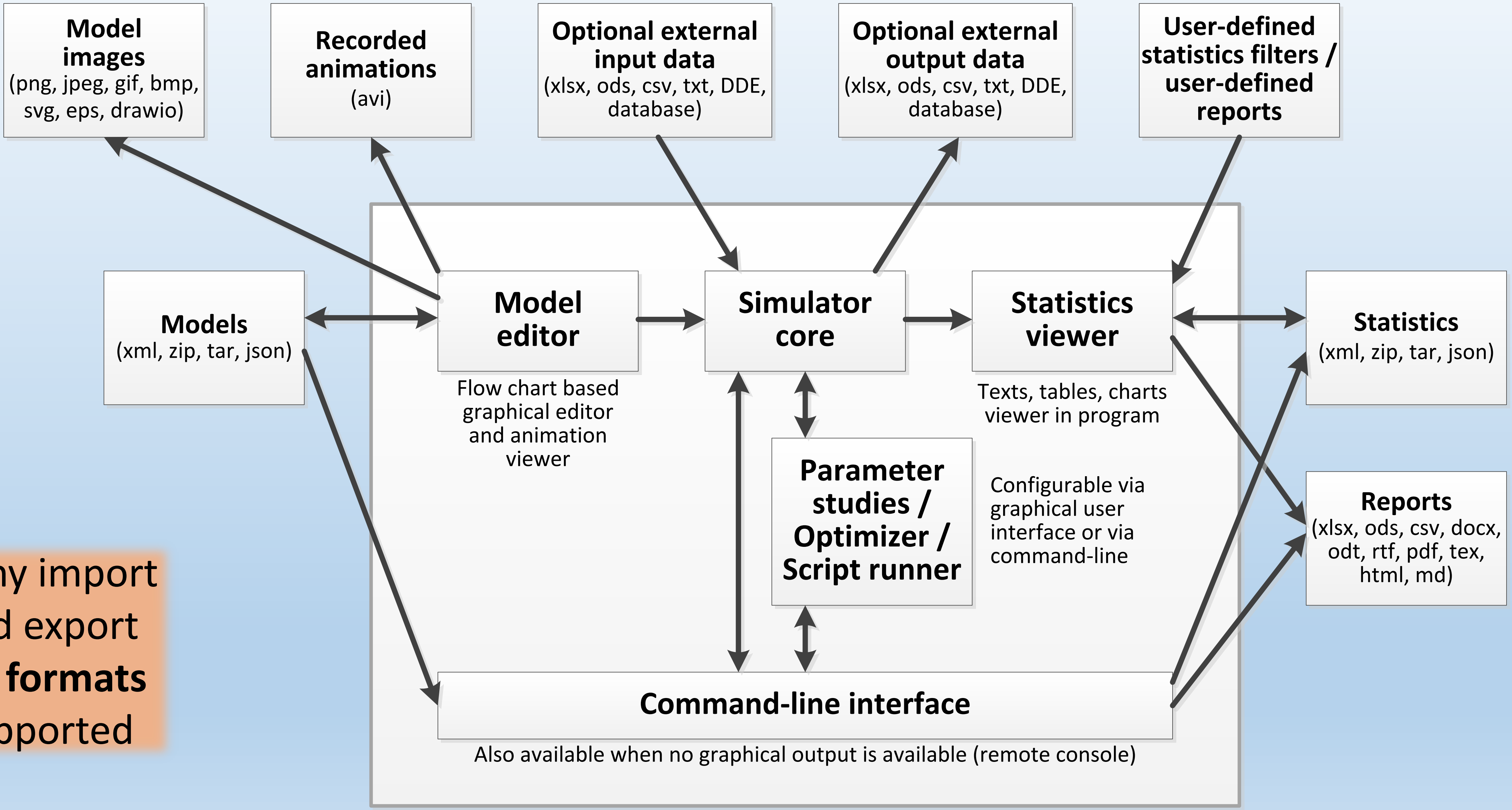
Socket server: Port: 1000 ☐ Auto start

Output of calculation server:

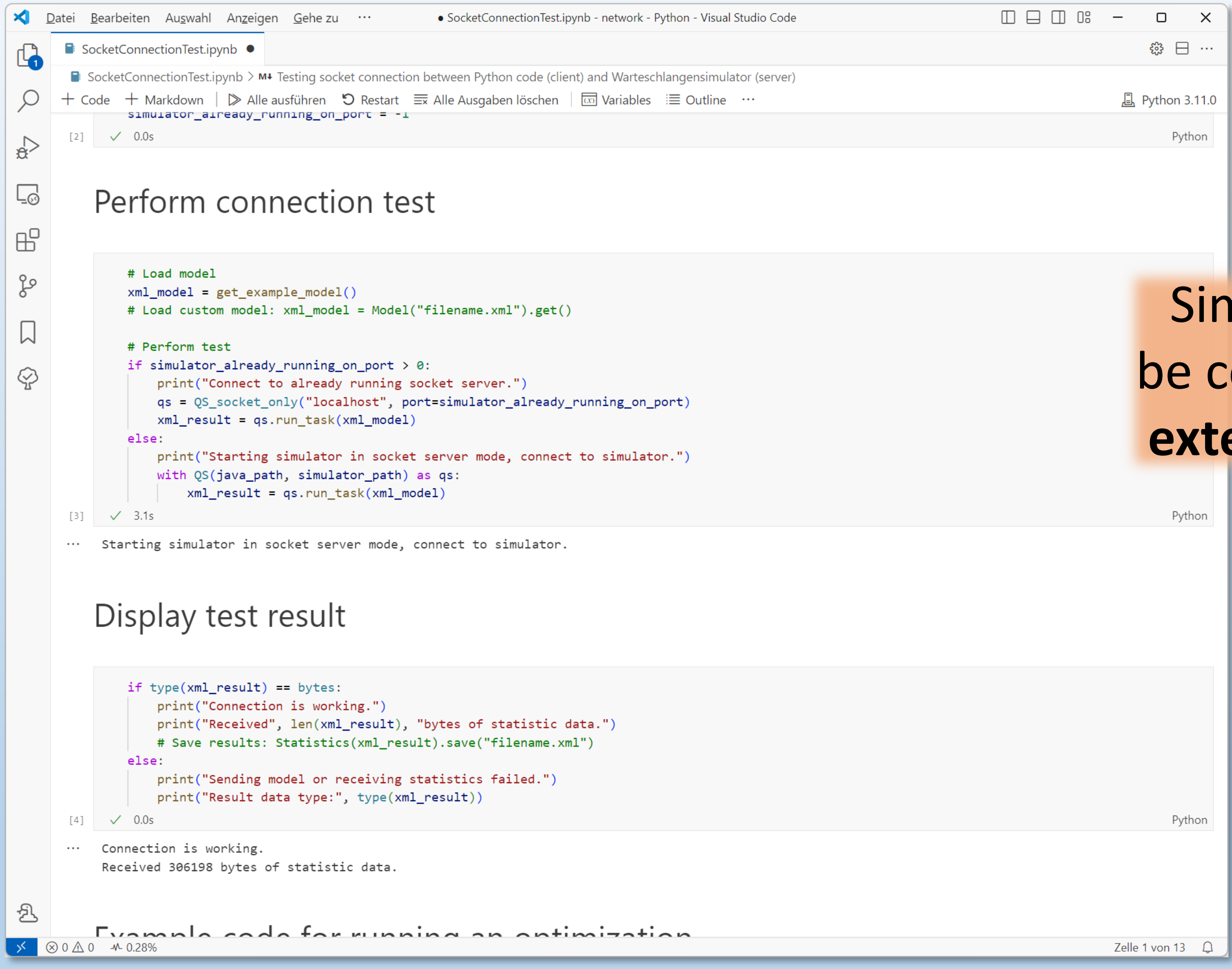
Simulation server: off Web server: off Remote control: off MQTT client: off DDE server: off Socket: off

Command-line and **server operation** available

Simulator can be used on Linux-based HPC systems


Model images (png, jpeg, gif, bmp, svg, eps, drawio)
Recorded animations (avi)
Optional external input data (xlsx, ods, csv, txt, DDE, database)
Optional external output data (xlsx, ods, csv, txt, DDE, database)
User-defined statistics filters / user-defined reports
Models (xml, zip, tar, json)
Model editor
Flow chart based graphical editor and animation viewer
Simulator core
Statistics viewer
Texts, tables, charts viewer in program
Statistics (xml, zip, tar, json)
Parameter studies / Optimizer / Script runner
Configurable via graphical user interface or via command-line
Reports (xlsx, ods, csv, docx, odt, rtf, pdf, tex, html, md)
Command-line interface
Also available when no graphical output is available (remote console)

Many import and export **file formats** supported


Datei Bearbeiten Auswahl Anzeigen Gehe zu
● SocketConnectionTest.ipynb - network - Python - Visual Studio Code
SocketConnectionTest.ipynb
SocketConnectionTest.ipynb > M↓ Testing socket connection between Python code (client) and Warteschlangensimulator (server)
+ Code + Markdown Alle ausführen Restart Alle Ausgaben löschen Variables Outline
Python 3.11.0
Zelle 1 von 13

```
simulator_already_running_on_port = -1
```

[2] ✓ 0.0s Python

Perform connection test

```
# Load model
xml_model = get_example_model()
# Load custom model: xml_model = Model("filename.xml").get()

# Perform test
if simulator_already_running_on_port > 0:
    print("Connect to already running socket server.")
    qs = QS_socket_only("localhost", port=simulator_already_running_on_port)
    xml_result = qs.run_task(xml_model)
else:
    print("Starting simulator in socket server mode, connect to simulator.")
    with QS(java_path, simulator_path) as qs:
        xml_result = qs.run_task(xml_model)
```

[3] ✓ 3.1s Python

```
Starting simulator in socket server mode, connect to simulator.
```

Display test result

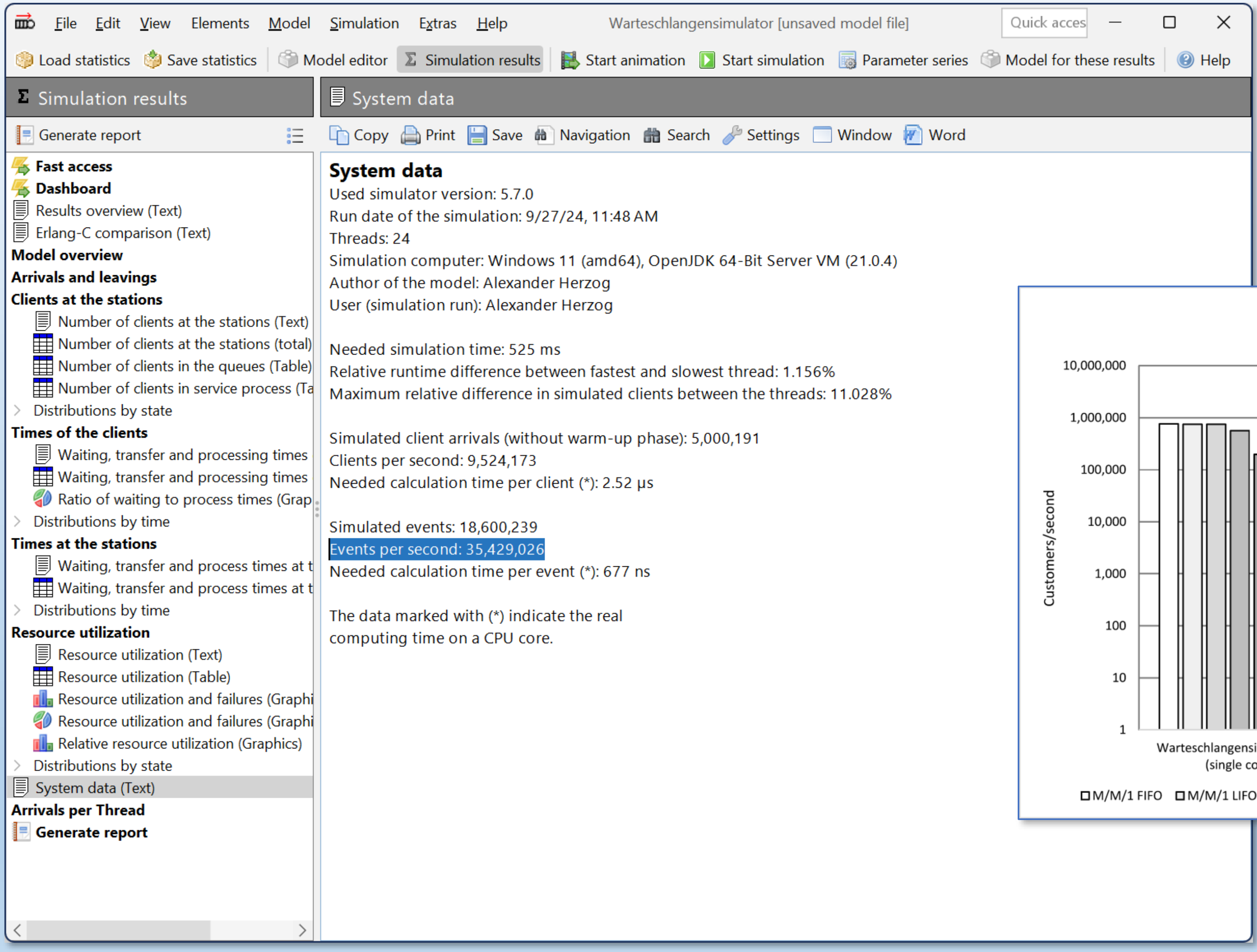
```
if type(xml_result) == bytes:
    print("Connection is working.")
    print("Received", len(xml_result), "bytes of statistic data.")
    # Save results: Statistics(xml_result).save("filename.xml")
else:
    print("Sending model or receiving statistics failed.")
    print("Result data type:", type(xml_result))
```

[4] ✓ 0.0s Python

```
Connection is working.
Received 306198 bytes of statistic data.
```

Simulator can be controlled via **external scripts**

Warteschlangensimulator – Event-driven stochastic simulation a-herzog.github.io/Warteschlangensimulator


File Edit View Elements Model Simulation Extras Help
Warteschlangensimulator [unsaved model file]
Quick acces
Load statistics
Save statistics
Model editor
Simulation results
Start animation
Start simulation
Parameter series
Model for these results
Help
Simulation results
System data
Generate report
Copy
Print
Save
Navigation
Search
Settings
Window
Word
Fast access
Dashboard
Results overview (Text)
Erlang-C comparison (Text)
Model overview
Arrivals and leavings
Clients at the stations
Number of clients at the stations (Text)
Number of clients at the stations (total)
Number of clients in the queues (Table)
Number of clients in service process (Ta
Distributions by state
Times of the clients
Waiting, transfer and processing times
Waiting, transfer and processing times
Ratio of waiting to process times (Grap
Distributions by time
Times at the stations
Waiting, transfer and process times at t
Waiting, transfer and process times at t
Distributions by time
Resource utilization
Resource utilization (Text)
Resource utilization (Table)
Resource utilization and failures (Graphi
Resource utilization and failures (Graphi
Relative resource utilization (Graphics)
Distributions by state
System data (Text)
Arrivals per Thread
Generate report

System data

Used simulator version: 5.7.0
Run date of the simulation: 9/27/24, 11:48 AM
Threads: 24
Simulation computer: Windows 11 (amd64), OpenJDK 64-Bit Server VM (21.0.4)
Author of the model: Alexander Herzog
User (simulation run): Alexander Herzog

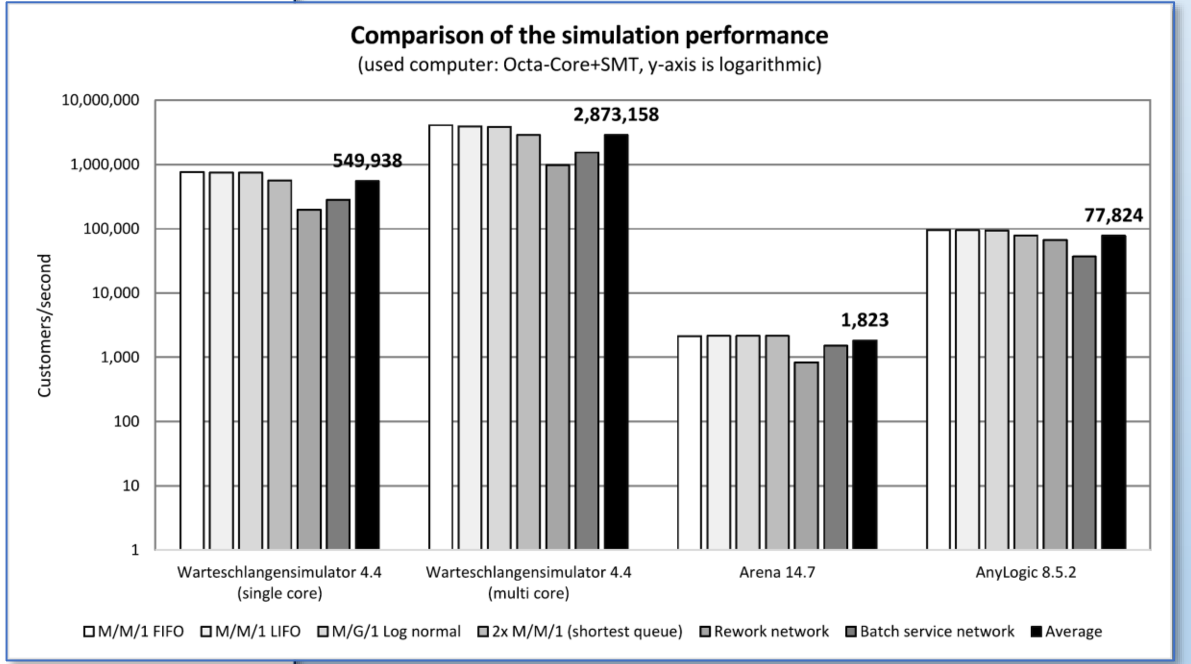
Needed simulation time: 525 ms
Relative runtime difference between fastest and slowest thread: 1.156%
Maximum relative difference in simulated clients between the threads: 11.028%

Simulated client arrivals (without warm-up phase): 5,000,191
Clients per second: 9,524,173
Needed calculation time per client (*): 2.52 µs

Simulated events: 18,600,239
Events per second: 35,429,026
Needed calculation time per event (*): 677 ns

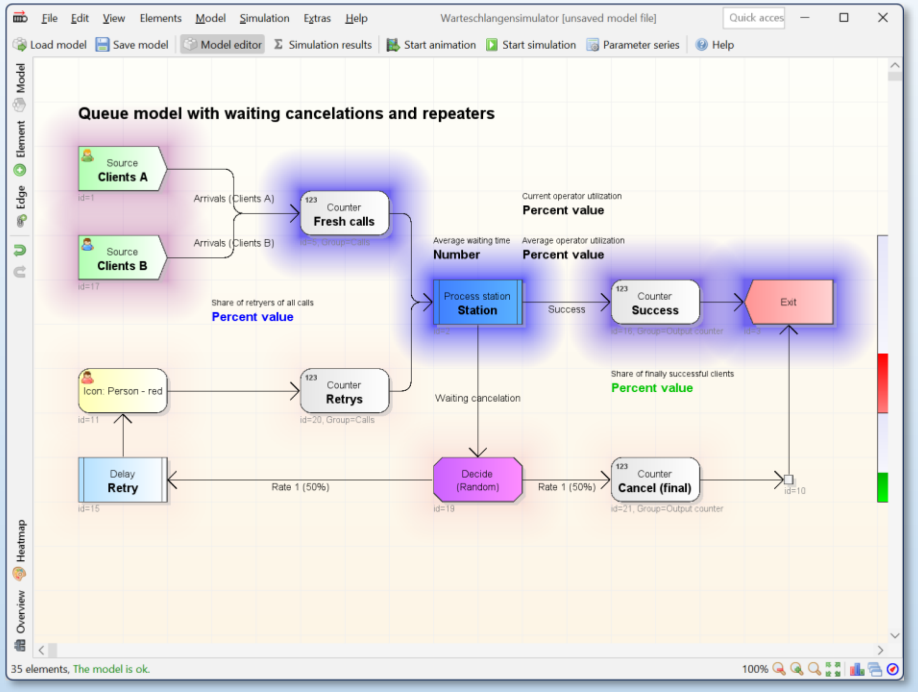
The data marked with (*) indicate the real computing time on a CPU core.

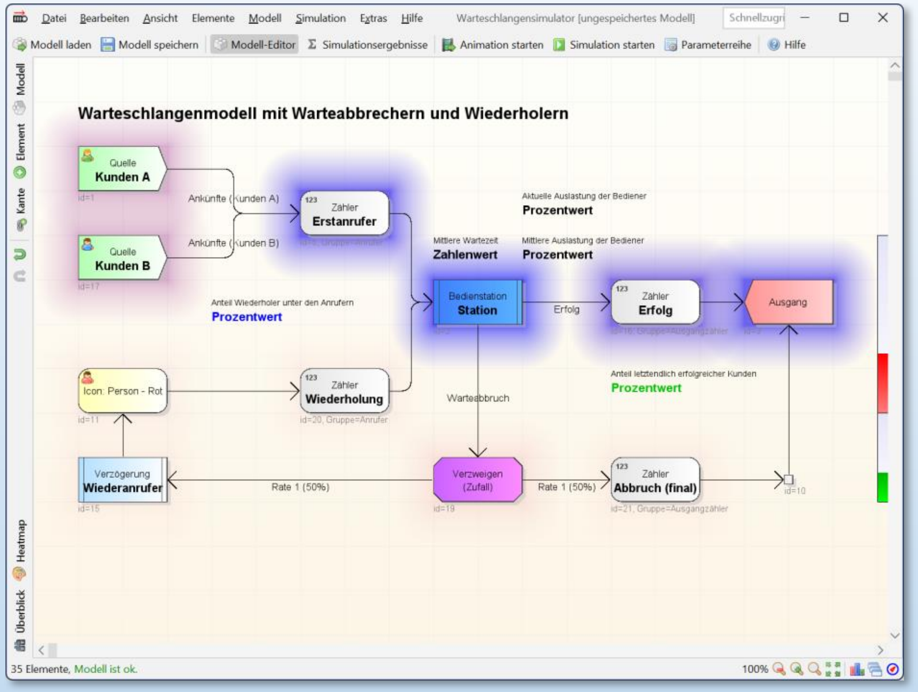
Fast simulation
supporting multi-core CPUs

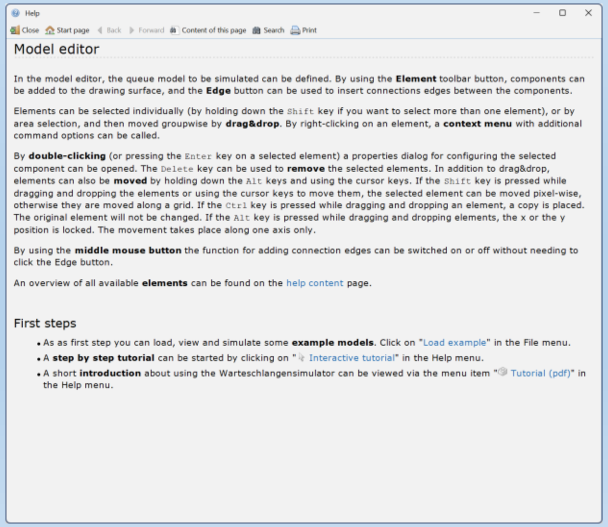


Warteschlangensimulator – Event-driven stochastic simulation

a-herzog.github.io/Warteschlangensimulator




Datei Bearbeiten Ansicht Elemente Modell Simulation Extras Hilfe
Warteschlangensimulator [ungespeichertes Modell]
Modell laden
Modell speichern
Modell-Editor
Simulationsergebnisse
Animation starten
Simulation starten
Parameterreihe
Hilfe
Warteschlangenmodell mit Warteabbrechern und Wiederholern
Quelle Kunden A
Quelle Kunden B
Ankünfte (Kunden A)
Ankünfte (Kunden B)
Zähler Erstanrufer
Aktuelle Auslastung der Bediener Prozentwert
Mittlere Wartezeit Zahlenwert
Mittlere Auslastung der Bediener Prozentwert
Bedienstation Station
Erfolg
Zähler Erfolg
Ausgang
Anteil Wiederholer unter den Anrufern Prozentwert
Icon: Person - Rot
Zähler Wiederholung
Warteabbruch
Anteil letztendlich erfolgreicher Kunden Prozentwert
Verzögerung Wiederanrufer
Rate 1 (50%)
Verzweigen (Zufall)
Zähler Abbruch (final)
Modell
Element
Kante
Heatmap
Überblick
35 Elemente, Modell ist ok.
100%



Model editor

In the model editor, the queue model to be simulated can be defined. By using the **Element** toolbar button, components can be added to the drawing surface, and the **Edge** button can be used to insert connections edges between the components.

Elements can be selected individually (by holding down the `Shift` key if you want to select more than one element), or by area selection, and then moved groupwise by **drag&drop**. By right-clicking on an element, a **context menu** with additional command options can be called.

By **double-clicking** (or pressing the `Enter` key on a selected element) a properties dialog for configuring the selected component can be opened. The `Delete` key can be used to **remove** the selected elements. In addition to drag&drop, elements can also be **moved** by holding down the `Alt` keys and using the cursor keys. If the `Shift` key is pressed while dragging and dropping the elements or using the cursor keys to move them, the selected element can be moved pixel-wise, otherwise they are moved along a grid. If the `Ctrl` key is pressed while dragging and dropping an element, a copy is placed. The original element will not be changed. If the `Alt` key is pressed while dragging and dropping elements, the x or the y position is locked. The movement takes place along one axis only.

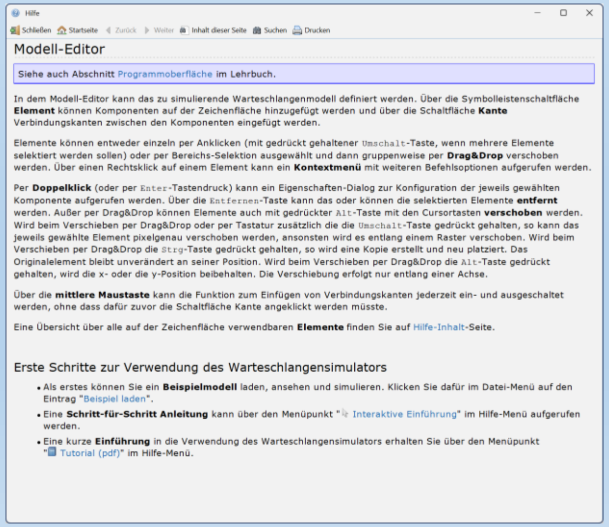
By using the **middle mouse button** the function for adding connection edges can be switched on or off without needing to click the Edge button.

An overview of all available **elements** can be found on the help content page.

First steps

- As as first step you can load, view and simulate some **example models**. Click on "Load example" in the File menu.
- A **step by step tutorial** can be started by clicking on " Interactive tutorial" in the Help menu.
- A short **introduction** about using the Warteschlangensimulator can be viewed via the menu item " Tutorial (pdf)" in the Help menu.

User-interface and full documentation available in **English and German**



Modell-Editor

Siehe auch Abschnitt Programmoberfläche im Lehrbuch.

In dem Modell-Editor kann das zu simulierende Warteschlangenmodell definiert werden. Über die Symbolleistenschaltfläche **Element** können Komponenten auf der Zeichenfläche hinzugefügt werden und über die Schaltfläche **Kante** Verbindungskanten zwischen den Komponenten eingefügt werden.

Elemente können entweder einzeln per Anklicken (mit gedrückt gehaltener `Umschalt`-Taste, wenn mehrere Elemente selektiert werden sollen) oder per Bereichs-Selektion ausgewählt und dann gruppenweise per **Drag&Drop** verschoben werden. Über einen Rechtsklick auf einem Element kann ein **Kontextmenü** mit weiteren Befehlsoptionen aufgerufen werden.

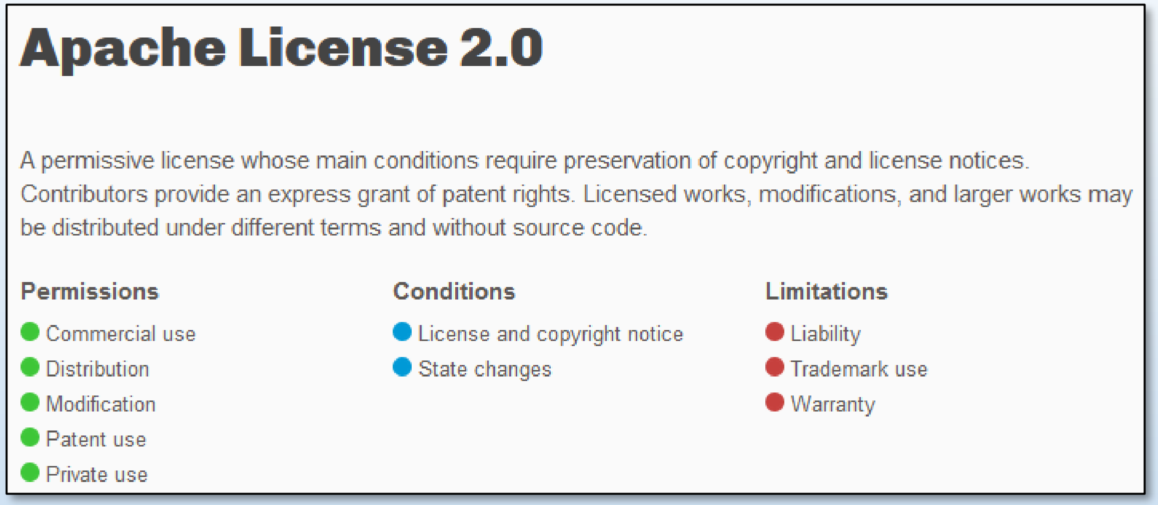
Per **Doppelklick** (oder per `Enter`-Tastendruck) kann ein Eigenschaften-Dialog zur Konfiguration der jeweils gewählten Komponente aufgerufen werden. Über die `Entfernen`-Taste kann das oder können die selektierten Elemente **entfernt** werden. Außer per Drag&Drop können Elemente auch mit gedrückter `Alt`-Taste mit den Cursortasten **verschoben** werden. Wird beim Verschieben per Drag&Drop oder per Tastatur zusätzlich die die `Umschalt`-Taste gedrückt gehalten, so kann das jeweils gewählte Element pixelgenau verschoben werden, ansonsten wird es entlang einem Raster verschoben. Wird beim Verschieben per Drag&Drop die `Strg`-Taste gedrückt gehalten, so wird eine Kopie erstellt und neu platziert. Das Originalelement bleibt unverändert an seiner Position. Wird beim Verschieben per Drag&Drop die `Alt`-Taste gedrückt gehalten, wird die x- oder die y-Position beibehalten. Die Verschiebung erfolgt nur entlang einer Achse.

Über die **mittlere Maustaste** kann die Funktion zum Einfügen von Verbindungskanten jederzeit ein- und ausgeschaltet werden, ohne dass dafür zuvor die Schaltfläche Kante angeklickt werden müsste.

Eine Übersicht über alle auf der Zeichenfläche verwendbaren **Elemente** finden Sie auf Hilfe-Inhalt-Seite.

Erste Schritte zur Verwendung des Warteschlangensimulators

- Als erstes können Sie ein **Beispielmodell** laden, ansehen und simulieren. Klicken Sie dafür im Datei-Menü auf den Eintrag "Beispiel laden".
- Eine **Schritt-für-Schritt Anleitung** kann über den Menüpunkt " Interaktive Einführung" im Hilfe-Menü aufgerufen werden.
- Eine kurze **Einführung** in die Verwendung des Warteschlangensimulators erhalten Sie über den Menüpunkt " Tutorial (pdf)" im Hilfe-Menü.



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● Patent use		
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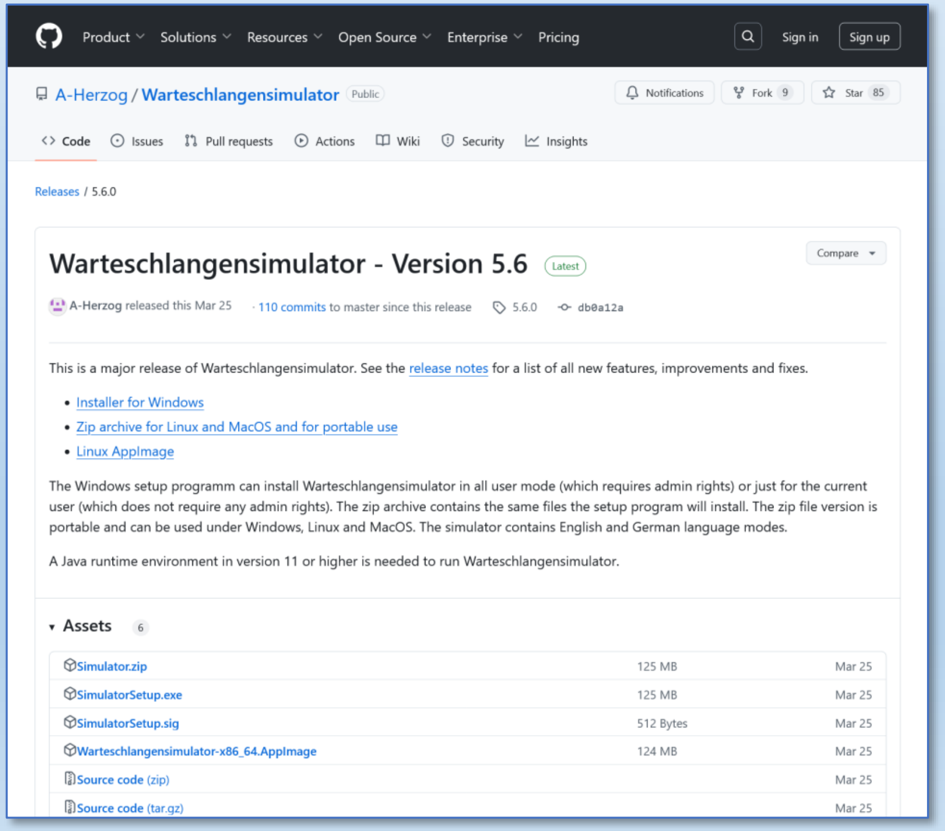
Available as **Opensource** on GitHub



A-Herzog / Warteschlangensimulator Public

Releases / 5.6.0

Warteschlangensimulator - Version 5.6 Latest

A-Herzog released this Mar 25 · 110 commits to master since this release 5.6.0 db0a12a

This is a major release of Warteschlangensimulator. See the release notes for a list of all new features, improvements and fixes.

- Installer for Windows
- Zip archive for Linux and MacOS and for portable use
- Linux AppImage

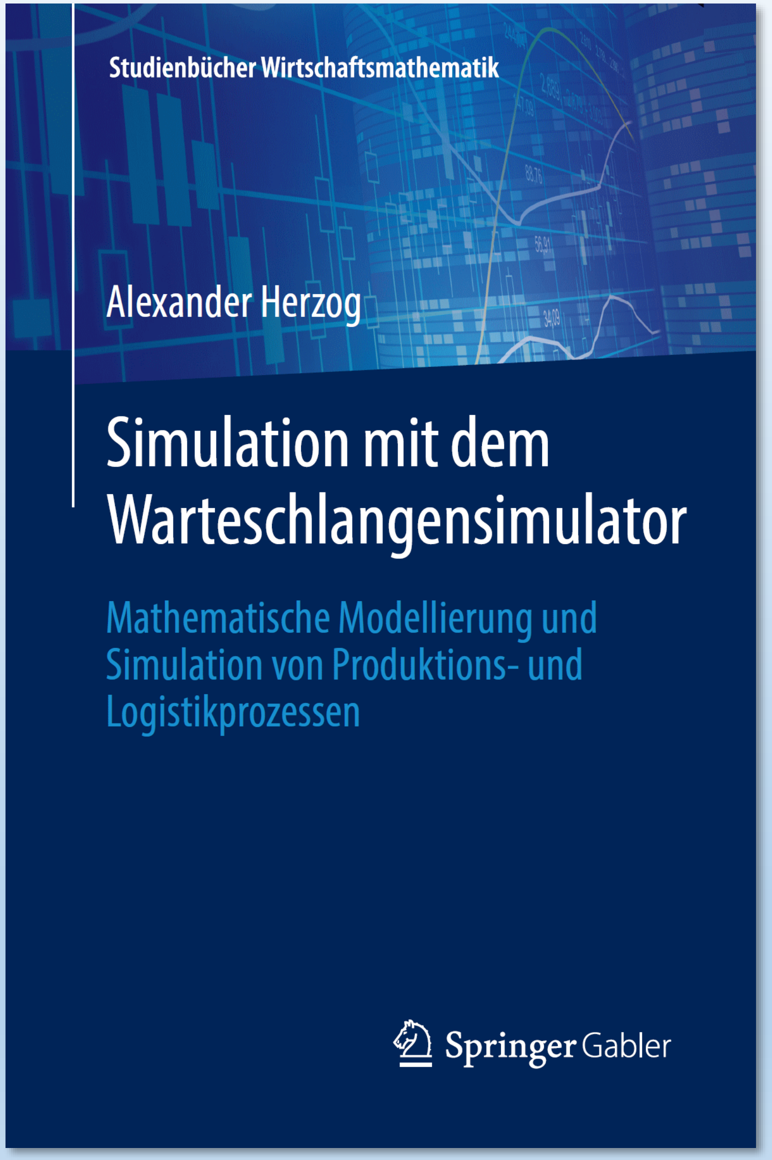
The Windows setup programm can install Warteschlangensimulator in all user mode (which requires admin rights) or just for the current user (which does not require any admin rights). The zip archive contains the same files the setup program will install. The zip file version is portable and can be used under Windows, Linux and MacOS. The simulator contains English and German language modes.

A Java runtime environment in version 11 or higher is needed to run Warteschlangensimulator.

▾ Assets 6

Simulator.zip	125 MB	Mar 25
SimulatorSetup.exe	125 MB	Mar 25
SimulatorSetup.sig	512 Bytes	Mar 25
Warteschlangensimulator-x86_64.AppImage	124 MB	Mar 25
Source code (zip)		Mar 25
Source code (tar.gz)		Mar 25

Windows installer and **zip file archive** (for Windows and Linux) available



Studienbücher Wirtschaftsmathematik

Alexander Herzog

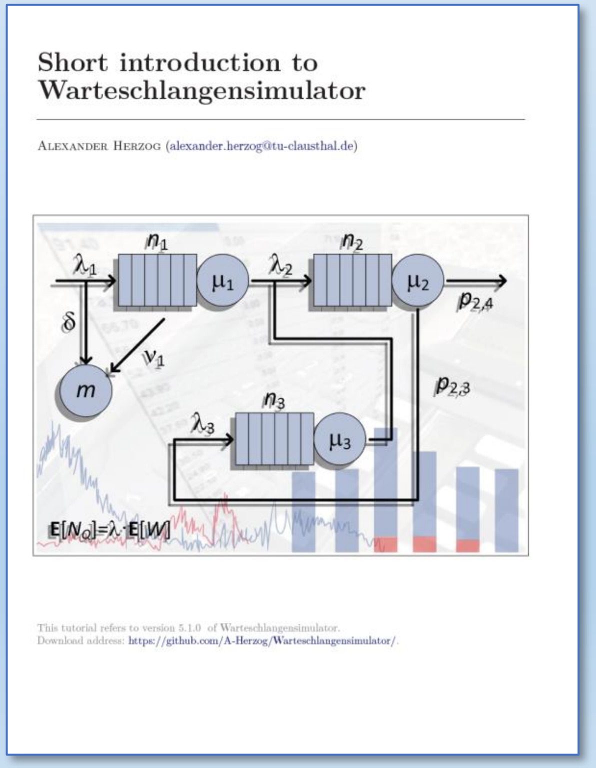
Simulation mit dem Warteschlangensimulator

Mathematische Modellierung und Simulation von Produktions- und Logistikprozessen

Springer Gabler

Textbook
(in German language)

… but tutorials, references, online help etc. directly built-in in Warteschlangensimulator



Short introduction to Warteschlangensimulator

Alexander Herzog (alexander.herzog@tu-clausthal.de)

This tutorial refers to version 5.1.0 of Warteschlangensimulator.
Download address: https://github.com/A-Herzog/Warteschlangensimulator/.