

# DT - CP

## Digital Twin for Control and Planning

### User Manual



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## INTRODUCTION

The purpose of this manual is to explain the user what the application does, how to set it up and use the main functionalities.

The Digital Twin for planning and control (DT-CP) allows the users to create a virtual replica of the production line facilitated by the use case. The component is divided into two parts: A time-based simulator, that uses shopfloor information (e.g., line topology) and DB data (e.g. predefined skill level) to create a virtual 2D replica of the production line for analysis purposes, and a monitoring dashboard that provides an overview of the line using 2D visualization, handles notifications from other systems and suggest the operator's rotations based on their performance.

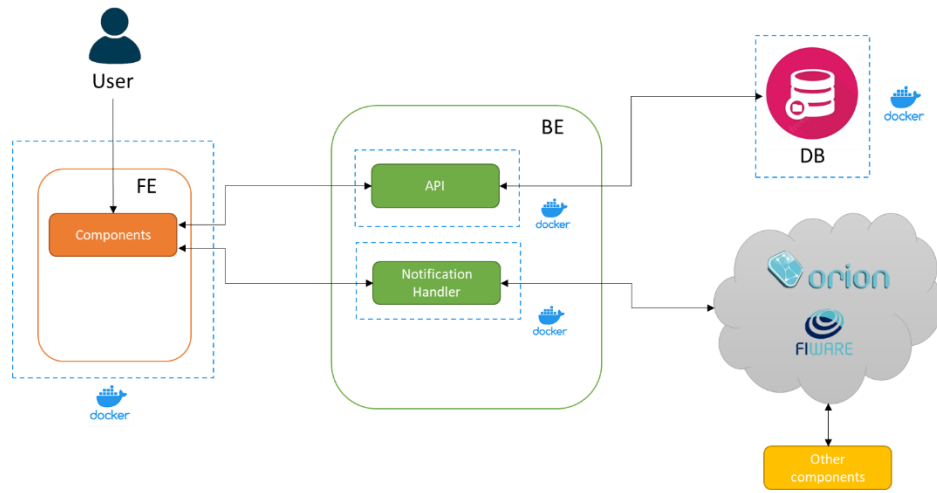
The monitoring dashboard is a tailored solution for a SHOP4CF use case since it requires a lot of specific information of the process to be monitored (for example, layout, working shifts, rest slots, ...). In case you are interested in these features to exploit your process, please contact the web developers of the DT-CP in: [TAU-FASTLab/dt-cp \(github.com\)](https://github.com/TAU-FASTLab/dt-cp). In the meanwhile, the general idea behind the monitoring dashboard can be consulted in the following publication: [Enhancing Digital Twins of Semi-Automatic Production Lines by Digitizing Operator Skills](#).

The monitoring dashboard is connected to the shopfloor directly via FIWARE, so it is regularly updated with new input data that is processed to inform the user about the general state of the factory and suggest the operator's rotations based on their performance. To do that, some assumptions are made regarding the process:

- The production line or process to monitor is made up of several workstations and many operators can work on them. Each station has its process description composed of several tasks. For each workstation, every worker has a skill level regarding their level of expertise to ranked from 1 (assistant) to 4 (master).
- The logic of the dashboard that tells the user if a workstation is working normally or not, assumes that for each workstation there are two sensors: one that detects the product arriving to the station and one that detects the product leaving. This logic alerts the user if a workstation has not fulfilled its tasks in 2 minutes.
- The execution of the monitoring dashboard needs to be done every 8h since it implies the selection of workers, and they cannot work more than 8h per day.
- The workers are rotated every few hours of work (once the rotations are triggered) to help in balancing the workloads. The rotations are based on their daily previous performance.
- Operators cannot repeat workstations on the same day. That is, if an operator has already worked at one of the assigned workstations in a day, the rotation logic cannot make them repeat or let him/her continue working in the same workstation on that shift. This restriction is established to reduce the risk of suffering muscular disorders and balance the workloads.

The application is made up of three main blocks:

- Frontend (FE): Provides the interface with which the user interacts (simulator and monitoring dashboard)
- Backend (BE): Define the endpoints that receive or send information to the FE and run the simulation. Additionally, it creates the entities following the project data models and communicates with other components or the shopfloor directly via FIWARE.
- Database (DB): Provides all the necessary data that the application needs.



## DOWNLOAD

All the documentation can be found in this [GitHub repository](#) (same repository where the manual is located)

All the needed application files except the Docker images can be found here:

```
git clone https://github.com/TAU-FASTLab/dt-cp.git
```

The Docker images of the component are available in the SHOP4CF repository of [RAMP Docker Registry](#). In order to use DT-CP correctly, it is necessary to download the three of them:

- dt-fe
- dt-be
- dt-nh

### Software requirements

To use the component, it is necessary to have the following:

- Windows PC.
- Docker.
- Downloaded all the needed DT-CP docker images.
- Database with skill level of the workers for each WS, collection of tasks with the time it takes to do each one and collection with the most used lists of tasks.

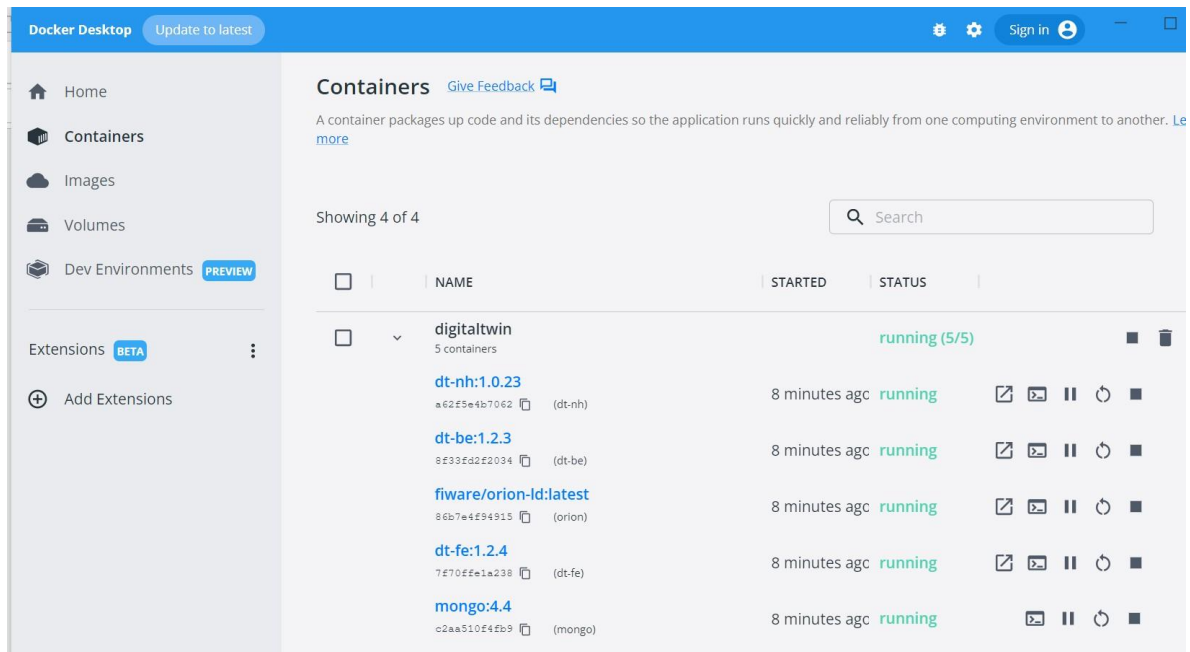
Additionally, it is advisable to run the application in a browser such as Google Chrome or similar and integrate DCF component at the same time.

## SETUP

For next steps it is needed to pull the docker images (dt-fe, dt-be and dt-nh) from the RAMP docker registry. Docker images can be launched at the same time with the provided docker-compose.yml -file.

Once this file is downloaded, it will be necessary to execute it with the command: **docker-compose up**.

If the user uses Docker Desktop, you can check that the application has been deployed correctly in the Containers tab:

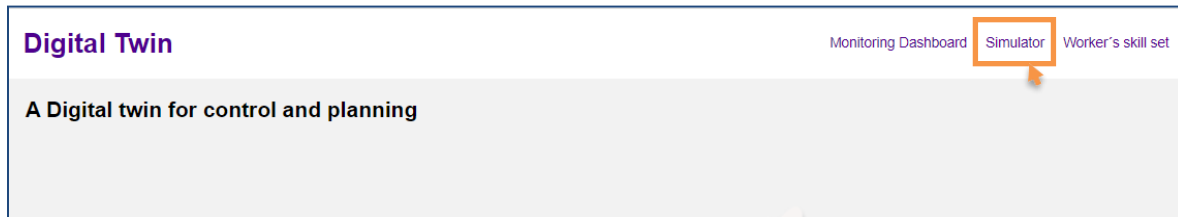


To stop the application, use the command: **docker-compose down -v**, it will destroy the cluster and the data volumes.

## USER INTERFACE

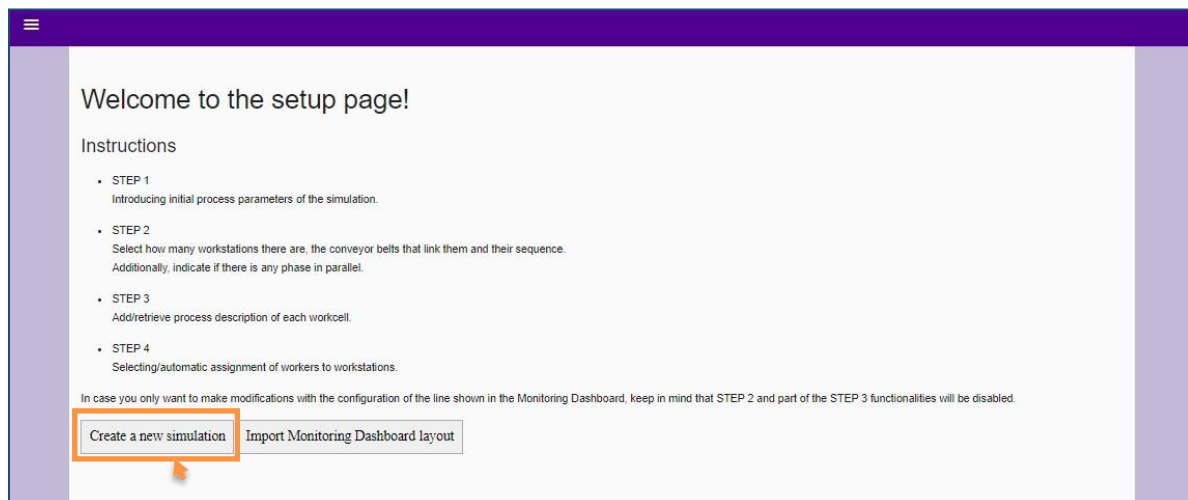
When the containers are running, the UI can be reached from the host computer by navigating *localhost:2308* or in providing the IP of the host when using another computer. Short explanation of the UI:

First, we have **the home page**. It allows the user to choose which of the sections to use: the monitoring dashboard, the simulator, or the viewer of the skill level of the operators.



### Simulator

Once the user clicks in the simulator button which is located in the upper right section of the window, some instructions about this section appear:



It is a 4-step simulator, where the user must complete information (e.g. layout, worker's info, ..) in 4 pages prior to running the simulation.

Two options are shown in this window: Start a simulation from 0 (4 steps) or import one of the already predefined layouts (3 steps).

The manual reviews the most complete option.

### **Step 1**

In this step, the user introduces some initial parameters of the simulation:

- Shift duration: Duration of the shift in hours to run the simulation. It is a mandatory parameter.
- Expected production: Production of the number of pieces to be expected of the simulated. Optional data to compare in the results.
- Expected takt time: Expected total takt time of the line permitted to simulate. Optional data to compare in the results.

**Initial Parameters**

Introducing initial process parameters of the simulation.  
The shift duration is required to run the simulation, while the other two parameters are optional.

Shift duration

Expected production (optional)

Expected takt time (optional)

**Next**

## Step 2

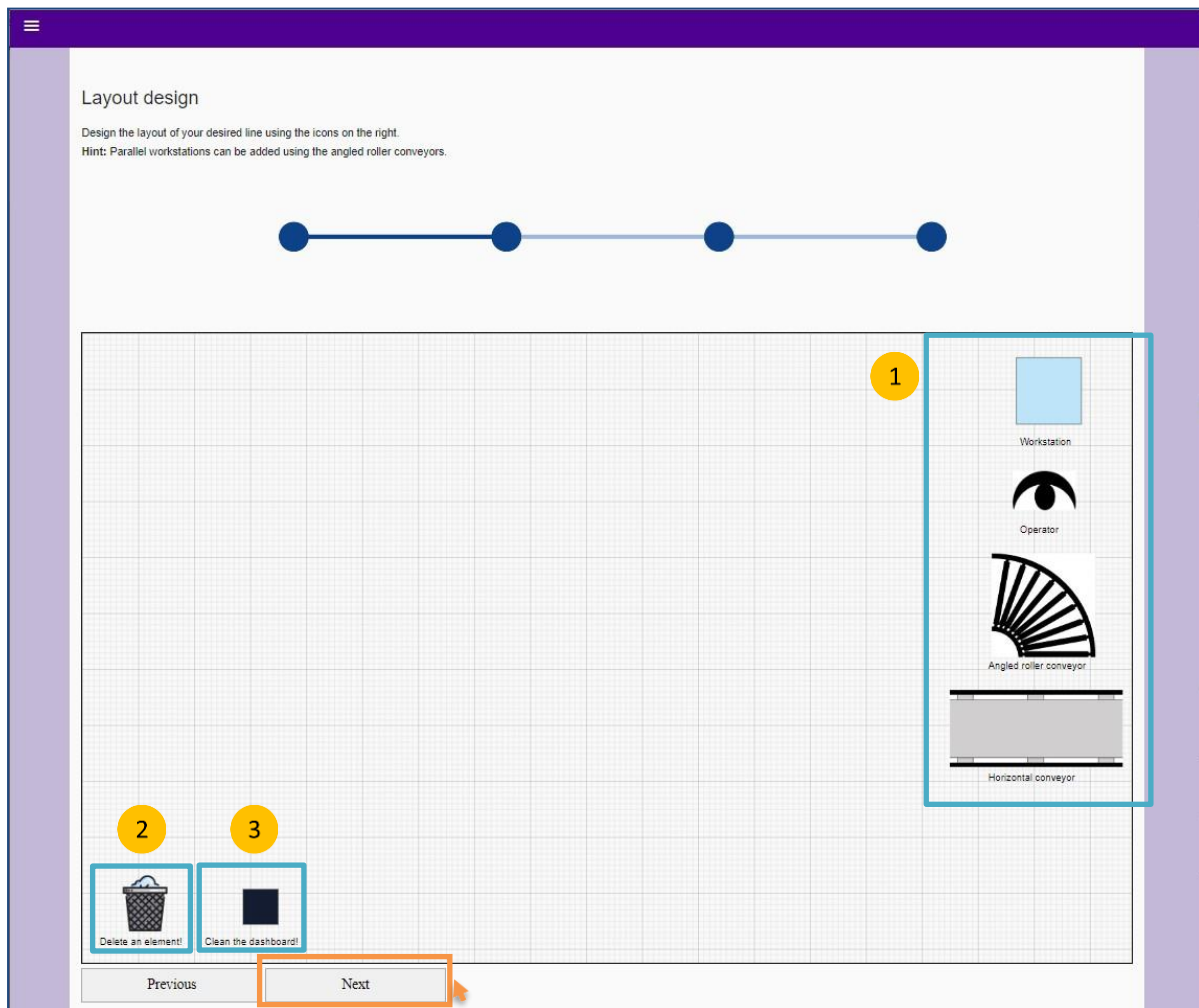
The layout to be simulated is designed by dragging and dropping elements (e.g. operator, workstation, ...) from the inventory placed on the right side of the screen.

To build the layout, the ideal process to follow is, first, place the serial conveyors with the desired length, then, the workstations on top and the operators who are going to work on them. For more information, check the example bellow.

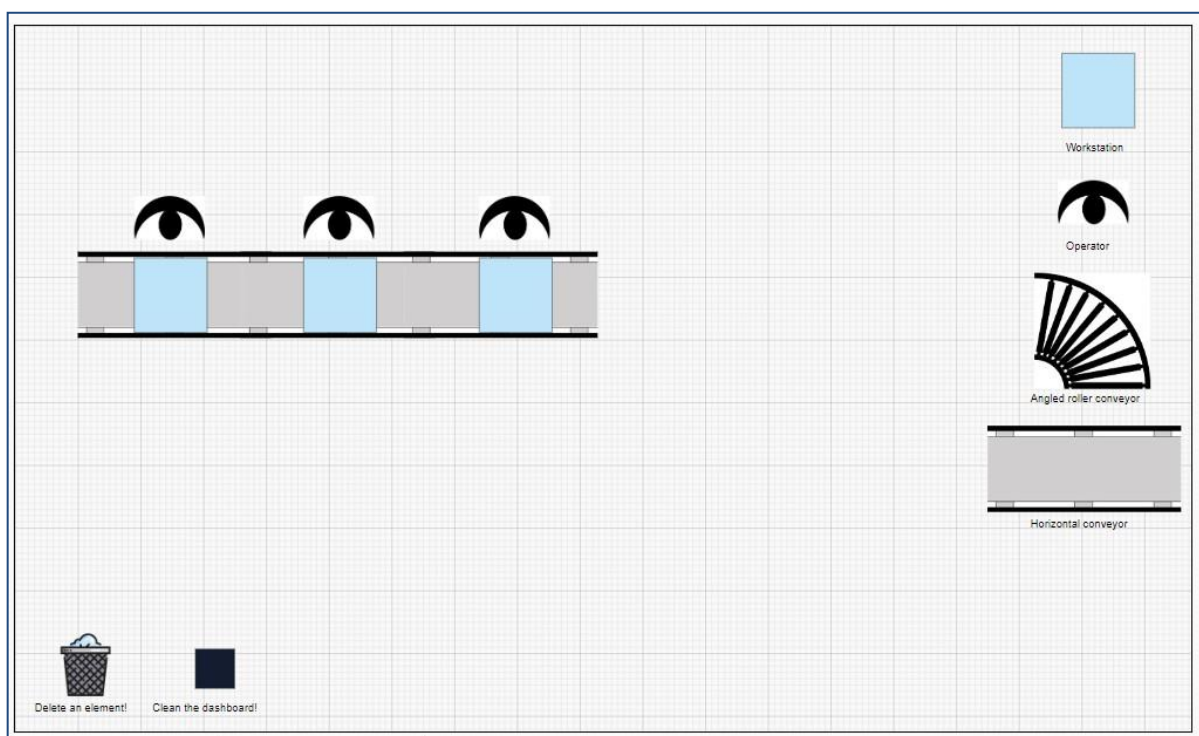
The simulator only accepts linear layouts for now. It is important to delete the not used dragged elements of the board so the simulator don't count them in the following steps.

1. Elements of the inventory. Try can be rotated by double clicking on them.
2. Delete an element by dragging it and dropping in the bin.
3. Clean the dashboard by pressing the button.





Example of a designed layout:

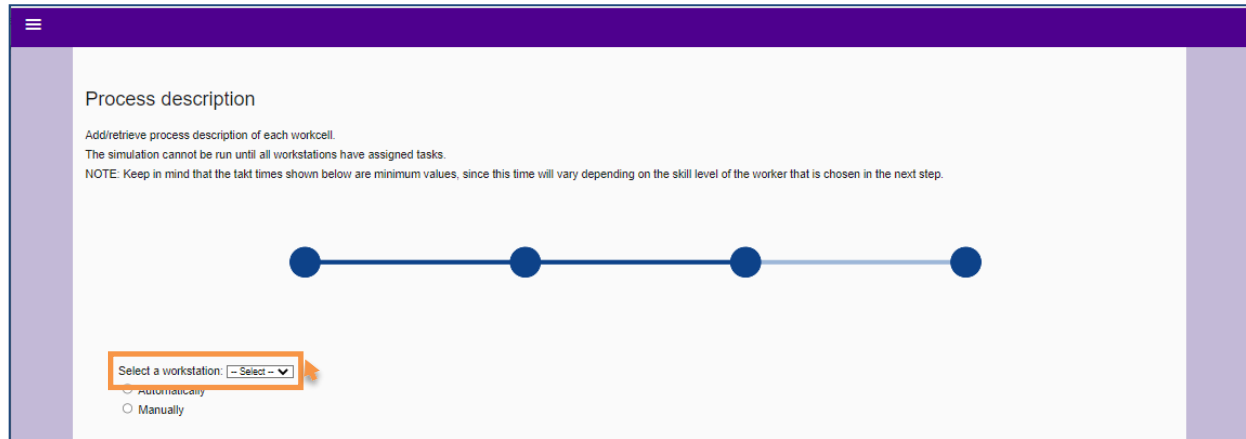


### Step 3

In this step, the user characterizes the workstations created in the previous step with the descriptions of the processes that are carried out.

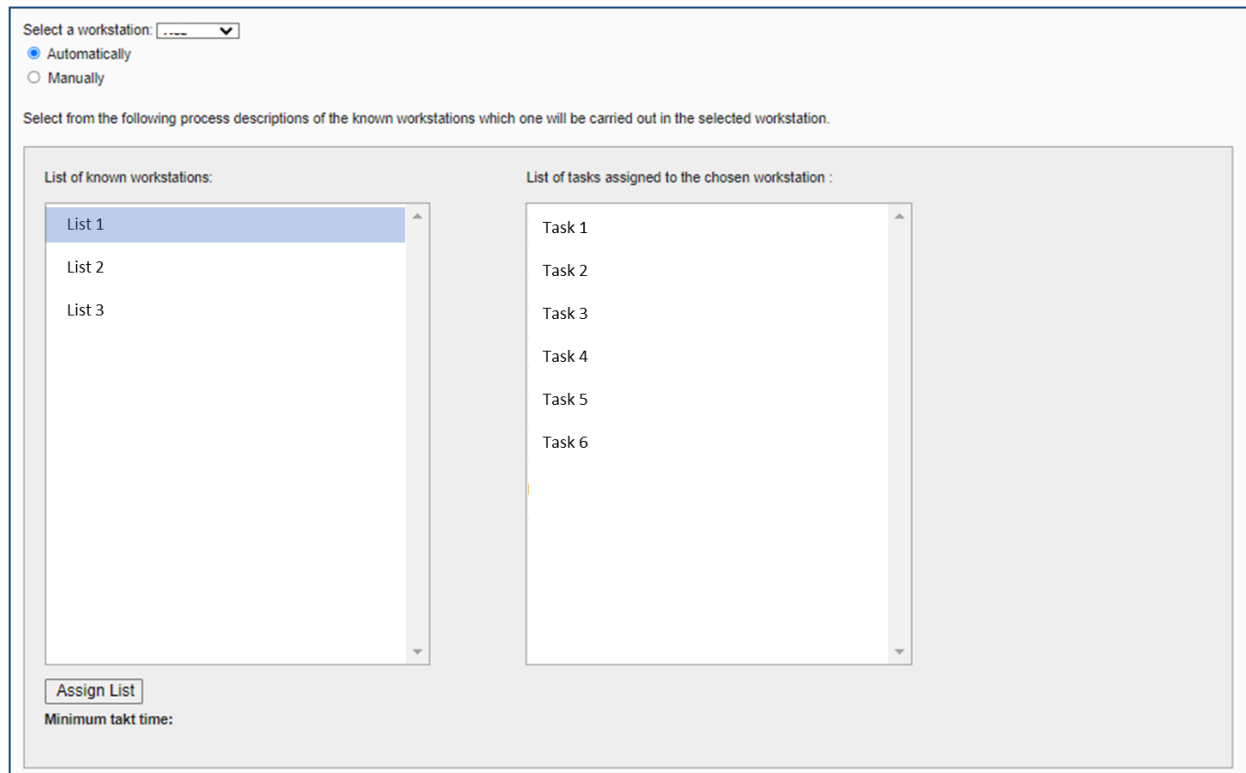
To do this, the DT-CP database is used.

First, one of the workstations is selected in the Select. Then assignment of tasks can be done in two ways:



#### Automatic:

The user chooses from a list of predefined tasks and assign the selected list to the workstation pressing the “Assign list” button.



#### Manual:

The user individually chooses the tasks that make up a list to assign to the workstation.

Select a workstation:

☐ Automatically  
☒ Manually

Select from the following list of tasks, in order of execution, which ones will be carried out in the selected workstation.

List of tasks:

- Task 1
- Task 2
- Task 3
- Task 4
- Task 5
- Task 6
- Task 7
- Task 8
- Task 9
- Task 10
- Task 11
- Task 12
- Task 13

Import task →

Selected tasks:

- Task 14
- Task 22
- Task 3
- Task 1
- Task 15
- Task 6

Up Down

← Return task Assign List

1. Import task button to copy an individual task into the list to be assigned to the workstation (move from the left general list to the right one).
2. Up/Down buttons to modify the order of the selected tasks list (right list).
3. Return task button to remove a task from the list to be assigned to the workstation.
4. Assign list button.

The user cannot leave this page until all workstations have a process description.

Process description

Add/retrieve process description of each workcell.

The simulation cannot be run until all workstations have assigned tasks.

NOTE: Keep in mind that the task times shown below are minimum values, since this time will vary depending on the skill level of the worker that is chosen in the next step.

● — ● — ● — ●

Select a workstation:

☐ Automatically  
☐ Manually

Previous Next

#### Step 4

The last step consists of assigning workers to the workstations. The number of workers to be selected are based on the simulation hours chosen in step 1.

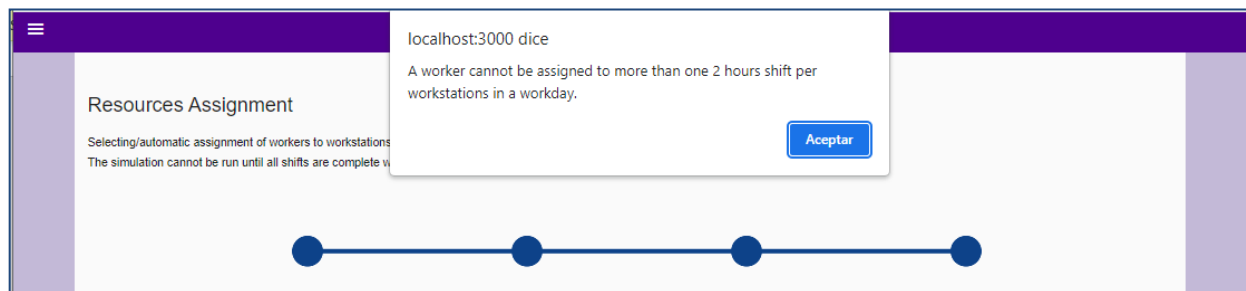
To do this, the DT-CP database is used.

Simulation hours can be less than or equal to a working day, that is, 8 hours or more than this, which implies two different working days, so it is allowed to repeat the selection of workers as long as they are on different days.

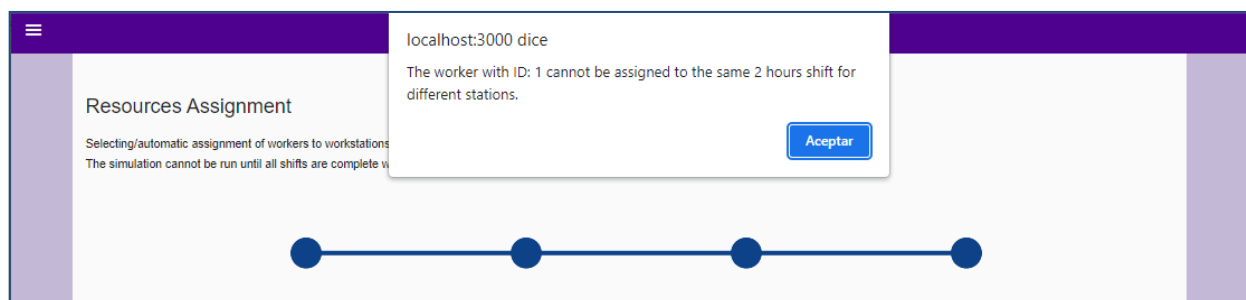
The simulator assumes a rotation of the workers every two hours to guarantee their concentration, ergonomics and well-being. For example, if the simulation period chosen in step 1 is 8 hours, the simulator requests 4 workers for each selected workstation.

There are certain restrictions when selecting workers that are accompanied by informative pop-ups when any of them are violated:

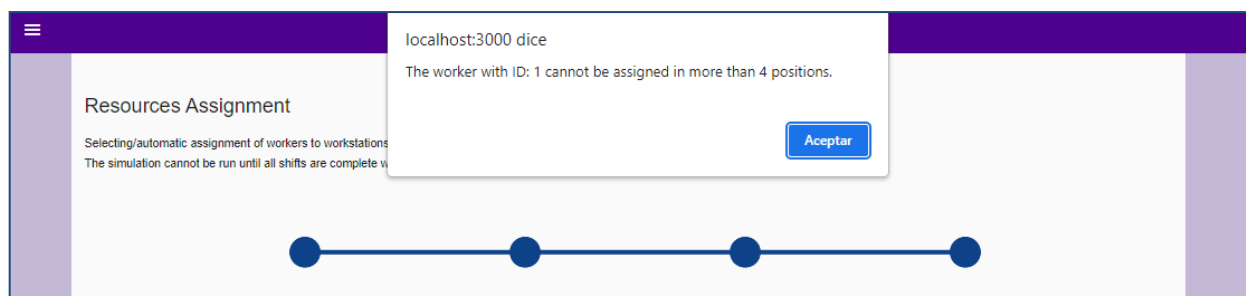
- The same worker cannot be assigned to a workstation twice in the same shift.



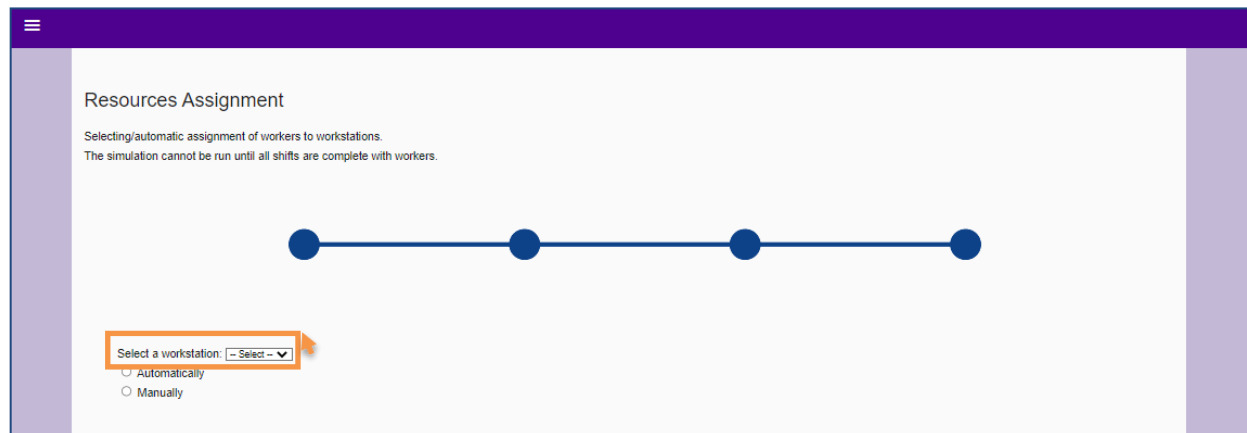
- The same worker cannot be assigned to two different workstations at the same time.



- A worker cannot be assigned more than 4 times in a simulation in the same shift. Selecting it 4 times implies that it already works 8 hours and working hours longer than that are not accepted.

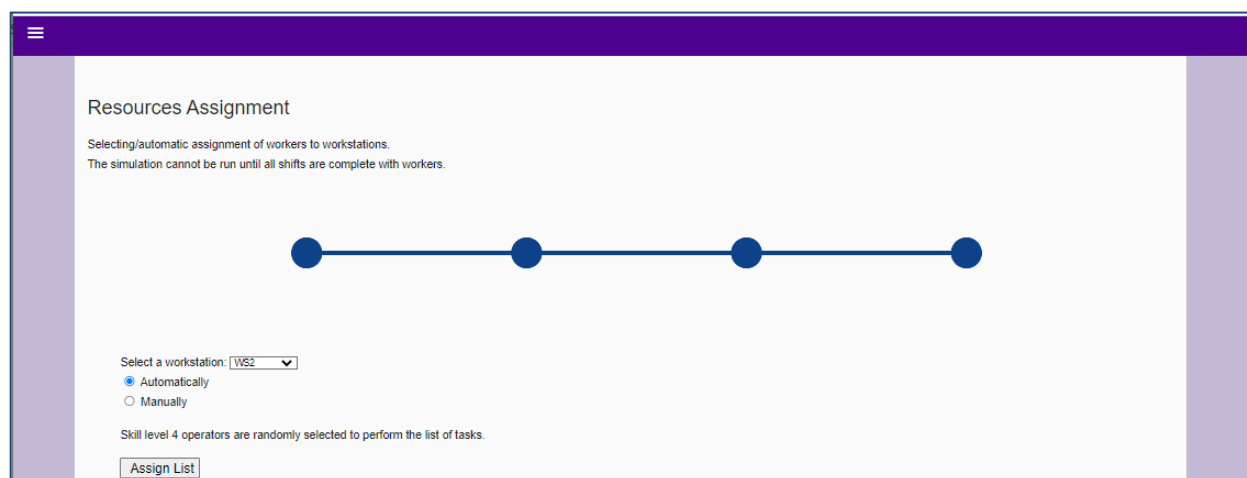


First, one of the workstations is selected in the Select. Then assignment of workers can be done in two ways:



#### Automatic:

The workers are assigned randomly to the workstation. This automatic assignment is made only considering the highest-ranking workers, i.e., skill level 4 experts.



#### Manual:

The user selects the workers that are going to performance the simulation.

Resources Assignment

Selecting/automatic assignment of workers to workstations.  
The simulation cannot be run until all shifts are complete with workers.

Select a workstation: WS2

☐ Automatically  
☒ Manually

Select from the following list of workers, which ones will perform the tasks in the selected workstation.

List of operators:

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16
- 17
- 18
- 19
- 20
- 21

Select worker ->

The skill Level of the selected operator for WS2 : is 4

Selected operators:

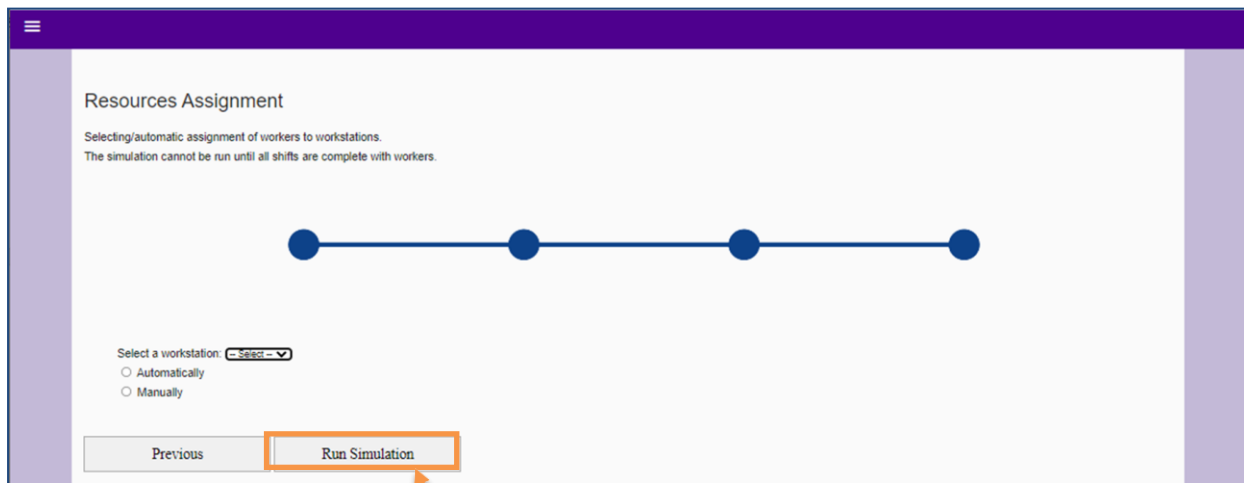
Up Down

The duration of the shift is: 8 h. 4 operators can be selected.

Return worker Assign List

1. Select worker button to copy a worker into the list to be assigned to the workstation (move from the left general list to the right one).
2. Information that shows the skill level of the selected operator for the designed workstation
3. Up/Down buttons to modify the order of the selected operators list (right list).
4. Information that shows the duration of the shift and the number of workers that are needed.
5. Return worker button to remove an operator from the list to be assigned to the workstation.
6. Assign list button.

The user cannot leave this page until all workstations have operators assigned.



Once the user clicks the “Run Simulation” button, the simulation code is executed.

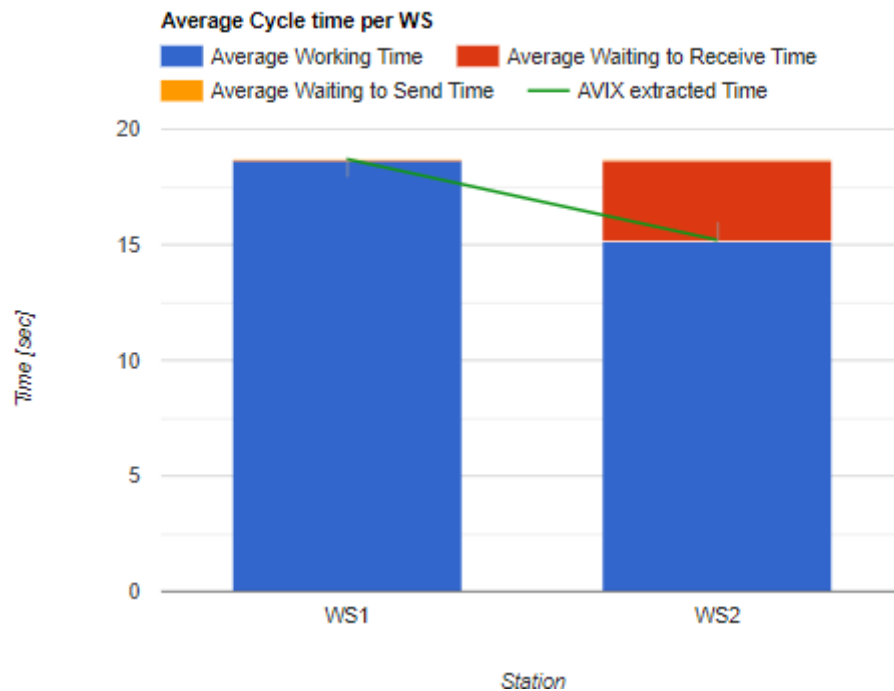
This logic considers that:

- There is a buffer of  $n$  units between workstations (default  $n = 1$ , but can be changed)
- Three states are established for workstations:
  - Working Time: where the operator is working on a product.
  - Waiting to Receive Time: where the operator is waiting to receive product to work from the previous station.
  - Waiting to Send: where the operator has the finished product in his workstation but cannot send it to the next one because the buffer is full.
- To simulate the real behavior of the operators, there is no repetitiveness in the times it takes to make a piece (they can be tenths of a second or seconds apart), each time a product arrives at a workstation in the simulation, the operator working time for that product is calculated with a randomness defined by the skill level of the operator and applicable to the nominal working time.

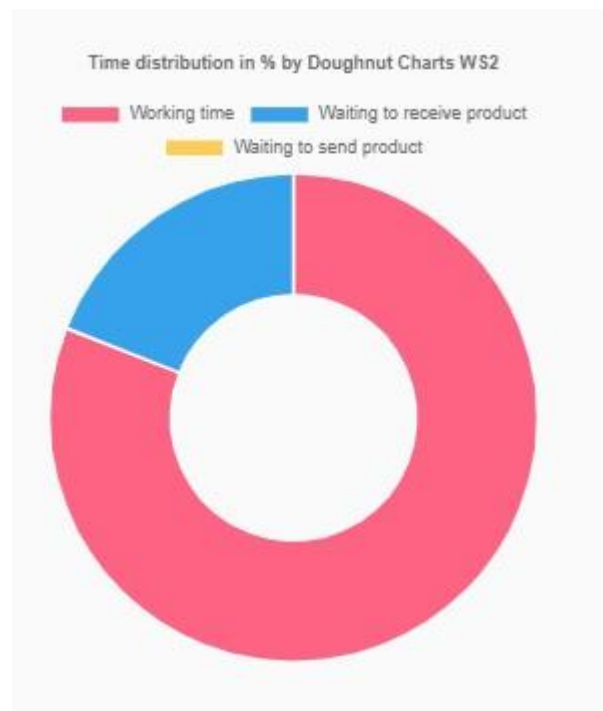
## Results



The results of the simulation show different types of graphs, among them: one that includes the comparison of the nominal work time (estimated according to the database) and the real one depending on the workstation, for example:



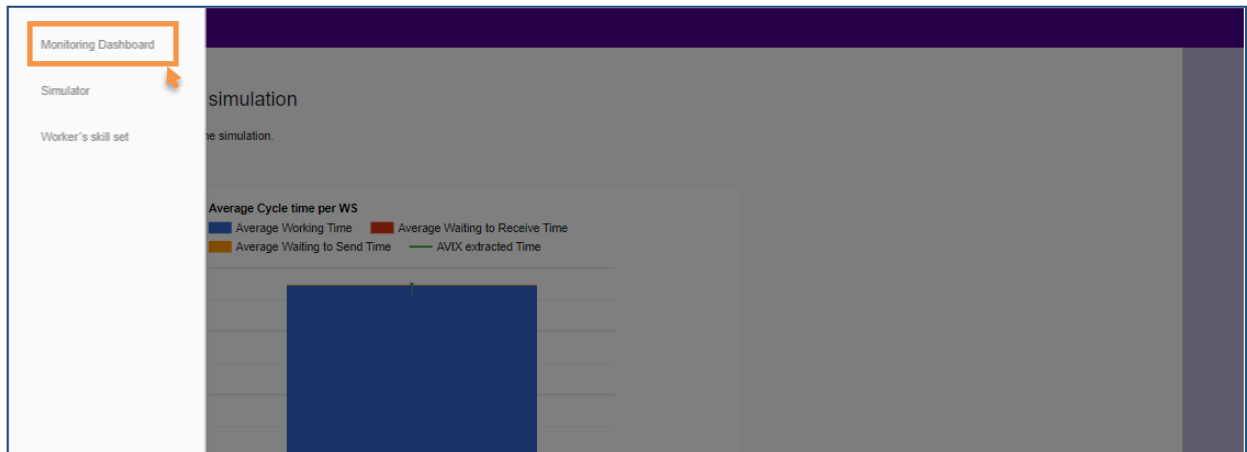
Another one that shows the distribution of the time spent in each workstation, as:



Finally, the number of units produced is calculated with the settings introduced in the steps and a comparison between the expected takt time and the number of units produced (optional data Step 1) with the results obtained.

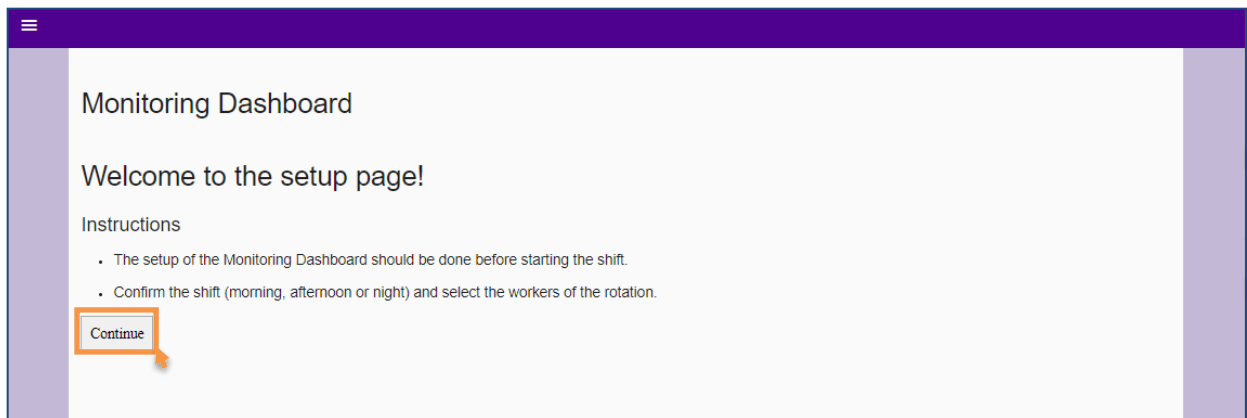
Another way to access the other parts of the component without having to go through the main page is by clicking on the bar that displays the side menu:





### **Monitoring Dashboard**

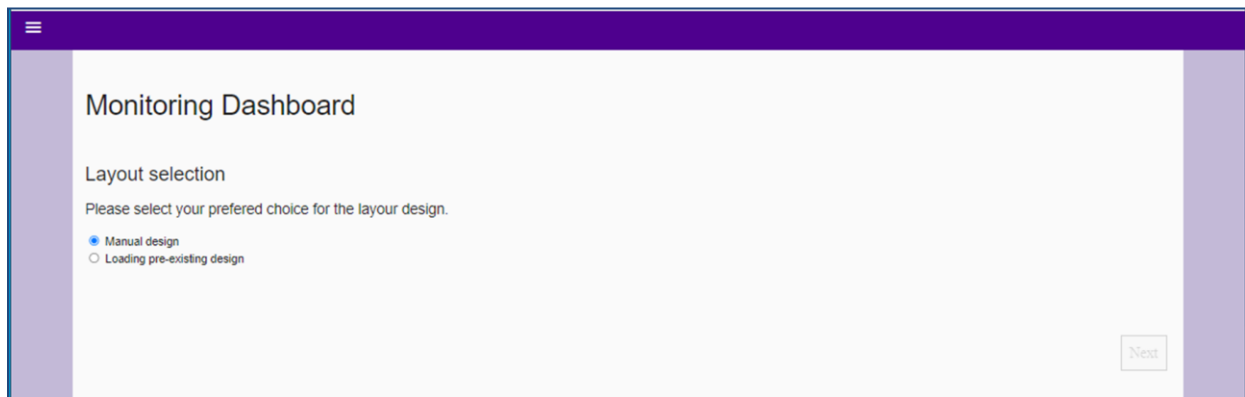
Once the user clicks in the Monitoring Dashboard button, some instructions about this section appear because is necessary to setup some parameter before going to the visualization of the line:



First the user selects the layout to display in the monitoring dashboard:



## Manual design

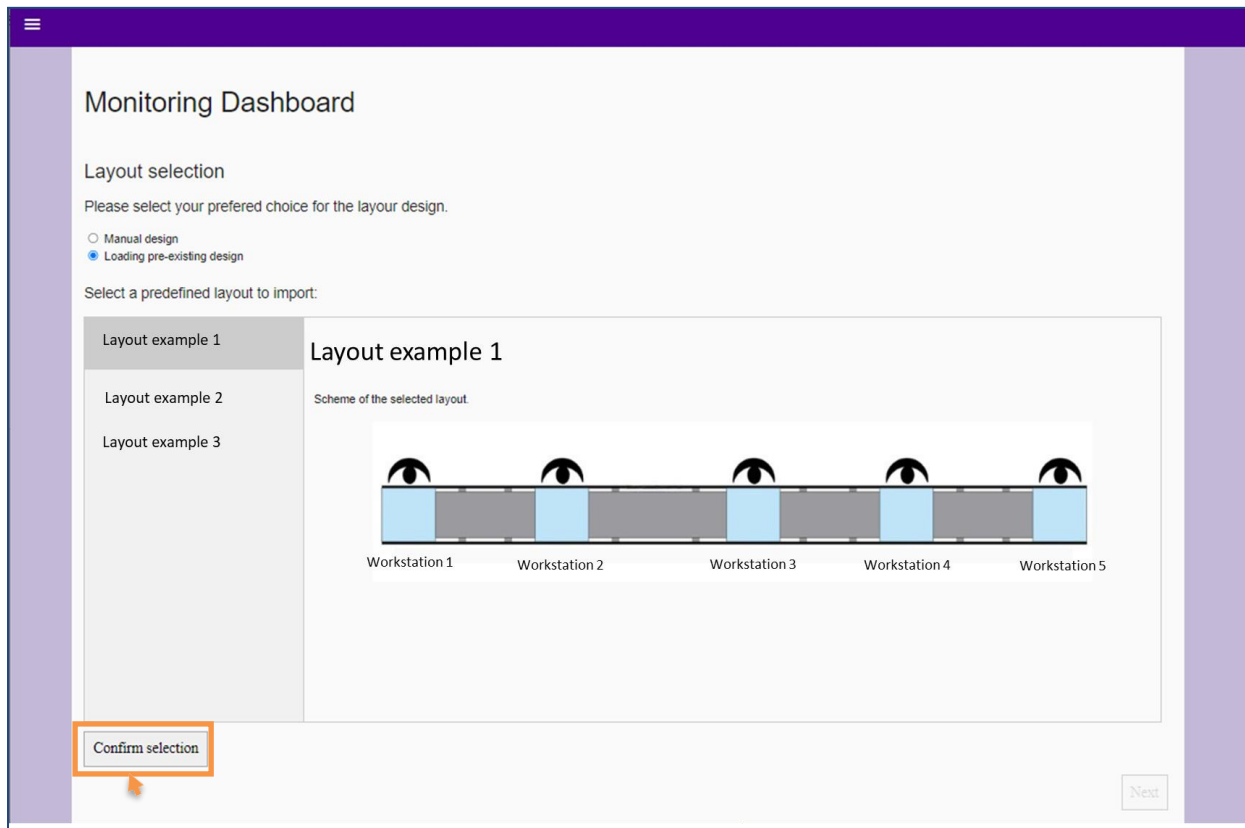


The screenshot shows a web application interface with a purple header and a light purple sidebar. The main content area is titled "Monitoring Dashboard" and contains a "Layout selection" section. Below the title, it says "Please select your preferred choice for the layout design." There are two radio buttons: "Manual design" (selected) and "Loading pre-existing design". A "Next" button is located in the bottom right corner.

(Status: Under development)

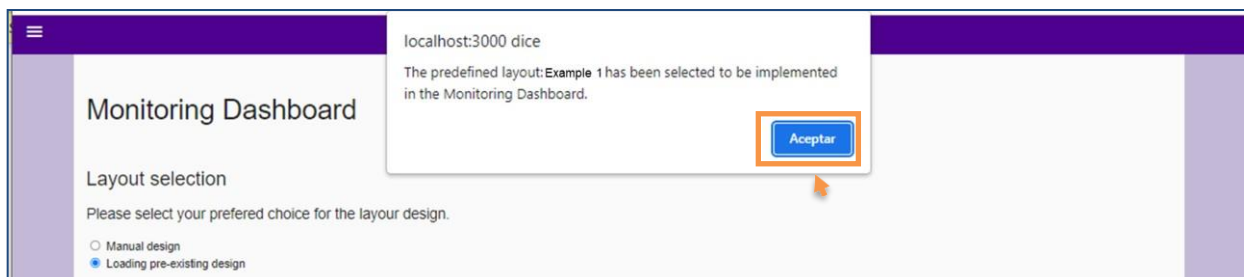
## Loading a pre-existing design

The user can choose between the layouts predesigned for their shopfloor.

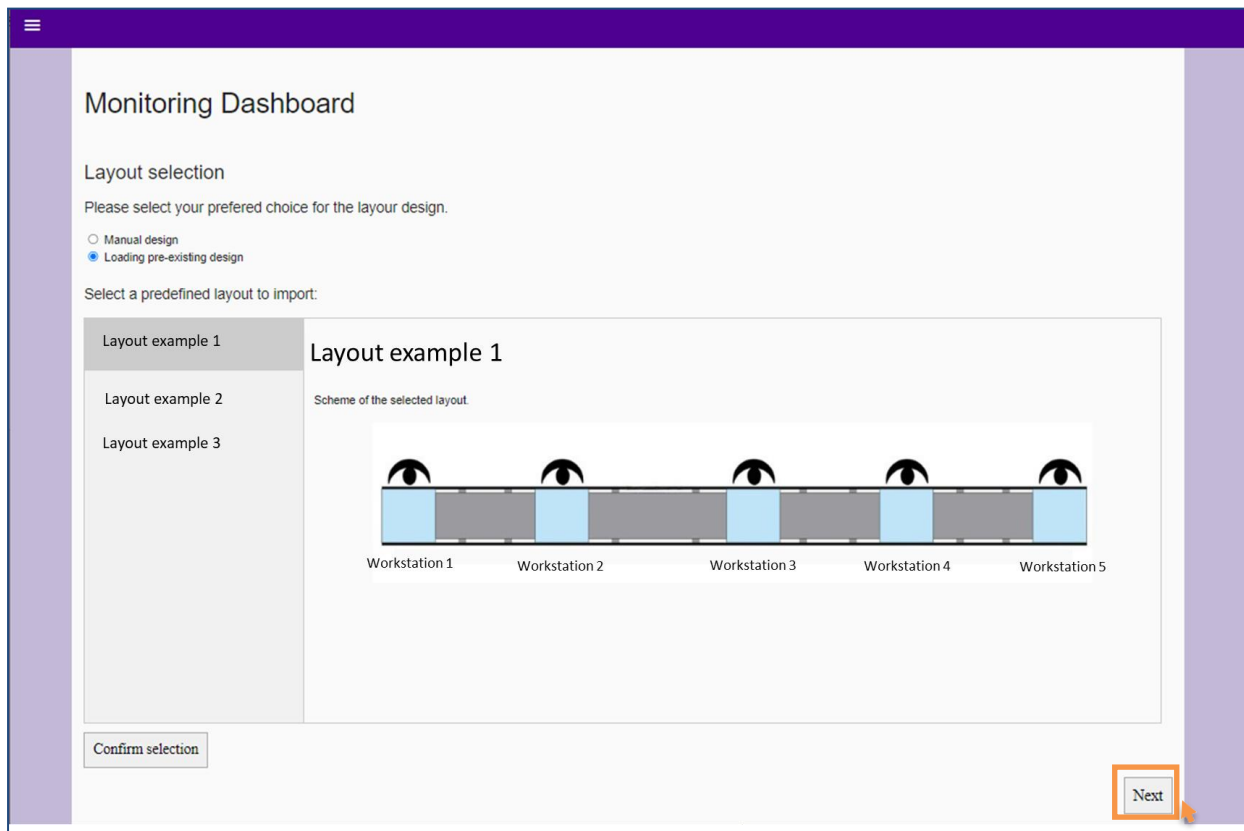


This screenshot shows the same "Monitoring Dashboard" interface, but with the "Loading pre-existing design" radio button selected. Below the radio buttons, it says "Select a predefined layout to import:". There is a list of three layout examples on the left: "Layout example 1", "Layout example 2", and "Layout example 3". "Layout example 1" is selected and highlighted. To the right of the list, under the heading "Layout example 1", is a diagram titled "Scheme of the selected layout." The diagram shows a horizontal line with five eye icons above it, representing workstations. Below the line, the workstations are labeled "Workstation 1", "Workstation 2", "Workstation 3", "Workstation 4", and "Workstation 5". A "Confirm selection" button is located at the bottom left of the layout selection area, highlighted with an orange box and an arrow. A "Next" button is in the bottom right corner.

After clicking on the "Confirm selection" button of the layout, a popup appears at the top of the screen confirming the selected layout.



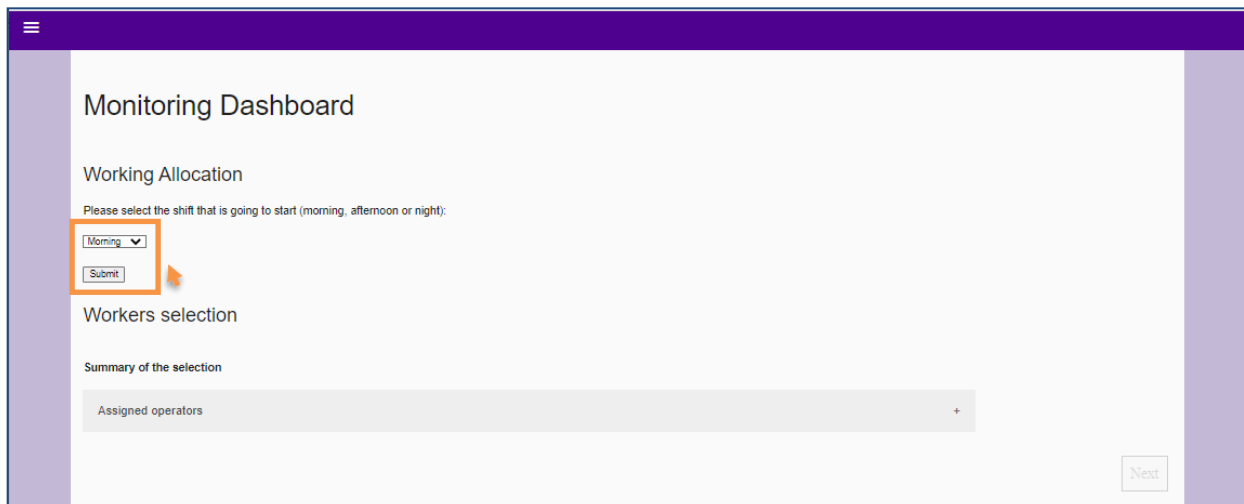
This screenshot shows the "Monitoring Dashboard" interface with a confirmation popup. The popup is titled "localhost:3000 dice" and contains the text "The predefined layout: Example 1 has been selected to be implemented in the Monitoring Dashboard." There is a blue "Aceptar" button in the bottom right corner of the popup, highlighted with an orange box and an arrow. The background interface is partially visible, showing the "Layout selection" section with the "Loading pre-existing design" radio button selected.



The screenshot shows a web application interface titled "Monitoring Dashboard". Under the "Layout selection" section, there is a prompt: "Please select your preferred choice for the layout design." Below this, two radio buttons are present: "Manual design" (unselected) and "Loading pre-existing design" (selected). A sub-section titled "Select a predefined layout to import:" contains a list on the left with "Layout example 1", "Layout example 2", and "Layout example 3". "Layout example 1" is highlighted. To the right, a larger area titled "Layout example 1" shows a "Scheme of the selected layout" which is a horizontal line with five eye icons above it, each positioned over a light blue rectangular block. These blocks are labeled "Workstation 1" through "Workstation 5" from left to right. At the bottom left of the main content area is a "Confirm selection" button. At the bottom right, there is a "Next" button highlighted with an orange box and a mouse cursor pointing at it.

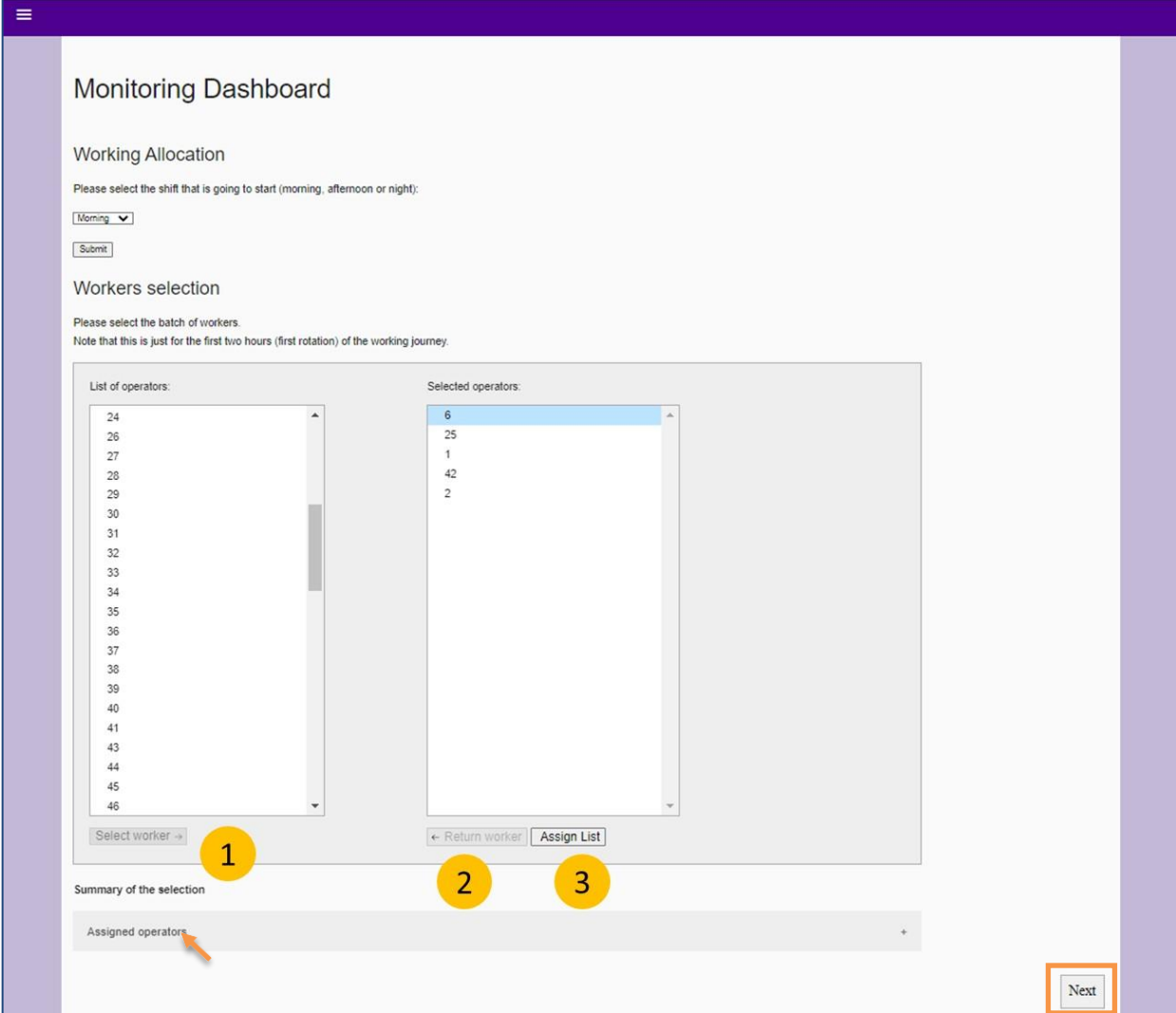
After clicking the "Next" button, the user must select the workers who will work during their working day at the workstations defined in the previous step.

It is important to know that the user only chooses the list of operators, and it is the system that assigns them to the stations with the aim of minimizing the time it takes to obtain the product.



The screenshot shows the "Working Allocation" section of the "Monitoring Dashboard". It prompts the user to "Please select the shift that is going to start (morning, afternoon or night):". Below this is a dropdown menu currently showing "Morning", which is highlighted with an orange box and a mouse cursor. A "Submit" button is located directly below the dropdown. Under the "Workers selection" section, there is a "Summary of the selection" area containing a box labeled "Assigned operators" with a plus sign (+) to its right. A "Next" button is located at the bottom right of the interface.

The user defines the work shift, and then a list with the known operators in that shift is shown:



The image shows a web application interface titled "Monitoring Dashboard". Under the "Working Allocation" section, there is a dropdown menu for selecting a shift (currently set to "Morning") and a "Submit" button. Below this is the "Workers selection" section, which includes instructions to select a batch of workers for the first two hours of the first rotation. The interface features two side-by-side lists: "List of operators" on the left and "Selected operators" on the right. The "List of operators" contains a scrollable list of numbers from 24 to 46. The "Selected operators" list contains the numbers 6, 25, 1, 42, and 2. Between these lists are three buttons: "Select worker" (labeled with a yellow circle and the number 1), "Return worker" (labeled with a yellow circle and the number 2), and "Assign List" (labeled with a yellow circle and the number 3). Below the lists is a "Summary of the selection" section with a label "Assigned operators" and a plus icon. An orange arrow points to the "Assigned operators" label. In the bottom right corner, there is a "Next" button highlighted with an orange border, with an orange arrow pointing to it from below.

Monitoring Dashboard

Working Allocation

Please select the shift that is going to start (morning, afternoon or night):

Morning

Submit

Workers selection

Please select the batch of workers.

Note that this is just for the first two hours (first rotation) of the working journey.

List of operators:

24  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
43  
44  
45  
46

Select worker

Selected operators:

6  
25  
1  
42  
2

Return worker

Assign List

Summary of the selection

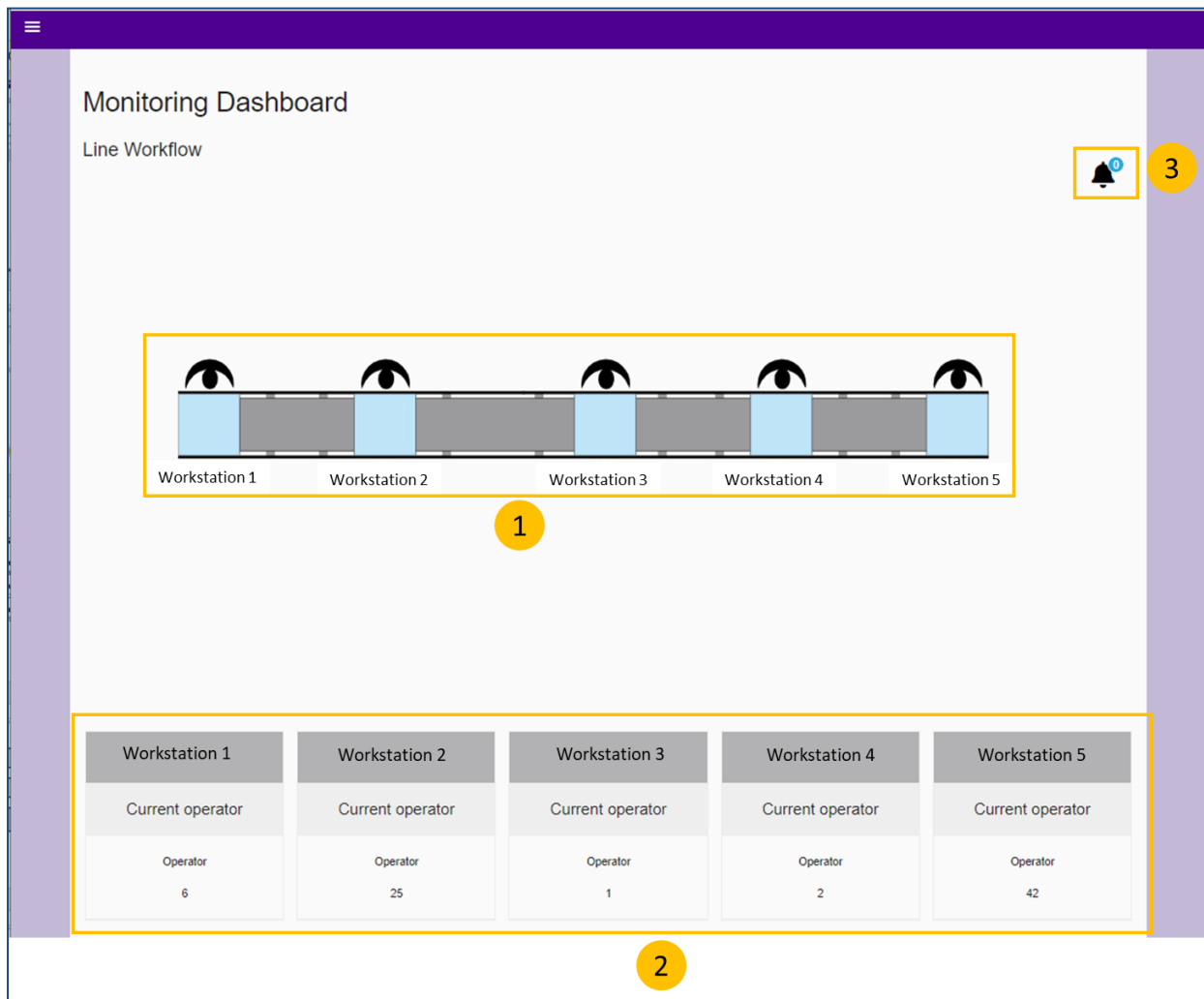
Assigned operators

Next

1. Select worker button to move a worker into the list to be assigned.
2. Return worker button to remove an operator from the list to be assigned.
3. Assign list button.

The user needs to select as many workers as the number of workstations the layout has in the step before. Once they are selected, the user "Assign the list" and check that is done in the "Summary of the selection" clicking in "Assigned operators".

After, click the "Next" button.



1. 2D representation of the line layout.
2. Tables with the rotation of the workers.
3. Bell that shows the notifications.

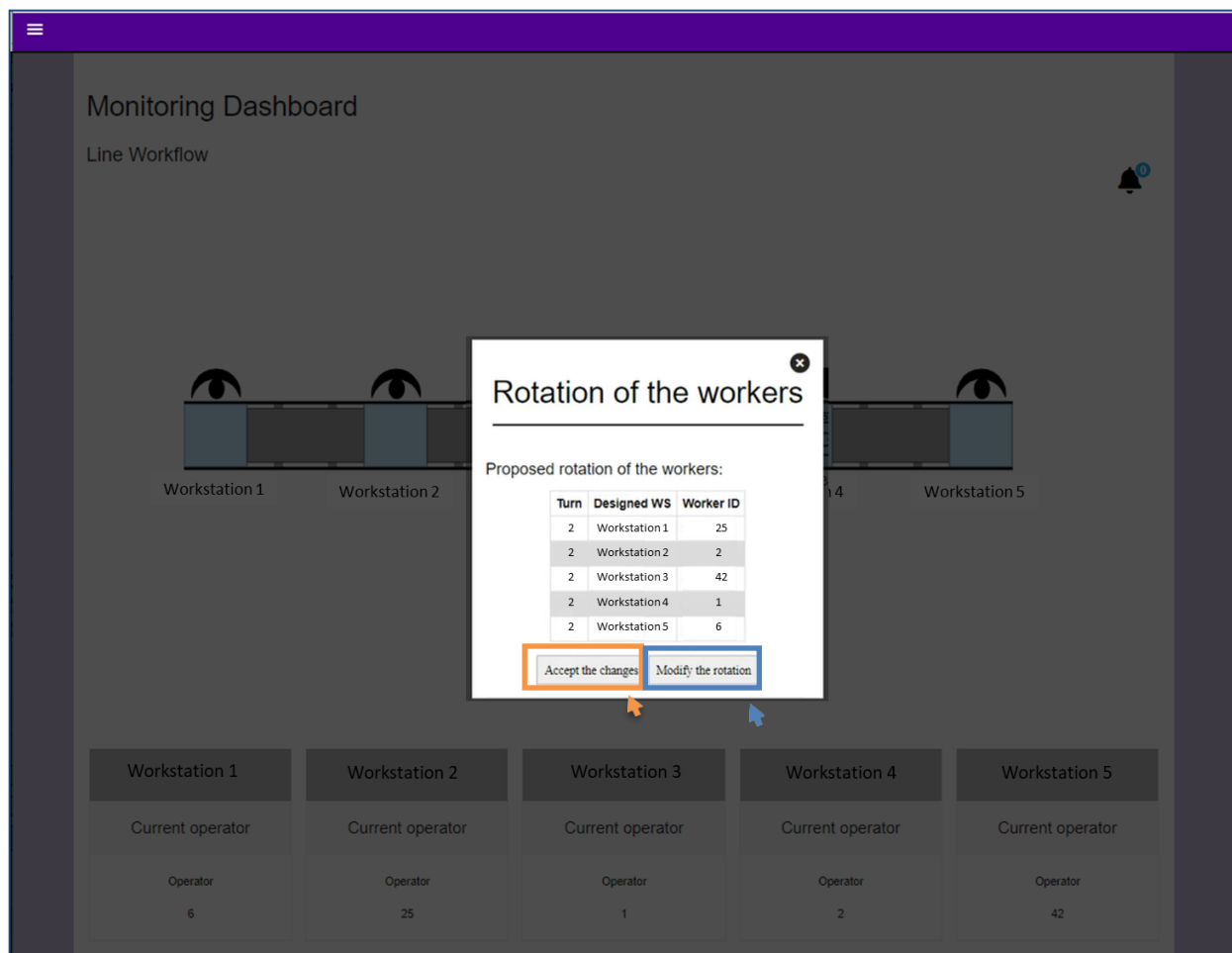
The monitoring dashboard main page has a 2D representation of the line that shows the state of the workstations (when they have busy with product or when they're not).

In the lower part, it shows the operators that should be working in those station. The names are going to be actualized eventually with the proposed rotation. The rotations are notified in the bell when the monitoring dashboard receives the notification that the workers should change their position (aiming for the well-being of the operators).

The bell will show the notifications that appear related to the confirmation or modification of the rotation and the replacement of workers. In case of the proposition of the new rotation:

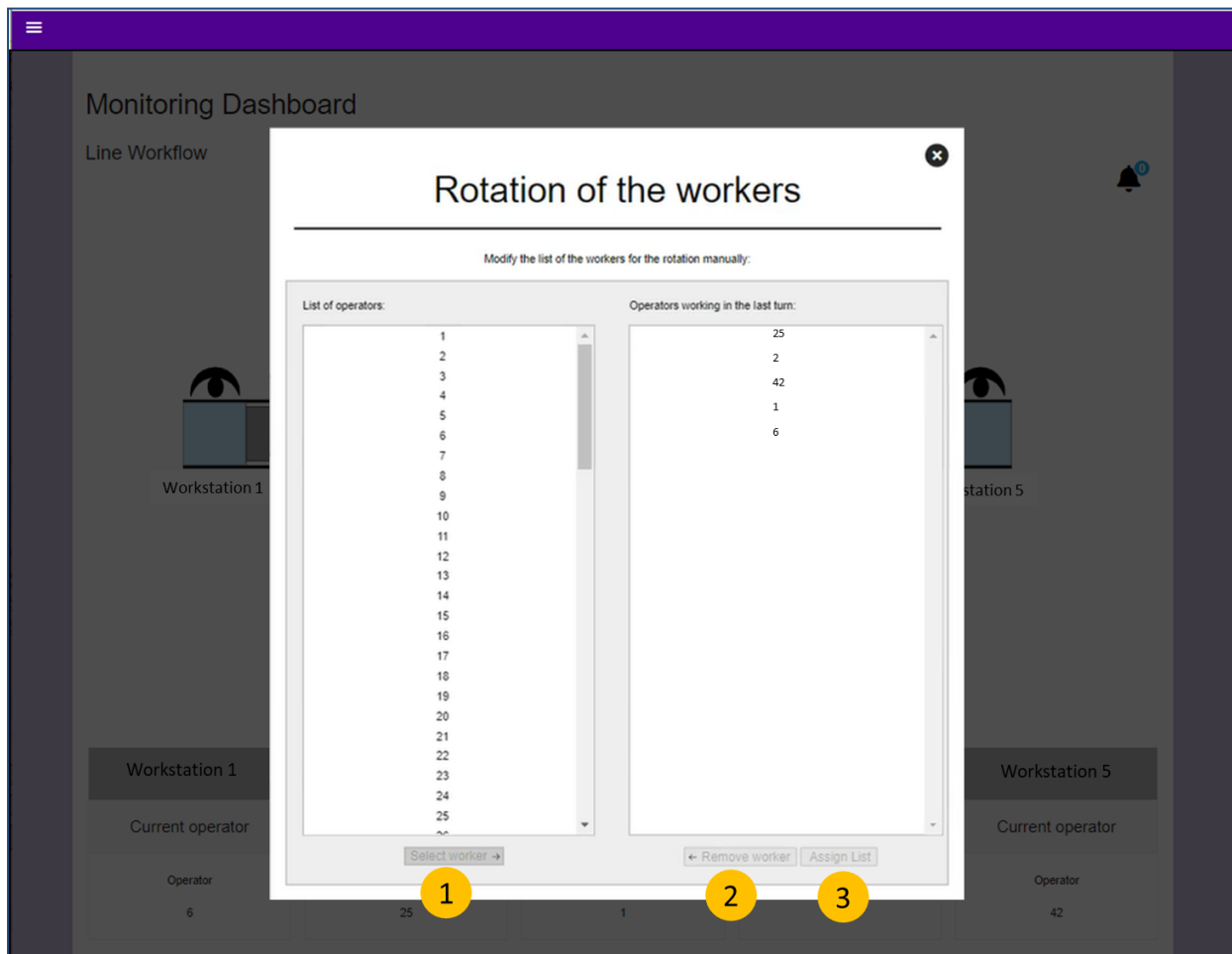


The user clicks in the notification and confirm or modify the rotation:



If the rotation is accepted, the user clicks in the “Accept the changes” button (orange square) and the operators name changes in the tables with the rotation of the workers (2.).

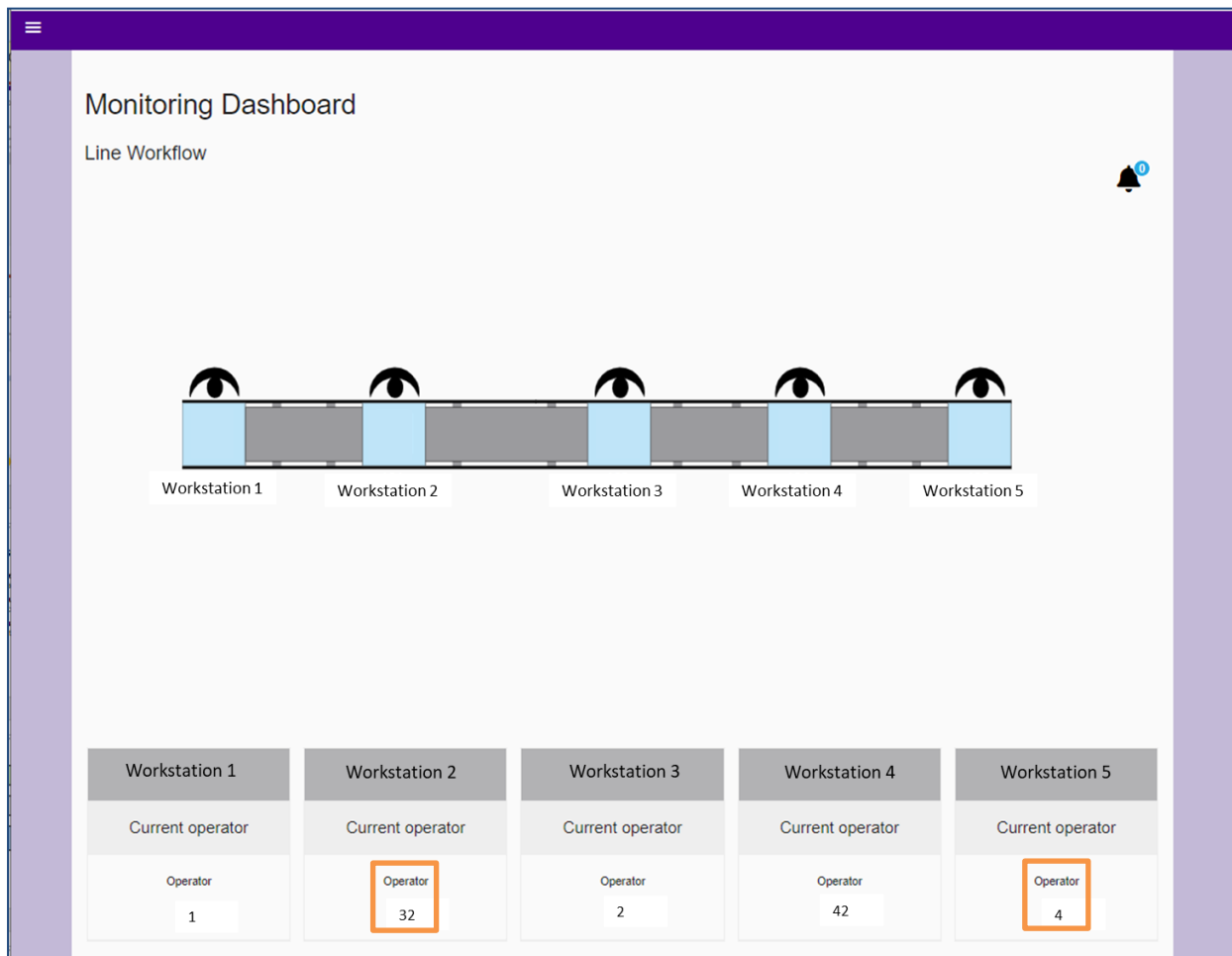
If the user needs to modify the rotation and replace a worker, click in the “Modify the rotation” button (blue):



A list with all the workers appears and let the user to replace some of the selected workers. The selected operator takes the place of the replaced in the rotation.

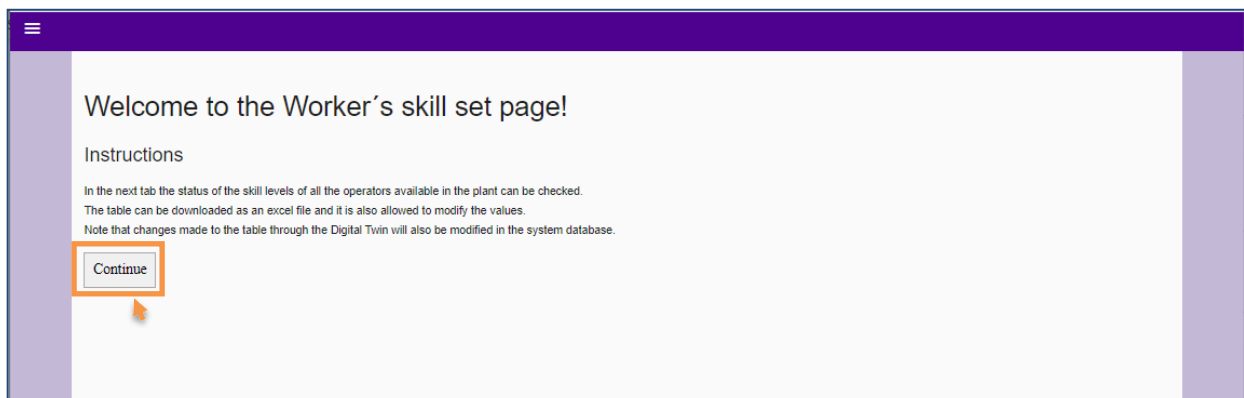
1. Select worker button to move a worker into the list to be assigned.
2. Return worker button to remove an operator from the list to be assigned.
3. Assign list button.

Once the user clicks in the "Assign list" button, the new rotation is confirmed, and the changes can be seen in tables with the rotation of the workers.



### Worker's skill set

In this tab the user can check the operator's skill level for each workstation and modify it if the worker has more experience. In these ways skills can easily be kept up to date.





Select a worker

-- Select --

Select a workstation

-- Select --

Apply ChangesExport Table Data To Excel File

The changes made are saved and updated in the database as well.

Additionally, the user can download the table in excel format.