Description of the
Tecnomatix Plant Simulation
Small Parts Production Demo Model
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1 Description

This model shows a production and assembly system with pallet-based transport. The system contains manual and automatic workstations. One part per pallet runs through the system and is processed on the stations according to the processing times.

Each station has processing times and a certain availability. The manual stations need a worker to start. These parameters determine how long a part stays on the station.

We created the model using the basic objects of Plant Simulation. We inserted the objects and connected them to reflect the layout of the real production line.

1.1 Purpose

Our purpose is to optimize the number of pallets and the capacity of the buffers to maximize the throughput. The model demonstrates how to solve two typical problems every simulation engineer faces:

1. A real production system always has several values you can optimize (e.g. maximize throughput rate and minimize throughput time) and a number of parameters you can change (capacities, logic, layout). In most cases, some parameters affect other parameters too (e.g., if you decide to decrease the capacity of buffers the optimum number of pallets might also decrease). The user should then run several experiments for all possible combinations of values for those parameters to find the best result. Normally, this is not possible. The ExperimentManager in Plant Simulation can solve this problem by executing a certain number of simulation runs by itself.

2. Some values in a real system exhibit random behavior (e.g. the point in time when a machine breaks down or the processing time of manual operations). In this case, it does not suffice to run just one simulation experiment because the results of this experiment are based on the random numbers from this single simulation run alone. When you run the same experiment with different random numbers, it will generate different results. So how can you base a decision for a multi-million dollar system on simulation experiments? The solution is to run multiple experiments with different random numbers and to calculate a confidence interval from the results. The ExperimentManager in Plant Simulation can tell you that, for example, with a confidence level of 90%, the mean throughput of your system will be in the range between 45.2 and 45.5 units per hour.

2 Demo Instructions

2.1 Study Overview

Start a simulation run in the Frame Assembly1 by clicking the Start button in the model.

![Start/Stop button in the Frame](image)

Figure 1: Start/Stop button in the Frame
Watch the simulation run. Pallets enter the system on the left hand side. The LoadStation in the upper left corner of the production line loads one part onto a pallet. Then, the pallets move along passing several manual and automated workstations. When a pallet enters a manual workstation, a worker is allocated from the worker pool. On the station MS3 on the right-hand side, sub-parts are attached to the main part. The sub-parts arrive from the station PreProduction.

Double-click this station to view its contents. Plant Simulation allows structuring your production line in a hierarchical way. The number of hierarchical layers is unlimited.

The pallets move on to additional stations on the conveyors F5 and F6. At the bottom of the production line, 40% of the pallets are loaded onto a cross-transfer element and have to pass a test station. At the UnloadStation, the main part is unloaded from the pallet and leaves the system. The pallet moves on to the LoadStation to be loaded with the next part.

2.2 System Parameters

You will notice that several objects are located on the yellow background in the model. These objects are used to control and parameterize the simulation model.

On the left-hand side is the EventController. This object controls all events in your simulation model. It tracks the time and controls all activities in your model during a simulation run.

The second object is the AttributeExplorer called ManuParameters. Right-click the object and click Show on the context menu to open a table showing the attributes of interest. Use this object to quickly and easily parameterize several objects in your simulation model at one time. You can see that we use the Normal
distribution to determine the processing time of the manual stations MS1 to MS4. All stations have an availability of 98%.

Figure 3: AttributeExplorer for the manual workstations

The third object is the AttributeExplorer called AutoParameters. Click the right mouse button to open the context menu and select Show. You'll notice that we use the Uniform distribution to calculate the processing time of the automatic stations AS1 to AS5. These stations have an availability of 99%.

Figure 4: AttributeExplorer for the automated workstations

The other objects are described in detailed below.

Our production line is working in two shifts. For this we use the ShiftCalendar. Double-click the object to open the times table of the ShiftCalendar.
Figure 5: ShiftCalendar

Only the manual stations are assigned to the *ShiftCalendar*. Click the tab **Resources** to view the assigned resources.

Figure 6: Assigned resources of the ShiftCalendar

The object called supplies the *Workers* required at the manual stations. Double-click the object to open its dialog and click the button **Creation Table** to open the definition table of the *Workers*.

The first column shows the class object of the *Worker* which will be used to create the *Worker* for the simulation run. This is useful when *Workers* have different skills. The second column defines how many *Workers* will be created and the third column defines during which shift the *Worker* performs work.
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![Figure 7: Creation table of the WorkerPool](image)

Note that the shift name in the column Shift corresponds to the shift name in the ShiftCalendar.

2.3 Objects of the Simulation Model

On the left hand side of the production line you see a Source object Start Pallets. This object creates a defined number of pallets. The pallets move along the conveyor F0. The source object Raw Parts creates the parts for the production line. These parts are loaded onto the arriving pallets.

After passing several processing stations, the pallets arrive at the station UnloadStation. The parts are unloaded and move to a Drain object Finished Parts. The Drain collects statistical data of the arriving parts and removes the parts from your simulation model.

3 Working with the Simulation Model

3.1 Find the Optimum Number of Pallets

We would like to find out the optimum number of pallets to maximize the throughput of the system. To do so, we will change the number of pallets (Quantity) and we will run several simulation experiments with different random numbers for each value to receive statistically reliable results. Doing this manually would be a labor-intensive and time-consuming project. The ExperimentManager assists you in quickly and effectively executing your simulation studies.

Double-click the ExperimentManager called PalletOptimization.
Figure 8: The ExperimentManager – tab Definition

Click **Define Output Values** on the tab **Definition**. This opens a table that shows the result value we would like to optimize.

<table>
<thead>
<tr>
<th>Output Values</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>root.Drain.statDeleted</td>
<td>Throughput</td>
</tr>
</tbody>
</table>

Then, click **Define Input Variables**. This table shows the parameter we would like to change to optimize the result. You can add descriptions to both tables to make the meaning of the attribute more comprehensive. This description will appear in the evaluation of the experiments.

<table>
<thead>
<tr>
<th>Input Values</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>root.Quantity</td>
<td>Number of pallets</td>
</tr>
</tbody>
</table>

Click **Define Experiments** to open a table showing the values for the number of pallets.

<table>
<thead>
<tr>
<th>Active</th>
<th>Number of pallets</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>35</td>
</tr>
<tr>
<td>6</td>
<td>40</td>
</tr>
<tr>
<td>7</td>
<td>45</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
</tr>
</tbody>
</table>

The number to the right of **Observations per Experiment** defines how many simulation runs using different random numbers will be executed for each experiment.
Click the buttons **Reset** and **Start** to start the *ExperimentManager*. After a short time the program opens a report.

The page **Overview** shows a table with the number of pallets and the resulting throughput.

The page **Visualization** for each experiment shows the resulting throughput. It also shows the confidence interval as a small bar next to the mean value.

You'll notice that the throughput of the production line increases when you increase the number of pallets. At a certain number of pallets the increase of the number of produced parts is only very small, meaning that the throughput decreases again.

In our experiment the reasonable number of pallets is 35, shown in experiment number 5.

**Conclusion:** Using the *ExperimentManager* of Plant Simulation makes it easy to run multiple simulation experiments with different random numbers. Different values for the parameters can be tested to determine the optimal value of the parameter.
3.2 Find the Bottleneck

We now define the number of pallets in the production line. Double-click the variable Quantity to open its dialog. There, enter the value 35.

Start the simulation run. When the simulation run stops, double-click the object StationUtilization. A bar chart opens, showing the utilization of every station.

The chart shows the time percentages during which a station was:

- Working (green)
- Setting-up (brown)
- Waiting (grey)
- Blocked (yellow)
- Failed (red)
- Stopped (pink)

Figure 9: Utilization chart of the stations
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• Paused (dark blue)
• Unplanned (light blue)

The Chart shows that the stations MS2, MS3, MS4 as well as AS2 show a certain blocking percentage (yellow). On the other hand, you’ll see that most stations show a waiting percentage (grey). This indicates that there is a bottleneck in the sequence of the stations AS2, MS2, MS3 and MS4.

Double-click the BufferUsage histogram. It shows the percentage of time a certain quantity of parts was located on a conveyor.

Figure 10: Occupation of conveyors

Note that, quite often, the conveyors F4 and F5 (yellow and turquoise) are fully occupied. Again, this indicates that there is a bottleneck at station MS3/MS4. So, the problem seems to be the direct connection of manual and automated workstations. To solve the problem, we insert a Buffer B between MS4 and AS3.

3.3 Test the New Layout

Look at the Frame Assembly2. It shows a Buffer B between MS4 and AS3. Double-click the Buffer. In the dialog of the buffer you’ll see that it has a capacity of 6 pallets.
To find the optimal capacity, we’ll use the ExperimentManager.

We inserted a second ExperimentManager into the simulation model. There, we define the capacity of the Buffer as the input value and the throughput of the production line as the output value. After running the experiments, the program opens the results. The page Overview shows that the capacity of 10 suffices for the Buffer. A greater capacity of the Buffer does increase the throughput, but only by an insignificant value.

The chart Evaluation of the output value Throughput also shows this. The chart increases, but there is only a very small increasing step from experiment 6 to experiment 8.
4 Worker Utilization

In order to check the utilization of the Workers, right-click the object Worker-Utilization and select View Chart on the context menu.

Figure 12: The worker utilization chart

The chart shows the percentage of time during which a Worker was:

- Working (green)
- Waiting (grey)
- Paused (light blue)
- Unplanned, meaning there was no shift time (dark blue)

The chart shows you that the Workers at the manual workstations have a high utilization. The utilization of the Adjusters is very low.

5 Summary

Even a system that looks so simple shows complex behavior due to stochastic parameters.
Even if two stations have the same mean value for the **cycle time**, the second station can be a bottleneck, if the two stations use a different random number distribution.

**Conclusion:** Plant Simulation provides multiple easy-to-use tools to evaluate your system and to base your decisions on reliable results. These tools allow you to identify bottlenecks and to detect resources that are not well utilized.

### 6 Optimizing Energy Consumption

Now that we have optimized the throughput of our production line, we would like to evaluate the energy consumption of this system. Double-click the conveyor *F0* to open its dialog. Click the tab **Energy**.

![Figure 13: Tab Energy of conveyor F0](image)

On this tab, you define the energy consumption of the conveyor. When the conveyor is working, the power consumption is 1 kW (field *working*). If the conveying speed is 0, then the power consumption is 0.3 kW (field *operational*). These settings are inherited from the class object *Line* and are the same in all conveyors in our model.

Double-click the icon of the **EnergyAnalyzer** to open its dialog window.
Click the tab **Objects** to add the objects for which you want to analyze energy consumption.

To add an object to this list, drag the object over the icon of the *EnergyAnalyzer* and drop it there. If you want to add all objects of your simulation model, click the button **Add All**.

Next, click the tab **Settings**. Select the checkbox **Display panel**. This shows an animated display panel below the icon of the *EnergyAnalyzer* during the simulation run.

The display panel shows the accumulated energy consumption of all assigned resources. The second row shows the accumulated energy consumption of all resources while they are in the operational state. The next row shows the current power consumption and the last row shows the maximum power consumption.

Now, run the simulation for one day.

The production line had a total energy consumption of 837.9 kWh per day. The current power consumption was 23.6 kW and the maximum power consumption was 46.0 kW.

In our next step, we want to reduce the power consumption. To do so, we set the speed of the conveyor to zero if the conveyor is empty. The simulation model contains an object of type *Checkbox* in the middle of the model called *Energy saving measures*.

When you click this checkbox, the attribute **Automatic stop** of each conveyor in the simulation model will be set to true. The causes the conveyor to stop (speed=0) when the conveyor is empty. This will also reduce the energy consumption of the conveyor to zero.

Start the simulation run again and watch the display panel of the *EnergyAnalyzer*.

This time we have a total energy consumption of 600.3 kWh.

Stopping the conveyors when they are empty reduces the total energy consumption by 237.6 kWh in one day.

The maximum energy consumption during the simulation run...
was reduced from 46k W to 41.8 kW. This is important if you are planning a new production line and you have to decide the wire-cross-section for supplying the production line with power.

Open the Energy Analyzer and click the button Show next to Visualization. This draws colored circles around the objects, which show the energy consumption of the objects in the simulation model.

The color and thickness of the circles is defined as shown in the figure below.

Click the button Show next to Diagram of the energy consumption to open a chart showing the energy consumption of the selected objects.
During the simulation run you can plot the current power consumption. Click **Show** next to **Plot of power input** to open the plotter.

Summary: Plant Simulation provides powerful tools for analyzing the power consumption of your production system. These tools allow you to easily set parameters for power consumption, to identify the main energy users in your system and to analyze your strategies for reducing power consumption.