

# OptaWeb Employee Rostering User Guide

The OptaPlanner Team

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# Chapter 1. OptaWeb Employee Rostering

## Introduction

### 1.1. What is OptaWeb Employee Rostering?

Every organization faces planning problems: providing products or services with a limited set of *constrained* resources (employees, assets, time and money). One such planning problem is employee shift rostering: assigning shifts to employees. OptaWeb is a web application and REST service that solves employee shift rostering problems using the [OptaPlanner engine](#).

### 1.2. Build and Run the Application

To build the project with Maven, run the following command in the project's root directory:

```
mvn clean install -DskipTests
```

After building the project, run the application with:

```
java -jar optaweb-employee-rostering-standalone/target/optaweb-employee-rostering-standalone-*-exec.jar
```

Then open <http://localhost:8080/> to see the web application.

Alternatively, run `npm start` in the `optaweb-employee-rostering-frontend` directory to start the frontend in one terminal, and run `mvn quarkus:dev` in the `optaweb-employee-rostering-backend` directory to start the backend in another terminal.

To run on another port, use `-Dquarkus.http.port=...`:

```
java -Dquarkus.http.port=18080 -jar optaweb-employee-rostering-standalone/target/quarkus-app/quarkus-run.jar
```

### 1.3. System Properties

These system properties can overwrite default properties of the application, for example, by passing `-Doptaweb.generator.zoneId="America/New_York"` to Quarkus. These system properties might also be exposed as OpenShift template parameters.

- **optaweb.generator.timeZoneId**: The time zone ID for the automatically generated tenants. For example `America/New_York`. This defaults to the system default Zone ID.
- **optaweb.generator.initial.data**: What data to initially put in the database. Supported values are: `EMPTY` (no data) and `DEMO_DATA` (several tenants of various sizes). This defaults to `DEMO_DATA`

# Chapter 2. Architecture

## OptaWeb Employee Rostering Architecture

Use the powerful REST interface or the user friendly web interface.



# OptaWeb Employee Rostering Class Diagram



# Solving with OptaPlanner

OptaPlanner automatically assigns the shifts, according to our constraints.



# Chapter 3. Project Structure

The project is structured in the following folders:

- **optaweb-employee-rostering-backend** core planning domain model and backend REST api implemented with Quarkus
- **optaweb-employee-rostering-benchmark** solution benchmark
- **optaweb-employee-rostering-distribution** assembly logic for the deployment assets
- **optaweb-employee-rostering-docs** this documentation
- **optaweb-employee-rostering-frontend** user interface implemented with ReactJS

## 3.1. Domain Model

The domain model is the most important piece of a project based on OptaPlanner. A careful design simplifies the constraint definition. The classes of the domain model are placed in the **optaweb-employee-rostering-backend** module.

The most important classes to understand the domain model are:

- **Shift** is the *planning entity*, where is the defined the relationship with the *planning variable* employee. Other important fields: `spot`, `rotationEmployee`, `startDateTime`, `endDateTime`.
- **Employee** is the *planning variable*, it's identified by the `name` and has a set of skills (`skillProficiencySet`).
- **Roster** is the *planning solution*, `employeeList` is the list of employees (the range of values that can be assigned to the *planning variable*), the field `score` holds the score (3 levels: hard, medium, soft), the other problem facts are: `skillList`, `spotList`, `employeeAvailabilityList`, `rosterConstraintConfiguration`, `rosterState`, `shiftList`.

## 3.2. Constraints

The constraints are defined in the **optaweb-employee-rostering-backend** module, with the implementation of the backend REST service.

- The solver configuration file: `optaweb-employee-rostering-backend/src/main/resources/org/optaweb/employee rostering/service/solver/employeeRosteringSolverConfig.xml`
- The constraints definition file: `optaweb-employee-rostering-backend/src/main/resources/org/optaweb/employee rostering/service/solver/employeeRosteringScoreRules.drl`

### 3.2.1. Constraint definition

The constraints are defined using the DRL language. See: [Implementing a score rule](#).

### 3.2.1.1. Hard Constraints

#### Required skill for a shift

```
rule "Required skill for a shift"
  when
    Shift(
      employee != null,
      !getEmployee().hasSkills(getSpot().getRequiredSkillSet())
  then
    scoreHolder.addHardConstraintMatch(kcontext, -100);
  end
```

Condition: there is a shift with an assigned employee that has NOT the skill set required by the spot.

Action: the hard score is decreased by 100 units.

#### Unavailable time slot for an employee

```
rule "Unavailable time slot for an employee"
  when
    EmployeeAvailability(
      state == EmployeeAvailabilityState.UNAVAILABLE,
      $e : employee,
      $startDateTime : startDateTime,
      $endDateTime : endDateTime)
    Shift(
      employee == $e,
      DateTimeUtils.doTimeslotsIntersect($startDateTime,$endDateTime,
                                          startDateTime, endDateTime))
  then
    scoreHolder.addHardConstraintMatch(kcontext, -50);
  end
```

Condition: Given an employee unavailability, there is a shift for this employee, the date time interval of the shift intersects the date time interval of the unavailability.

Action: The hard score is decreased by 50 units.

#### At most one shift assignment per day per employee



```

rule "At most one shift assignment per day per employee"
  when
    $s : Shift(
      employee != null,
      $e : employee,
      $leftDay : startDateTime.toLocalDate())
    Shift(
      employee == $e,
      startDateTime.toLocalDate() == $leftDay,
      this != $s)
  then
    scoreHolder.addHardConstraintMatch(kcontext, -10);
  end

```

Condition: There are two shifts assigned to the same employee, the start date of one shift is equal to the start date of the other shift.

Action: The hard score is decreased by 10 units.



This rule triggers for any combination of shifts for each employee. So considering  $n$  employees and  $m$  shifts, it triggers  $n*m^2$  times. Luckily, the rule triggers just for shifts that are impacted by a change.

### No 2 shifts within 10 hours from each other

```

rule "No 2 shifts within 10 hours from each other"
  when
    $s : Shift(
      employee != null,
      $e : employee,
      $leftEndDateTime : endDateTime)
    Shift(
      employee == $e,
      $leftEndDateTime <= endDateTime,
      $leftEndDateTime.until(startDateTime, ChronoUnit.HOURS) < 10,
      this != $s)
  then
    scoreHolder.addHardConstraintMatch(kcontext, -1);
  end

```

Condition: There are two shifts assigned to the same employee, the end time of the *left* shift is prior of the other end time, the time difference between the end time of the *left* shift and the start time of the other is less than 10 hours.

Action: The hard score is decreased by 1 unit.

### Daily minutes must not exceed contract maximum

```

rule "Daily minutes must not exceed contract maximum"
  when
    $employee : Employee($contract : contract, $contract.getMaximumMinutesPerDay()
    != null)
    $s : Shift(employee == $employee, $startDateTime : startDateTime)
    Number( intValue > $contract.getMaximumMinutesPerDay() ) from accumulate(
      Shift(employee == $employee, $shiftStart : startDateTime,
        $shiftEnd : endDateTime,
        $shiftStart.toLocalDate().equals($startDateTime.toLocalDate())),
      sum(Duration.between($shiftStart, $shiftEnd).toMinutes())
    )
  then
    scoreHolder.addHardConstraintMatch(kcontext, -1);
end

```

Condition: The sum of the total minutes assigned to one employee in a day is greater than the maximum minutes specified by the employee's contract.

Action: The hard score is decreased by 1 unit.

The remaining three hard constraints are similar to this last one, but for different time frames specified by the contract (weekly, monthly, yearly).

### 3.2.1.2. Medium Constraints

#### Assign every shift

```

rule "Assign every shift"
  when
    Shift(employee == null)
  then
    scoreHolder.addMediumConstraintMatch(kcontext, -1);
end

```

Condition: There is a shift with no employees assigned.

Action: The medium score is decreased by 1 unit.

### 3.2.1.3. Soft Constraints

#### Undesired time slot for an employee

```

rule "Undesired time slot for an employee"
  when
    $rosterConstraintConfiguration : RosterConstraintConfiguration
    (undesiredTimeSlotWeight != 0)
    EmployeeAvailability(
      state == EmployeeAvailabilityState.UNDESIRED,
      $e : employee,
      $startDateTime : startDateTime,
      $endDateTime : endDateTime)
    Shift(
      employee == $e,
      DateTimeUtils.doTimeslotsIntersect($startDateTime,$endDateTime,
                                          startDateTime, endDateTime))
  then
    scoreHolder.addSoftConstraintMatch(kcontext, -$rosterConstraintConfiguration
    .getUndesiredTimeSlotWeight());
  end

```



The first line of the **when** clause is a technique to dynamically change the weight of the constraint. If **undesiredTimeSlotWeight** is 0 the constraint is disregarded.

**Condition:** Given an employee's undesired date and time slot, there is a shift for this employee such that the date and time interval of the shift intersects the undesired date and time slot.

**Action:** The soft score is decreased by *undesiredTimeSlotWeight* units.

### Desired time slot for an employee

```

rule "Desired time slot for an employee"
  when
    $rosterConstraintConfiguration : RosterConstraintConfiguration
    (desiredTimeSlotWeight != 0)
    EmployeeAvailability(
      state == EmployeeAvailabilityState.DESIRED,
      $e : employee,
      $startDateTime : startDateTime,
      $endDateTime : endDateTime)
    Shift(
      employee == $e,
      DateTimeUtils.doTimeslotsIntersect($startDateTime,$endDateTime,
                                          startDateTime, endDateTime))
  then
    scoreHolder.addSoftConstraintMatch(kcontext, +$rosterConstraintConfiguration
    .getDesiredTimeSlotWeight());
  end

```



The first line of the **when** clause is a technique to dynamically change the weight of the constraint. If **desiredTimeSlotWeight** is 0 the constraint is disregarded.

Condition: Given an employee desired date and time slot, there is a shift for this employee such that the date and time interval of the shift intersects the desired date and time slot.

Action: The soft score is increased by *desiredTimeSlotWeight* units.

### Employee is not rotation employee

```
rule "Employee is not rotation employee"
when
    $rosterConstraintConfiguration : RosterConstraintConfiguration
    (rotationEmployeeMatchWeight != 0)
    Shift(
        rotationEmployee != null, employee != null, employee !=
rotationEmployee)
then
    scoreHolder.addSoftConstraintMatch(kcontext, -$rosterConstraintConfiguration
.rotationEmployeeMatchWeight());
end
```



The first line of the **when** clause is a technique to dynamically change the weight of the constraint. If **rotationEmployeeMatchWeight** is 0 the constraint is disregarded.



In general, employees desire to work following a regular schedule: a rotation plan. This represents a starting point for the actual schedule that is influenced by other factors (e.g. temporary unavailability). For this reason, all Shifts are initialized with a **rotationEmployee**.

Condition: There a shift that is assigned to an employee which is not the rotation employee.

Action: The soft score is decreased by *rotationEmployeeMatchWeight* units.

# Chapter 4. Features in OptaWeb Employee Rostering

## 4.1. Test the JPA Database with H2

Before testing the database, make sure the application backend is running. If the application isn't running, run the following in the `optaweb-employee-rostering-backend` directory:

```
mvn quarkus:dev
```

Go to <http://localhost:8080/h2-console> to view the H2 database console. Enter `org.h2.Driver` in the `Driver Class` field and `jdbc:h2:mem:employeerostering` in the `JDBC URL` field, and keep the other default values. Connect, and click on the entities on the left to run SQL statements. This console allows you to view and modify the application database.

## 4.2. Test the REST API

As with testing the database, make sure the application backend is running to test the REST API. Go to <http://localhost:8080/swagger-ui.html> to view documentation and test the REST methods.