

1 TUTORIAL

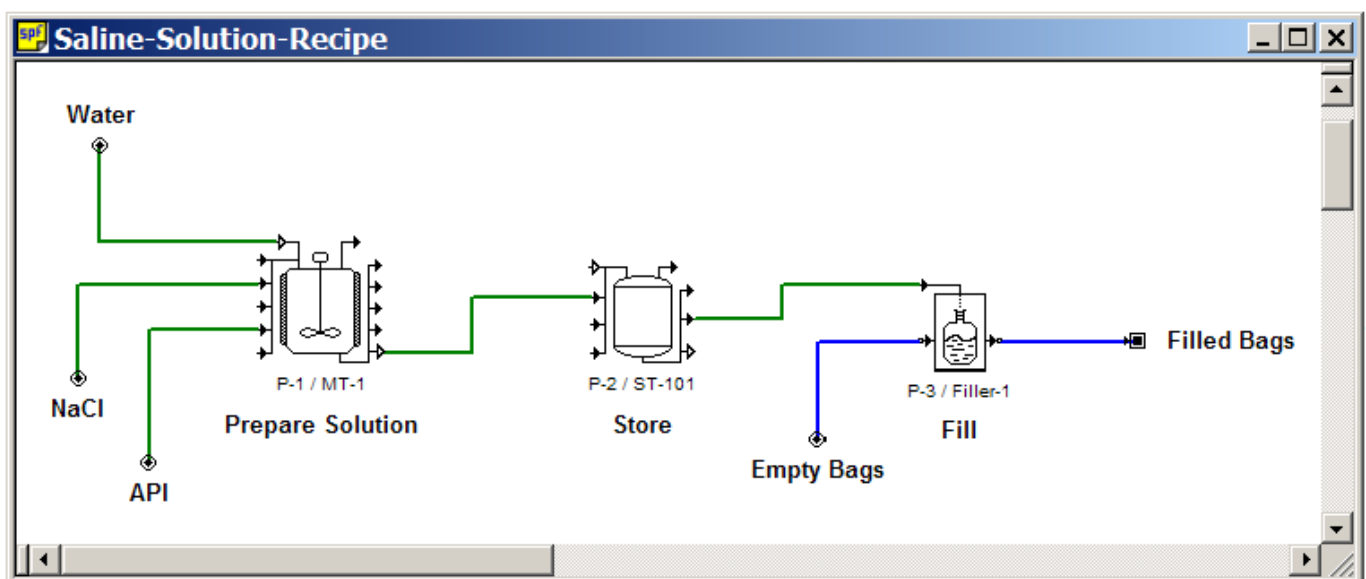
1.1 Tutorial Introduction

This document will guide you through the steps of creating a production schedule with SchedulePro Cloud. We will start with simple concepts and incrementally introduce more advanced features and capabilities of the tool.

Through a step-by-step process that you can follow as you move along, you will learn how to:

- Declare a workspace and a scheduling board
- Declare a facility and its resources.
- Define a recipe with procedures and operations.
- Declare and schedule a campaign.
- Retrieve the scheduling results in the form of Gantt and resource utilization charts.
- Include facility and equipment downtimes and operation flexible time shifts, and investigate their effect on scheduling.
- Declare usage and generation of materials, and track their profiles and inventories.
- Identify and eliminate bottlenecks.
- Scale recipes and investigate their impact on equipment selection and duration of operations.

The tutorial will make use of a simplified version of a batch recipe for the production of a saline solution (for medical applications). The recipe (process) as modeled in SuperPro Designer™ is shown below.



The simplified recipe includes three procedures (processing steps): (a) preparing the solution in a mixing tank, (b) storing the solution in a storage tank and (c) putting the solution in plastic bags using a filling machine.

The following table lists the operations that are included in each of the three procedures along with their duration and information on their relative ordering. The saline solution is prepared from three basic ingredients: water-for-injection (WFI), Sodium Chloride, and API-A (an Active Pharmaceutical Ingredient).

The recipe will be executed in a facility called “Medical Solutions Plant”. The facility is equipped with a mixing tank (MT-1), a storage tank (ST-101) and a bag filler (Filler-1). Also, a clean-in-place skid (CIP-Skid-1) is available for cleaning the equipment.

Procedure	Equipment	Operation	Start Time Relation	Duration
P-1				
Prepare Solution	MT-1	Charge Water	Batch start	30 min
		Charge Sodium Chloride	At the end of its previous operation	15 min
		Charge API	At the end of its previous operation	15 min
		Mix Thoroughly	At the end of its previous operation	60 min
		Transfer to Storage Tank	At the end of its previous operation	30 min
		Clean Tank	At the end of its previous operation	90 min
P-2				
Store	ST-101			
		Receive from Mixing Tank	When “Transfer to Storage ...” in P-1 starts	Equal to “Transfer to Storage” in P-1
		Feed Filler	10 min after start of its previous operation	Equal to “Fill Bags” in P-3
		Clean Tank	At the end of its previous operation	90 min
P-3				
Fill	Filler-1	Fill Bags	When “Feed Filler” in P-2 starts	320 min
		Clean Filler	At the end of its previous operation When “Clean Tank” in P-2 starts	90 min

1.2 Tutorial Structure

The tutorial is based on the following incremental structure. Each section is accompanied by a SchedulePro Cloud sample workspace/scheduling board. To access the desired sample, you select the “Sample Workspace / Scheduling Board” option on the main page and then the desired tutorial. Then you are prompted to confirm the Workspace and Scheduling Board name (see figures below).

SCP Cloud Planning
Tutorial_1a-1

Scheduling-board-1

HomeEocGanttLine Charts ▼FacilitiesMaterialsRecipesOptions ▼Logout

CREATE A WORKSPACE / SCHEDULING BOARD

+

Sample Workspace / Scheduling Board
Select this option if:

- You are new to the application and want to see a demo in just a few clicks.
- You want to follow one of our tutorials to learn more about using the application or get modelling insights by experimenting with one of our industry-specific examples.

What you get:

- A new Workspace with the sample assets: resources (e.g. materials, facilities, equipment, staff) and recipes.
- A new Scheduling Board with a number of pre-scheduled campaigns.

+

Empty Scheduling Board
Select this option if:

- You already have a Workspace and want to create an additional Scheduling Board for scheduling campaigns using the Workspace assets (resources/recipes).
- You want to start modelling your plant assets from scratch as part of a new Workspace (advanced).

What you get:

- A new Scheduling Board without any campaigns.
- Optionally, a new Workspace without any assets.

SELECT A WORKSPACE / SCHEDULING BOARD

Select Scheduling Board... ▼

SET

MANAGE WORKSPACES / SCHEDULING BOARDS

Click to manage workspaces & scheduling boards

After pressing the “Create” button, the Scheduling Board is created and you are transferred to the relevant EOC chart. You may also create the same files on your own to solidify your understanding of the tool, by choosing the “Empty Scheduling Board” option.

Select a Scheduling Board Example

☒ Tutorial 1a Simplified production of saline solution, Creating and Scheduling a Simple Recipe

☐ Tutorial 1b Considering the Impact of Equipment Pools

☐ Tutorial 1c Scheduling with Flexible Shifts

☐ Tutorial 2a Multiple Recipes and Equipment Routing

☐ Tutorial 2b Considering Changeover Times

☐ Tutorial 4a Resource tracking

☐ Tutorial 4b Inventory tracking

☐ Tutorial 5a Debottlenecking, Recipe -> default no Flexible shifts

☐ Tutorial 5b Debottlenecking, Recipe -> add flexible shifts to reduce makespan

☐ Tutorial 5c Debottlenecking, Recipe -> add an equipment for the bottleneck (CIP_Skid-2)

☐ Tutorial 6a Scheduling with Facility Downtimes

☐ Tutorial 6b Interruptible Operations

☐ Tutorial 7 Scaling Recipes and Campaigns

NEXT

Confirm Workspace / Scheduling Board name

☒ Add in new workspace

Tutorial_1a-3

Scheduling Board name

Scheduling-board-1

BACK

CREATE

Tutorial-1a	Creating and Scheduling a Simple Recipe Demonstrates most basic features of SchedulePro. Provides a quick start guide for beginner users who wish to schedule their first case and view scheduling results.
Tutorial-1b	Considering the Impact of Equipment Pools Demonstrates the impact of equipment pools on cycle time and plant throughput.
Tutorial-1c	Scheduling with Flexible Shift Times Demonstrates the use of flexible shift times and their impact on equipment utilization and make-span reduction.
Tutorial-2a	Multiple Recipes and Equipment Routing Explains how to clone recipes and deal with equipment routings.

Tutorial-2b	Considering Changeover Times Demonstrates the specification and usage of equipment changeovers.
Tutorial-3	Schedule Adjustments Demonstrates how to manually adjust and improve schedules through the Equipment Occupancy chart by dragging and dropping procedures and explains how to represent process delays.
Tutorial-4a	Resource Tracking Demonstrates how to declare and track resource demand as a function of time. Resources include materials, heating/cooling utilities, electrical power, and labor. It also explains how to use material tracking charts for sizing supply units and storage tanks.
Tutorial-4b	Inventory Tracking Explains the role of storage units and the extra information required for tracking inventories of materials.
Tutorial-5	Debottlenecking Production Lines Provides information on debottlenecking strategies that involve Flexible Shift times and Equipment Pools.
Tutorial-6	Scheduling with Facility Downtimes Provides information on how to specify facility and equipment downtimes and their impact on production scheduling. It also explains how to make use of interruptible operations and flexible shift times for accommodating facility outages.
Tutorial-7	Scaling Batches Explains how batches are scaled and the impact of batch size on equipment selection and calculation of operation durations.

1.3 The Tutorials

1.3.1 Tutorial-1a: Creating and Scheduling a Simple Recipe

1.3.1.1 Adding the Facility and its Resources

Recipes created in SchedulePro Cloud make use of facilities and their resources. Recipes, facilities and resources should all be part of the same workspace. From a practical point of view, it is more convenient to declare the facility information first before the declaration of the recipes, especially if both are to be entered directly in SchedulePro Cloud. This is because recipes make use of resources declared in the facility.

The key data in SchedulePro Cloud are displayed on the main menu (top side of the page, see figure below). The three major data categories are Facilities, Materials and Recipes.

SCP Cloud Planning
Tutorial_1a-1

Scheduling-board-1

HomeEocGanttLine Charts▼FacilitiesMaterialsRecipesOptions▼Logout

Scheduling-board-1 > Home

NameScheduling-board-1Start1/1/2022, 2:00:00 AMDescriptionN/AEdit

Duration26 weeks

DeleteFilter

ScheduleRescheduleUnschedule

☐	Name	Scheduled	Release Time	Recipe	Number of Batches
☐	Campaign-1	✓	1/1/2022, 2:00:00 AM	1L-Bag-Recipe	4

Enter campaign name...

+↺

Clicking the “Facilities” menu item, opens the facilities page, where you can enter the name of the facility. There are four different categories of resources that a facility can have (see figure below): Equipment, Staff, Labor, and Storage Units.

SCP Cloud Planning
Tutorial_1a-1

Scheduling-board-1

HomeEocGanttLine Charts▼FacilitiesMaterialsRecipesOptions▼Logout

Facilities

DeleteSortFilter

☐	Name	Description	Location
☐	Medical Solutions Plant		EquipmentStaffLaborStorageUnits

Enter facility name...

+↺

To declare the mixing tank (MT-1) in the facility, select the Equipment link (see previous figure) and type the equipment name (“MT-1”) on the “Enter equipment name...” field.

SCP Cloud Planning
Tutorial_1a-1

Scheduling-board-1

HomeEocGanttLine Charts▼FacilitiesMaterialsRecipesOptions▼Logout

Facilities > Medical Solutions Plant > Equipment

DeleteSortFilter

☐	Name	Type	Description
☐	CIP-Skid	CIP-Skid	
☐	Filler-1	Filler	
☐	ST-101	Receiver Tank	
☐	MT-1	Vessel	

Enter equipment name...

+↺

Then click the created equipment (“MT-1”) to reveal a side panel with the equipment details. Clicking the Identification edit link in the General tab you can identify the equipment type (“Blending Tank” for MT-1) by typing it in the “Select Type..” field and finally pressing the “SAVE” button.

Repeat the above step three times to declare the storage tank ST-101 (type: “Receiver Tank”), the filler Filler-1 (type: “Filler”), and the CIP skid CIP-Skid-1 (type: “CIP Skid”). If, after declaring an equipment, you wish to view or edit its properties, click the specific equipment item in the equipment table. If you just want to change the equipment name, click on the edit link that appears when hovering over the equipment name.

1.3.1.2 Creating the Recipe

Next select the “Recipes” menu item that transfers you to the “recipes” page. To add a new recipe type its name in the “Enter recipe name..” field. Optionally you can add a Description by going to the “Edit” link that appears when hovering over the description column of the recipes table. Clicking the “View” link you can access the recipe details.

In the recipe contents, under the main menu, you can find the recipe information (Name, Description and Recipe Size). Clicking the “Edit” link, allows you to specify the recipe information. In particular, you can specify the recipe batch-size by clicking the Edit link of the “Size” tab. SchedulePro Cloud utilizes this

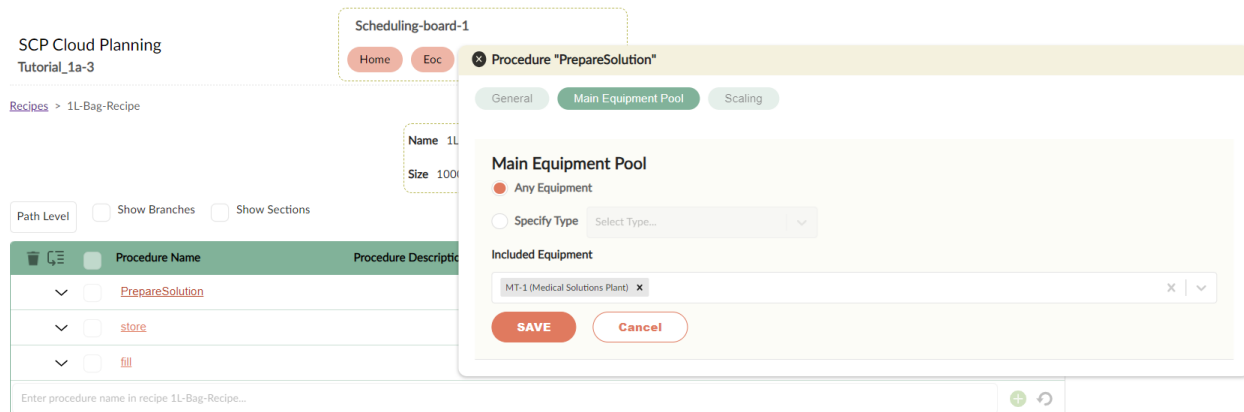
optional information for recipe scaling, equipment selection based on batch-size and size-based operation duration calculations.

The top screenshot shows the SCP Cloud Planning interface for 'Tutorial_1a'. The 'Recipes' tab is active, displaying a table for the '1L Bag Recipe'. The table has columns for 'Name', 'Description', and 'Main Equipment Pool'. The 'Name' column shows '1L Bag Recipe' and 'Size' is '10000 L'. An 'Edit' button is highlighted in the top right corner of the table.

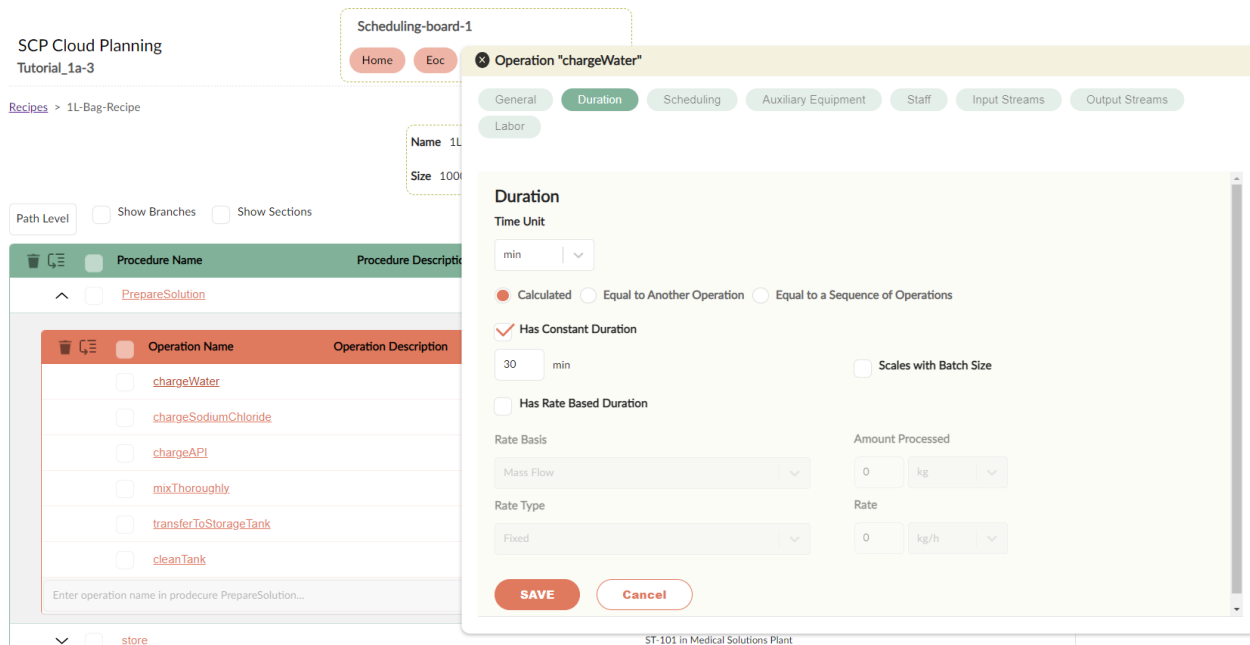
The bottom screenshot shows the 'Recipe Size' dialog box for '1L-Bag-Recipe'. The dialog has two tabs: 'General' and 'Size'. The 'Size' tab is active, showing 'Recipe Size' settings. The 'Size Basis' is set to 'Volume' and the 'Amount Size' is '10000 L'. There are 'SAVE' and 'Cancel' buttons at the bottom.

Every recipe consists of a number of procedures (processing steps). Optionally these can be categorized into Sections and Branches. In SchedulePro Cloud, sections correspond to a hierarchical level below the “recipe” level but above the “procedure” level. They allow you to group procedures that serve a common processing objective (e.g., purification) or share a common resource (e.g., a suite). In this simple tutorial example, there is no need to define sections. The user can specify whether he wants to show the recipe branches and sections or not, by checking the corresponding boxes. To add a procedure, type its name in the “Enter procedure name in recipe...” field (“Prepare Solution” in this case).

Select procedure “Prepare Solution” to display the procedure properties side panel. Select the Main Equipment Pool tab to declare the equipment used to execute this procedure. Select MT-1 (“Medical Solutions Plant”) and click the “SAVE” button to bring MT-1 into the “Equipment in Pool”. Notice that MT-1 is now associated with the Prepare Solution procedure in the Main Equipment Pool column of the procedures table.



Press the downwards arrow on the left of the "Prepare Solution" procedure to expand its operations. To add the "Charge Water" operation, type its name in the "Enter operation name in procedure Prepare Solution" field. Next click the newly created operation to display the side panel with the operation details. Select the Duration Tab to set the duration to 30min.



Visit the Scheduling tab and notice that this tab already displays the correct start time reference (i.e., the start time of this operation coincides with the batch start).

At this point, we will ignore consumption of materials and labor associated with the execution of operations. Instead we will concentrate on scheduling-related issues, i.e. the duration of operations and the sequencing of their start times. Later, we will see how resource-related information can be entered through the other tabs of the operation properties dialog.

Two values define the timing of operations in SchedulePro Cloud: the start time and the duration. The start-time may be relative to the batch-start or to the start or end of another operation. The duration may be either fixed, calculated based on batch size and processing rate, or, set equal to the duration of another operation or sequence of operations.

Due to the inter-dependent nature of operation scheduling, it is usually easier to first declare all procedures and operations in the recipe and then visit each operation's properties dialog to declare the scheduling details.

In Prepare Solution we need to add five more operations: "Charge Sodium Chloride", "Charge API", "Mix Thoroughly", "Transfer to Storage", and "Clean Tank". The new operations will appear in the list of operations belonging to the edited procedure. Select the second operation ("Charge Sodium Chloride") in Prepare Solution and, as before, visit its properties dialog to enter its duration and start time options. Its duration will be fixed at 15 min and its start time will be set, by default, at the end of the previous operation ("Charge Water"). The default start option is also the desired specification in this case, so there is no need to make any change in the Scheduling tab.

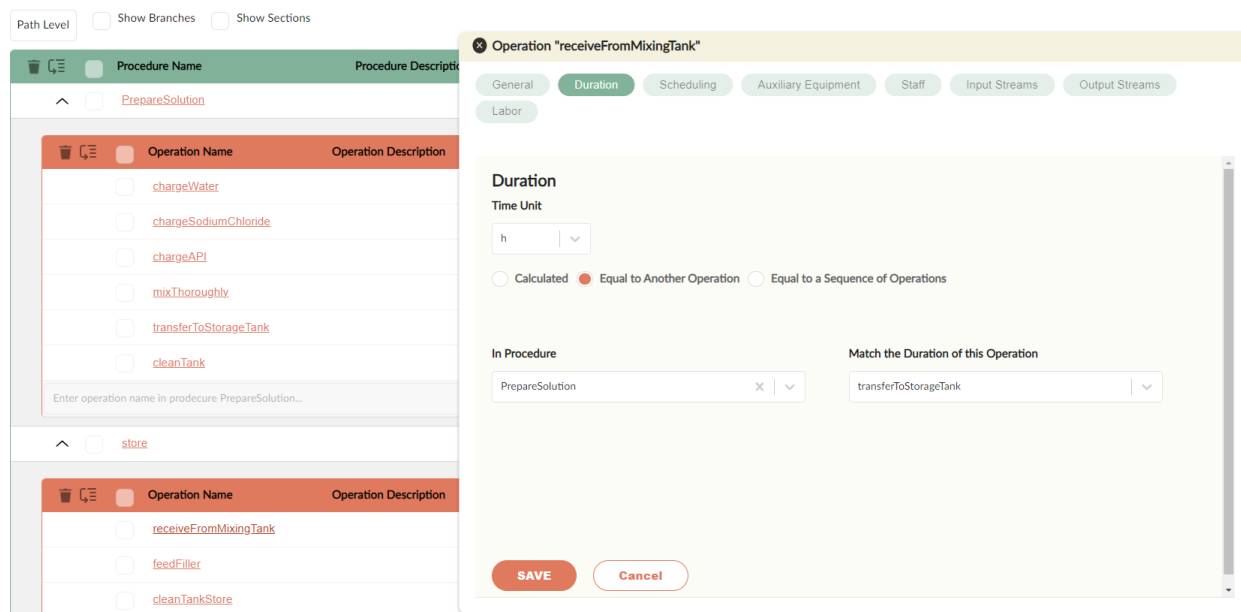
Follow the same steps for generating two more procedures and their operations. At the end, the recipe skeleton should contain the following information:

Procedure	Equipment	Operation (duration)
Prepare Solution	MT-1	Charge Water (30 min) Charge Sodium Chloride (15 min) Charge API (15 min) Mix Thoroughly (60 min) Transfer to Storage (30 min) Clean Tank (90 min)
Store	ST-101	Receive from Mix Tank (set by Transfer to Storage) Feed Filler (set by Fill Bags) Clean Tank (90 min)
Fill	Filler-1	Fill Bags (320 min) Clean Filler (90 min)

For most operations, the duration should be explicitly set to the values shown in the table above. The only exceptions are the "Store/Receive from Mix Tank" and "Store/Feed Filler" operations whose duration needs to be set equal to "Prepare Solution/Transfer to Storage" and "Fill/Fill Bags", respectively.

The figure below explains how this is done through the Duration tab of an operation's dialog. In this case, the duration of "Receive from Mixing Tank" in "Store" is set equal to the duration of "Transfer to Storage" in "Prepare Solution". This is equivalent to a "master-slave relationship": the operation "Receive from Mix Tank" in "Store" becomes a "slave" of the operation "Transfer to Storage" in "Prepare Solution" as far as its duration is concerned.

The duration of an operation can also be "slave" to the duration of a sequence of operations (instead of a single one).



With respect to scheduling of operations, the first operation in every procedure is by default scheduled to start at the batch start and every subsequent operation is scheduled to start at the end of its previous operation in the procedure sequence. The Scheduling tab offers additional options that allow us to relate the start or end of an operation with the start or end of other operations in the same or other procedures.

In our example, the following changes need to be made in the default scheduling:

The "Receive from Mix Tank" operation in "Store" should start at the same time as the "Transfer to Storage" operation in "Prepare Solution" (see figure below). Similarly, the "Fill Bags" operation in "Fill" should start at the beginning of the "Feed Filler" operation in "Store". The "Clean Filler" operation in "Fill" should also be set to begin at the same time as the "Clean Tank" operation in "Store" since these units are always cleaned together.

The screenshot displays the configuration interface for the 'Operation receiveFromMixingTank'. The 'Scheduling' tab is active, showing options to start with a batch or with respect to another operation. The 'Reference Procedure' is set to 'PrepareSolution' and the 'Reference Operation' is 'transferToStorageTank'. The 'Link Relation' is 'Starts with Start of Reference Task'. The 'Time Shift' is set to '+ = delay, - = lead'. The 'Outage Behavior' is 'Consider Outages'. The background shows a list of operations for 'PrepareSolution' and 'store' procedures.

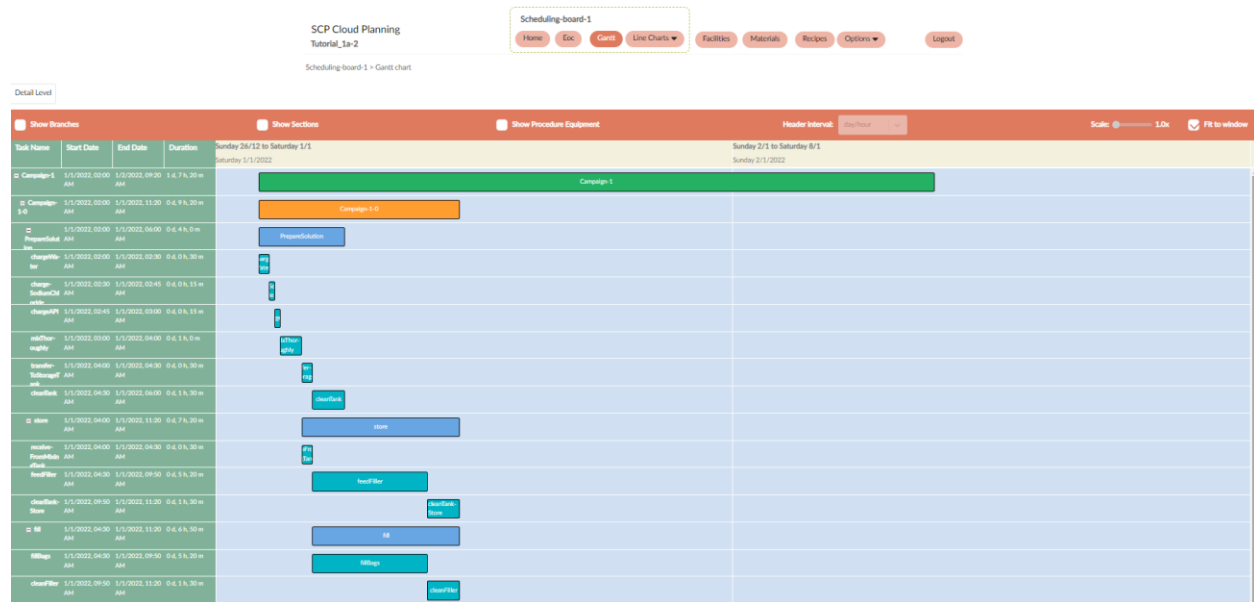
Operations can also claim auxiliary equipment for their execution. Main equipment is assigned to procedures and auxiliary equipment is assigned to operations. For instance, a CIP-skid utilized for vessel cleaning is auxiliary equipment associated with the cleaning operation. Auxiliary equipment is assigned to operations through the Auxiliary Equipment tab.

The figure below shows the assignment of CIP-Skid to “Clean Tank” in “Prepare Solution”. If several CIP skids are assigned to an operation, then, the scheduling algorithm will select the first one that is available (searching from top to bottom). Next, assign the same CIP skid to “Clean Tank” in “Store”. Do not assign a CIP skid to “Clean Filler”. We assume that Filler-1 will be cleaned at the same time as ST-101 utilizing the same skid.

The screenshot displays the configuration interface for the 'Operation cleanTank'. The 'Auxiliary Equipment' tab is active, showing the 'Any Equipment' option selected. The 'Included Equipment' is 'CIP-Skid (Medical Solutions Plant)'. The background shows a list of operations for 'PrepareSolution' and 'store' procedures.

Note that declaring auxiliary equipment and other operation resources is optional. The only mandatory operation information that SchedulePro Cloud needs is the operation duration and start time specification.

Once a recipe has been defined, it can be visualized with a chart that can be brought up by clicking on the “Gantt” menu item on the uppermost part of the page. In this chart a single batch of the recipe is displayed. The figure below corresponds to the “1L-Bag-Recipe” that we created. Note that, in accordance with the above specifications, “Transfer to Storage” in “Prepare Solution” and “Receive from Mix Tank” in “Store” operate in parallel and have the same duration. The same is true for “Feed Filler” in “Store” and “Fill Bags” in “Fill”.



1.3.1.3 Planning and Scheduling Campaigns

After declaring recipes and facilities, we are ready to declare campaigns which represent a series of batches of a given recipe. In SchedulePro Cloud, each scheduled batch represents the realization of a recipe at a given time and with the use of specific equipment and resources. Unless otherwise stated by the user, the only constraint that SchedulePro Cloud takes into account in generating a schedule is the availability of equipment and facilities. To add a new campaign first select the scheduling board’s “Home” menu item and then type the campaign name in the “Enter campaign name...” field.

SCP Cloud Planning
Tutorial_1a-1

Scheduling-board-1

Home Eoc Gantt Line Charts Facilities Materials Recipes Options Logout

Scheduling-board-1 > Campaigns

Name Scheduling-board-1 Start 1/1/2022, 2:00:00 AM Description N/A Edit

Duration 26 weeks

Delete Filter Schedule Reschedule Unschedule

Name	Scheduled	Release Time	Recipe	Number of Batches
Campaign-1		1/1/2022, 2:00:00 AM	1L-Bag-Recipe	4

Enter campaign name...

You can setup the newly added campaign by clicking on its name. In the “General” tab you can set the campaign name, description, associated recipe, release time and the number of batches. The “Amount” tab specifies the campaign’s batch size through the scale factor of directly the batch size. Alternatively, you can change basic campaign information like the release time, the associated recipe and the number of batches by clicking the edit option that appears when hovering over a specific column in the campaigns table.

The screenshot displays the SCP Cloud Planning interface. At the top, there's a header for "Scheduling-board-1" with tabs for "Home", "Eoc", and "Gantt". Below this, a breadcrumb shows "Scheduling-board-1 > Campaigns". A table lists campaigns with columns "Name", "Scheduled", and "Release Time". One campaign, "Campaign-1", is highlighted. To the right, a modal window for "Campaign 'Campaign-1'" is open, showing tabs for "General" and "Amount". The "General" tab is active, displaying sections for "Identification", "Scheduling", and "Others". The "Identification" section shows the campaign name and color. The "Scheduling" section shows release time, recipe, and batch number. The "Others" section includes a checkbox for "Post (Equipment) Changeover".

With the campaign definition complete, you are now ready to generate a production schedule by clicking on the “Schedule” button. The production schedule is displayed by clicking on the “View” link located in the campaign’s table right side. Here the user can define the displayed schedule detail in the “Path Level” dropdown. For example, selecting the “Operation Entry” option displays the scheduling of all operation entries in detail, while selecting the “Batch” option creates a coarser report of the production schedule, where only the schedule information for each batch is visible. On this page, the user can access the duration, start and end of each scheduling entity (batch, procedure, operation), as well as the equipment (main or auxiliary), that processes each processing task (procedure or operation).

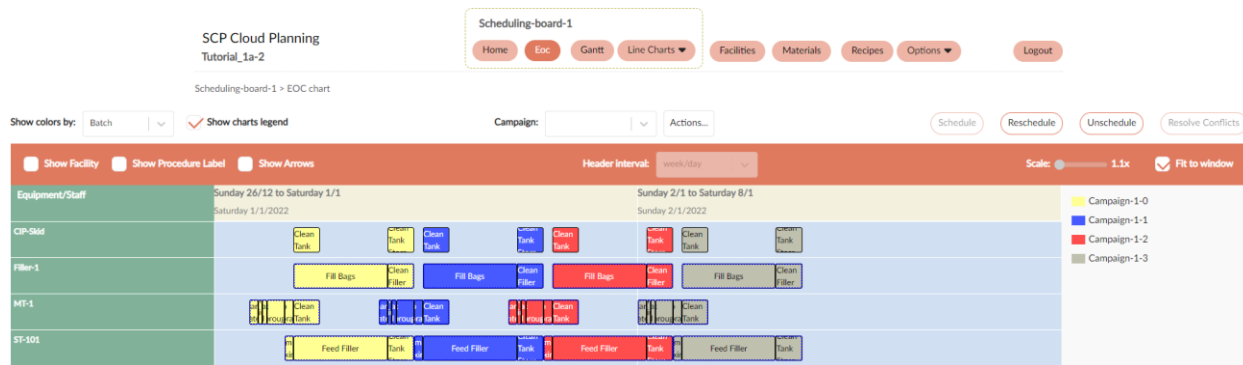
Campaigns > Campaign-1

Path Level

Batch name	Duration	Start	End	
^ Campaign-1-0	9.33 h	1/1/2022, 2:00:00 AM	1/1/2022, 11:20:00 AM	
Procedure entry name	Duration	Start	End	Main equipment
^ PrepareSolution	4.00 h	1/1/2022, 2:00:00 AM	1/1/2022, 6:00:00 AM	MT-1
Operation entry name	Duration	Start	End	Aux equipment
chargeWater	30.00 min	1/1/2022, 2:00:00 AM	1/1/2022, 2:30:00 AM	
chargeSodiumChloride	15.00 min	1/1/2022, 2:30:00 AM	1/1/2022, 2:45:00 AM	
chargeAPI	15.00 min	1/1/2022, 2:45:00 AM	1/1/2022, 3:00:00 AM	
mixThoroughly	60.00 min	1/1/2022, 3:00:00 AM	1/1/2022, 4:00:00 AM	
transferToStorageTank	30.00 min	1/1/2022, 4:00:00 AM	1/1/2022, 4:30:00 AM	
cleanTank	1.50 h	1/1/2022, 4:30:00 AM	1/1/2022, 6:00:00 AM	CIP-Skid
^ store	7.33 h	1/1/2022, 4:00:00 AM	1/1/2022, 11:20:00 AM	ST-101
Operation entry name	Duration	Start	End	Aux equipment
receiveFromMixingTank	30.00 min	1/1/2022, 4:00:00 AM	1/1/2022, 4:30:00 AM	
feedFiller	5.33 h	1/1/2022, 4:30:00 AM	1/1/2022, 9:50:00 AM	

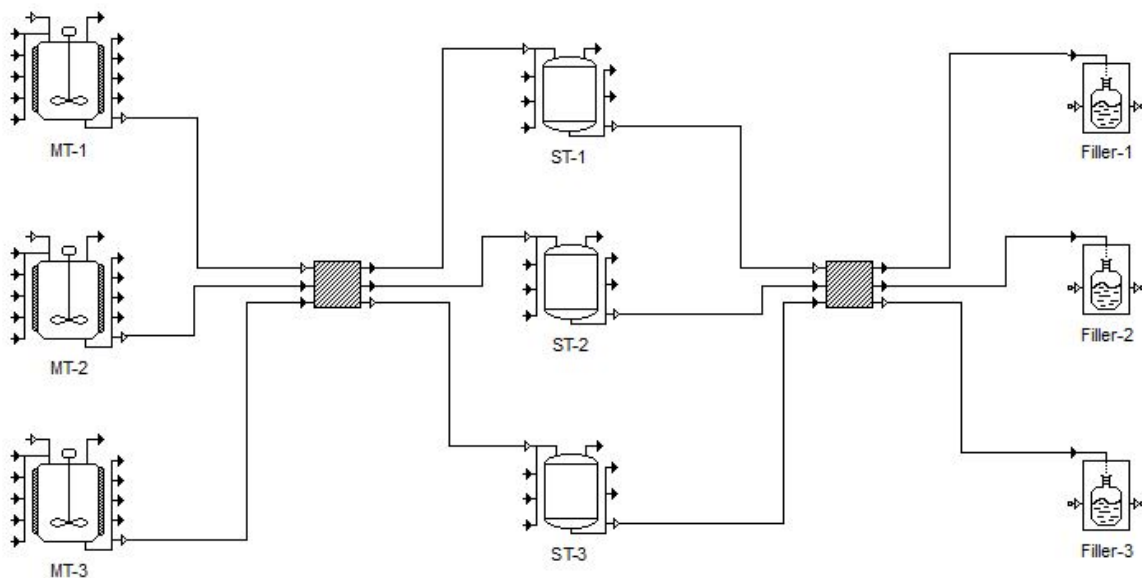
1.3.1.4 Visualizing the Production Schedule

In addition to the scheduled campaign view, the schedule can also be visualized in an Equipment Occupancy Chart (EOC) that can be accessed by clicking on the relevant item found in main menu. To view the full chart, you can click on the “Fit to Window” button. The legend on the right designates batches by distinct colors. This is the default color-coding option. The top line corresponds to CIP-Skid-1. Notice how its use is displayed. The first yellow bar corresponds to the cleaning of the mixing tank (MT-1). The second yellow bar corresponds to the simultaneous cleaning of the storage tank (ST-101) and the filler (Filler-1). The storage tank (ST-101) is the overall bottleneck (has the longest cycle time). However, the utilization of the filler is pretty close to that of the storage tank. The details of the chart can be modified by clicking on the “Show Facility”, “Show Procedure Label” and “Show Arrows” checkboxes. The chart’s time scale can be adjusted by unchecking the “Fit to Window” checkbox and changing the chart’s “Scale”. Alternatively, the user can choose the desired time scale through the “Header Interval” dropdown.



1.3.2 Tutorial-1b: Impact of Equipment Pools

In this version of the tutorial we will investigate the impact of equipment pools on cycle times. This example case is based on the following equipment configuration. Three identical equipment items are available for each procedure as shown in the following sketch:



The extra equipment items can be quickly added through the Equipment view (see figure below) displayed when you select the Equipment link of the facility under study found on the Facilities page. To add a new equipment you simply enter its name in the “Enter equipment name...” field. Then select the newly added equipment to optionally alter other properties (e.g. description or equipment type).

SCP Cloud Planning
Tutorial_1b-2

Scheduling-board-1

Home Eoc Gantt Line Charts ▾ Facilities Materials Recipes Options ▾ Logout

Facilities > Medical Solutions Plant > Equipment

Delete Sort Filter

☐	Name	Type	Description
☐	CIP-Skid	CIP-Skid	
☐	Filler-3	Filler	
☐	Filler-2	Filler	
☐	Filler-1	Filler	
☐	ST-103	Receiver Tank	
☐	ST-102	Receiver Tank	
☐	ST-101	Receiver Tank	
☐	MT-3	Vessel	
☐	MT-2	Vessel	
☐	MT-1	Vessel	

Next, reset the production schedule by clicking the Unschedule button on the campaigns page. This allows you to make modifications to your recipes and subsequently schedule the new (modified) recipes. After your production schedule is reset, make the new equipment items available to the appropriate procedures within your recipe. For instance, select the “Prepare Solution” procedure and navigate to the “Main Equipment Pool” tab to bring up the procedure details shown below. Add MT-2 and MT-3 to the equipment pool utilized by “Prepare Solution” by selecting them in the Included Equipment drop-down. Next, assign ST-102 and ST-103 to store and Filler-2 & Filler-3 to fill.

SCP Cloud Planning
Tutorial_1b-2

Scheduling-board-1

Home Eoc Gantt Procedure "Prepare Solution"

General Main Equipment Pool Scaling

Name 1L Bag Recipe
Size 10000 L

Path Level ☐ Show Branches ☐ Show Sections

☐	Procedure Name	Procedure Description
☐	Prepare Solution	Prepare Solution
☐	Store	Store
☐	Fill	Fill

Enter procedure name in recipe 1L Bag Recipe...

Main Equipment Pool

☒ Any Equipment

☐ Specify Type

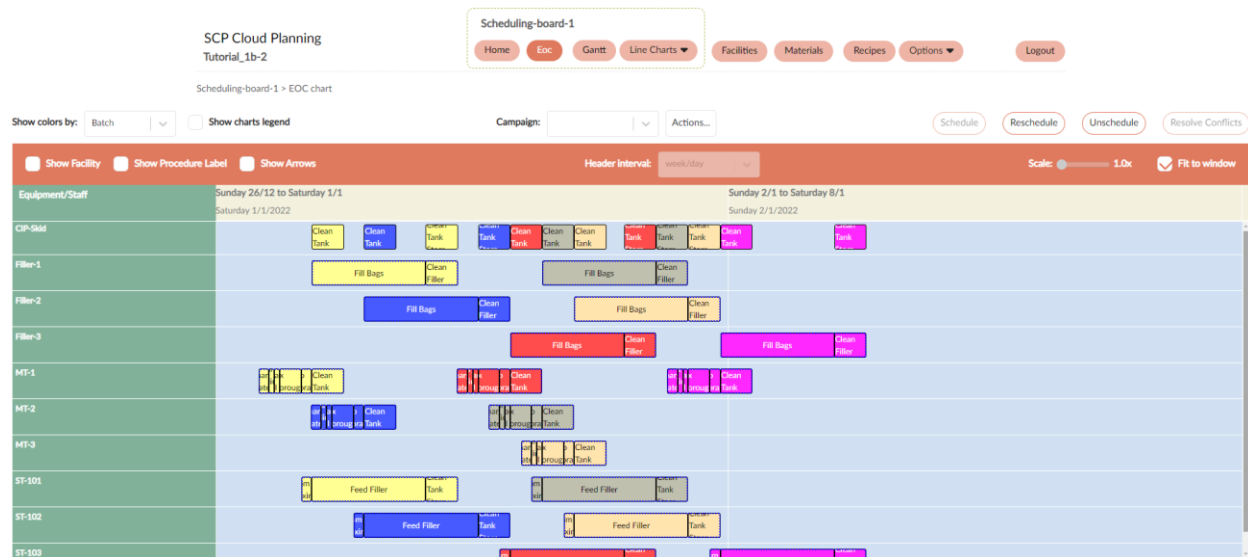
Included Equipment

MT-1 (Medical Solutions Plant) X MT-2 (Medical Solutions Plant) X MT-3 (Medical Solutions Plant) X

SAVE Cancel

Next, plan and schedule a campaign of six batches. To do this, you may edit the original campaign to increase the number of batches to 6. Just navigate to the campaign’s page by clicking the “Home” menu item and hover over the “Number of Batches” column to uncover the “Edit” link. Clicking this allows you to set the desired number of batches for this campaign. Then schedule the campaign using the “Schedule” button, and bring up the Equipment Occupancy chart by clicking the “EOC” menu item. The updated chart is shown below. Notice that batches alternate between the various mix tanks, storage tanks, and fillers.

This reduces the cycle time of the process and increases the plant throughput. However, the added equipment cannot be fully utilized because now the bottleneck is the CIP-Skid.



1.3.3 Tutorial-1c: Scheduling with Flexible Shifts

The performance of the previous case can be improved (i.e., the total time or make-span of the campaign can be reduced) by introducing some flexibility in the scheduling of the cleaning operations that utilize the single CIP skid (which is the current bottleneck).

Scheduling flexibility can be introduced through the “Time Shift” group found in the “Scheduling” tab of an operation (see figure below) by making use of the flexible shift variable. Flexible shifts are maximum permissible delays in the start of an operation’s execution; used properly, they can help reduce idle times of key equipment units and/or eliminate scheduling conflicts.

SCP Cloud Planning
Tutorial_1c-1

Recipes > 1L Bag Recipe

Path Level ☐ Show Branches ☐ Show Sections

Procedure Name **Procedure Description**

Prepare Solution Prepare Solution

Operation Name **Operation Description** **Duration**

☐ Charge Water		30 s
☐ Charge Sodium Chloride		15 s
☐ Charge API		15 s
☐ Mix Thoroughly		1 h
☐ Transfer to Storage Tank		30 s
☐ Clean Tank		90 s

Enter operation name in procedure Prepare Solution...

Store Store

Operation Name **Operation Description** **Duration** **Links**

☐ Receive from Mixing Tank		Equal to Another Operation: Transfer to St...	Transfer to Storage Tank in Prepare Solutio...
---	--	---	--

Scheduling-board-1

Home Eoc Gantt **Operation "Clean Tank"**

General Duration **Scheduling** Auxiliary Equipment Staff Input Streams Output Streams Labor

Scheduling Transfer to Storage Tank in Prepare Solution (Starts with Finish of Reference Task) [Edit](#)

Time Shift (+ = delay, - = lead)

Fixed Time Shift 0 h

Operation can Shift or Break for: ☒ Equipment Availability ☒ Staff Availability ☒ Labor Availability

☒ Use Flexible Shift 8 h

☐ Use Breaks 0 h

☐ Has Minimum Time Between Breaks 0 h

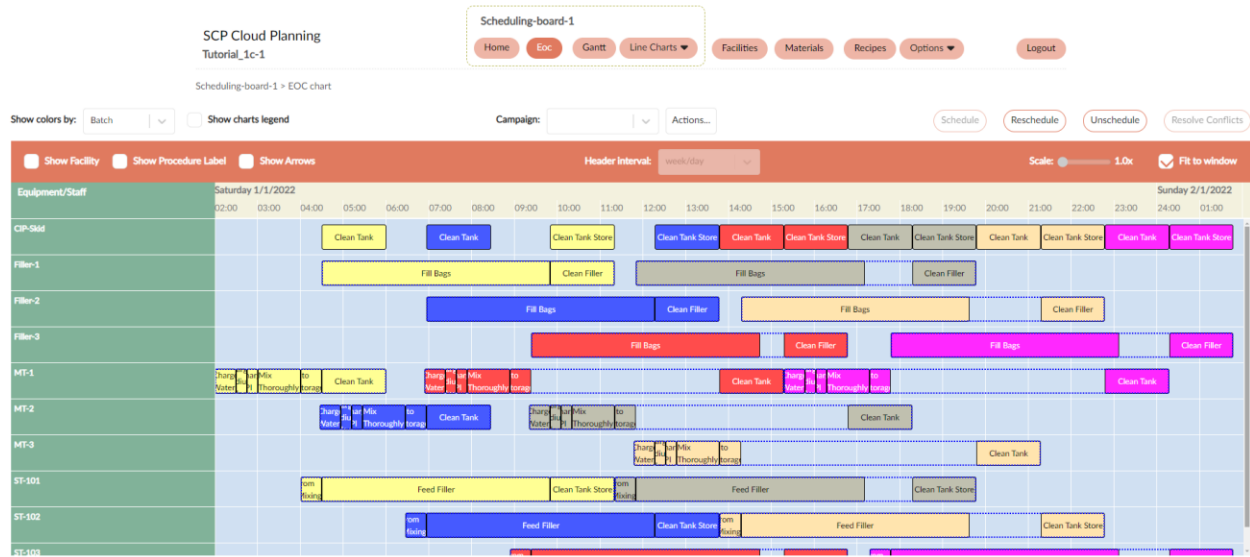
☐ Has Maximum Break Instances 0

SAVE **Cancel**

Outage Behavior Consider Outages [Edit](#)

To bring up the options of "Clean Tank" in "Prepare Solution", select operation "Clean Tank" in the recipe's contents, click the "Scheduling" tab and then on the "Edit" link of the "Time Shift" group. To check the "Use Flexible Shift" box, first you will have to check at least one of the shift or break options. These define the occasions in which an operation can Shift or Break. For this example check the operation can Shift or Break for: Equipment Availability checkbox. Then specify a value of 8 h, and click "SAVE" to save these changes.

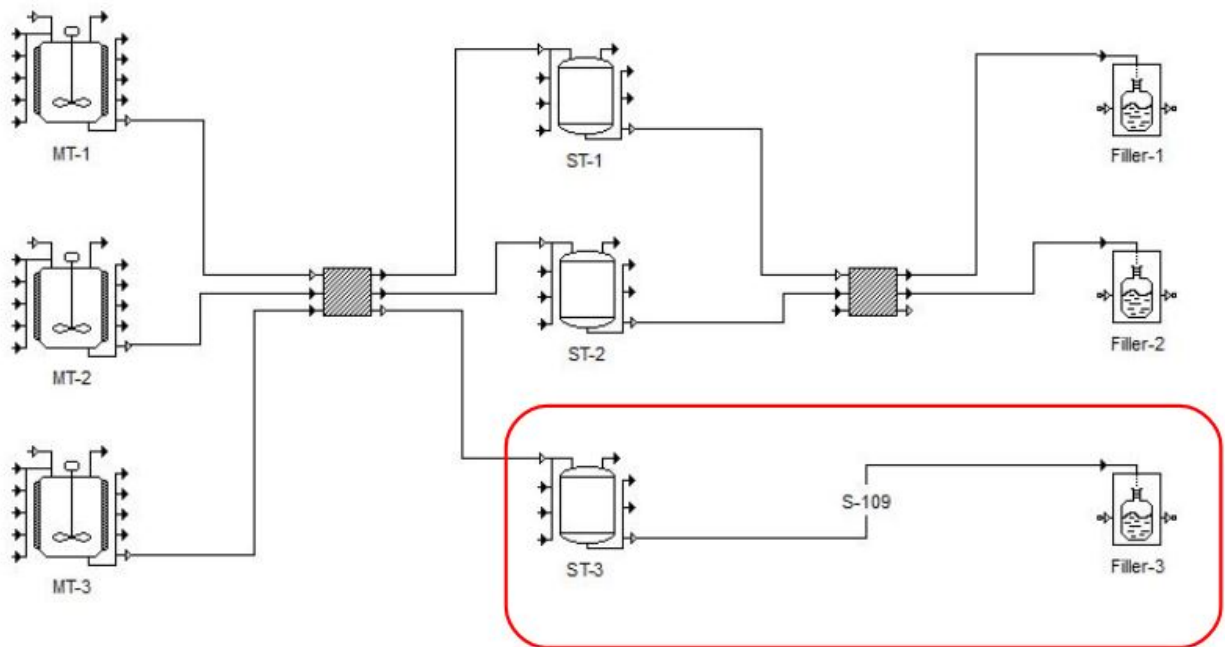
Specify a similar Flexible Shift for "Clean Tank" in "store". There is no need for the specification of flexible shift in "fill", as the cleaning operation of "fill" takes place simultaneously with the cleaning operation in "store" and it is using the same CIP skid item. Next, plan and schedule a campaign of six batches. Then bring up the Equipment Occupancy chart by clicking on the "EOC" button (the chart is shown below).



The use of flexible time shifts in cleaning operations has reduced the idle time between batches as well as the make-span of the entire campaign (total make-span dropped from over 29 hrs in Tutorial case 1b to roughly 24 hrs in this case.)

1.3.4 Tutorial-2a: Multiple Recipes and Equipment Routing

In this version of the tutorial you will learn to generate production schedules that involve multiple recipes, and deal with equipment routing issues. This example case is based on the following equipment configuration. Filler-1 and Filler-2 handle the filling of 1-L bags, whereas Filler-3 handles the filling of 0.5-L bags. The filling rates are different as well; filling the 0.5-L size takes twice as much time for the same overall recipe batch size of 10,000 L. Fillers-1 and Filler-2 are fed by storage tanks ST-101 and ST-102, whereas Filler-3 is fed by tank ST-103 only.



A new recipe is required to represent the manufacturing of 0.5 L bags. The manufacturing of 0.5 L bags is quite similar to the 1 L bags, with the only difference being the resources used in the equipment pools and the duration of the “fill bags” operation. Since the manufacturing of 0.5 L bags is quite similar to the 1 L bags, we can save time by copying and modifying the existing recipe. To do that navigate to the “Recipes” page and click the downwards arrow that appears when hovering over the 1L Bag recipe. Click “Duplicate” to create a new recipe with the same characteristics. Then change the recipe name to “0.5L Bag Recipe.”

Next remove ST-103 and Filler-3 from the 1L recipe and assign ST-103 to the “Store” procedure and Filler-3 to the “Fill” procedure of the 0.5L Bag recipe. Please note that ST-101 and ST-102 must be removed from the “Store” procedure of the 0.5L Bag recipe since only ST-103 is available for storing batches that are filled in 0.5 L bags. Similarly, Filler-1 and Filler-2 must be removed from the “Fill” procedure of the 0.5L-Bag recipe. The duration of the filling operation in the previous versions of the tutorial was specified by the user. The value of that variable, however, can also be calculated based on the batch size and the processing rates of the fillers. To specify the processing rate of Filler-1, select the “Equipment” link on the Facilities page, then select “Filler-1” in the Equipment table (right side of Equipment view), click on the “Size” tab, and finally on the Edit link in the “Processing Rate” group (see figure below). Check the box titled “Enable” to specify a processing rate of 30 entities/min. Specify the same information for Filler-2 and Filler-3.

SCP Cloud Planning
Tutorial_2a-1

Scheduling-board-1

Home Eoc Gantt

Equipment "Filler-1" in facility "Medical Solutions Plant"

General Changeover Size Cost Auxiliary/Main Compatibility Outages

Batch Size Limit No batch size limit [Edit](#)

Processing Rate

☒ Enable

Rate Basis Processing Rate

Entity Flow 30 entities/...

[SAVE](#) [Cancel](#)

Name	Type
☐ CIP-Skid	
☐ Filler-3	
☐ Filler-2	
☐ Filler-1	
☐ ST-103	
☐ ST-102	
☐ ST-101	
☐ MT-3	
☐ MT-2	
☐ MT-1	

Next, visit the "Fill Bags" operation in "Fill" procedure of the 1L-Bag recipe, move to the Duration group in the Duration tab and uncheck the Has Constant Duration box. Then check the "Has Rate Based Duration" box and set the Rate Basis to Entity Flow and the Rate Type to Equipment-dependent. Next you must specify the appropriate amount that is processed. In this case enter 10000 entities since the batch size is 10000L and we use 1L bags. The processing rate is either specified by the user or retrieved from the equipment utilized for this step. In this case you have selected the latter option. This way, if the main equipment pool for filling in "Filler" contains more than one equipment items of different processing rates, the rate will be updated automatically at run-time based on the selected main equipment item.

Repeat the same steps for "Fill Bags" in Filler of "0.5L-Bag-Recipe", but specify 20,000 entities for the amount processed since we use 0.5 L bags to fill the same amount of bulk material (10,000 L).

1 h Charge API in Prepare Solution (Starts ...)

Operation "Fill Bags"

General Duration Scheduling Auxiliary Equipment Staff Input Streams Output Streams Labor

Duration

Time Unit

h

☒ Calculated ☐ Equal to Another Operation ☐ Equal to a Sequence of Operations

☐ Has Constant Duration

1 h ☐ Scales with Batch Size

☒ Has Rate Based Duration

Rate Basis Amount Processed

Entity Flow 10000 entities

Rate Type Rate

Equipment-dependent (if available) 30 entities/...

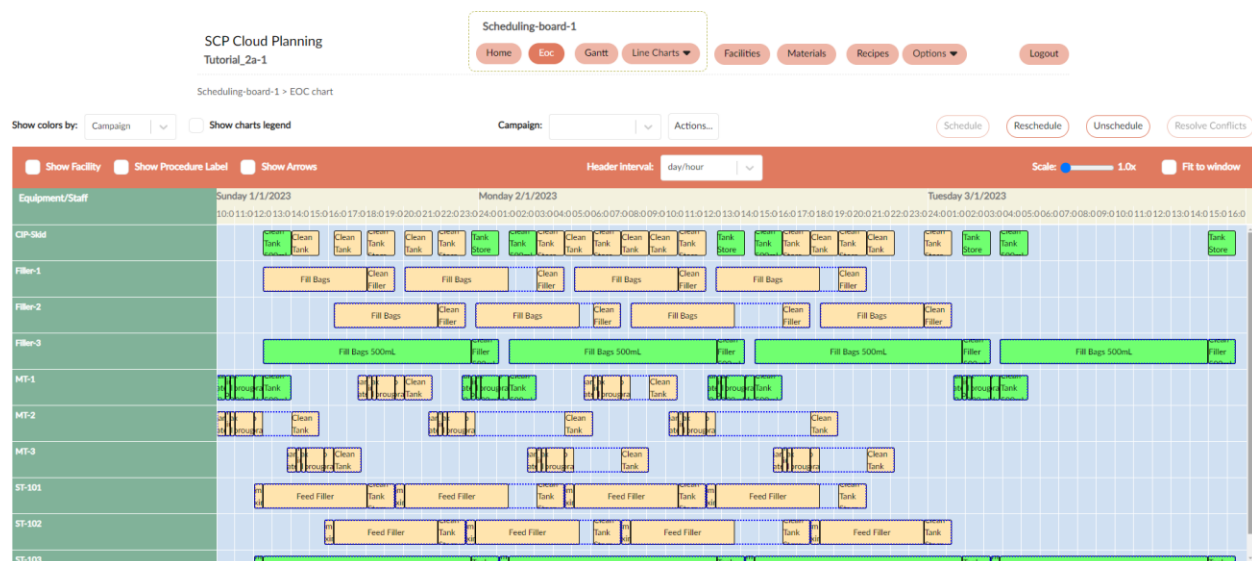
[SAVE](#) [Cancel](#)

Operation Name	Operation Description
☐ Mix Thoroughly	
☐ Transfer to Storage T...	
☐ Clean Tank	
☐ Store	
☐ Receive from Mixing...	
☐ Feed Filler	
☐ Clean Tank Store	
☐ Fill Bags	
☐ Clean Filler	

Please note that one could use a similar approach for calculating the durations of the charge and transfer operations by specifying appropriate amounts and processing (pumping) rates.

Next, plan two campaigns, 4 batches of the 0.5L-Bag recipe followed by 8 batches of the 1L-Bag recipe and schedule. The Equipment Occupancy chart for this case is shown below. The legend on the right designates campaigns by distinct colors. The legend appears by checking the Show charts legend box and the color scheme (show colors by campaign in this case) can be adjusted through the “Show colors by:” dropdown.

Notice how CIP-Skid is the main equipment bottleneck for the 1L-Bag campaign, whereas storage tank ST-3 is the bottleneck for the 0.5L-Bag campaign. Also, notice the wait times (white spaces within procedure bars) that the scheduling algorithm has generated using the flexible shift times of the cleaning operations in order to reduce the make-span of the two campaigns.



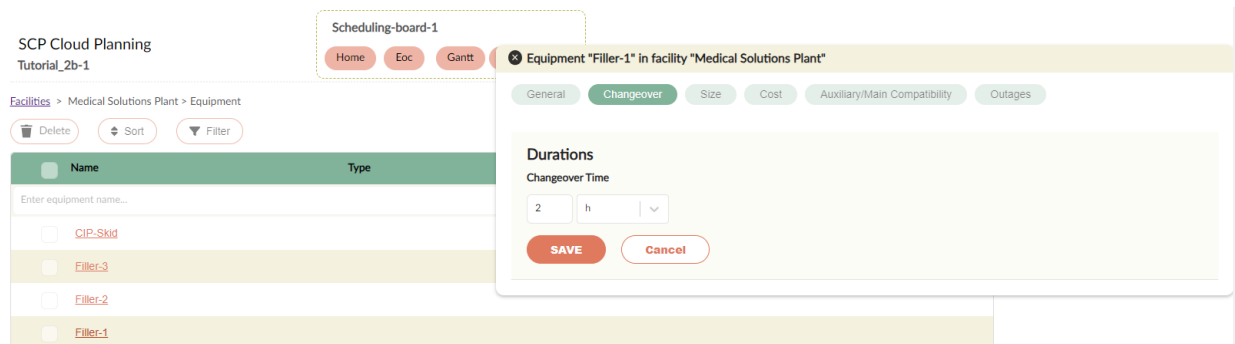
1.3.5 Tutorial-2b: Considering Changeover Times

This tutorial demonstrates handling of equipment changeovers in SchedulePro. Delays due to changeover times are common in multi-product manufacturing facilities and occur particularly often in packaging/filling processing steps. For instance, they may account for the time required to adjust a filling machine for handling a container of a different size. Since we will be modifying our current recipe and then re-scheduling production, be sure to reset the production schedule by clicking the Unschedule button on the campaigns page.

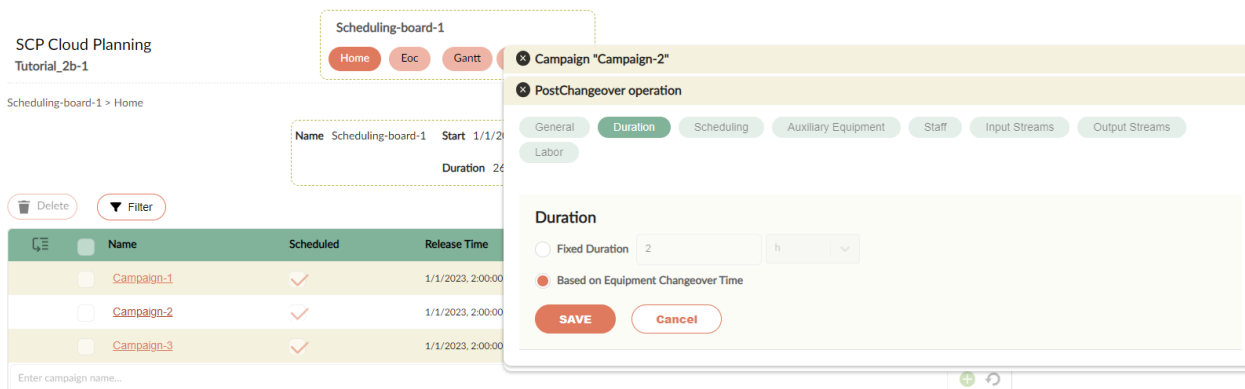
Duplicate the 1L Bag Recipe to create another recipe (called 2L Bag Recipe) to represent manufacturing of 2L bags. The 2L Bag Recipe is like the 1L Bag Recipe with the only difference being the duration of the “Fill” operation. Therefore, you will need to visit the Duration group in the Duration tab (as shown in Tutorial-2a) of the “Fill Bags” operation in the “Fill” procedure of the 2L-Bag recipe to specify that it has a rate based duration with an Equipment-dependent rate type and a batch amount of 5000 entities

(corresponding to 10,000 L filled in 2L bags). We are assuming that the filling time is not a function of bag size.

Changeover times can be specified at the campaign or equipment level. In this case we will make use of equipment-specific changeover times for Filler-1 and Filler-2. To do so, go to the Durations group of the Changeover tab of Filler-1 (see figure below). Here you can set the equipment-specific changeover duration. Repeat the same specification of 2 h changeover for Filler-2. There is no need to specify a changeover time for Filler-3 since it is dedicated to 0.5L bags.



Then you will have to specify that the 1-L-Bag campaign will have a post changeover operation. To do that navigate to the General tab of Campaign-2 (associated with the 1-L-Bag recipe) and check the Post (Equipment) Changeover box. Next click the Edit link to specify the changeover duration in the “Duration” tab. The changeover duration can be fixed or equipment-dependent. If the Fixed Duration option is selected, the same changeover time will be applied to all equipment utilized by that campaign. Instead of using a fixed changeover time, select the Based on Equipment Changeover option. With the above specifications, an equipment-dependent changeover time will be applied to all equipment as soon as they are done executing the last task related to this campaign.



Finally, in the Scheduling tab ensure that the “Last Equipment Use” option is enabled. Enabling this option inserts a postprocessing operation after the campaign’s operation that uses last each equipment. Choosing the alternative option (“End of Last Batch”) would insert a postprocessing operation at the same time (completion of campaign’s last batch) for all equipment.

×

Campaign "Campaign-2"

×

PostChangeover operation

General

Duration

Scheduling

Auxiliary Equipment

Staff

Input Streams

Output Streams

Labor

Scheduling

☐ End of Last Batch

☒ Last Equipment Use

SAVE

Cancel

Time Shift (+ = delay, - = lead)

Edit

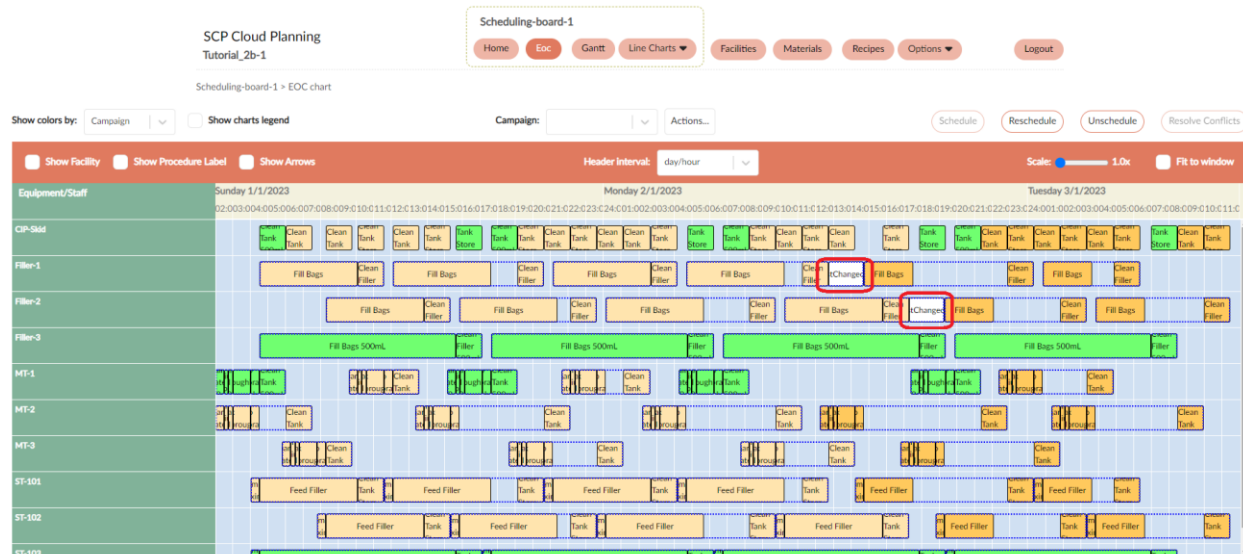
Outage Behavior

Consider Outages

Edit

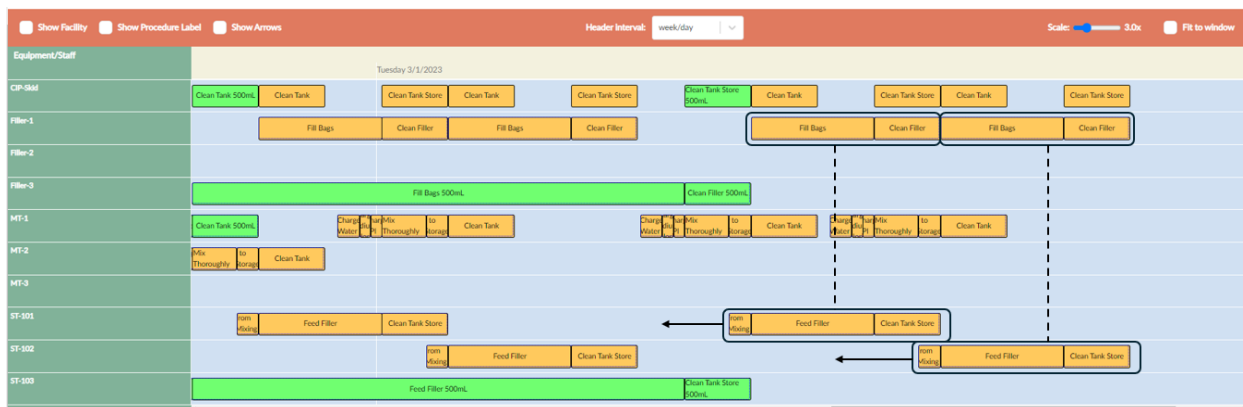
Next, unschedule the campaigns by clicking the “Unschedule” button on the campaigns page. Plan and schedule a campaign of 4 batches of the 0.5L-Bag recipe, followed by a campaign of 8 batches of the 1L-Bag recipe, followed by a campaign of 4 batches of the 2L-Bag recipe. Changeover times should be applied to the second campaign (8 batches of the 1L-Bag recipe) because at the end of that campaign Filler-1 and Filler-2 must be adjusted to handle 2L bags. There is no need to apply changeover times to the first campaign because Filler-3 is dedicated to 0.5L bags.

The results of the production schedule are shown below. The changeover times for Filler-1 and Filler-2 at the end of the second campaign are represented by the white bars (circled in red for emphasis). Note that only Filler-1 and Filler-2 have changeover bars, because the nominal changeover duration for all other equipment is zero.

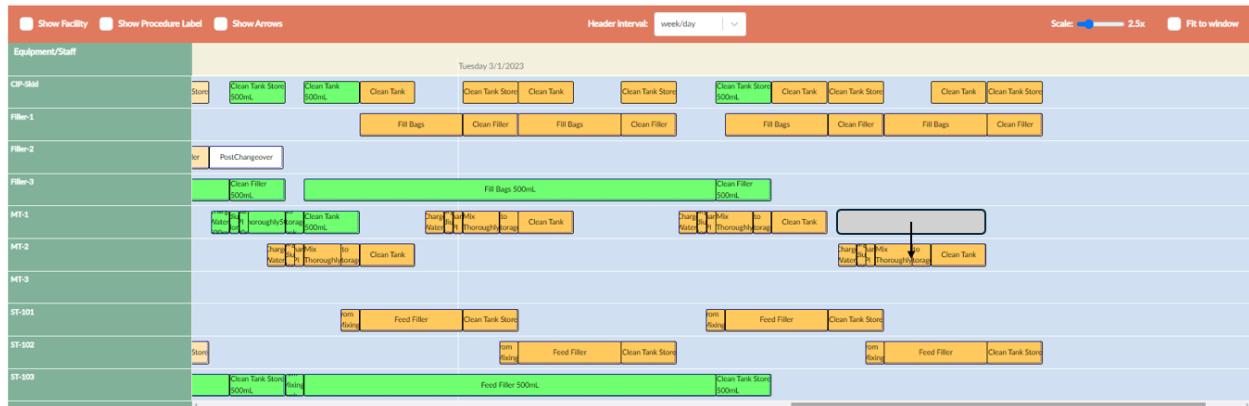


1.3.6 Tutorial-3: Schedule Adjustments

The following Equipment Occupancy chart corresponds to the case of Tutorial-2b but without Flexible Shift times in the 2L-Bag recipe. Under these conditions, the scheduling algorithm delays the start of the second batch of the 2L-Bag recipe to avoid conflicts with the use of the single CIP skid and that leads to an increased make-span of the campaign. SchedulePro Cloud provides drag & drop functionality on the Equipment Occupancy charts. Procedures can be dragged and dropped to facilitate manual schedule adjustments. In this case the user can drag the “Store” procedures of the two last batches of the 2L-Bag campaign to the left. Notice how any slave procedures (“Fill” in this case) follows the user’s adjustment.



Drag and drop actions can also adjust the equipment utilization. For example you can drag the last “Store” procedure from MT-1 to MT-2, as seen in the following EOC. Notice that drag and drop actions to an equipment that is not in a procedure’s main equipment pool are not allowed.



In manufacturing environments the execution of certain operations may be delayed due to equipment failures and other unexpected events. Such delays may lead to scheduling conflicts with future activities. SchedulePro Cloud allows you to modify scheduled activities to represent process delays and other deviations from the original production schedule. For any scheduled operation but especially for those that have started and are in-progress, it makes sense to be able to change its duration or end time if its actual execution diverted from planning. To view this feature, let's pick operation "Feed Filler" of the third batch of the 0.5L-Bag campaign executed in ST-103. Right click on the bar corresponding to this operation and select "Operation->Properties...". The side panel that pops up consists of four tabs, where the user can adjust the operation's timing, resources (auxilliary equipment, staff, labor, streams) and breaks. Going to the "Schedule" tab, the user can adjust the operation's start time, end time or duration. This information can be changed to represent scheduling diversions. To practice that, change the duration of this operation to 16 hrs (to represent a process delay) and click SAVE.

×
Scheduled Operation "Feed Filler 500mL"

Schedule

Reusables

Consumables

Breaks

Timing

Start

01/02/2023 06:43 AM

Now

End

Set Time

01/02/2023 10:43 PM

Now

Set Duration

16

h

▼

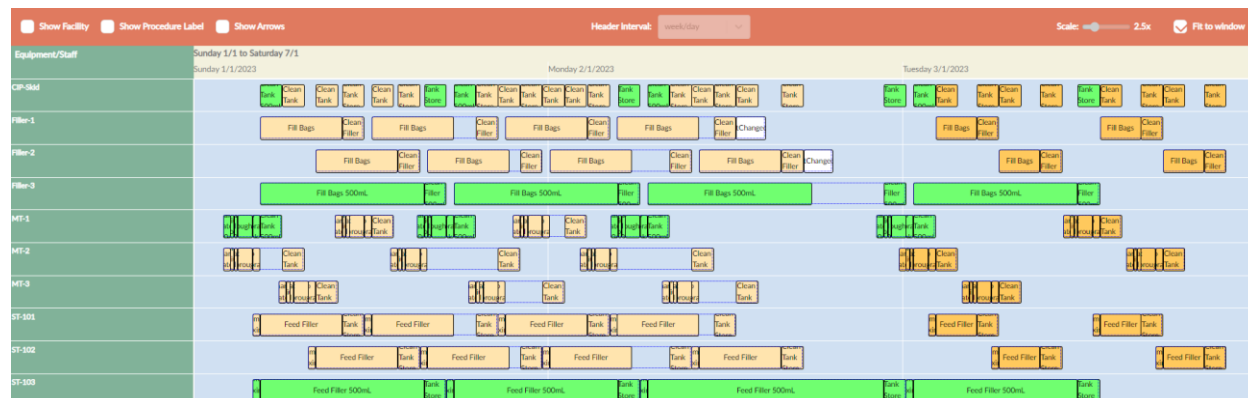
SAVE

Cancel

The delay in that operation obviously creates conflicts with future operations that were planned based on the nominal duration of that operation. As indicated above, SchedulePro Cloud will display the conflicts but will not automatically attempt to resolve them. You can either try to manually resolve the conflicts using the drag and drop functionality or you can engage SchedulePro Cloud to do that. To do the latter you

27

must click the Resolve Conflicts button on the chart toolbar. Note that when there is a conflict between two batches, it is in the latter in hierarchy (and, in time) batch that the conflict is assigned to.



1.3.7 Tutorial-4a: Resource Tracking

SchedulePro Cloud keeps track of the demand for materials (consumption and generation) and labor. Materials whose consumption (or generation) is to be tracked by SchedulePro Cloud must first be registered. In our example, we will need to declare the following materials with their corresponding types:

Material	Type
WFI	Pure component
Sodium Chloride	Pure component
API-A	Pure component
1L-Bag	Discrete
2L-Bag	Discrete
0.5L-Bag	Discrete

To enter the first material, select the “Materials” item in the main menu and type the material name (WFI in this case) in the “Enter material name...” field. Then click the newly added material and go to the Type group in the General tab to specify the material type (Basis: Volume, Unit: L, Density 1 g/cm³). Repeat the above process for “Sodium Chloride”, “API-A”, “1L-Bag”, “2L-Bag”, and “0.5L-Bag”. Please note that the bags must be specified as discrete materials (Basis: Entity). If a material is specified as a Stock Mixture (e.g., 10% w/w Sodium Chloride solution in WFI), you must also specify its composition (by clicking the Composition group) so that SchedulePro Cloud can track the demand of its constituents.

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Tutorial_4a-1

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Materials

Delete Sort Filter

Name	Type	Trade Name
1L-Bag	Discrete Entity	
API-A	Pure Component	
Sodium Chloride	Pure Component	
WFI	Pure Component	

Material "WFI"

General Economics

Identification Name: WFI Edit

Type

Basis
Volume

Unit
L

Density
1 g/cm3

SAVE Cancel

Composition Pure Component Edit

Raw material consumption is linked to recipes via input streams. Input streams are specified at the Operation level. Now select the "Charge Water" operation in "Prepare Solution" procedure of the 1L-Bag recipe, and go to the "Input Streams" tab. Here enter the name of the input stream (Input stream charge water) and click to edit the "Usage Information" group. In this group the user can specify the stream resource (material WFI) and amount (10,000L). These specifications simply mean that a batch of this recipe requires 10,000 L of WFI to be supplied during the "Charge Water" operation of "Prepare Solution". Instead of specifying an amount, one could specify the flowrate by which the material is consumed. In this case, the total amount used by the operation will be calculated by the product of the flowrate and the operation duration. In either case (specify Amount or specify Flowrate) the corresponding quantity can be declared as scaleable with the batch size using the relevant flag in the dialog. Also note that since the amount in this case has been defined in volumetric terms, the stream density in the bottom of the dialog should be specified so that SchedulePro Cloud can convert volume to mass (if needed).

SCP Cloud Planning
Tutorial_4a-1

Scheduling-board-1
Home Eoc Gantt

Recipes > 1L Bag Recipe

Path Level Show Branches Show Sections

Procedure Name Procedure Description

Prepare Solution Prepare Solution

Operation Name Operation Description Duration

Charge Water 30 s

Charge Sodium Chloride 15 s

Charge API 15 s

Mix Thoroughly 1 h

Transfer to Storage Tank 30 s

Clean Tank 90 s

Enter operation name in procedure Prepare Solution...

Operation "Charge Water"

Input Stream "Input Stream Charge Water"

Identification Name: Input Stream Charge Water

Usage Information

Resource

Material WFI (Bulk) X Storage Unit Select Storage Unit to be added...

Basis

Volume (Bulk)

Amount 10000 L

Flow Rate 0 m3/s

Scale Factor 1

Scale with Batch Size

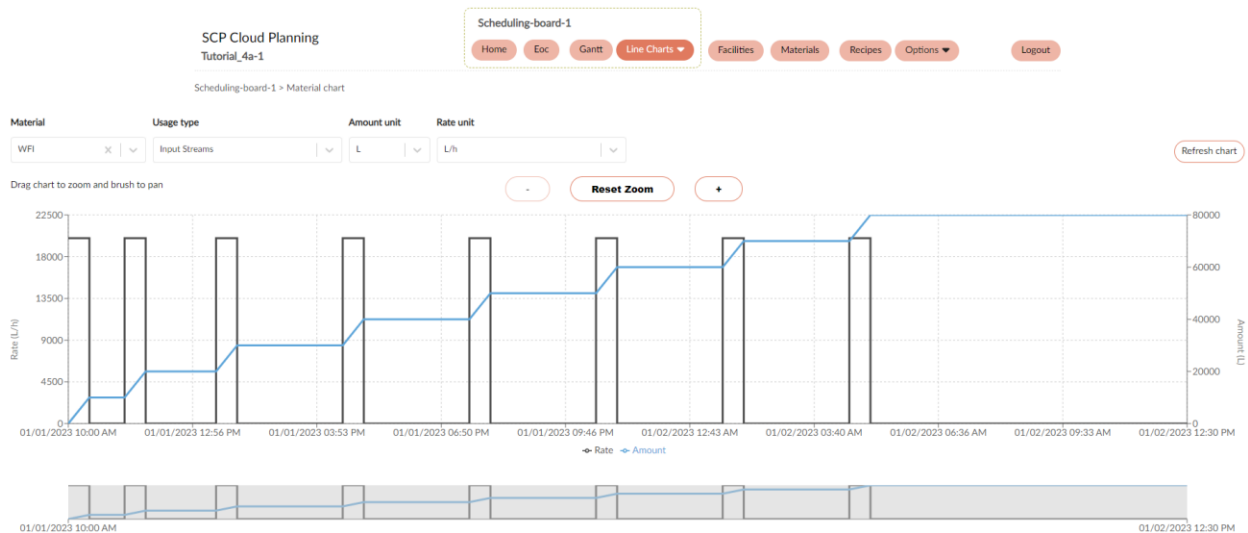
SAVE Cancel

Next associate input streams with the “Charge Sodium Chloride” and “Charge API” operations to represent supply of 90 kg of Sodium Chloride and 1 kg of API-A per batch, respectively. If you also wish to track the generation of 1L-Bags, you may associate an output stream with the “Fill Bags” operation of “Fill” (1L-Bag recipe) and specify a production of 10,000 entities (i.e., bags) per batch. The type of this stream must be “Discrete” because it represents flow of discrete entities (1L bags).

Please note that SchedulePro Cloud does not attempt to close material balances, it simply keeps track of input and output flows without balancing them.

Now schedule a campaign with 8 batches of the 1L-bag recipe.

SchedulePro Cloud generates graphs that display the consumption of materials (raw) and the generation of intermediate or final products and wastes. To visualize the profile of a material resource, select the “Material Chart” from the “Line Charts” dropdown found in the main menu. Then specify the material whose consumption/generation you wish to visualize (WFI) and the usage type (input, output or all streams). Finally, you can specify the amount and rate unit used in the material chart.



The following graph shows the raw material profile for WFI. The black line denotes instantaneous demand in volume flow units (Rate in L/h). The blue line (that corresponds to the y-axis on the right side) denotes cumulative demand in volume units (Amount in L) over the entire period. Using the + and – buttons you can zoom in and out in the graph respectively, and Reset to the default zoom by pressing the respective button. Finally, you can move in the x-axis by using the scrollbar under the chart (grey part denotes current time frame).

Labor resources can also be declared at the facility level and used by recipes. To insert a new labor type, select the “Labor” link in the “Facilities” menu item and type the name in the “Enter labor name...” field. Click the added labor type and then go to the “General” tab and more specifically the “Base Availability” group, and finally check the “Has Unlimited Persons” box. Checking this option means that the Labor resource is not constrained.

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Facilities > Medical Solutions Plant > Labor

Delete Sort Filter

Name	Description
Labor1	

Enter labor name...

Identification Name: Labor1 [Edit](#)

Base Availability

✓ Has Unlimited Persons

Number of Persons 5

SAVE Cancel

Cost Base Hourly Rate: 0 [Edit](#)

Demand for labor in an operation is specified through the operation's "Labor" tab. You should enter the labor resource name in the relevant field and then click to edit its information in the "Usage Information" group. More specifically, you can specify the labor type being used and either the rate or the amount of labor used. For example, if a rate of 2 persons is defined then this operation requires the constant presence of 2 persons and the total amount of required person hours depends on the operation's duration. In this example, define a rate of 1 person for all operations.

SCP Cloud Planning
Tutorial_4a-1

Scheduling-board-1

Home Eoc Gantt

Recipes > 1L Bag Recipe

Name 1L Bag Recipe
Size 10000 L

Path Level Show Branches Show Sections

Procedure Name	Procedure Description
Prepare Solution	Prepare Solution

Operation Name	Operation Description	Duration
Charge Water		30 min
Charge Sodium Chloride		15 min
Charge API		15 min
Mix Thoroughly		1 h
Transfer to Storage Tank	Mix Thoroughly in Prepare Solution (Starts...	30 min
Clean Tank	Transfer to Storage Tank in Prepare Solution...	90 min

Enter operation name in procedure Prepare Solution...

Store ST-101 in Medical Solutions Plant, ST-102 in Medical Solutions Pla...

Fill Filler-1 in Medical Solutions Plant, Filler-2 in Medical Solutions Pla...

Enter procedure name in recipe 1L Bag Recipe...

Operation "Charge Water"

Labor "Charge Water"

Identification Name: Charge Water

Usage Information

Labor Labor1

Usage

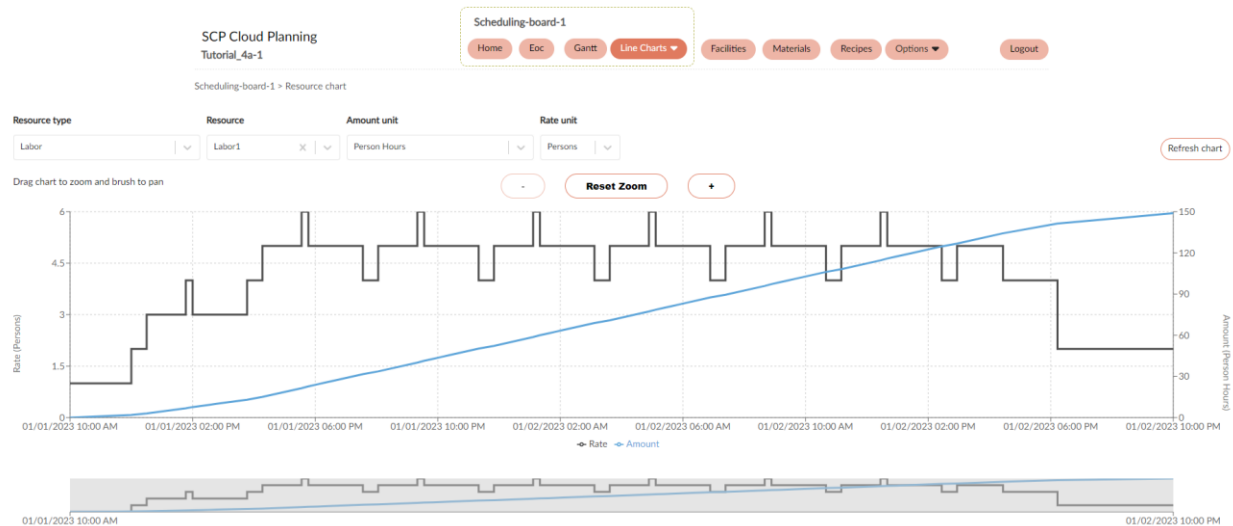
Rate 1 Persons

Amount 0 Person Hours

Scales with Batch Size

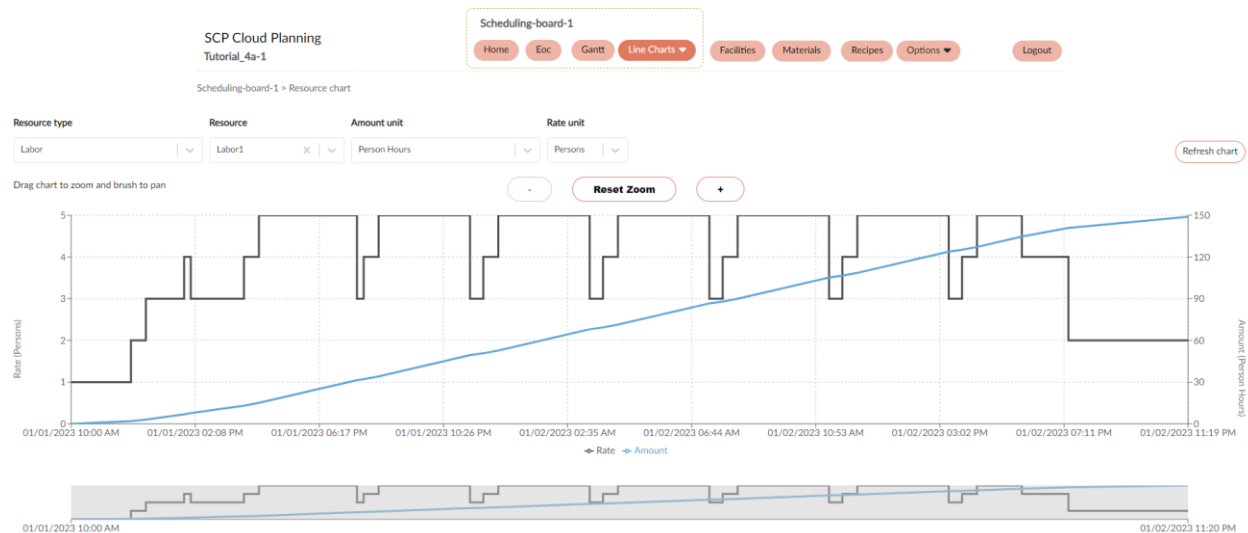
SAVE Cancel

After completing the labor specifications as shown above, reschedule the 8-batch 1L bag campaign. The figure below displays the labor demand chart for this case. The black line represents the instantaneous demand expressed in persons. The blue line represents the cumulative amount required.



Now let us assume that the labor type has an availability limit of 5 persons. Based on this constraint, the previous schedule is infeasible since for short periods of time the demand exceeds the availability limit. To enforce this constraint go to the “Base Availability” group, uncheck the “Has Unlimited Persons” box and enter “5” in the Number of Persons box to denote that the facility has a limit of 5 operators. This is the base availability of this labor resource in the corresponding facility. Deviations from the base availability (e.g., 5 operators during the morning and afternoon shifts but only 2 operators during the night shift) can be specified through the Outages tab.

After these changes reschedule the campaign pressing the “Reschedule” button. You will notice that in order to accommodate the aforementioned limitation, the execution of some operations must be delayed so that the demand never exceeds the limit. After rescheduling the 1L-Bag Recipe, view the Labor chart again (see below). Notice that the labor violations are eliminated, but the makespan of the entire campaign increases from 36 hours to almost 38 hours.



1.3.8 Tutorial-4b: Inventory Tracking

SchedulePro Cloud keeps track of inventories of input, output, and intermediate materials in storage units. Storage units can supply input streams, or receive material from output streams. They can also function as intermediate containers that both receive and supply materials. A storage unit can be added to a facility by selecting the “Storage” link under “Facilities” and entering the storage unit name (e.g., “Aqueous Storage Tank”). Click the storage unit name and then go to the “Type” group in the “General” tab to classify its type as “Receiving Unit”.

SCP Cloud Planning
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Scheduling-board-1

Home Eoc Gantt

Storage Unit "Aqueous Storage Tank" in facility "Medical Solutions Plant"

General Supply / Reception Limits Info Receipts / Discharges

Identification Name: Aqueous Storage Tank, Basis: Mass Edit

Type

☐ Supply Unit ☒ Receiving Unit ☐ Intermediate Unit

SAVE Cancel

Material No materials Edit

Now, switch to the “Info” tab. Check the “Track Inventory” box and specify its capacity to 20,000 kg as shown below. The material that accumulates in output storage units such as waste tanks must be discharged from time-to-time.

×
Storage Unit "Aqueous Storage Tank" in facility "Medical Solutions Plant"

General
Supply / Reception Limits
Info
Receipts / Discharges

Others

☒ Track Inventory

Capacity Info

Capacity: 20000 kg.
Edit

Inventory Limits

Edit

Receipt / Discharge Data

☒ Continuous Receipt / Discharge
☐ Periodic Receipts / Discharges

Discharge Rate
20000
kg/h

On Level
80
(%)

Off Level
0
(%)

For continuous discharge, set both the On and Off level to 100%

SAVE

Cancel

2. Alternatively, if you select the Periodic Receipts/Discharges option, you can specify removal of certain amounts on specific dates and times in the Receipts/Discharges tab.

To calculate inventories in storage units, SchedulePro Cloud requires a link between the output streams of operations and their relevant storage units. This link must be specified in the “Output Streams” tab of an operation. The figure below, for instance, shows a stream generated during the cleaning of a mixing tank in the 1L-Bag recipe. It is necessary to name the stream, specify the amount, the basis and the amount (or flow rate or scale factor), and the resource which in that case is a Storage Unit. Therefore, you have to enable the “Storage Unit” flag, and select the “Aqueous Storage Tank” from the list to indicate that this stream is deposited to the new storage unit.

SCP Cloud Planning
Tutorial_4b-1

Recipes > 1L Bag Recipe

Path Level ☐ Show Branches ☐ Show Sections

Procedure Name	Procedure Description
Prepare Solution	Prepare Solution

Operation Name	Operation Description	Duration
Charge Water		30 s
Charge Sodium Chloride		15 s
Charge API		15 s
Mix Thoroughly		1 h
Transfer to Storage Tank		30 s
Clean Tank		90 s

Enter operation name in procedure Prepare Solution...

Store

ST-101 in Medical Solutions Plant, ST-102 in Medical Solutions Pla...

Scheduling-board-1

Home Eoc Gantt **Operation "Clean Tank"**

Output Stream "Stream Wf Rinse"

Identification Name: Stream Wf Rinse

Usage Information

Resource

☐ Material WFI (Bulk) ☒ Storage Unit Aqueous Storage Tank (Bul... x v

Basis

Mass (Bulk) v

☒ Amount 2000 kg v

☐ Flow Rate 0 kg/s v

☐ Scale Factor 1

☒ Scale with Batch Size

SAVE Cancel

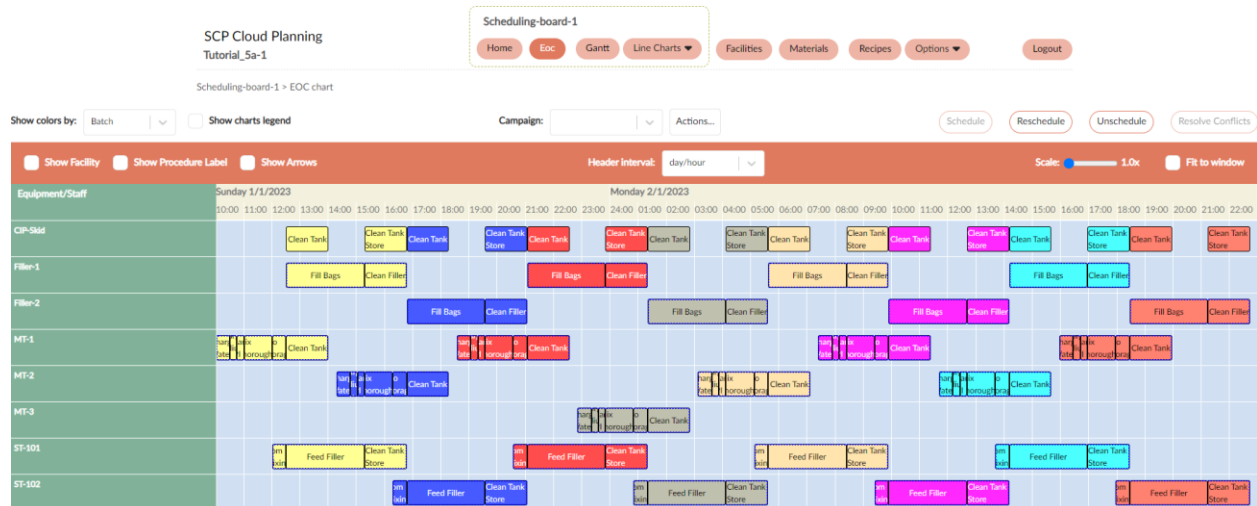
To update your model so that it incorporates tracking of aqueous cleaning waste, define output streams for the cleaning operations in procedures “Prepare Solution” and “Store” of the 1L-Bag recipe based on the specifications in the dialog above. Next, reschedule the 8 batch campaign for the 1L-Bag recipe. You may then view the inventory profile of the storage tank by selecting the “Inventory Chart” from the “Line Charts” dropdown in the main menu. Then select the Aqueous Storage Tank and the desired Amount unit and Rate unit and refresh the chart. The inventory chart for this case is shown below.



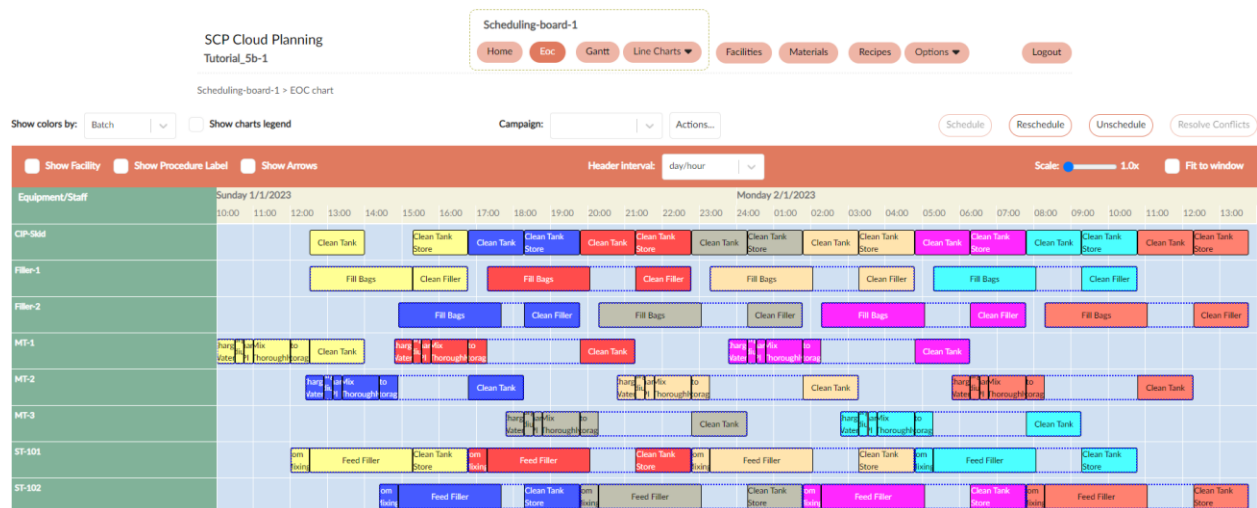
The black line denotes the receiving rate (left-side x-axis), while the orange line depicts the accumulative inventory level (amount in the ride-side x-axis). Note than when the inventory level reaches 80% of the total capacity a discharge of rate 20000kg/h takes place (blue line).

1.3.9 Tutorial-5: Debottlenecking Production Lines

The figure below displays the Equipment Occupancy chart for a campaign of 8 batches of the 2L-Bag recipe without Flexible Shift times in the cleaning operations (this corresponds to Tutorial-5a). Each of the batches was assigned a different color by SchedulePro Cloud.



The figure below corresponds to the same 8 batches of the 2L-Bag recipe but with flexible shift times in the cleaning operations (Tutorial-5b).



The use of flexible shift times reduces the makespan of the campaign. To further reduce the makespan and increase the number of batches that can be processed within a certain period of time, we must eliminate the current bottleneck, which is the single CIP skid (CIP-Skid-1). The bottleneck can be eliminated by installing another CIP skid. To add a new CIP skid, type the new equipment name in the equipments table (Facilities tab -> Equipment link). The equipment view should look as follows.

Facilities > Medical Solutions Plant > Equipment

Delete

Sort

Filter

☐	Name	Type	Description
	Enter equipment name...		
☐	CIP-Skid-2	CIP-Skid	
☐	CIP-Skid	CIP-Skid	
☐	Filler-2	Filler	
☐	Filler-1	Filler	
☐	ST-102	Receiver Tank	
☐	ST-101	Receiver Tank	
☐	MT-3	Vessel	
☐	MT-2	Vessel	
☐	MT-1	Vessel	

Next, CIP-Skid-2 should be made available to the cleaning operations in procedures “Prepare Solution” and “Store” of the 2L-Bag recipe through the Auxiliary Equipment tab (see figure below).

Operation "Clean Tank"

General

Duration

Scheduling

Auxiliary Equipment

Staff

Input Streams

Output Streams

Labor

Auxiliary Equipment

☒ Any Equipment

☐ Use all

☐ Specify Type

Select Type...

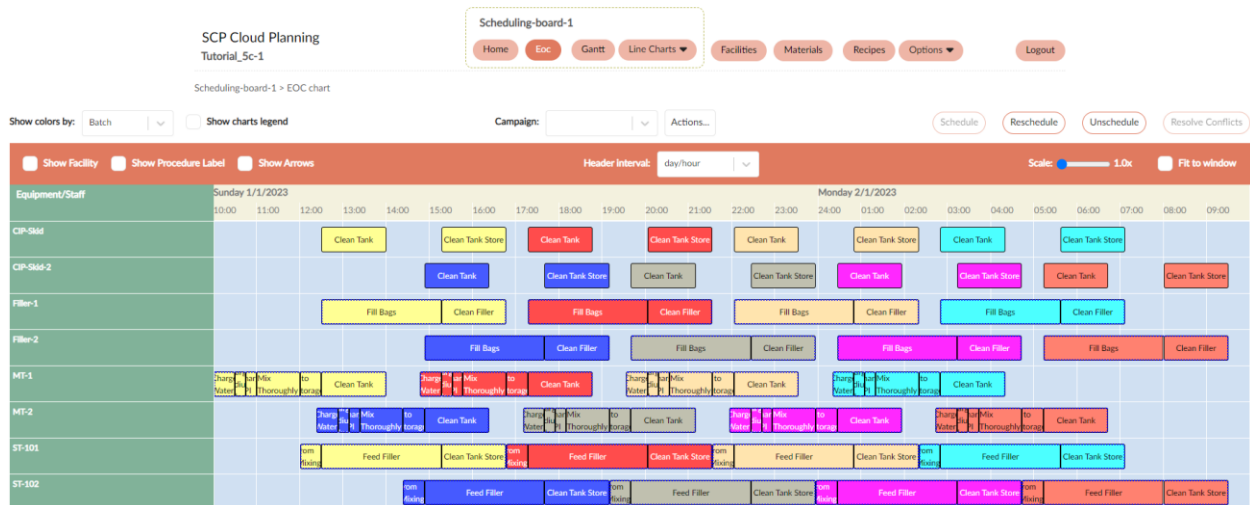
Included Equipment

CIP-Skid (Medical Solutions Plant) X CIP-Skid-2 (Medical Solutions Plant) X

SAVE

Cancel

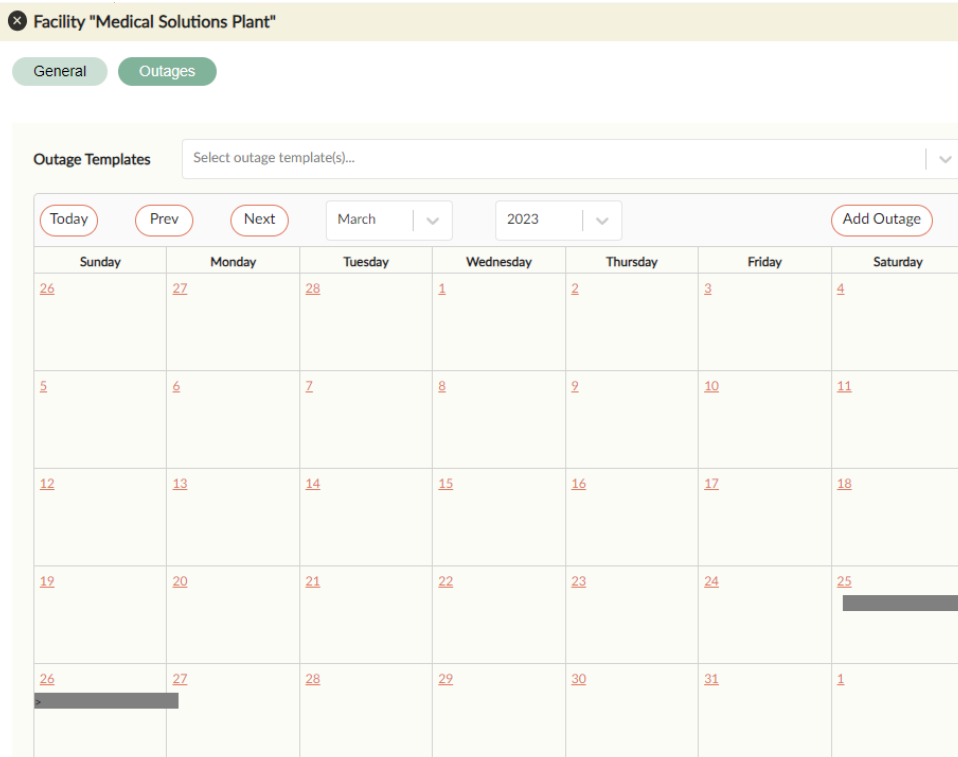
Now reset the current production schedule by clicking the “Reschedule” button in the campaigns table. The figure below displays the Equipment Occupancy chart for the new production plan (which corresponds to Tutorial-5c). The use of the second skid removes the bottleneck and reduces the campaign makespan by approximately 4 hours so that the campaign now finishes on January 2nd at 9:30 AM.



Using SchedulePro one can readily perform this type of analysis for multi-product facilities. Bottlenecks imposed by resource constraints can be evaluated as well.

1.3.10 Tutorial-6a: Scheduling with Facility Downtimes

This case demonstrates the use of SchedulePro Cloud’s calendar capabilities for representing downtime of facilities. You can specify facility downtimes (outages) by selecting the facility of interest (“Medical Solutions Plant” in this case) and navigate to the “Outages” tab. Here the facility outages are shown in a calendar view (Outage calendar). Any existing outages are denoted by a grey line (see figure below).



Click the “Add Outage” button to add a new facility outage. In this tutorial example, we set weekend breaks starting at midnight on Fridays and completing at midnight on Sundays (48 h downtime). After setting this downtime and saving the Calendar Entry, you will see the downtimes displayed graphically on the calendar window by grey bars.

Add Outage

Description

Down

☐ Is Exception

Start

25/03/2023 12:00:00 AM Now

End (first occurrence)

☐ Set Time 3/27/2023, 12:00:00 AM Now

☒ Set Duration 48 h

Repeat Pattern Every

Weekly 48

Repeat Until

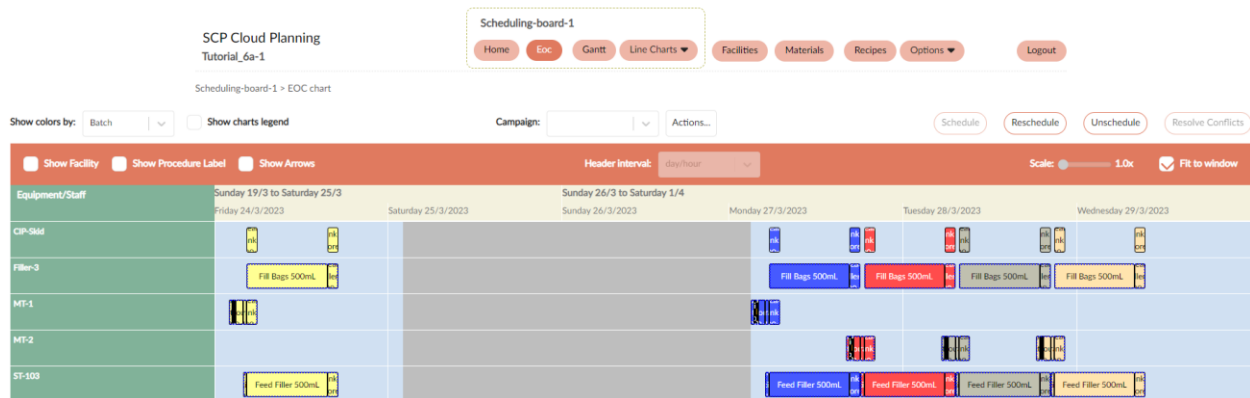
31/12/2023 12:00:00 AM Now

OK **Cancel**

Alternatively the user can define “Outage Templates” that can be used in any facility (equipment/staff/labor) of the workspace. These can be in the “Outage Templates” link found in the “Options” dropdown. Here you can type a template. Let us assume that we want to create a template that simulates a weekend break. Type the template name “Weekend Break” in the relative field (“Enter new item name...”) then click the template name, navigate to the “Outages” tab and add an outage like the one you created before. This way an outage template is saved that can be used in any facility of the current workspace, without the need to create the outage every time.

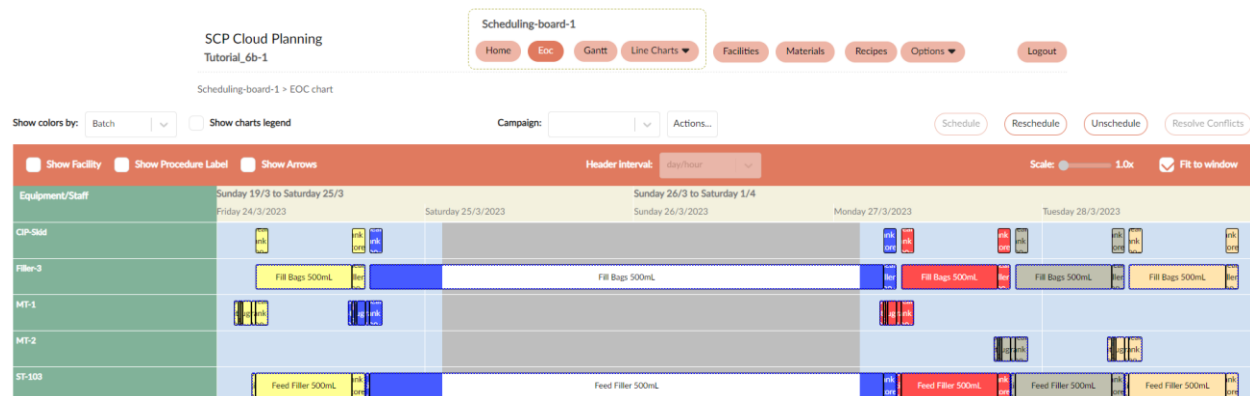
Notice that each facility item (equipment, staff, labor and storage unit) inherits the facility outages. For example, after inserting the weekend downtime outage in the “Medical Solutions Plant” facility, go to any equipment (e.g. Filler-3) and you will verify that the equipment has the same Outages. SchedulePro Cloud provides a high level of flexibility for the creation of unique Outage calendars. For example, an equipment could ignore the facility outages by checking the relative box, add new outages on top of the ones defined in the facility level or even ignore only specific outage entries.

Now schedule a campaign of 5 batches of the 0.5L-Bag recipe. The figure below shows the equipment occupancy chart for such a campaign (it corresponds to Tutorial-6a). The grey column corresponds to a weekend break.



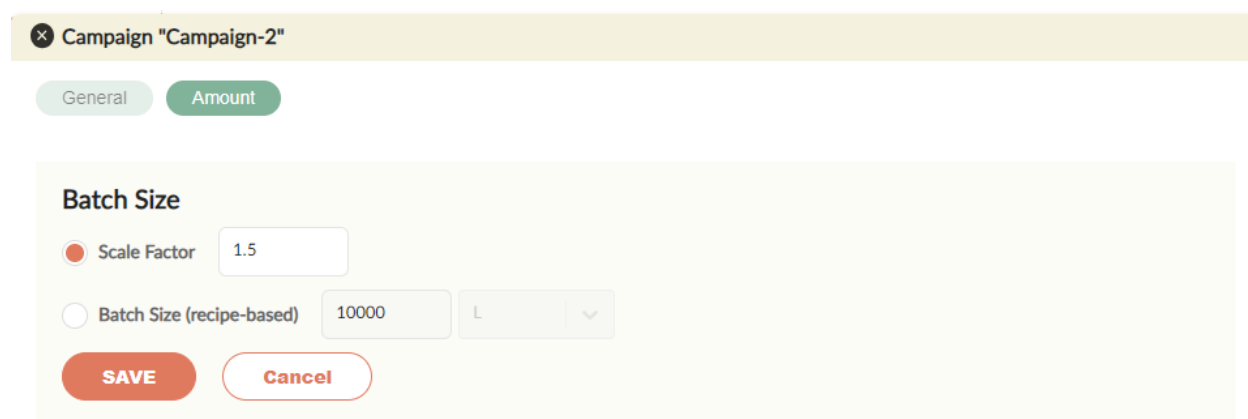
1.3.11 Tutorial-6b: Interruptible Operations

Notice that in the previous scenario, the equipment is underutilized on Friday. The start of the next batch is delayed until the following Monday morning because there is not enough time to complete it by midnight on Friday (which is the start of the weekend break). However, if the product is stable and can remain in the storage tank during a weekend break without any deterioration in its quality, one could initiate another batch on Friday and simply interrupt it for the weekend break at midnight on Friday. Such a solution is shown below (this corresponds to Tutorial-6b). The second (blue) batch is interrupted for the weekend and completed on Monday morning.



For this solution to be generated automatically, the user must specify that the “Fill Bags” operation in “Fill” procedure of the 0.5L-Bag recipe is interruptible. This is done through the “Scheduling” tab of that operation and more specifically the “Time Shift” group (see figure below). “Fill Bags” in this case can be interrupted for up to 4 days due to equipment, staff or labor unavailability (notice the checkmark for all boxes in the right of the “Operation Can Shift or Break for:” option). Repeat the same for the “Feed Filler” operation in “Store”.

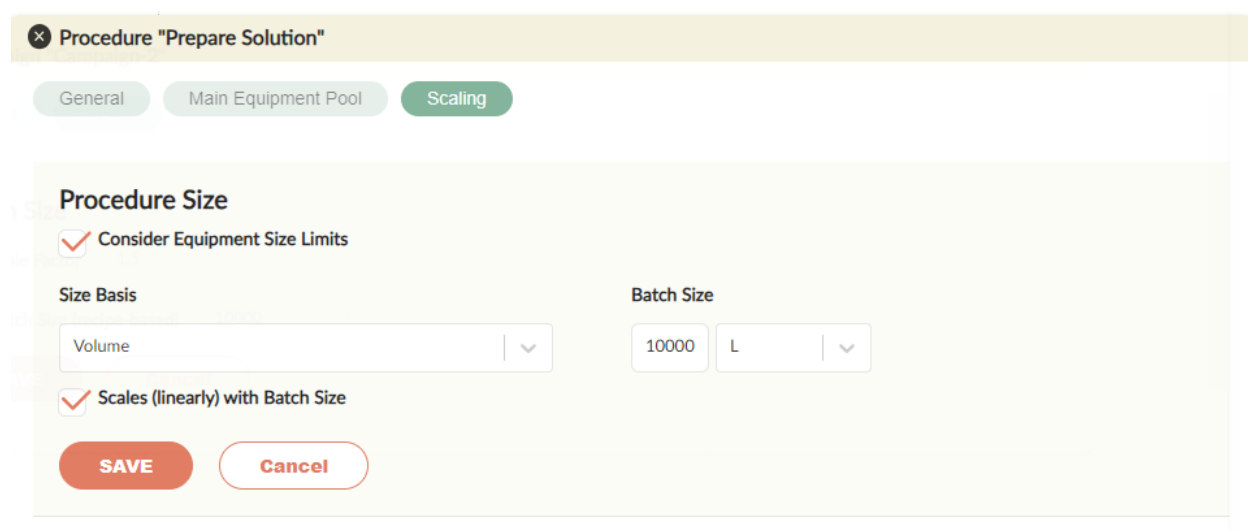
To edit the batch size for this campaign, go to the “Batch Size” group in the campaign’s “Amount” tab and set the Scale Factor of the campaign to 1.5. The scale factor is defined with respect to the nominal batch size defined at the recipe level. In this case, the nominal size is 10,000L so with a scale factor of 1.5 the batch size of this campaign is 15,000L. That, in turn, means that all procedure and operation-related amounts or rates that were specified to be “scaleable with the batch size” will also be scaled by the same factor.



The screenshot shows the 'Campaign "Campaign-2"' window. At the top, there are two tabs: 'General' and 'Amount', with 'Amount' being the active tab. Below the tabs, the 'Batch Size' section is visible. It contains two radio buttons: 'Scale Factor' (which is selected) and 'Batch Size (recipe-based)'. The 'Scale Factor' radio button is followed by a text input field containing the value '1.5'. The 'Batch Size (recipe-based)' radio button is followed by a text input field containing '10000' and a dropdown menu currently showing 'L'. At the bottom of the section, there are two buttons: 'SAVE' and 'Cancel'.

The batch size of a procedure is specified through the “Scaling” tab (see figure below). This is optional information that only plays a role in equipment selection (see later). For instance, it may represent the liquid volume in a mixing vessel. Please note that during batch scale up/down the batch size of a procedure will be adjusted only if the Scales (linearly) with batch size box is checked.

At this point, edit the scaling for procedures “Prepare Solution” and “Store”. Check the box entitled Consider Equipment Size Limits, select “Volume” as the Size Basis, set the size to 10,000L and check the “Scales (linearly) with Batch Size” box.



The screenshot shows the 'Procedure "Prepare Solution"' window. At the top, there are three tabs: 'General', 'Main Equipment Pool', and 'Scaling', with 'Scaling' being the active tab. Below the tabs, the 'Procedure Size' section is visible. It contains a checked checkbox labeled 'Consider Equipment Size Limits'. Below this, there are two columns. The left column is titled 'Size Basis' and has a dropdown menu currently showing 'Volume'. The right column is titled 'Batch Size' and has a text input field containing '10000' and a dropdown menu currently showing 'L'. At the bottom of the section, there is a checked checkbox labeled 'Scales (linearly) with Batch Size'. At the very bottom, there are two buttons: 'SAVE' and 'Cancel'.

Operation "Fill Bags"

General

Duration

Scheduling

Auxiliary Equipment

Staff

Input Streams

Output Streams

Labor

Duration

Time Unit

h

☒ Calculated

☐ Equal to Another Operation

☐ Equal to a Sequence of Operations

☐ Has Constant Duration

1

h

☒ Scales with Batch Size

☒ Has Rate Based Duration

Rate Basis

Entity Flow

Amount Processed

10000

entities

☒ Scales with Batch Size

Rate Type

Equipment-dependent (if available)

Rate

30

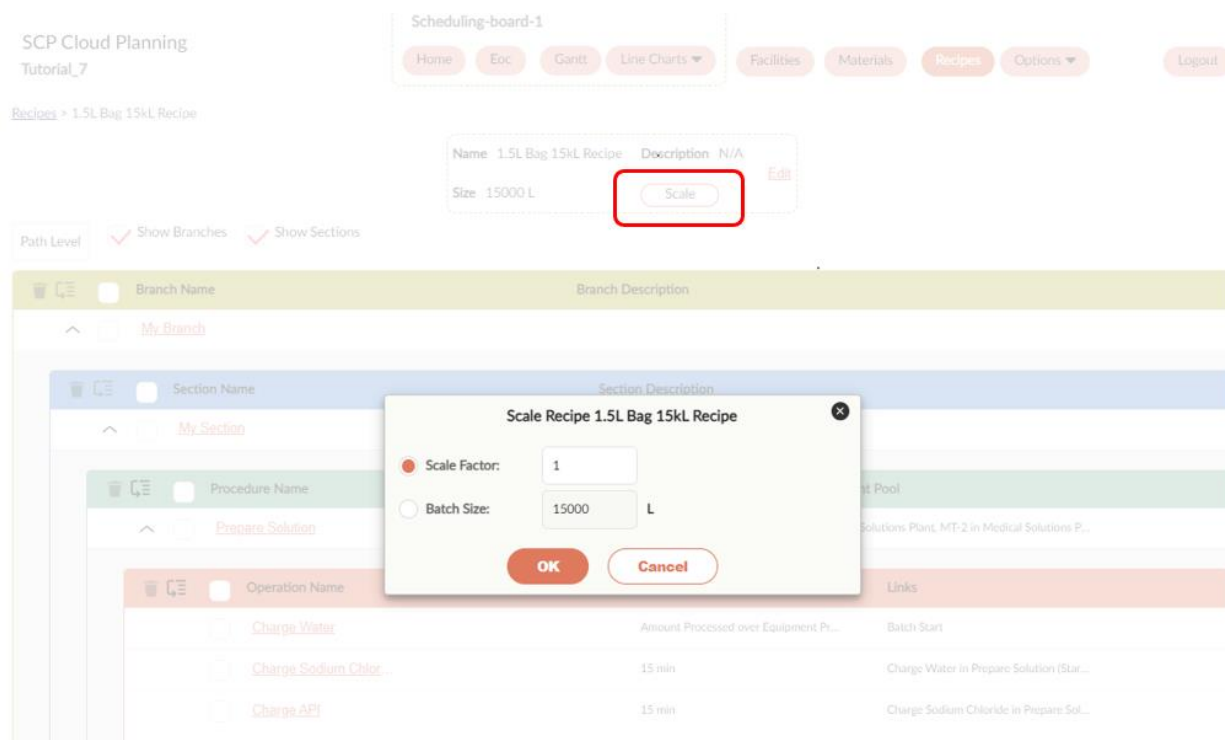
entities/...

SAVE

Cancel

44

Next, scale the new recipe by a factor of 1.5 so that its batch size becomes 15,000 L. This is done by selecting the Scale button (shown below) in the new recipe, and then type 1.5 for Scale Factor or 15,000 L for Batch Size and click OK.



Now navigate to the Medical Solutions Plant within the Facilities page. Select the Equipment link within this facility. Then select vessel MT-1 in the table, visit the "Size" tab and go to the "Batch Size Limit" group (see figure below) and specify that it can handle batch sizes between 3000 and 12000 L. Do the same for vessel MT-2 and storage tanks ST-101 and ST-102.

✕ Equipment "MT-1" in facility "Medical Solutions Plant"

General
Changeover
Size
Cost
Auxiliary/Main Compatibility
Outages

Batch Size Limit

☒ Enable

Limit Basis
Has Maximum
Has Minimum
Unit

Volume
☒ 12000
☒ 3000
L

SAVE
Cancel

Processing Rate
No processing rate
Edit

Also, edit the sizes of mixing tank (MT-3) and storage tank (ST-103) that both can handle batches of sizes between 5000 and 20000 L. Finally, make all the tanks available to all the recipes.

The Equipment Occupancy chart below (corresponding to Tutorial-7) shows a campaign of four batches of the original (10,000 L) 1-L-Bag recipe (green color) followed by four batches of the same recipe that has been scaled up at the campaign level (light orange color), followed by four batches of the 1-L-Bag 15kL recipe which was scaled up at the recipe level (yellow color). Note that the Style of this chart was modified so that the bars were colored based on campaign identity rather than batch identity. Also notice the following:

- The batches of the original recipe can be processed using any of the mix tanks and storage tanks. MT-3 is unused in this campaign simply because there is sufficient time to process all four batches in MT-1 and MT-2 without negatively impacting the schedule.
- The second and third campaigns (which have been scaled up to 15,000 L in different ways) can only be processed using MT-3 and ST-103; the other tanks are too small to process these large batches. In addition, notice that the Fill Bags operation in these scaled-up recipes takes 50% longer than it does in the first campaign because the duration of the Fill Bags operation is calculated based on the 50% larger batch size.

