

trinity

# DYNAMIC TASK PLANNING & WORK RE-ORGANIZATION TUTORIAL

Laboratory of Manufacturing Systems and Automation (LMS)

 [www.trinityrobotics.eu](http://www.trinityrobotics.eu)



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# Pre-requisites

- Operating system: Linux Ubuntu 16.04
- Software components required:
  - ROS Kinetic.
  - Gazebo simulation engine 10.
  - Development environment JDK 13.
  - Apache Tomcat 9.
  - Docker Engine for Linux Ubuntu 16.04.
  - Web browser (Firefox, Chrome etc.).
  - Selected robots ROS controllers for simulated motions' execution.
  - Gradle build tool for Ubuntu Linux 16.04.
  - GZWeb software for GAZEBO simulation visualization in a Web browser tab.
- Minimum desktop related hardware requirements:
  - CPU: Intel Core i7 10th Generation.
  - Disk: SSD 250 GB.
  - RAM: 32 GB.
  - GPU: NVIDIA GTX 1050.



## Overview of the module features

Task planner module provides a User Interface for production manager's interaction with the task planner in order to:

- ✓ Initialize task plans creation and evaluation parameters.
- ✓ Visually check the top 3 task plan alternatives generated by the task planner.
- ✓ Select the best alternative and save the task plan for execution in the physical environment.



# Pre-installation Tasks

- Check ROS 1 Kinetic and Gazebo simulation engine 10 installation.
- Create the GAZEBO world for the selected use case layout.
- Launch GAZEBO world file and robot resources with the corresponding ROS controllers.
- Add the "Pick", "Place" and "Navigation" frames in ROS TF tree to be used for objects' manipulation in the simulated environment.





# Installation Procedure

1. Receive Task Planner module docker image project from LMS.
2. Set your account credentials to build the docker image as received by LMS under the main gradle.properties file.
3. Place Task Planner docker image project in linux home folder.
4. Connect to internet.
5. Build received project for Docker. The commands that should be executed in a linux terminal to build the task planner module are presented in the next slide.



# Installation Procedure

Step	User	Command to execute	Remarks
1	Linux user	cd task_planner_parent	
2	Linux user	sudo ./gradlew clean	
3	Linux user	sudo ./gradlew war	
4	Linux user	sudo ./gradlew installDist	
5	Linux user	sudo ./gradlew docker_system_trinity:prepareForDockerImage	In case of building errors try to execute again commands 3,4 and 5. In case that the errors still exist, contact product provider for support.
6	Linux user	sudo ./gradlew copyInstallToExternalDirectory	



# Database

- Edit an excel file about:
  - The available resources for tasks' allocation to be used by the task planner.
  - Which resources are capable to execute each task and how many time the operator need to execute these tasks in the current manual assembly operation.
  - The "Pick", "Place" and "Navigation" frames to be used by the task planner for tasks' simulated execution and validation.
- Edit a Java file by adding the actions for each human and robot task to be used during the task planning process. In each action, the "Pick", "Place" or "Navigation" frame to be used as reference for mobile robots' navigation or fixed robots' motion is defined.



# Systems

Installation done by user administrator.

# Configuration

Configure task planner ROS action servers based on the MoveIt configuration files used and the "Pick", "Place" and "Navigate" frame defined in the excel and json files by the user.





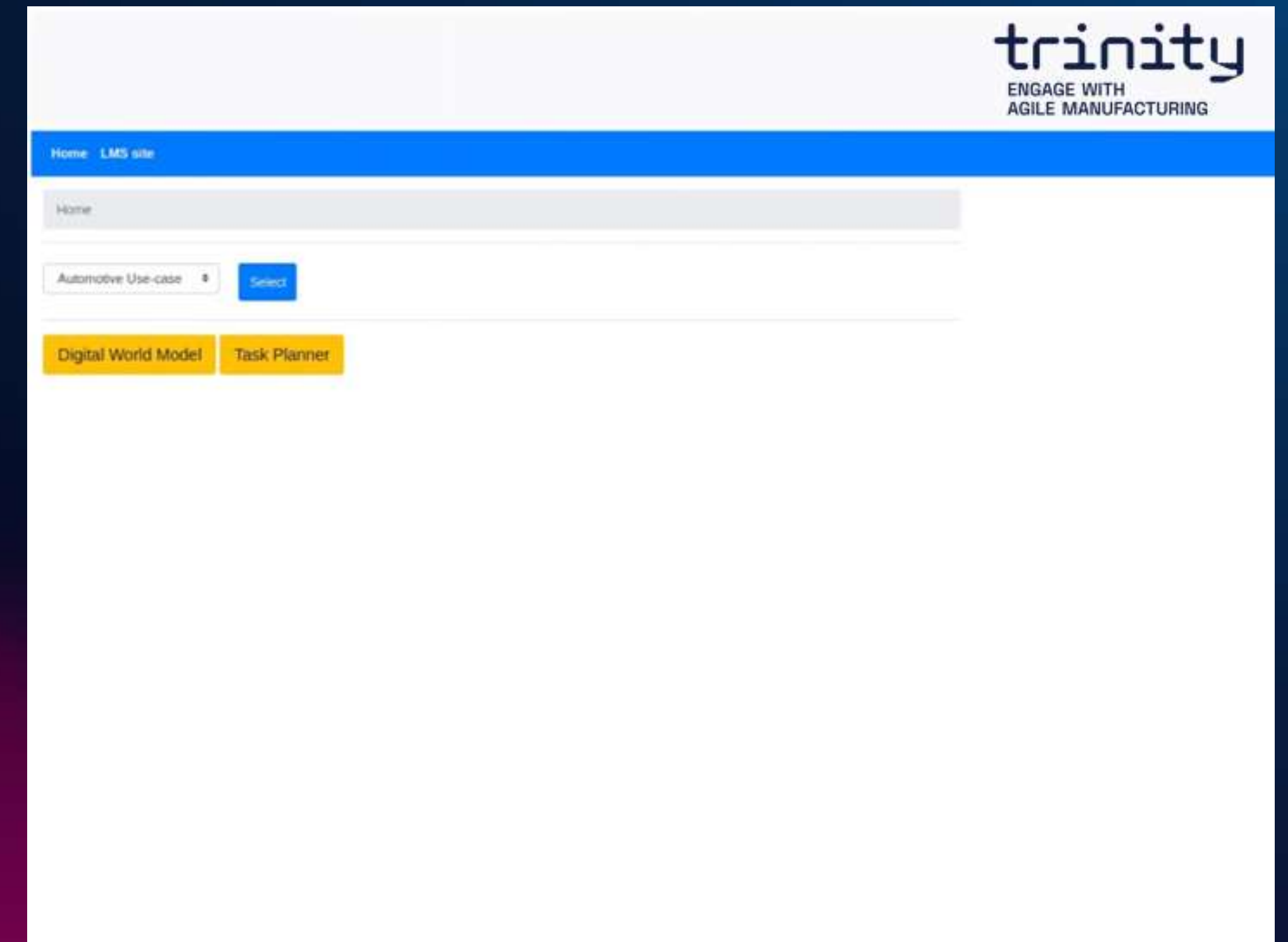
# Execution

1. Prepare ROS environment for the task planner.
  - i. Launch GAZEBO simulator with the required .world file and resources (Human, Robots).
  - ii. Launch robots' ROS controllers and MoveIt for robots' motion planning.
  - iii. Launch a list of action servers for communication between the GAZEBO simulator and the Task Planner module.
  - iv. Launch ROS nodes for assembly actions' execution time duration calculation.
  - v. Launch GZWeb on <http://127.0.0.1:65200>.



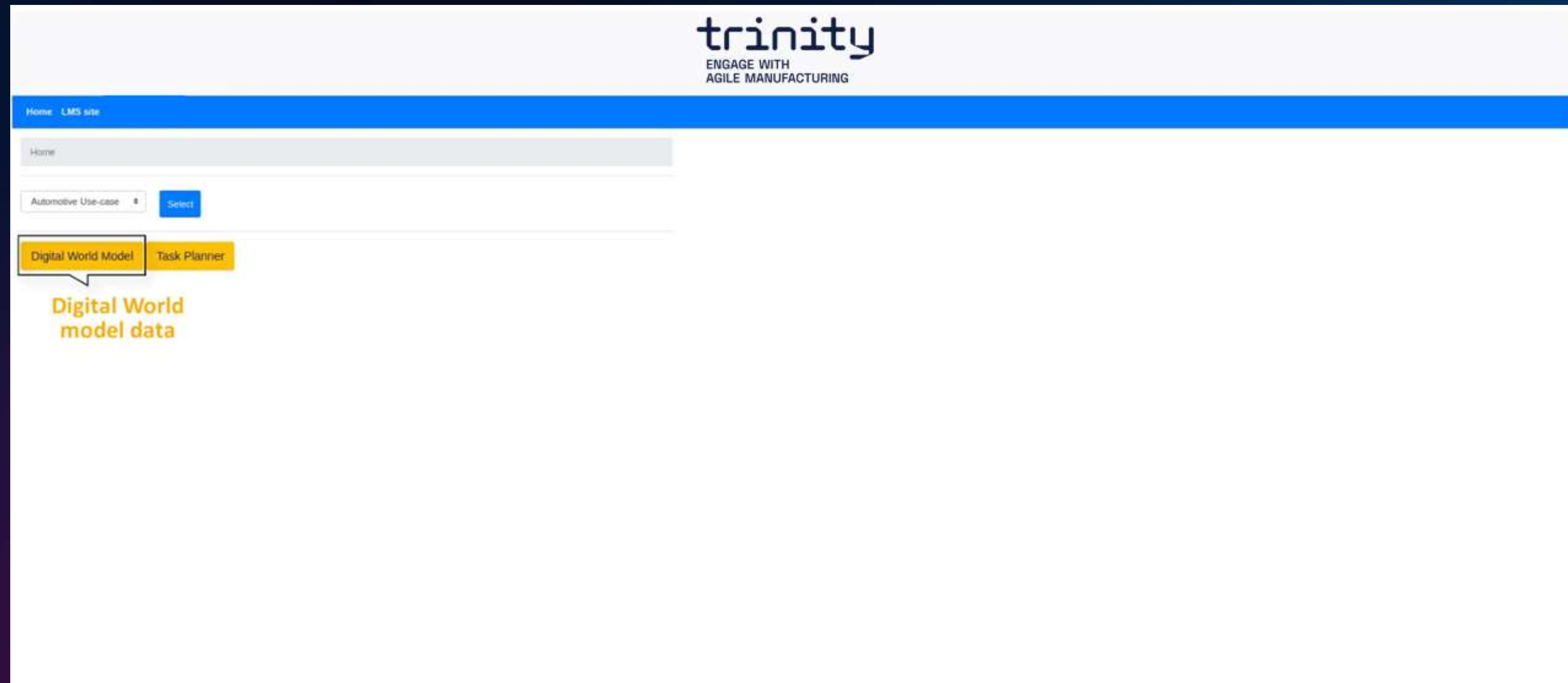
# Execution

1. Start the task planner with running the following commands in linux terminal:
  1. `cd task_planner_parent/docker_system_trinity/build/docker`
  2. `sudo docker-compose up --build --remove-orphans --force-recreate`
2. Fill the database of the task planner module with the required data for planning.
  1. `cd ~/task_planner_parent`
  2. `./gradlew data_entry_trinity:run`
3. CONTROL + C to close the data entry script.
4. Open a web browser (Chrome, Firefox etc.) and go to: <http://127.0.0.1:8081/taskPlanner>



# Execution

5. Go to "Digital World Model" tab to check the loaded data of the Digital World model.



# Execution

6. Go to "Workstations" tab to check the loaded data about the available workstations.

The screenshot shows the Trinity LMS interface. At the top, the Trinity logo is displayed with the tagline "ENGAGE WITH AGILE MANUFACTURING". Below the logo, there is a navigation bar with "Home" and "LMS site" links. A breadcrumb trail shows "Home / Digital World Model". On the left, a "Model:" menu is visible with three options: "Workstations" (highlighted with a yellow box), "Tasks", and "Resources". The main content area is titled "Workstations" and contains a table with the following data:

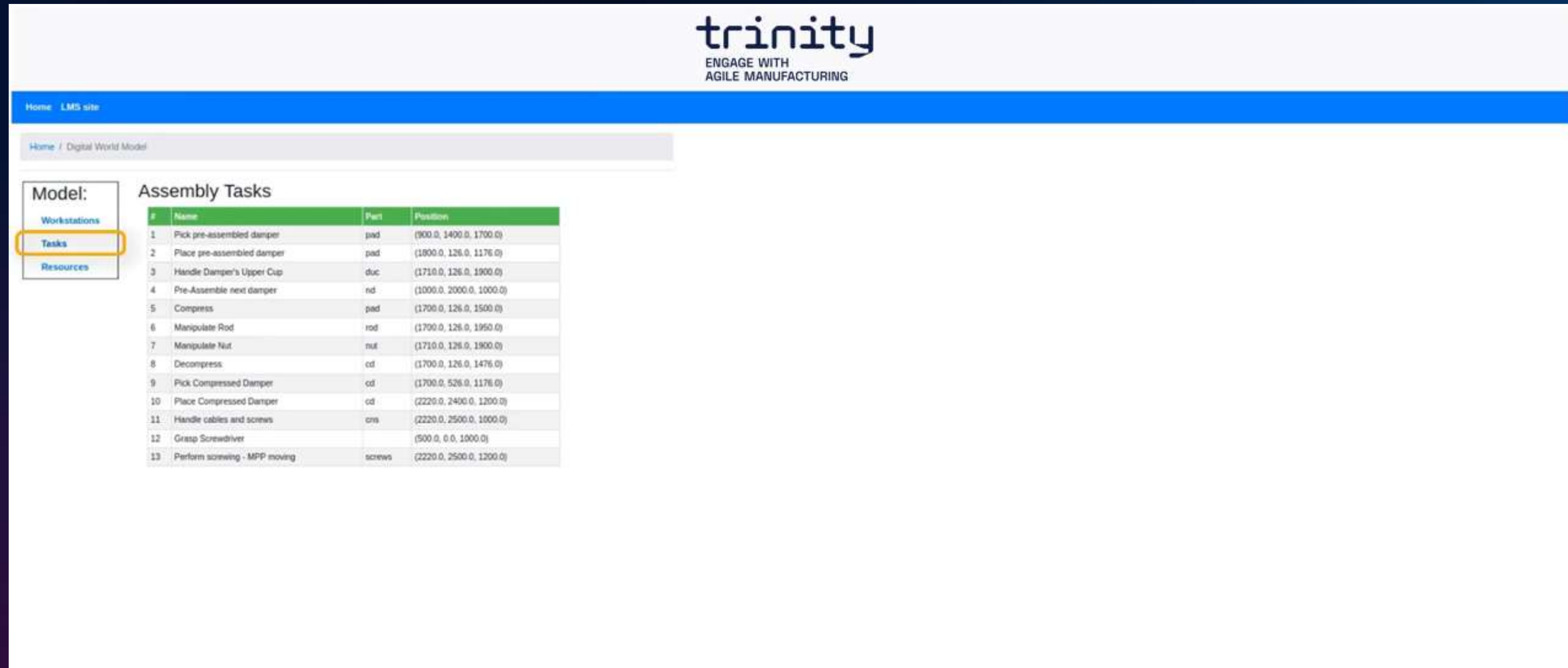
Workstation	Working Area	Abbreviation
Damper Assembly Station	Pre-Assembly Table	PT
Damper Assembly Station	Compression Machine	CM
General Assembly Station	Mobile Product Platform	MPP
Recharge Station	Battery Recharger	BR





# Execution

7. Go to "Tasks" tab to check the loaded data about the assembly tasks.



The screenshot displays the Trinity LMS interface. At the top, the Trinity logo is accompanied by the tagline 'ENGAGE WITH AGILE MANUFACTURING'. Below the logo, a navigation bar includes 'Home' and 'LMS site'. A breadcrumb trail shows 'Home / Digital World Model'. On the left, a 'Model:' sidebar contains three tabs: 'Workstations', 'Tasks' (highlighted with a yellow box), and 'Resources'. The main content area, titled 'Assembly Tasks', features a table with 13 rows of task data.

#	Name	Part	Position
1	Pick pre-assembled damper	pad	(900.0, 1400.0, 1700.0)
2	Place pre-assembled damper	pad	(1800.0, 126.0, 1176.0)
3	Handle Damper's Upper Cup	duc	(1710.0, 126.0, 1900.0)
4	Pre-Assemble next damper	nd	(1000.0, 2000.0, 1000.0)
5	Compress	pad	(1700.0, 126.0, 1500.0)
6	Manipulate Rod	rod	(1700.0, 126.0, 1950.0)
7	Manipulate Nut	nut	(1710.0, 126.0, 1900.0)
8	Decompress	cd	(1700.0, 126.0, 1476.0)
9	Pick Compressed Damper	cd	(1700.0, 526.0, 1176.0)
10	Place Compressed Damper	cd	(2220.0, 2400.0, 1200.0)
11	Handle cables and screws	crs	(2220.0, 2500.0, 1800.0)
12	Grasp Screwdriver		(500.0, 0.0, 1000.0)
13	Perform screwing - MPP moving	screws	(2220.0, 2500.0, 1200.0)



# Execution

8. Go to "Resources" tab to check the loaded data about the available resources.



trinity  
ENGAGE WITH  
AGILE MANUFACTURING

Home LMS site

Home / Digital World Model

Model:

- Workstations
- Tasks
- Resources

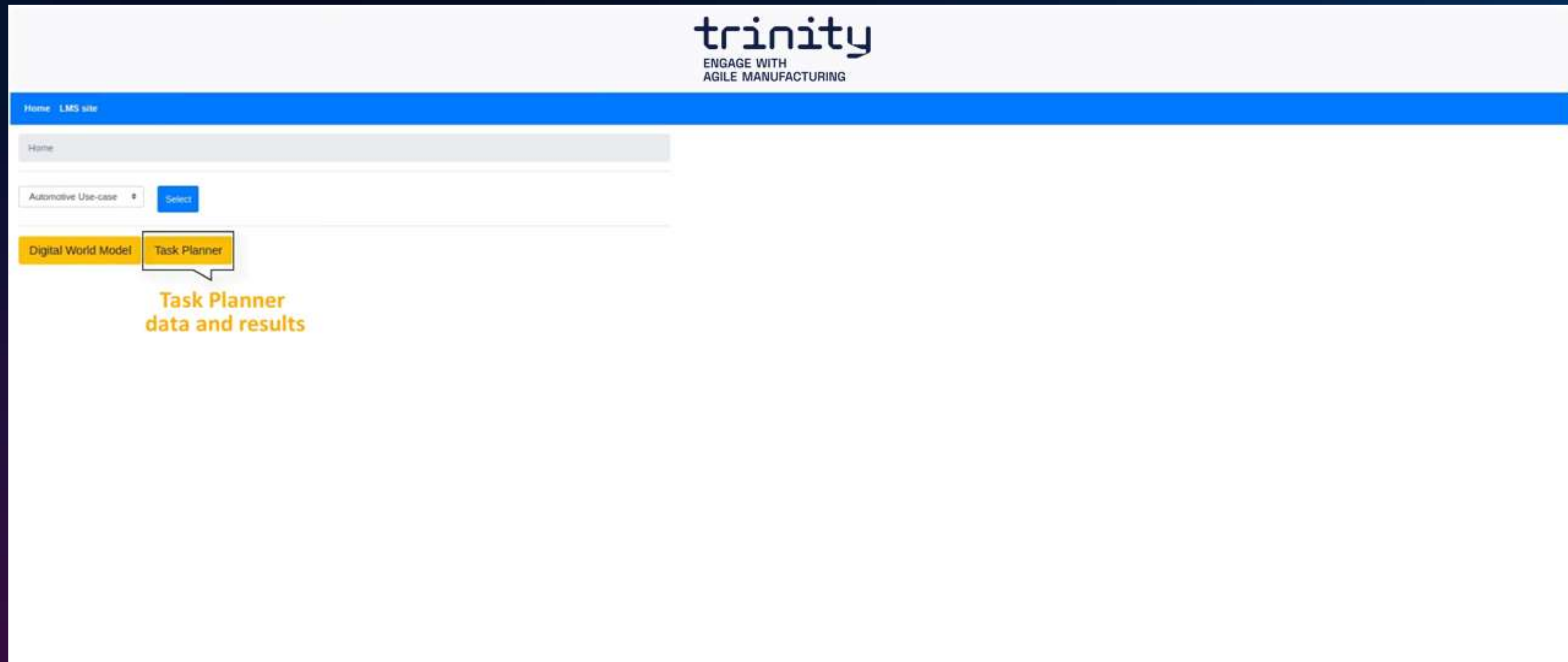
### Available Resources

#	Name	Speed (m/s)	Max Payload (kg)
1	Human	0.8	20
2	MRP	2	20
3	Compression Machine	0	100
4	WaitServer	0	0



# Execution

9. Go to back to the starting page and navigate to "Task Planner" tab to initialize the task planner module and check the planning results.



# Execution

10. Initialize the task planning parameters' values. More information for each parameter will be provided by LMS together with the Task Planner module.

The screenshot displays the Trinity Task Planner interface. At the top, the Trinity logo is accompanied by the tagline "ENGAGE WITH AGILE MANUFACTURING". Below this, a blue navigation bar contains "Home" and "LMS site". A breadcrumb trail shows "Home / Task Planner".

The main content area is divided into two sections:

- Parameter values:** This section, highlighted with a yellow border, contains four sliders:
  - Maximum Number of Alternatives: 6
  - Decision Horizon: 7
  - Search Rate: 9
  - Number of plans: 3
- Plan Evaluation:** This section contains several toggle switches and sliders:
  - Total Flowtime (checked), Weight: 50%
  - Payload handled by human (checked), Weight: 70%
  - Human Busy time (checked), Weight: 50%
  - Distance Covered (checked), Weight: 30%
  - Non-Adding values act. time (unchecked), Weight: 20%
  - Utilization of Resources (unchecked), Weight: 20%
  - Simulator Enabled (unchecked)
  - Manual Compression (unchecked)

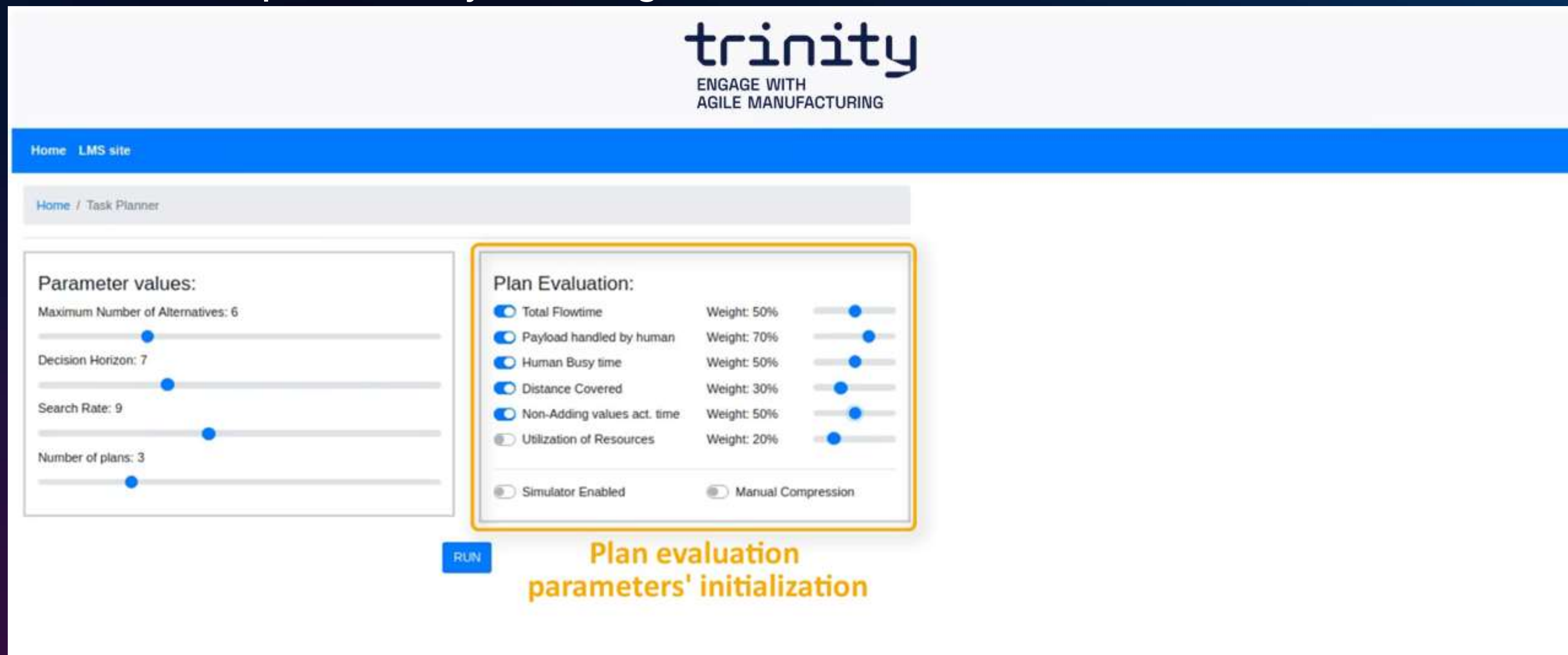
At the bottom of the parameter section, the text "Task planner parameters' initialization" is displayed in orange, followed by a blue "RUN" button.





# Execution

11. Initialize the task planning evaluation parameters' values. More information for each parameter to be provided by LMS together with the Task Planner module.



The screenshot displays the Trinity Task Planner interface. At the top, the Trinity logo is accompanied by the tagline "ENGAGE WITH AGILE MANUFACTURING". Below this, a navigation bar shows "Home" and "LMS site". The main content area is titled "Home / Task Planner".

On the left, a "Parameter values:" section contains four sliders with the following values: "Maximum Number of Alternatives: 6", "Decision Horizon: 7", "Search Rate: 9", and "Number of plans: 3".

On the right, a "Plan Evaluation:" section is highlighted with a yellow border. It lists several parameters with their respective weights and toggle switches:

- Total Flowtime: Weight: 50%
- Payload handled by human: Weight: 70%
- Human Busy time: Weight: 50%
- Distance Covered: Weight: 30%
- Non-Adding values act. time: Weight: 50%
- Utilization of Resources: Weight: 20%
- Simulator Enabled: (toggle switch)
- Manual Compression: (toggle switch)

Below the sliders, a blue "RUN" button is visible. At the bottom center, the text "Plan evaluation parameters' initialization" is displayed in yellow.



# Execution

12. Start the task planner algorithm using the "Run" button.

The screenshot displays the Trinity Task Planner interface. At the top, the Trinity logo is accompanied by the tagline "ENGAGE WITH AGILE MANUFACTURING". Below this, a navigation bar shows "Home" and "LMS site". The main content area is titled "Home / Task Planner" and is divided into two sections: "Parameter values" and "Plan Evaluation".

**Parameter values:**

- Maximum Number of Alternatives: 6
- Decision Horizon: 7
- Search Rate: 9
- Number of plans: 3

**Plan Evaluation:**

- Total Flowtime (Weight: 50%)
- Payload handled by human (Weight: 70%)
- Human Busy time (Weight: 50%)
- Distance Covered (Weight: 30%)
- Non-Adding values act. time (Weight: 50%)
- Utilization of Resources (Weight: 20%)

Additional settings:  Simulator Enabled,  Manual Compression.

At the bottom center, there is a prominent blue "RUN" button with the text "Run Task Planner algorithm" below it.



# Execution

13. Wait for task plans generation, validation and evaluation.

The screenshot shows a software interface for task plan generation and evaluation. A modal window titled "Generated Alternatives:" is open, showing a "Choose alternative:" dropdown and a yellow progress bar labeled "RUNNING". A red "Close" button is visible in the bottom right of the modal. A yellow callout box points to the modal with the text "Task Plans generation, validation and evaluation".

The main interface has a "Home" button in the top left. Below it, there are two main sections:

- Parameter values:** Includes sliders for "Maximum Number of Alternatives: 6", "Decision Horizon: 7", "Search Rate: 9", and "Number of plans: 3".
- Plan Evaluation:** Includes a table of evaluation criteria with weights and sliders, and two checkboxes: "Simulator Enabled" and "Manual Compression".

A blue "RUN" button is located at the bottom center of the interface.





# Execution

14. Use "Choose alternative" tab to view the top 3 generated alternatives.

The screenshot displays the TRINITY software interface. On the left, there are sliders for 'Parameter values' (Maximum Number of Alternatives: 6, Decision Horizon: 7, Search Rate: 9, Number of plans: 3) and a 'RUN' button. On the right, the 'Plan Evaluation' section shows various criteria with weights and checkboxes. A modal window titled 'Generated Alternatives' is open, showing a table of 'Top ranked plans' criteria means. A dropdown menu 'Choose alternative' is open, listing 'Plan 1', 'Plan 2', and 'Plan 3'. A yellow box highlights the 'Alternative Task Plans visualization' button. A 'Close' button is visible in the bottom right of the modal window.

Flowtime (min)	Accumulative weight handled humans (kg)	Delay time (min)	Distance covered (m)	NAVAT (min)	Utilization of Resources (%)
7.82	26.23	2.89	16.66	0.67	40.19





# Execution

15. Choose an alternative task plan to check useful information (Flowtime, Human busy time, Distance covered by each resource, Resource Utilization etc.)

Generated Alternatives: [Choose alternative](#)

Top ranked plans' criteria mean values:

Flowtime (min)	Accumulative weight handled by humans (kg)	Human busy time (min)	Distance covered (m)	NAVAT (min)	Utilization of Resources (%)
7.82	26.23	2.89	16.66	0.67	40.19

Plan 2: [View Gazebo simulation](#) [Save plan for execution](#)

Flowtime (min)	Accumulative weight handled by humans (kg)	Human busy time (min)	Distance covered (m)	NAVAT (min)	Utilization of Resources (%)
7.02	26.30	2.98	17.16	0.67	40.93

#	Task	Resource	Dispatch date	Duration (sec)	Working Area
1	Pick pre-assembled damper	Human	25 Feb 2021 11:38:37	9	PT
2	Place pre-assembled damper	Human	25 Feb 2021 11:38:46	10	CM
3	Handle Damper's Upper Cup	Human	25 Feb 2021 11:38:56	20	CM
4	Pre-Assemble next damper	Human	25 Feb 2021 11:39:16	21	PT
5	Compress	Compression Machine	25 Feb 2021 11:39:16	15	CM
6	Manipulate Rod	MRP	25 Feb 2021 11:39:31	78	CM
7	Manipulate Nut	Human	25 Feb 2021 11:40:49	8	CM
8	Decompress	Compression Machine	25 Feb 2021 11:40:57	15	CM
9	Pick Compressed Damper	Human	25 Feb 2021 11:41:12	8	CM
10	Place Compressed Damper	Human	25 Feb 2021 11:41:20	13	MPP
11	Handle cables and screws	Human	25 Feb 2021 11:41:33	90	MPP
12	Grasp Screwdriver	MRP	25 Feb 2021 11:41:33	75	MPP
13	Perform screwing - MPP moving	MRP	25 Feb 2021 11:43:03	155	MPP



# Execution

16. Use the "View Gazebo simulation" tab to visually check a generated task plan.

The screenshot displays a software interface for task plan generation. A modal window titled "Generated Alternatives:" is open, showing a table of metrics for top-ranked plans. Below this, "Plan 3:" is highlighted, with a callout box stating "Send a Task Plan for execution in the simulated environment". A "View Gazebo simulation" button is visible above the task plan table. The task plan table lists 13 tasks with their respective resources, dispatch dates, durations, and working areas.

Flowtime (min)	Accumulative weight handled by humans (kg)	Human busy time (min)	Distance covered (m)	NAVAT (min)	Utilization of Resources (%)
7.82	26.23	2.89	16.66	0.67	40.19

Flowtime (min)	Accumulative weight handled by humans (kg)	Human busy time (min)	Distance covered (m)	NAVAT (min)	Utilization of Resources (%)
8.22	26.23	2.89	16.66	0.67	39.82

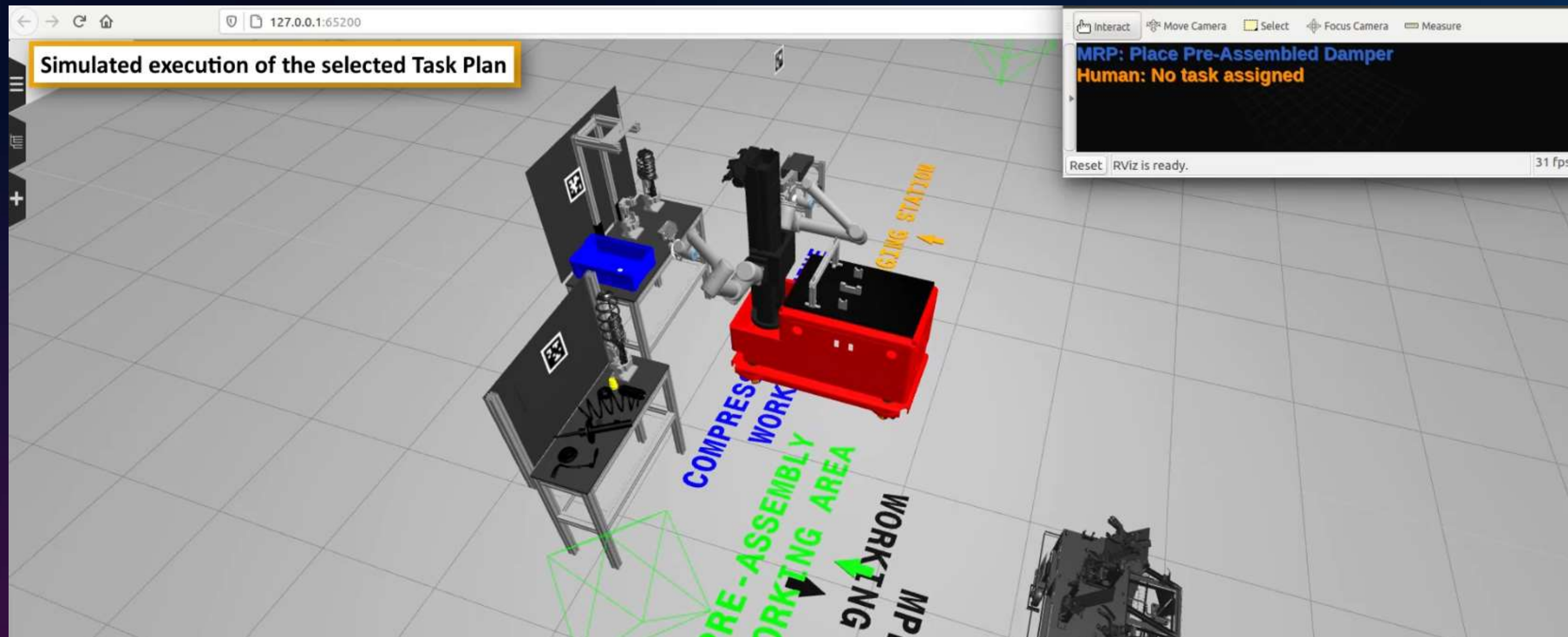
#	Task	Resource	Dispatch date	Duration (sec)	Working Area
1	Pick pre-assembled damper	MRP	25 Feb 2021 11:38:38	9	PT
2	Place pre-assembled damper	MRP	25 Feb 2021 11:38:47	10	CM
3	Handle Damper's Upper Cup	Human	25 Feb 2021 11:38:57	20	CM
4	Pre-Assemble next damper	Human	25 Feb 2021 11:39:17	21	PT
5	Compress	Compression Machine	25 Feb 2021 11:39:17	15	CM
6	Manipulate Rod	MRP	25 Feb 2021 11:39:32	78	CM
7	Manipulate Nut	MRP	25 Feb 2021 11:40:50	60	CM
8	Decompress	Compression Machine	25 Feb 2021 11:42:10	15	CM
9	Pick Compressed Damper	MRP	25 Feb 2021 11:42:25	8	CM
10	Place Compressed Damper	MRP	25 Feb 2021 11:42:33	13	MPP
11	Handle cables and screws	Human	25 Feb 2021 11:42:46	90	MPP
12	Grasp Screwdriver	MRP	25 Feb 2021 11:42:46	75	MPP
13	Perform assembly - MPP machine	MPP	25 Feb 2021 11:44:16	155	MPP





# Execution

17. Visually check a generated task plan using GZWeb software.



# Execution

18. Use the "Save plan for execution" button to save selected task plan in the database for execution in the physical environment.

The screenshot shows a software interface with a 'Generated Alternatives' dialog box. The dialog displays 'Top ranked plans' criteria mean values' and 'Plan 3' details. A yellow callout box highlights the 'Save plan for execution' button and the text 'Save selected Task Plan in the database for execution in the physical environment'.

**Generated Alternatives:** Choose alternative: ▾

**Top ranked plans' criteria mean values:**

Flowtime (min)	Accumulative weight handled by humans (kg)	Human busy time (min)	Distance covered (m)	NAVAT (min)	Utilization of Resources (%)
7.82	26.23	2.89	16.66	0.67	40.19

**Plan 3:** View Gazebo simulation Save plan for execution

**Save selected Task Plan in the database for execution in the physical environment**

Flowtime (min)	Accumulative weight handled by humans (kg)	Human busy time (min)	Distance covered (m)	NAVAT (min)	Utilization of Resources (%)
8.22	26.20	2.85	16.41	0.67	38.82

#	Task	Resource	Dispatch date	Duration (sec)	Working Area
1	Pick pre-assembled damper	MRP	25 Feb 2021 11:38:38	9	PT
2	Place pre-assembled damper	MRP	25 Feb 2021 11:38:47	10	CM
3	Handle Damper's Upper Cup	Human	25 Feb 2021 11:38:57	20	CM
4	Pre-Assemble next damper	Human	25 Feb 2021 11:39:17	21	PT
5	Compress	Compression Machine	25 Feb 2021 11:39:17	15	CM
6	Manipulate Rod	MRP	25 Feb 2021 11:39:32	78	CM
7	Manipulate Nut	MRP	25 Feb 2021 11:40:50	80	CM
8	Decompress	Compression Machine	25 Feb 2021 11:42:10	15	CM
9	Pick Compressed Damper	MRP	25 Feb 2021 11:42:25	8	CM
10	Place Compressed Damper	MRP	25 Feb 2021 11:42:33	13	MPP
11	Handle cables and screws	Human	25 Feb 2021 11:42:46	90	MPP
12	Grasp Screwdriver	MRP	25 Feb 2021 11:42:46	75	MPP
13	Perform screwing - MPP moving	MRP	25 Feb 2021 11:44:16	155	MPP





# Execution

19. Specify the name of the saved task plan in the database.

The screenshot displays a software interface for task planning. On the left, there are sliders for 'Parameter values' such as 'Maximum number of Alternatives: 6', 'Decision Horizon: 7', 'Search Rate: 9', and 'Number of plans: 3'. A 'RUN' button is visible below these sliders. The main area shows 'Generated Alternatives' with a table of 'Top ranked plans' criteria mean values. Below this, 'Plan 3' is detailed with a table of tasks, resources, dispatch dates, durations, and working areas. A modal window is open over the task table, allowing the user to specify a name for the saved task plan, with a 'Save' button. A yellow callout box points to this modal with the text: 'Specify the name of the saved Task Plan in the database'.

Generated Alternatives: Choose alternative: ▾

Top ranked plans' criteria mean values:

Flowtime (min)	Accumulative weight handled by humans (kg)	Human busy time (min)	Distance covered (m)	NAVAT (min)	Utilization of Resources (%)
7.82	26.23	2.89	16.66	0.67	40.19

Plan 3: View Gazebo simulation Save plan for execution

Flowtime (min)	Accumulative weight handled by humans (kg)	Human busy time (min)	Distance covered (m)	NAVAT (min)	Utilization of Resources (%)
8.22	26.20	2.85	16.41	0.67	39.82

#	Task	Resource	Dispatch date	Duration (sec)	Working Area
1	Pick pre-assembled damper	Human	25 Feb 2021 11:38:38	9	PT
2	Place pre-assembled damper	Human	25 Feb 2021 11:38:47	10	CM
3	Handle Damper's Upper Cap	Human	25 Feb 2021 11:39:57	20	CM
4	Pre-Assemble next damper	Human	25 Feb 2021 11:39:17	21	PT
5	Compress	MRP	25 Feb 2021 11:40:50	80	CM
6	Manipulate Rod	Compression Machine	25 Feb 2021 11:42:10	15	CM
7	Manipulate Nut	MRP	25 Feb 2021 11:42:10	15	CM
8	Decompress	Compression Machine	25 Feb 2021 11:42:10	15	CM
9	Pick Compressed Damper	Human	25 Feb 2021 11:42:25	8	CM
10	Place Compressed Damper	Human	25 Feb 2021 11:42:33	13	MPP
11	Handle cables and screws	Human	25 Feb 2021 11:42:46	90	MPP
12	Grasp Screwdriver	MRP	25 Feb 2021 11:42:46	75	MPP
13	Perform screwing - MPP moving	MRP	25 Feb 2021 11:44:16	155	MPP

Specify the name of the saved Task Plan in the database



# Maintenance and Error Messages and Troubleshooting

In order to restart the Task Planner module, it is required to stop and remove any previous docker images and start again the Task Planner.



 [www.trinityrobotics.eu](http://www.trinityrobotics.eu)

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 [@TRINITY Robotics DIHs](https://www.linkedin.com/company/trinity-robotics)



# trinity

## Thank you!

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