# Sustainable Production Planning (SPP)

## *Application User Guide*

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# 1 Introduction

This Sustainable Production Planning (SPP) user guide explains how to interact with and use the SPP application to enable enhanced situational awareness of the operation planner for energy optimisation purposes.

The SPP is a tool developed by Idener[1] within the context of the DENiM project[2]. The main purpose of the tool is to enable our end user, Gorenje[3], to run predictions of the energy consumption for a specific machining operation. These predictions come from pre-trained machine-learning models for each of the available machines.

The application is prepared to integrate in a passive way with the company's Enterprise Resource Planning (ERP) system. A passive interaction means that the SPP application cannot freely or actively access information from the ERP for security and data privacy reasons. On the contrary, it exposes an API that allows the ERP to send only the relevant data with operational information.

Gorenje's operational information is mainly organised according to the following concepts:

**Working Order (WO)**. Top-level element of the manufacturing process organisation. A WO represents a full product and is related to a specific business order from a customer. WOs are identified with a unique ID within the company, consisting in a 5-digit number, e.g., '91501'.

**Position**. Each of the multiple elements in a WO. Each position represents an atomic part of the fully assembled product. Positions are also identified through an ID, e.g., '11001/0'.

**Operation**. The smallest part of the manufacturing process organisation representing one of the steps to manufacture a position. An operation is run on a specific machine, is time-measurable and is characterised by operational parameters. An example would be a drilling operation with ID '30000'. Operation IDs are not necessarily unique within the whole company.

# 2 User Interface

## 2.1 Application Access

The SPP is a web-based application, which means it needs to be accessed with a browser. Support is granted for the most common browsers: Google Chrome and Mozilla Firefox. Compatibility with other browsers is not validated.

[1] https://idener.ai
[2] DENiM is a Horizon 2020 initiative working on the optimisation of energy consumption for the industry (https://denim-fof.eu/)
[3] https://www.gorenje-orodjarna.si/

The web server is deployed within Gorenje's server, and available to Gorenje's workers through the local network. The application is exposed in port 40010 of the dedicated server, which means users can access through the URL *<server-IP-or-DNS>:40010*.

Additionally, and for development and debugging purposes, Idener has enabled remote access to the application by exposing it through a reverse proxy and assigning a public DNS. In this case, users outside Gorenje's local network can access the application at the link *https://spp-gorenje.dtenabler.com*.

From the security and user access point of view, there has been an agreement not to include authentication in this application. As the service does not allow accessing any sensitive information or modifying data from the company's own databases, it is safe to allow public access to the whole application and API. Additionally, the application is intended to be only accessible from the local network, which adds an additional security layer.

## 2.2 Pages

### 2.2.1 Navigation Flowchart

The application structure is relatively simple, with only five different pages. The following navigation flowchart governs the access to each page (Figure 1).

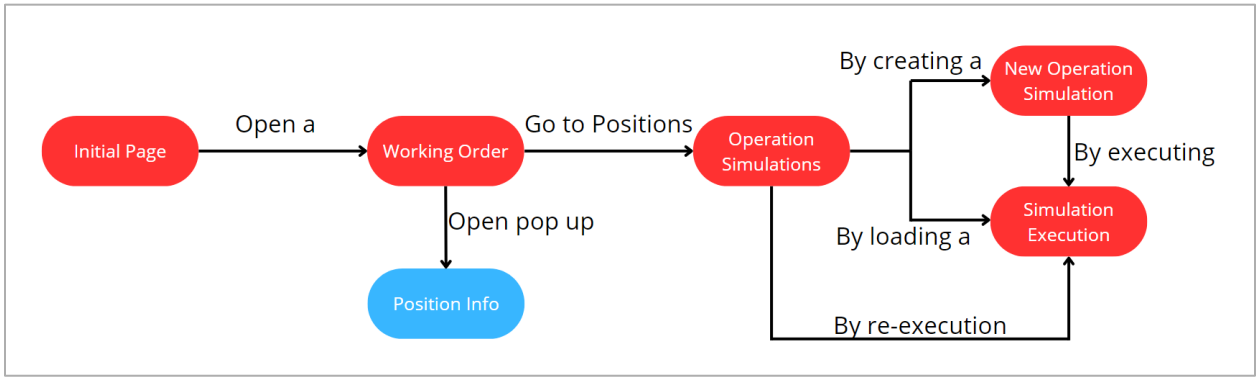


**Figure 1. Application structure and navigation flowchart**

Additional navigation can be achieved with the Back and Home buttons. The Back button will take the user to the previous page, while the Home button (application title at top-left cornet) returns to the Home page.

### 2.2.2 Home

The home page shows the different registered working orders, which have been received through input Working Orders API.

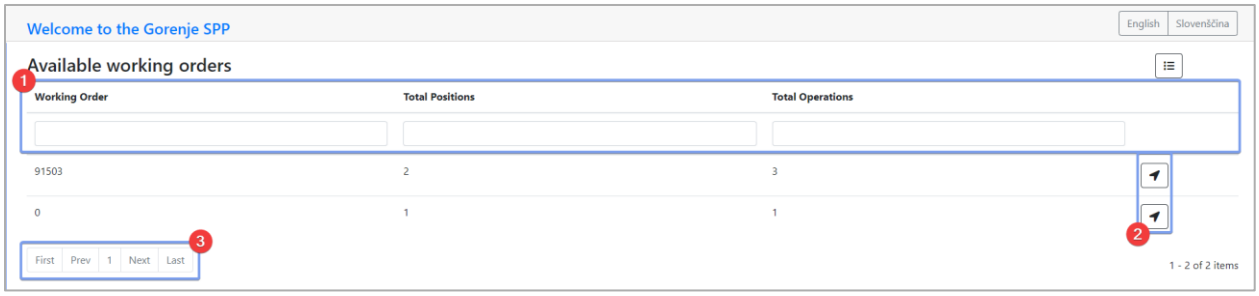


**Figure 2. SPP Home Page**

Elements according to the numbering in Figure 2:

1. Users can filter working orders based on the identification of the working order, the number of positions, and total operations. These filters can be combined.
2. The buttons inside this column will take the user to view the different positions of the selected working order.
3. The buttons below will help navigate all the registered working orders if there is more than one page to show.

### 2.2.3 Working Orders List

As previously mentioned, this page is accessible by clicking the button of each specific working order, showing all the different positions for a working order.

Users can also visualise the details of all the working orders at the same time by pressing the button on the Home page. This is especially useful for searching a specific working order by checking the inner details, such as the list of operations.

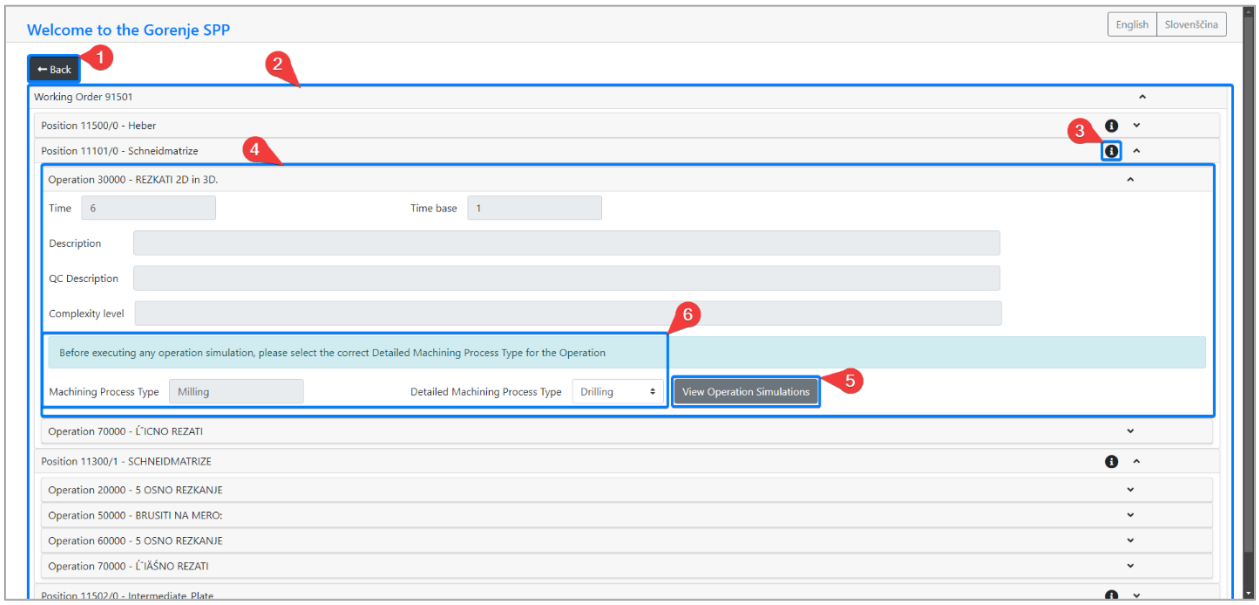


**Figure 3. Working Orders list page**

Elements according to the numbering in Figure 3:

1. Navigate to the previous page.
2. The accordion shows WOs, positions and operations in a set of collapsible headers and content.
3. This information button opens a pop-up window which contains information about the specific position, such as Material, Standard, width, etc. This is procedural information coming from the ERP. The user inputs specific operational parameters before running the predictions.

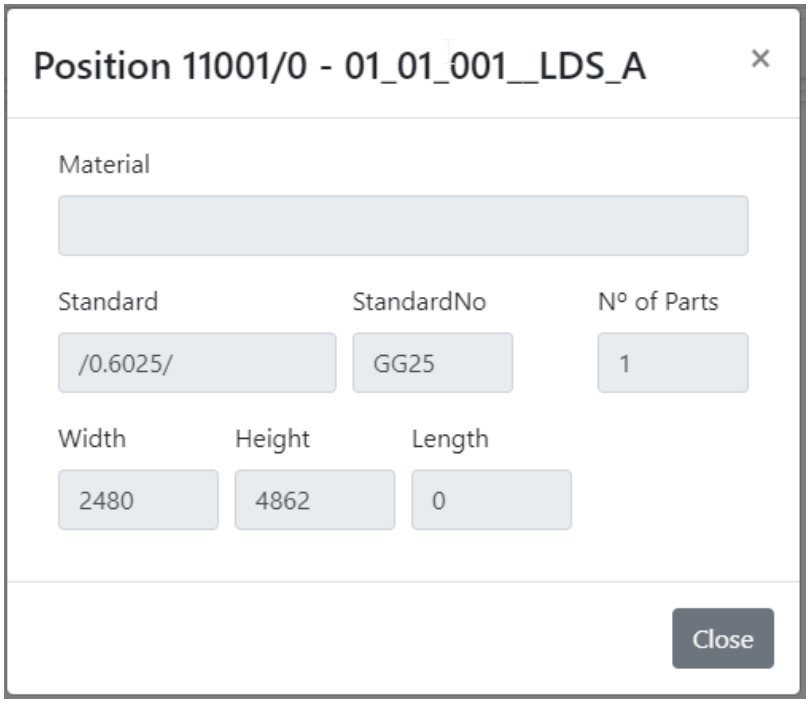


**Figure 4. Position information pop-up window**

4. Operational information about the position: Time, Timebase, Description, and Complexity level.
5. Button to navigate to the Operation Simulations related to this Operation.
6. The detailed machining process type needs to be set before executing any simulation (as the ERP system does not have this specific information and, therefore, it should be manually set by the user). After one simulation is done, this component will be fixed to the given value, and the message will disappear. The detailed machining process is a necessary input for the energy prediction models.

### 2.2.4 Operation Simulations for a Position

Operation Simulations that have been run before for a position operation inside a WO, each maintaining its configuration.

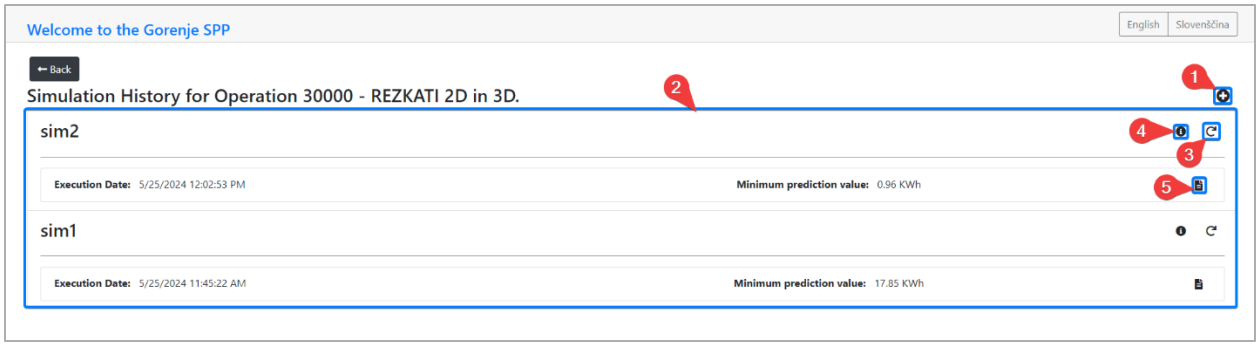


**Figure 5. Operation Simulations Page**

Elements according to the numbering in Figure 5:

1. Navigation to the New Operation Simulation page.
2. Record of all the different operation simulations created for the operation, with the minimum obtained prediction value for each execution.
3. Repeat simulation button that will repeat the same operation simulation with the same machines and configurations and automatically take the user to see the execution's result. The prediction models are automatically retrained to re-adapt themselves over time. This way, the same configuration for the same machines could have different estimation values from one execution to another.
4. Visualise configuration parameters for the simulation.
5. Go to simulation execution detailed results.

### 2.2.5 New Operation Simulation

The user can create and run a new operation simulation on this page that will be accessible later on the Operation Simulations Page.

The Operation type will delimit which machines are available to select in this view and, therefore, to make the predictions. Only machines belonging to that specific operation type and that have been used for model training (and are sensorised) are allowed to be selected.

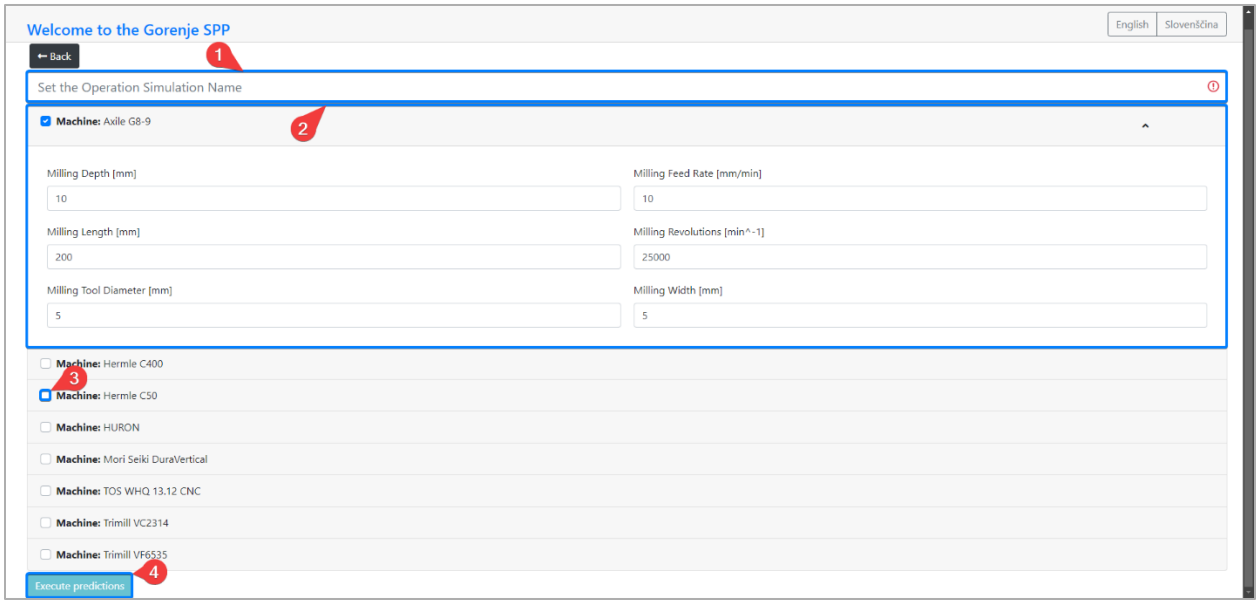


**Figure 6. New Operation Simulation page**

Elements according to the numbering in Figure 6:

1. Operation Simulation name. The user must provide a representative name to identify the operation simulation whenever the operation simulations page is accessed.
2. For each selected machine, the user can find the different machining parameters. If any prior simulation has been made for this process type, the parameters are initialised to those values. In case the user has manually changed or inputted parameters to another machine in this simulation, any newly selected machine will take those values as the default values. Normally, these values don't change significantly from one machine to another, providing a quick way for the user to fill in and prepare all the machine-level simulations.
3. The check fields are designed to select those machines to be compared.
4. Button to execute the energy predictions of the selected machines with the indicated parameters. Once this button is clicked, it will take the user to see the results of the predictions.

The SPP communicates with a prediction service in which each machine has a correspondent prediction model. A dedicated middleware API receives the prediction requests and forwards them with the correct format to the latest available version of each machine-specific model. If any prediction fails, an error message is received, and the user can attempt to run the prediction again.

### 2.2.6 Simulation Results

Please notice that this page does not have interactable components. It only allows the user to navigate backwards or see the parameter values of each machine.

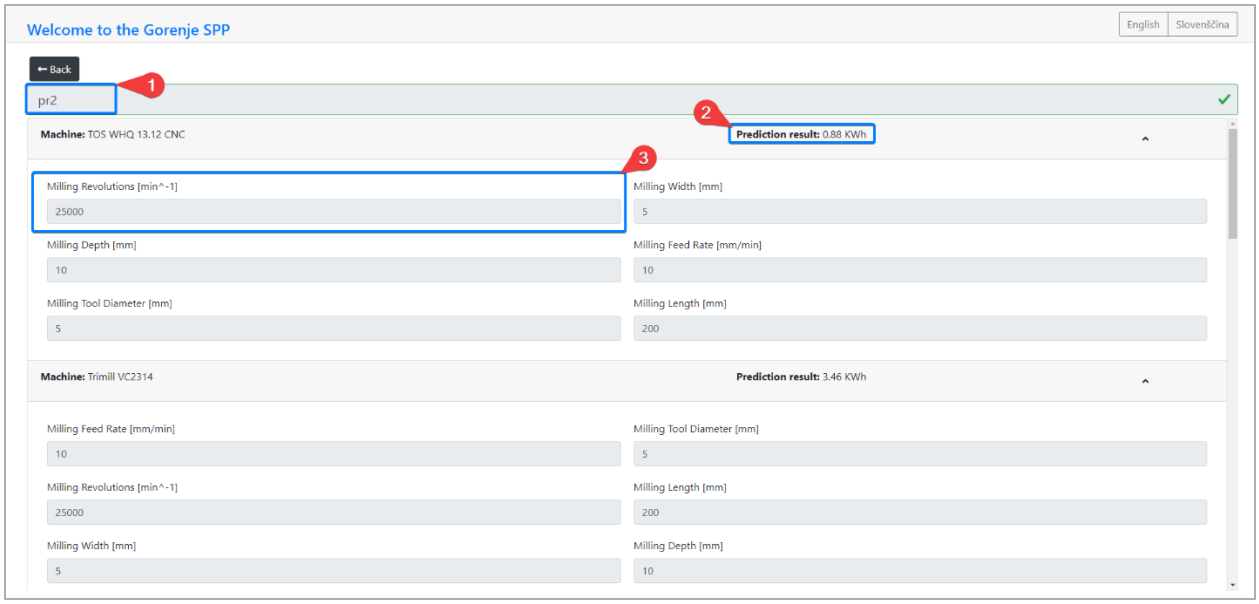


**Figure 7. Simulation results page**

Elements according to the numbering in Figure 7:

1. The name of the general operation simulation is not changeable. It comes from the manually entered name by the user during the simulation configuration
2. The prediction result indicates which will be the machine consumption for that machine given those parameter values. The machines are sorted in ascending order by the estimated prediction result, meaning that the top one is the most efficient for this specific operation.
3. The user can see the input parameter values only as informative data.

Please notice that only the selected machines will appear, as they are the only ones with values to be shown.

## 2.3 Language

SPP users can switch languages between English and Slovenian by using the language switch at the top-right corner of any page of the application. This affects labels, and buttons, but not user-filled information.

# 3 WorkingOrders API

The SPP tool exposes a public API to enable an external user or application to feed in the working orders that serve as input to the predictions and optimisation capabilities.

The API is documented with the open-source tool Swagger. Swagger is a tool to document an API and allow users to interact with it for testing and debugging purposes. It comprises two sections: one with the API endpoints and the other with information and composition about data schemas.

Swagger can be accessed through the same URL as the SPP application, adding /swagger at the end of the URL. If using the public DNS, the full URL will be https://spp-gorenje.dtenabler.com/swagger.

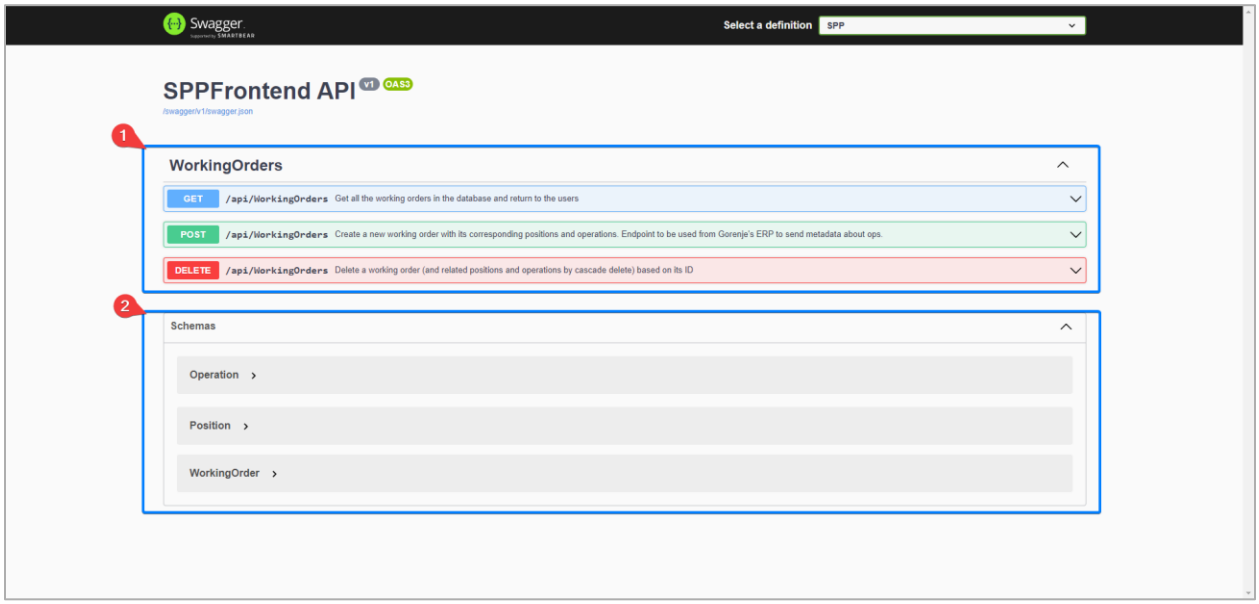


**Figure 8. SPP API Swagger documentation**

## 3.1 API Endpoints

### GET </api/WorkingOrders>

This method takes all the WOs available in the Database and returns them in JSON format according to the WO schema. If no WOs are available, an empty list will be retrieved.

### POST </api/WorkingOrders>

The method receives a JSON file with the schema of a WO and creates a new entry into the database. Several restrictions apply to WO creation:

- A WO object matching the data schema should be provided. Otherwise, a Bad Request (Error code 400) response will be returned.
- All the specified materials for each operation should exist in the local database. The full list of materials can be found in Annex I. The input material name is trimmed (removing leading and trailing whitespaces) and then compared with the available materials in a case-insensitive way. Using an unknown material will cause that operation to be ignored. The rest of the operations will still be processed.
- All the specified Work Centres (WC) for each operation should exist in the local database. Using an unknown WC will cause that operation to be ignored. The rest of the operations will still be processed.

- If the incoming WO identifier (wo_no) is already found in the database, the system will process all the child positions and operations. If new positions and operations are found, they will be added to the preexistent WO.
- No two positions within the WO should have the same ID (pos_no). Two positions may have the same ID if they belong to a different existing WO.
- No two operations within the same position should have the same ID (operation_no). Two operations may have the same ID if they belong to different positions.

**DELETE </api/WorkingOrders>**

Given the wo_no parameter (identifier for a working order), this method deletes the corresponding WO –and all the related elements by cascade delete– from the database.

## 3.2 Data Schema

All the interactions with the WorkingOrders API should respect the data schema, which is also documented in Swagger.

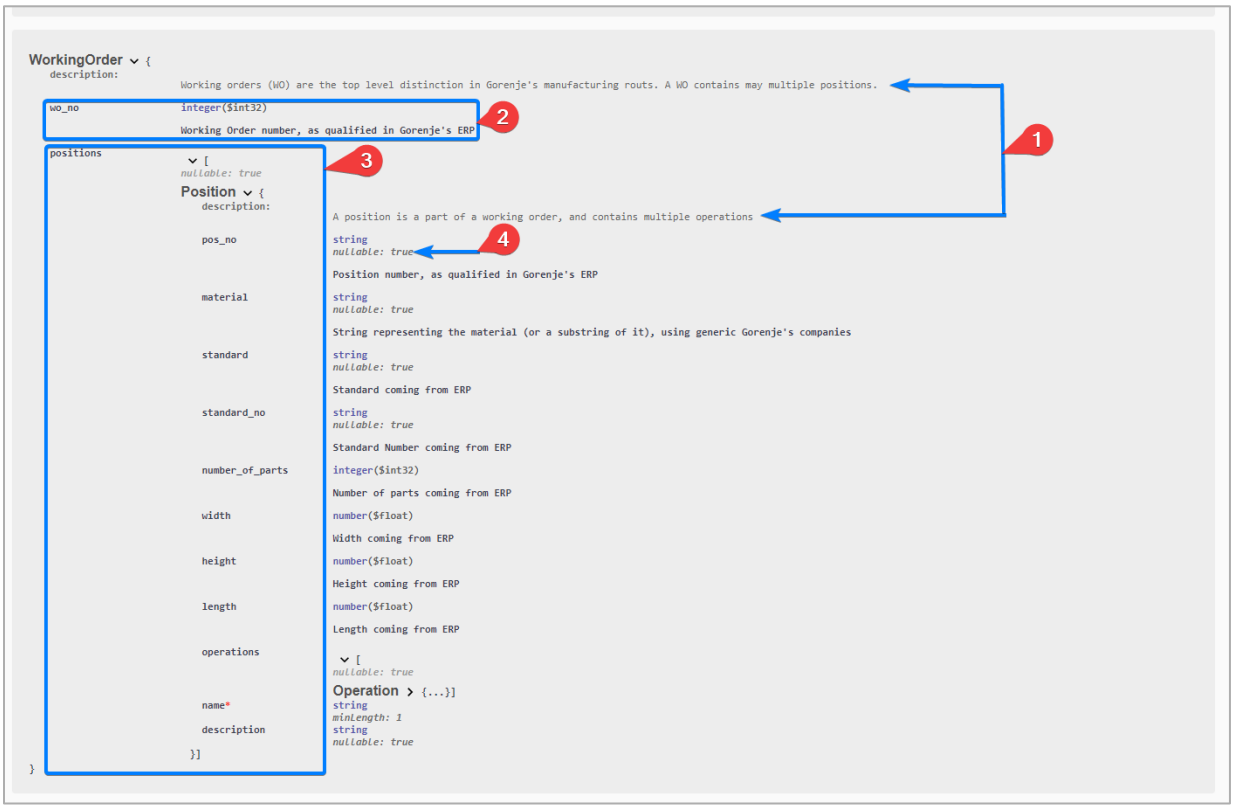


**Figure 9. SPP data schema in Swagger**

1. Top-level WO object description.
2. Field data type, nullability and description.
3. List of child positions and operations with their own fields, data types and descriptions.

## Annex I. Available materials and work centers

The following materials are accepted for the incoming operations:

**Table 1. Available materials**

| | |
|---|---|
| 1.0038 - | GGG50 - Cast |
| 1.2379 - OCR_Hardned | 1.1730 - |
| 1.2379 - OCR_Raw | 1.0570 - |
| 1.1191 - | 1.2343 - |
| 1.2312 - | 1.2842 - |
| GGG70 - Cast | Aluminium alloys |

Additionally, the following table details the list of registered machines. Each machine has a related Work Center, which is the parameter received in the working orders from the ERP. The association between operation and WC does not mean that the corresponding operation will be actually performed in that WC or machine/s. It is only used to extract the type of machining operation that needs to be done. From that type, all the machines that are eligible for prediction will be available for selection during the simulation configuration.

**Table 2. Available machines, work centers and prediction models**

| Machine Name | Work Center | Operation type | Eligible for prediction (Y/N) |
|---|---|---|---|
| Mori Seiki DuraVertical | 51920 | Milling | Y |
| Axile G8-9 | 51960 | | Y |
| Hermle C400 | 51960 | | Y |
| Hermle C50 | 51960 | | Y |
| HURON | 51940 | | Y |
| TOS WHQ 13.12 CNC | 51720 | | Y |
| Trimill VC2314 | 51950 | | Y |
| Trimill VF6535 | 51970 | | Y |
| Mori seiki SV400 | 51920 | | N |
| H2 - HURON | 51940 | | N |
| MS2 - Mori Seiki SH8000 | 51730 | | N |
| T2 - Trimill VC1011 | 51930 | | N |
| T3 - Trimill VC1011 | 51930 | | N |
| MS1 - Mori Seiki SH5000 | 51740 | | N |
| AX1 - Axile G8 | 51960 | | N |
| Obdelovalni Center Maho | 51820 | | N |
| Portalni Klasicni Rezk. Stroj FP20 | 51250 | | N |
| 1611-Rezkalni Horizontalni Stroj-srednji | 51610 | | N |
| Mori Seiki SV500 | 51920 | | N |
| Rezkalni Stroj | 51200 | | N |
| 2121-Koordinatni Vrtalni Stroj | 52110 | | N |
| B1 - Tos veliki | 51710 | | N |
| 1225-Rezkalni Stroj (CNC-2D)-Picomax | 51290 | | N |

| | | | |
|---|---|---|---|
| T1 - Trimill VC2314 | 51950 | | N |
| Mossini 6300 | 69320 | Press | N |
| Ravne Presses 800 | 69310 | | N |
| Excetek V1060 | 55110 | WEDM | Y |
| Makino DUO64 | 55110 | | Y |
| C2 - Robofil 510 | 55110 | | N |
| C1 - Robofil 240 | 551101 | | N |
| ELB CLASSIC B15 | 54130 | Grinding | Y |
| 4221-Brusilni Plosk. in Profilni Stroj | 54220 | | N |
| 4152-Brusilni Ploskovni Stroj | 54100 | | N |
| 5452-Brusilni Profilni Stroj mali | 54520 | | N |
| 4321-Brusilni Koordinatni Stroj | 54320 | | N |