Red Hat Decision Manager 7.11

Getting started with Red Hat Decision Manager

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Red Hat Decision Manager 7.11 Getting started with Red Hat Decision Manager

Abstract

This document describes how to get started with decision services and planning solutions in Red Hat Decision Manager.

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PREFACE

As a developer of business decisions , you can use Red Hat Decision Manager to develop decision services using a variety of available assets. You can also use Red Hat build of OptaPlanner to find the optimal solution to planning problems based on a set of limited resources and under specific constraints.

MAKING OPEN SOURCE MORE INCLUSIVE

Red Hat is committed to replacing problematic language in our code, documentation, and web properties. We are beginning with these four terms: master, slave, blacklist, and whitelist. Because of the enormity of this endeavor, these changes will be implemented gradually over several upcoming releases. For more details, see *our CTO Chris Wright's message* .

PART I. GETTING STARTED WITH DECISION SERVICES IN RED HAT DECISION MANAGER

As a business rules developer, you can use Business Central in Red Hat Decision Manager or the Red Hat Decision Manager DMN modeler in VSCode to design a variety of decision services. Red Hat Decision Manager provides example projects with example business assets directly in Business Central as a reference. This document describes how to create and test an example traffic violation project based on the **Traffic_Violation** sample project included in Business Central. This sample project uses a Decision Model and Notation (DMN) model to define driver penalty and suspension rules in a traffic violation decision service. You can follow the steps in this document to create the project and the assets it contains, or open and review the existing **Traffic_Violation** sample project.

For more information about the DMN components and implementation in Red Hat Decision Manager, see *Designing a decision service using DMN models* .

Prerequisites

- Red Hat JBoss Enterprise Application Platform 7.3 is installed. For installation information, see *Red Hat JBoss Enterprise Application Platform 7.3 Installation Guide* .
- Red Hat Decision Manager is installed and configured with KIE Server. For more information see *Installing and configuring Red Hat Decision Manager on Red Hat JBoss EAP 7.3* .
- Red Hat Decision Manager is running and you can log in to Business Central with the **developer** role. For more information, see *Planning a Red Hat Decision Manager installation* .

CHAPTER 1. SAMPLE PROJECTS AND BUSINESS ASSETS IN BUSINESS CENTRAL

Business Central contains sample projects with business assets that you can use as a reference for the rules or other assets that you create in your own Red Hat Decision Manager projects. Each sample project is designed differently to demonstrate decision management or business optimization assets and logic in Red Hat Decision Manager.

NOTE

Red Hat does not provide support for the sample code included in the Red Hat Decision Manager distribution.

The following sample projects are available in Business Central:

- **Course_Scheduling**: (Business optimization) Course scheduling and curriculum decision process. Assigns lectures to rooms and determines a student's curriculum based on factors, such as course conflicts and class room capacity.
- **Dinner_Party**: (Business optimization) Guest seating optimization using guided decision tables. Assigns guest seating based on each guest's job type, political beliefs, and known relationships.
- **Employee_Rostering**: (Business optimization) Employee rostering optimization using decision and solver assets. Assigns employees to shifts based on skills.
- **Evaluation_Process**: (Process automation) Evaluation process using business process assets. Evaluates employees based on performance.
- **IT_Orders**: (Process automation and case management) Ordering case using business process and case management assets. Places an IT hardware order based on needs and approvals.
- **Mortgages**: (Decision management with rules) Loan approval process using rule-based decision assets. Determines loan eligibility based on applicant data and qualifications.
- **Mortgage_Process**: (Process automation) Loan approval process using business process and decision assets. Determines loan eligibility based on applicant data and qualifications.
- **OptaCloud**: (Business optimization) Resource allocation optimization using decision and solver assets. Assigns processes to computers with limited resources.
- **Traffic_Violation**: (Decision management with DMN) Traffic violation decision service using a Decision Model and Notation (DMN) model. Determines driver penalty and suspension based on traffic violations.

1.1. ACCESSING SAMPLE PROJECTS AND BUSINESS ASSETS IN BUSINESS CENTRAL

You can use the sample projects in Business Central to explore business assets as a reference for the rules or other assets that you create in your own Red Hat Decision Manager projects.

Prerequisites

- Business Central is installed and running. For installation options, see *Planning a Red Hat Decision Manager installation*.

Procedure

1. In Business Central, go to **Menu** → **Design** → **Projects**. If there are existing projects, you can access the samples by clicking on the **MySpace** default space and selecting **Try Samples** from the **Add Project** drop-down menu. If there are no existing projects, click **Try samples**.

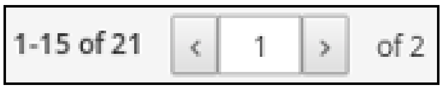
2. Review the descriptions for each sample project to determine which project you want to explore. Each sample project is designed differently to demonstrate decision management or business optimization assets and logic in Red Hat Decision Manager.

3. Select one or more sample projects and click **Ok** to add the projects to your space.

4. In the **Projects** page of your space, select one of the sample projects to view the assets for that project.

5. Select each asset to explore how the project is designed to achieve the specified goal or workflow. Some of the sample projects contain more than one page of assets. Click the left or right arrows in the upper-right corner to view the full asset list.

   Figure 1.1. Asset page selection

6. In the upper-right corner of the project **Assets** page, click **Build** to build the sample project or **Deploy** to build the project and then deploy it to KIE Server.

   NOTE

   You can also select the **Build & Install** option to build the project and publish the KJAR file to the configured Maven repository without deploying to a KIE Server. In a development environment, you can click **Deploy** to deploy the built KJAR file to a KIE Server without stopping any running instances (if applicable), or click **Redeploy** to deploy the built KJAR file and replace all instances. The next time you deploy or redeploy the built KJAR, the previous deployment unit (KIE container) is automatically updated in the same target KIE Server. In a production environment, the **Redeploy** option is disabled and you can click **Deploy** only to deploy the built KJAR file to a new deployment unit (KIE container) on a KIE Server.

   To configure the KIE Server environment mode, set the **org.kie.server.mode** system property to **org.kie.server.mode=development** or **org.kie.server.mode=production**. To configure the deployment behavior for a corresponding project in Business Central, go to project **Settings** → **General Settings** → **Version**, toggle the **Development Mode** option, and click **Save**. By default, KIE Server and all new projects in Business Central are in development mode. You cannot deploy a project with **Development Mode** turned on or with a manually added **SNAPSHOT** version suffix to a KIE Server that is in production mode.

   To review project deployment details, click **View deployment details** in the deployment banner at the top of the screen or in the **Deploy** drop-down menu. This option directs you to the **Menu** → **Deploy** → **Execution Servers** page.

CHAPTER 2. RED HAT DECISION MANAGER BPMN AND DMN MODELERS

Red Hat Decision Manager provides the following extensions or applications that you can use to design Business Process Model and Notation (BPMN) process models and Decision Model and Notation (DMN) decision models using graphical modelers.

- **Business Central**: Enables you to view and design BPMN models, DMN models, and test scenario files in a related embedded designer.
  To use Business Central, you can set up a development environment containing a Business Central to design business rules and processes, and a KIE Server to execute and test the created business rules and processes.

- **Red Hat Decision Manager VSCode extension** Enables you to view and design BPMN models, DMN models, and test scenario files in Visual Studio Code (VSCode). The VSCode extension requires VSCode 1.46.0 or later.
  To install the Red Hat Decision Manager VSCode extension, select the **Extensions** menu option in VSCode and search for and install the **Red Hat Business Automation Bundle**extension.

- **Standalone BPMN and DMN editors** Enable you to view and design BPMN and DMN models embedded in your web applications. To download the necessary files, you can either use the NPM artifacts from the NPM registry or download the JavaScript files directly for the DMN standalone editor library at **https://<YOUR_PAGE>/dmn/index.js** and for the BPMN standalone editor library at **https://<YOUR_PAGE>/bpmn/index.js**.

2.1. INSTALLING THE RED HAT DECISION MANAGER VSCODE EXTENSION BUNDLE

Red Hat Decision Manager provides a **Red Hat Business Automation Bundle**VSCode extension that enables you to design Decision Model and Notation (DMN) decision models, Business Process Model and Notation (BPMN) 2.0 business processes, and test scenarios directly in VSCode. VSCode is the preferred integrated development environment (IDE) for developing new business applications. Red Hat Decision Manager also provides individual **DMN Editor** and **BPMN Editor** VSCode extensions for DMN or BPMN support only, if needed.

IMPORTANT

The editors in the VSCode are partially compatible with the editors in the Business Central, and several Business Central features are not supported in the VSCode.

Prerequisites

- The latest stable version of VSCode is installed.

Procedure

1. In your VSCode IDE, select the **Extensions** menu option and search for **Red Hat Business Automation Bundle** for DMN, BPMN, and test scenario file support.
   For DMN or BPMN file support only, you can also search for the individual **DMN Editor** or **BPMN Editor** extensions.

2. When the **Red Hat Business Automation Bundle**extension appears in VSCode, select it and click **Install**.

3. For optimal VSCode editor behavior, after the extension installation is complete, reload or close and re-launch your instance of VSCode.

After you install the VSCode extension bundle, any **.dmn**, **.bpmn**, or **.bpmn2** files that you open or create in VSCode are automatically displayed as graphical models. Additionally, any **.scesim** files that you open or create are automatically displayed as tabular test scenario models for testing the functionality of your business decisions.

If the DMN, BPMN, or test scenario modelers open only the XML source of a DMN, BPMN, or test scenario file and displays an error message, review the reported errors and the model file to ensure that all elements are correctly defined.

NOTE

For new DMN or BPMN models, you can also enter **dmn.new** or **bpmn.new** in a web browser to design your DMN or BPMN model in the online modeler. When you finish creating your model, you can click **Download** in the online modeler page to import your DMN or BPMN file into your Red Hat Decision Manager project in VSCode.

2.2. CONFIGURING THE RED HAT DECISION MANAGER STANDALONE EDITORS

Red Hat Decision Manager provides standalone editors that are distributed in a self-contained library providing an all-in-one JavaScript file for each editor. The JavaScript file uses a comprehensive API to set and control the editor.

You can install the standalone editors in three ways:

- Download each JavaScript file manually
- Use the NPM package

Procedure

1. Install the standalone editors using one of the following methods:
   Download each JavaScript file manually: For this method, follow these steps:

   a. Download the JavaScript files.

   b. Add the downloaded Javascript files to your hosted application.

   c. Add the following **<script>** tag to your HTML page:

      Script tag for your HTML page for the DMN editor

      ```
      <script src="https://<YOUR_PAGE>/dmn/index.js"></script>
      ```

      Script tag for your HTML page for the BPMN editor

      ```
      <script src="https://<YOUR_PAGE>/bpmn/index.js"></script>
      ```

   Use the NPM package: For this method, follow these steps:

   a. Add the NPM package to your **package.json** file:

Adding the NPM package

```
npm install @redhat/kogito-tooling-kie-editors-standalone
```

b. Import each editor library to your TypeScript file:

Importing each editor

```
import * as DmnEditor from "@redhat/kogito-tooling-kie-editors-standalone/dist/dmn"
import * as BpmnEditor from "@redhat/kogito-tooling-kie-editors-standalone/dist/bpmn"
```

2. After you install the standalone editors, open the required editor by using the provided editor API, as shown in the following example for opening a DMN editor. The API is the same for each editor.

Opening the DMN standalone editor

```
const editor = DmnEditor.open({
  container: document.getElementById("dmn-editor-container"),
  initialContent: Promise.resolve(""),
  readOnly: false,
  origin: "",
  resources: new Map([
    [
      "MyIncludedModel.dmn",
      {
        contentType: "text",
        content: Promise.resolve("")
      }
    ]
  ])
});
```

Use the following parameters with the editor API:

Table 2.1. Example parameters

Parameter	Description
container	HTML element in which the editor is appended.
initialContent	Promise to a DMN model content. This parameter can be empty, as shown in the following examples: ● **Promise.resolve("")** ● **Promise.resolve("<DIAGRAM_CONTENT_DIRECTLY_HERE>")** ● **fetch("MyDmnModel.dmn").then(content ⇒ content.text())**

Parameter	Description
readOnly (Optional)	Enables you to allow changes in the editor. Set to **false** (default) to allow content editing and **true** for read-only mode in editor.
origin (Optional)	Origin of the repository. The default value is **window.location.origin**.
resources (Optional)	Map of resources for the editor. For example, this parameter is used to provide included models for the DMN editor or work item definitions for the BPMN editor. Each entry in the map contains a resource name and an object that consists of **content-type** (**text** or **binary**) and **content** (similar to the **initialContent** parameter).

The returned object contains the methods that are required to manipulate the editor.

Table 2.2. Returned object methods

Method	Description
getContent(): Promise<string>	Returns a promise containing the editor content.
setContent(content: string): void	Sets the content of the editor.
getPreview(): Promise<string>	Returns a promise containing an SVG string of the current diagram.
subscribeToContentChanges(callback: (isDirty: boolean) ⇒ void): (isDirty: boolean) ⇒ void	Sets a callback to be called when the content changes in the editor and returns the same callback to be used for unsubscription.
unsubscribeToContentChanges(callback: (isDirty: boolean) ⇒ void): void	Unsubscribes the passed callback when the content changes in the editor.
markAsSaved(): void	Resets the editor state that indicates that the content in the editor is saved. Also, it activates the subscribed callbacks related to content change.
undo(): void	Undoes the last change in the editor. Also, it activates the subscribed callbacks related to content change.
redo(): void	Redoes the last undone change in the editor. Also, it activates the subscribed callbacks related to content change.

Method	Description
close(): void	Closes the editor.
getElementPosition(selector: string): Promise<Rect>	Provides an alternative to extend the standard query selector when an element lives inside a canvas or a video component. The **selector** parameter must follow the **<PROVIDER>:::<SELECT>** format, such as **Canvas:::MySquare** or **Video:::PresenterHand**. This method returns a **Rect** representing the element position.
envelopeApi: MessageBusClientApi<KogitoEditorEnvelopeApi>	This is an advanced editor API. For more information about advanced editor API, see MessageBusClientApi and KogitoEditorEnvelopeApi.

CHAPTER 3. CREATING AND EXECUTING DMN AND BPMN MODELS USING MAVEN

You can use Maven archetypes to develop DMN and BPMN models in VSCode using the Red Hat Decision Manager VSCode extension instead of Business Central. You can then integrate your archetypes with your Red Hat Decision Manager decision and process services in Business Central as needed. This method of developing DMN and BPMN models is helpful for building new business applications using the Red Hat Decision Manager VSCode extension.

Procedure

1. In a command terminal, navigate to a local folder where you want to store the new Red Hat Decision Manager project.
2. Enter the following command to generate a project within a defined folder using the following Maven archetype:

   Generating a project using Maven archetype

   ```
   mvn archetype:generate \
       -DarchetypeGroupId=org.kie \
       -DarchetypeArtifactId=kie-kjar-archetype \
       -DarchetypeVersion=7.52.0.Final-redhat-00007
   ```

   This command generates a Maven project with required dependencies and generates required directories and files to build your business application. You can set up and use Git version-control system (recommended) when developing a project.

   If you want to generate multiple projects in the same directory, you can specify the **artifactId** and **groupId** of the generated business application by adding **-DgroupId=<groupid> -DartifactId=<artifactId>** to the previous command.
3. In your VSCode IDE, click **File**, select **Open Folder**, and navigate to the folder that is generated using the previous command.
4. Before creating the first asset, set a package for your business application, for example, **org.kie.businessapp**, and create respective directories in the following paths:
   - **PROJECT_HOME/src/main/java**
   - **PROJECT_HOME/src/main/resources**
   - **PROJECT_HOME/src/test/resources**

   For example, you can create **PROJECT_HOME/src/main/java/org/kie/businessapp** for **org.kie.businessapp** package.
5. Use VSCode to create assets for your business application. You can create the assets supported by Red Hat Decision Manager VSCode extension using the following ways:
   - To create a business process, create a new file with **.bpmn** or **.bpmn2** in **PROJECT_HOME/src/main/java/org/kie/businessapp** directory, such as **Process.bpmn**.

- To create a DMN model, create a new file with **.dmn** in **PROJECT_HOME/src/main/java/org/kie/businessapp** directory, such as **AgeDecision.dmn**.
- To create a test scenario simulation model, create a new file with **.scesim** in **PROJECT_HOME/src/main/java/org/kie/businessapp** directory, such as **TestAgeScenario.scesim**.

6. After you create the assets in your Maven archetype, navigate to the root directory (contains **pom.xml**) of the project in the command line and run the following command to build the knowledge JAR (KJAR) of your project:

```
mvn clean install
```

If the build fails, address any problems described in the command line error messages and try again to validate the project until the build is successful. However, if the build is successful, you can find the artifact of your business application in **PROJECT_HOME/target** directory.

NOTE

Use **mvn clean install** command often to validate your project after each major change during development.

You can deploy the generated knowledge JAR (KJAR) of your business application on a running KIE Server using the REST API. For more information about using REST API, see *Interacting with Red Hat Decision Manager using KIE APIs*.

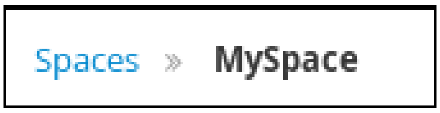
CHAPTER 4. CREATING THE TRAFFIC VIOLATIONS PROJECT IN BUSINESS CENTRAL

For this example, create a new project called **traffic-violation**. A project is a container for assets such as data objects, DMN assets, and test scenarios. This example project that you are creating is similar to the existing **Traffic_Violation** sample project in Business Central.

Procedure

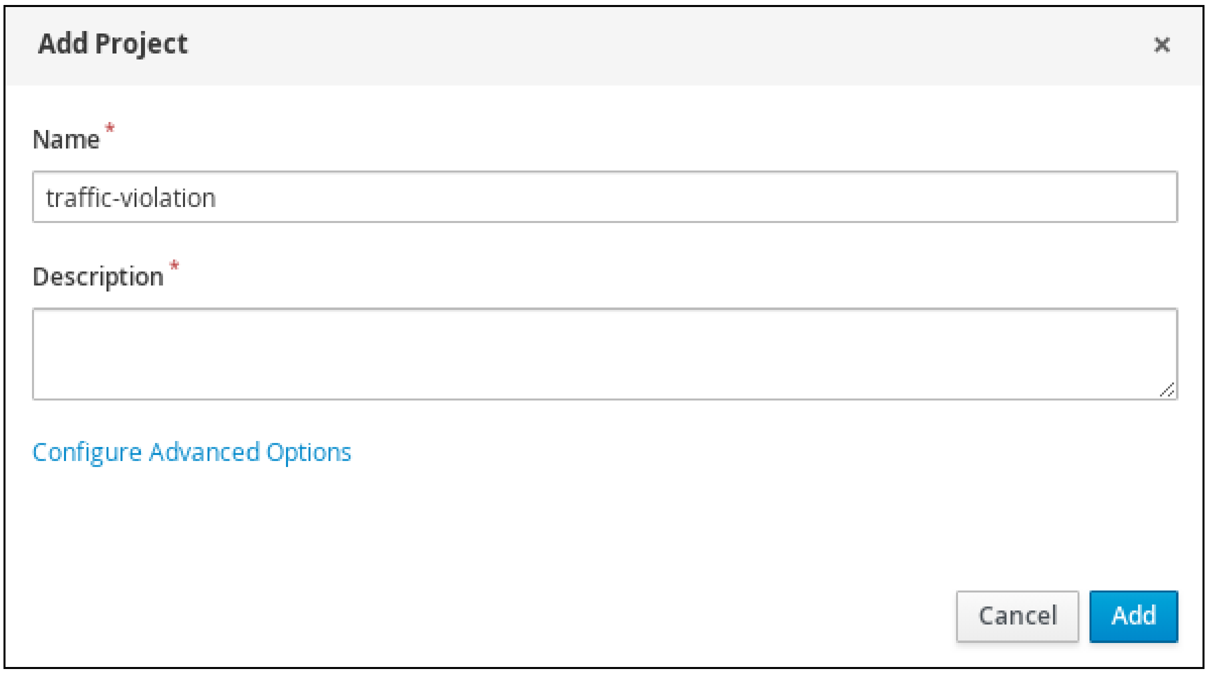
1. In Business Central, go to **Menu** → **Design** → **Projects**.
   Red Hat Decision Manager provides a default space called **MySpace**, as shown in the following image. You can use the default space to create and test example projects.

   Figure 4.1. Default space

2. Click **Add Project**.
3. Enter **traffic-violation** in the **Name** field.
4. Click **Add**.

   Figure 4.2. Add Project window

   The **Assets** view of the project opens.

CHAPTER 5. DECISION MODEL AND NOTATION (DMN)

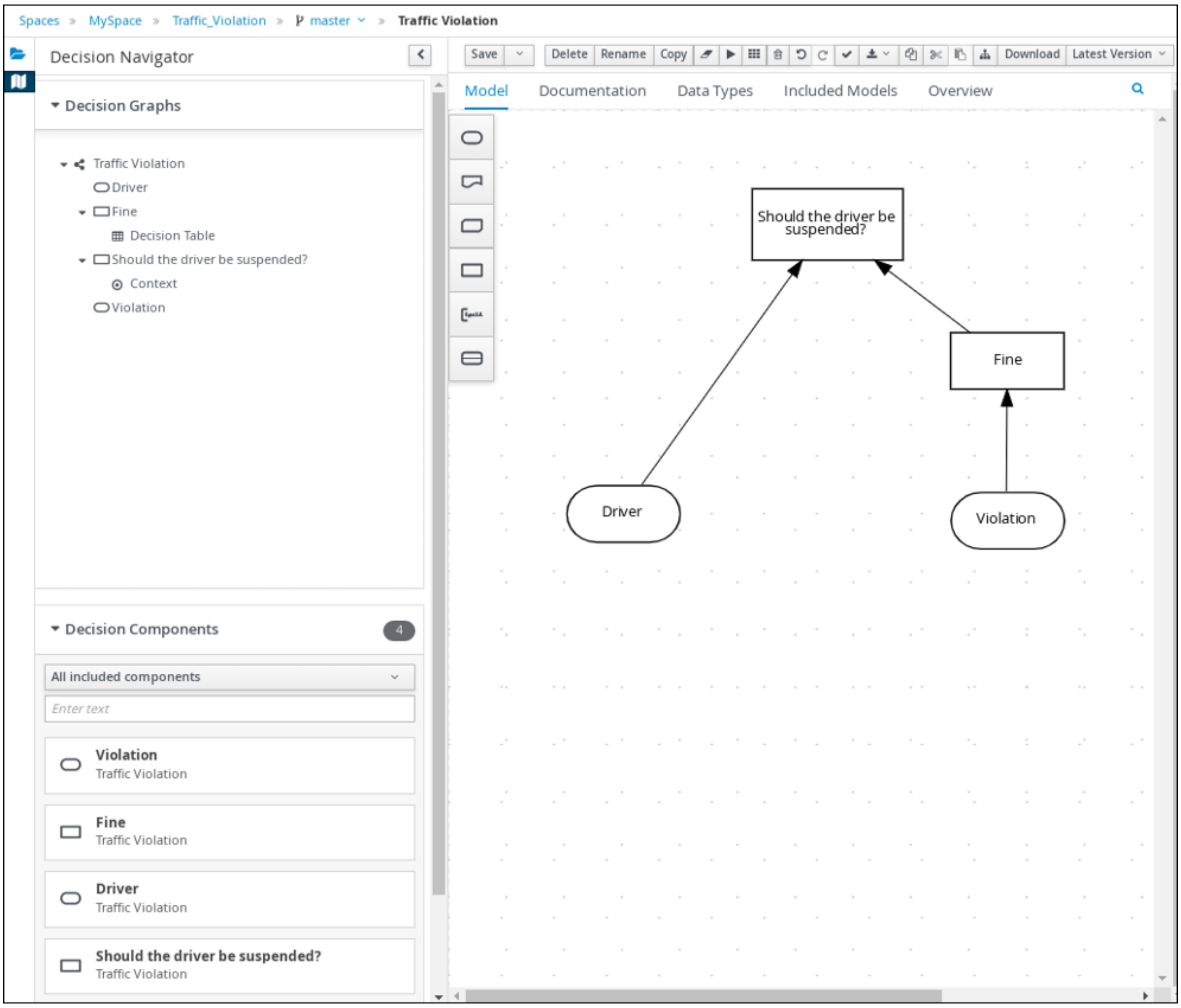
Decision Model and Notation (DMN) is a standard established by the Object Management Group (OMG) for describing and modeling operational decisions. DMN defines an XML schema that enables DMN models to be shared between DMN-compliant platforms and across organizations so that business analysts and business rules developers can collaborate in designing and implementing DMN decision services. The DMN standard is similar to and can be used together with the Business Process Model and Notation (BPMN) standard for designing and modeling business processes.

For more information about the background and applications of DMN, see the OMG Decision Model and Notation specification.

5.1. CREATING THE TRAFFIC VIOLATIONS DMN DECISION REQUIREMENTS DIAGRAM (DRD)

A decision requirements diagram (DRD) is a visual representation of your DMN model. Use the DMN designer in Business Central to design the DRD for the traffic violations project and to define the decision logic of the DRD components.

Figure 5.1. DRD for the Traffic Violations example



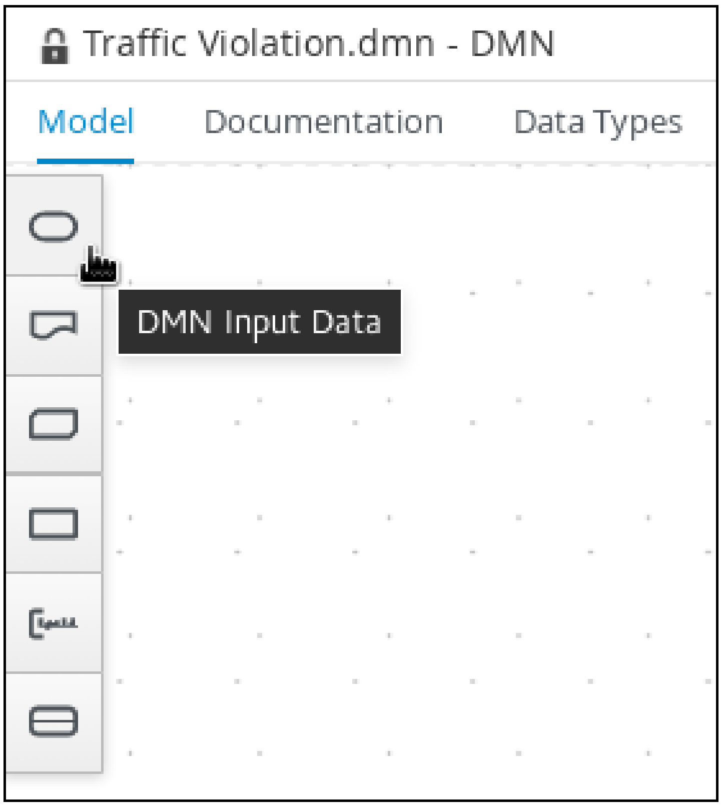
Prerequisites

- You have created the traffic violations project in Business Central.

Procedure

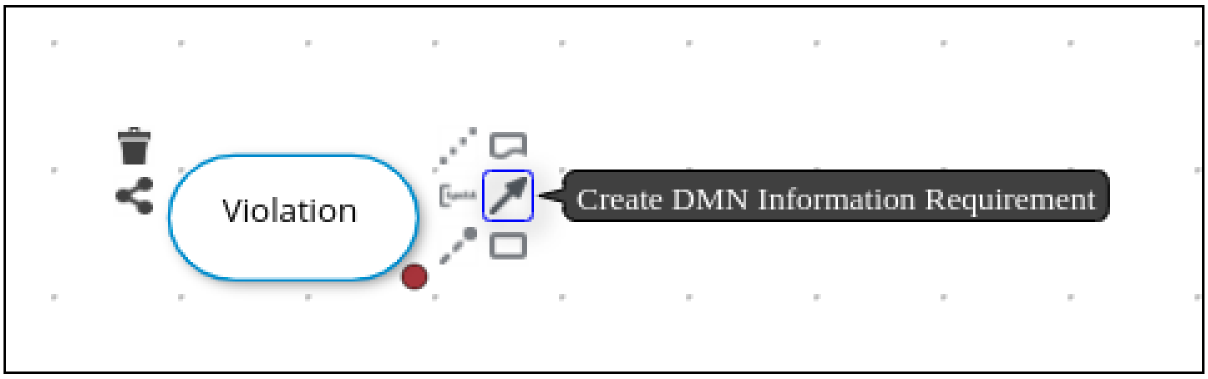
1. On the **traffic-violation** project's home page, click **Add Asset**.
2. On the **Add Asset** page, click **DMN**. The **Create new DMN** window is opened.
   a. In the **Create new DMN** window, enter **Traffic Violation** in the **DMN** name field.
   b. From the **Package** list, select **com.myspace.traffic_violation**.
   c. Click **Ok**. The DMN asset in the DMN designer is opened.
3. In the DMN designer canvas, drag two **DMN Input Data** input nodes onto the canvas.

Figure 5.2. DMN Input Data nodes



4. In the upper-right corner, click the icon.
5. Double-click the input nodes and rename one to **Driver** and the other to **Violation**.
6. Drag a **DMN Decision** decision node onto the canvas.
7. Double-click the decision node and rename it to **Fine**.
8. Click the **Violation** input node, select the **Create DMN Information Requirement** icon and click the **Fine** decision node to link the two nodes.

Figure 5.3. Create DMN Information Requirement icon



9. Drag a **DMN Decision** decision node onto the canvas.
10. Double-click the decision node and rename it to **Should the driver be suspended?**.
11. Click the **Driver** input node, select the **Create DMN Information Requirement** icon and click the **Should the driver be suspended?** decision node to link the two nodes.
12. Click the **Fine** decision node, select the **Create DMN Information Requirement** icon, and select the **Should the driver be suspended?** decision node.
13. Click **Save**.

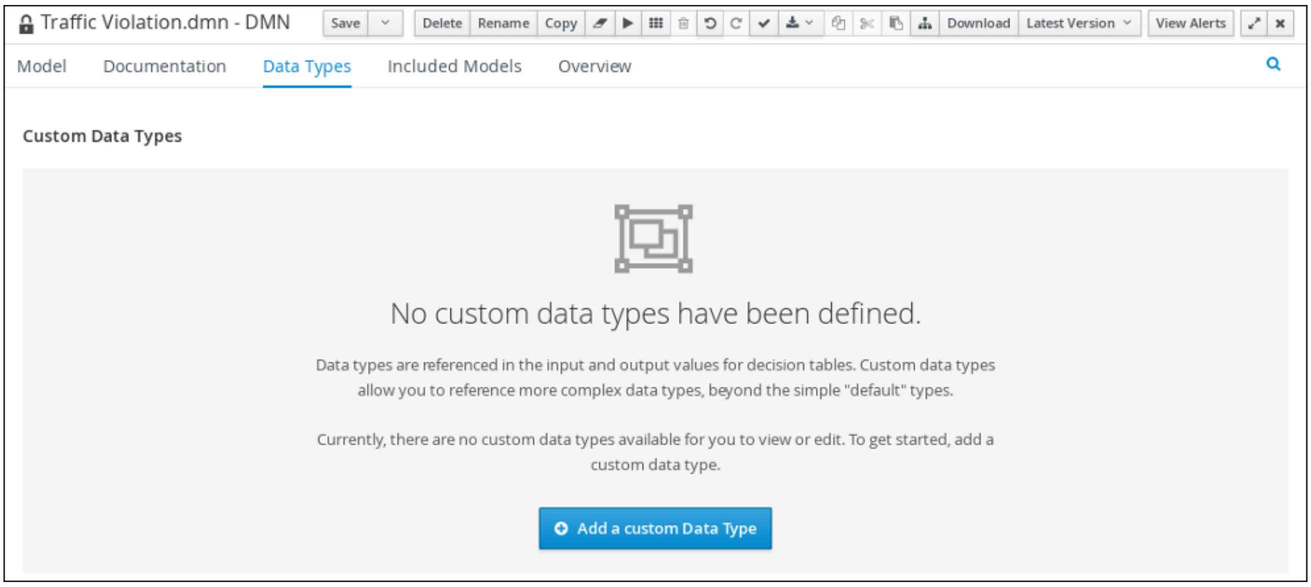
NOTE

As you periodically save a DRD, the DMN designer performs a static validation of the DMN model and might produce error messages until the model is defined completely. After you finish defining the DMN model completely, if any errors remain, troubleshoot the specified problems accordingly.

5.2. CREATING THE TRAFFIC VIOLATIONS DMN CUSTOM DATA TYPES

DMN data types determine the structure of the data that you use within a table, column, or field in a DMN boxed expression for defining decision logic. You can use default DMN data types (such as string, number, or boolean) or you can create custom data types to specify additional fields and constraints that you want to implement for the boxed expression values. Use the DMN designer’s **Data Types** tab in Business Central to define the custom data types for the traffic violations project.

Figure 5.4. The custom data types tab



Custom Data Types

No custom data types have been defined.

Data types are referenced in the input and output values for decision tables. Custom data types allow you to reference more complex data types, beyond the simple "default" types.

Currently, there are no custom data types available for you to view or edit. To get started, add a custom data type.

The following tables list the **tDriver**, **tViolation**, and **tFine** custom data types that you will create for this project.

Table 5.1. **tDriver** custom data type

Name	Type
tDriver	Structure
Name	string
Age	number
State	string
City	string
Points	number

Table 5.2. **tViolation** custom data type

Name	Type
tViolation	Structure
Code	string
Date	date
Type	string
Speed Limit	number

Name	Type
Actual Speed	number

Table 5.3. **tFine** custom data type

Name	Type
tFine	Structure
Amount	number
Points	number

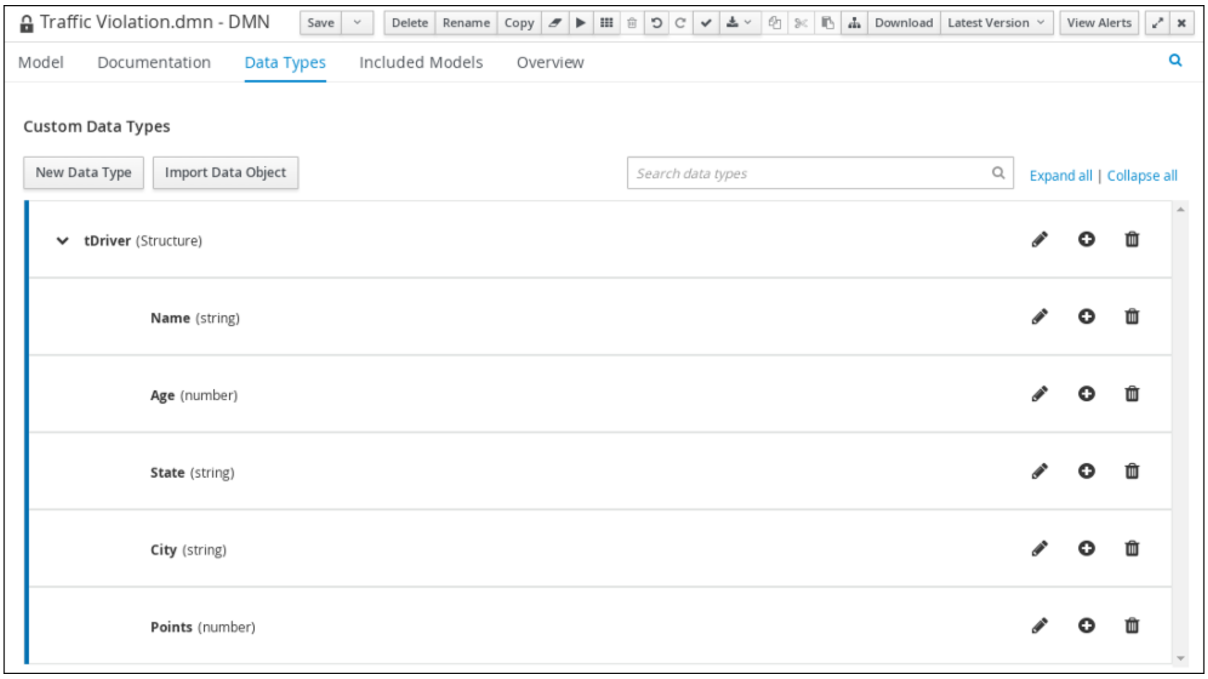
Prerequisites

- You created the traffic violations DMN decision requirements diagram (DRDs) in Business Central.

Procedure

1. To create the **tDriver** custom data type, click **Add a custom Data Type** on the **Data Types** tab, enter **tDriver** in the **Name** field, and select **Structure** from the **Type** list.
2. Click the check mark to the right of the new data type to save your changes.

   Figure 5.5. The tDriver custom data type

   tDriver (Structure)
   Name (string)
   Age (number)
   State (string)
   City (string)
   Points (number)

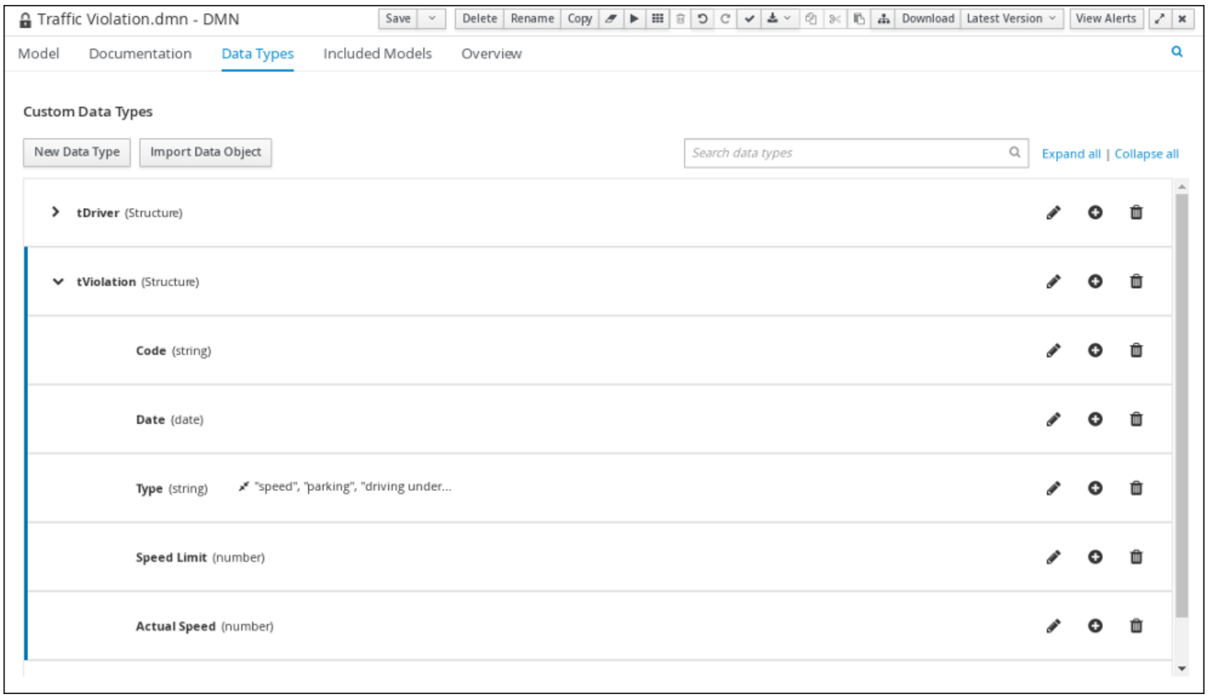
3. Add each of the following nested data types to the **tDriver** structured data type by clicking the plus sign next to **tDriver** for each new nested data type. Click the check mark to the right of each new data type to save your changes.
   - **Name** (string)

- **Age** (number)
- **State** (string)
- **City** (string)
- **Points** (number)

4. To create the **tViolation** custom data type, click **New Data Type**, enter **tViolation** in the **Name** field, and select **Structure** from the **Type** list.

5. Click the check mark to the right of the new data type to save your changes.

Figure 5.6. The tViolation custom data type



tDriver (Structure)
tViolation (Structure)
Code (string)
Date (date)
Type (string) "speed", "parking", "driving under...
Speed Limit (number)
Actual Speed (number)

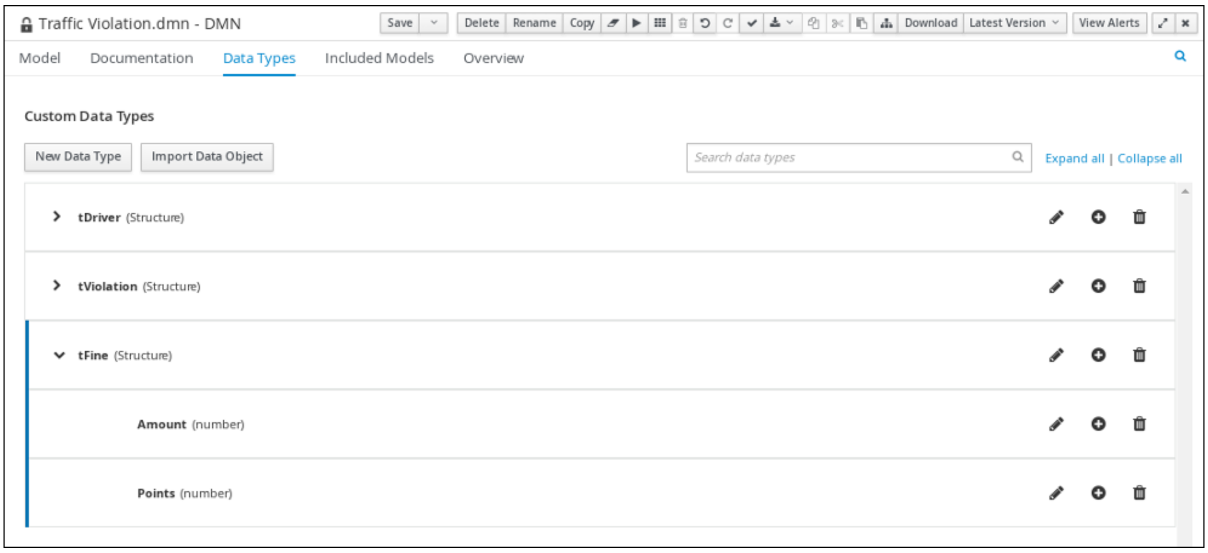
6. Add each of the following nested data types to the **tViolation** structured data type by clicking the plus sign next to **tViolation** for each new nested data type. Click the check mark to the right of each new data type to save your changes.
   - **Code** (string)
   - **Date** (date)
   - **Type** (string)
   - **Speed Limit** (number)
   - **Actual Speed** (number)

7. To add the following constraints to the **Type** nested data type, click the edit icon, click **Add Constraints**, and select **Enumeration** from the **Select constraint type** drop-down menu.
   - **speed**
   - **parking**
   - **driving under the influence**

8. Click **OK**, then click the check mark to the right of the **Type** data type to save your changes.

9. To create the **tFine** custom data type, click **New Data Type**, enter **tFine** in the **Name** field, select **Structure** from the **Type** list, and click **Save**.

Figure 5.7. The tFine custom data type



10. Add each of the following nested data types to the **tFine** structured data type by clicking the plus sign next to **tFine** for each new nested data type. Click the check mark to the right of each new data type to save your changes.

    - **Amount** (number)
    - **Points** (number)

11. Click **Save**.

5.3. ASSIGNING CUSTOM DATA TYPES TO THE DRD INPUT AND DECISION NODES

After you create the DMN custom data types, assign them to the appropriate **DMN Input Data** and **DMN Decision** nodes in the traffic violations DRD.

Prerequisites

- You have created the traffic violations DMN custom data types in Business Central.

Procedure

1. Click the **Model** tab on the DMN designer and click the **Properties** icon in the upper-right corner of the DMN designer to expose the DRD properties.

2. In the DRD, select the **Driver** input data node and in the **Properties** panel, select **tDriver** from the **Data type** drop-down menu.

3. Select the **Violation** input data node and select **tViolation** from the **Data type** drop-down menu.

4. Select the **Fine** decision node and select **tFine** from the **Data type** drop-down menu.

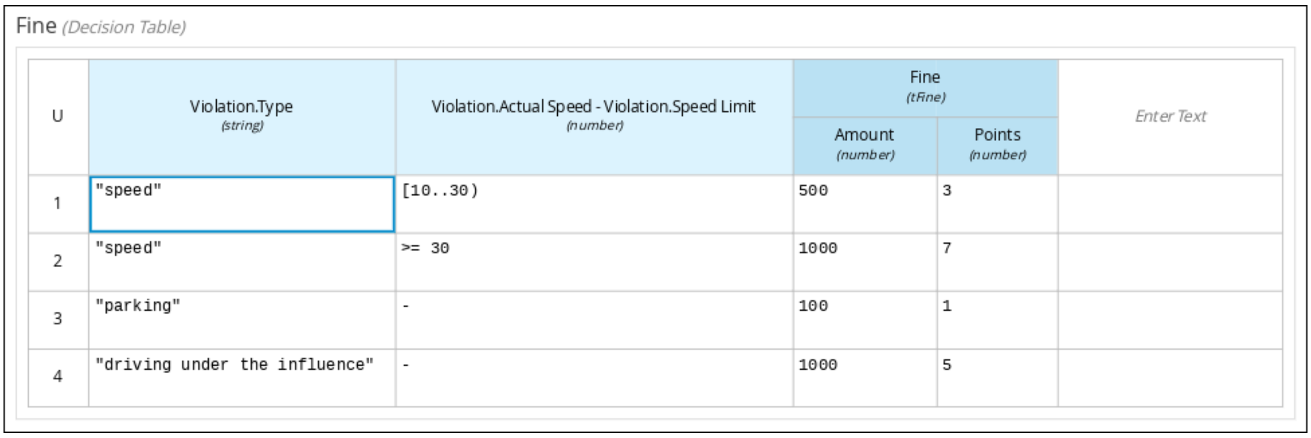
5. Select the **Should the driver be suspended?** decision node and set the following properties:
   - Data type: **string**
   - Question: **Should the driver be suspended due to points on his driver license?**
   - Allowed Answers: **Yes,No**
6. Click **Save**.

You have assigned the custom data types to your DRD's input and decision nodes.

5.4. DEFINING THE TRAFFIC VIOLATIONS DMN DECISION LOGIC

To calculate the fine and to decide whether the driver is to be suspended or not, you can define the traffic violations DMN decision logic using a DMN decision table and context boxed expression.

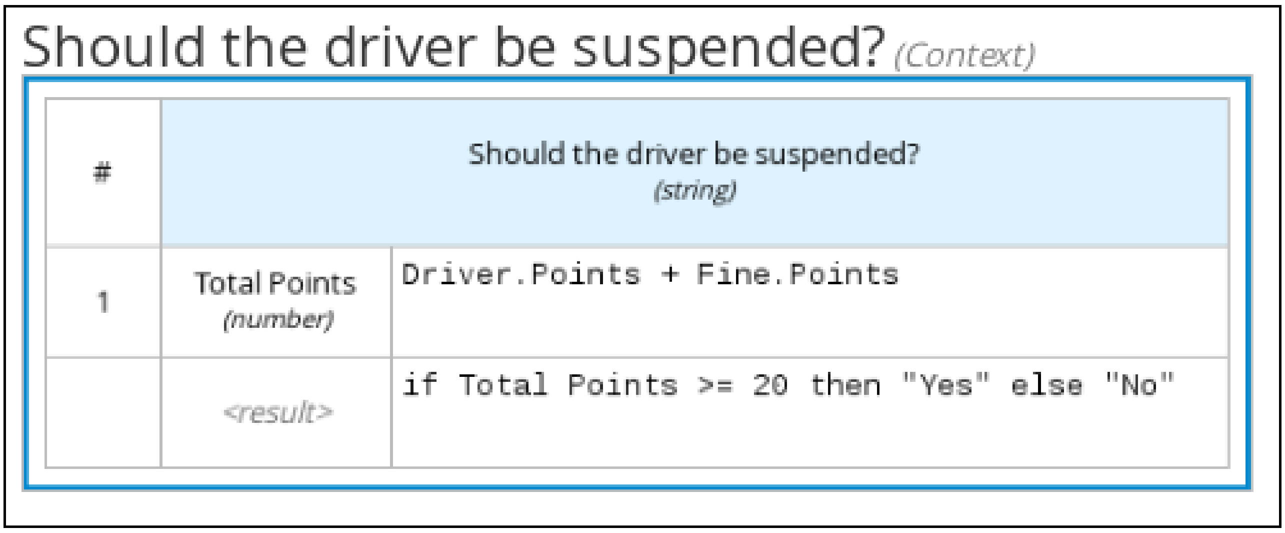
Figure 5.8. Fine expression



Fine *(Decision Table)*

U	Violation.Type *(string)*	Violation.Actual Speed - Violation.Speed Limit *(number)*	Fine *(tFine)* Amount *(number)*	Fine *(tFine)* Points *(number)*	Enter Text
1	"speed"	[10..30)	500	3	
2	"speed"	>= 30	1000	7	
3	"parking"	-	100	1	
4	"driving under the influence"	-	1000	5	

Figure 5.9. Should the driver be suspended expression



Should the driver be suspended? *(Context)*

#	Should the driver be suspended? *(string)*	
1	Total Points *(number)*	`Driver.Points + Fine.Points`
	<result>	`if Total Points >= 20 then "Yes" else "No"`

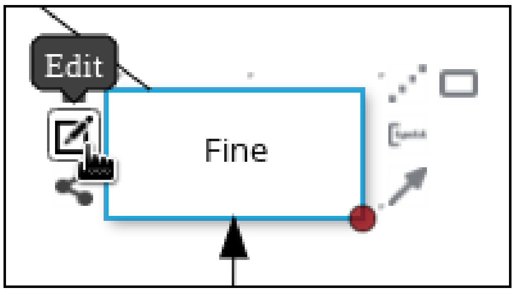
Prerequisites

- You have assigned the DMN custom data types to the appropriate decision and input nodes in the traffic violations DRD in Business Central.

Procedure

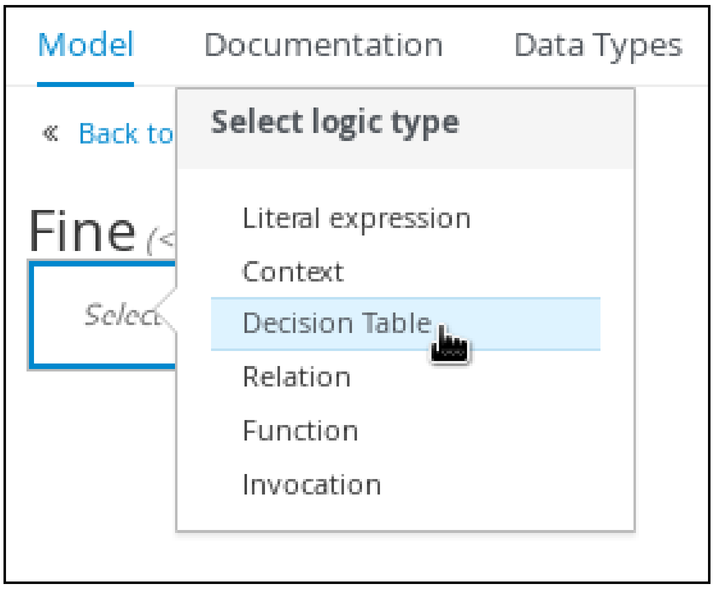
1. To calculate the fine, in the DMN designer canvas, select the **Fine** decision node and click the **Edit** icon to open the DMN boxed expression designer.

   Figure 5.10. Decision node edit icon

2. Click **Select expression → Decision Table**.

   Figure 5.11. Select Decisiong Table logic type

3. For the **Violation.Date**, **Violation.Code**, and **Violation.Speed Limit** columns, right-click and select **Delete** for each field.

4. Click the **Violation.Actual Speed** column header and enter the expression **Violation.Actual Speed - Violation.Speed Limit** in the **Expression** field."

5. Enter the following values in the first row of the decision table:
   - Violation.Type: **"speed"**
   - Violation.Actual Speed - Violation.Speed Limit **[10..30)**
   - Amount: **500**
   - Points: **3**
     Right-click the first row and select **Insert below** to add another row.

6. Enter the following values in the second row of the decision table:
   - Violation.Type: **"speed"**
   - Violation.Actual Speed - Violation.Speed Limit **>= 30**

- **Amount**: **1000**
- **Points**: **7**
  Right-click the second row and select **Insert below** to add another row.

7. Enter the following values in the third row of the decision table:
   - **Violation.Type**: **"parking"**
   - **Violation.Actual Speed - Violation.Speed Limit**: **-**
   - **Amount**: **100**
   - **Points**: **1**
     Right-click the third row and select **Insert below** to add another row.
8. Enter the following values in the fourth row of the decision table:
   - **Violation.Type**: **"driving under the influence"**
   - **Violation.Actual Speed - Violation.Speed Limit**: **-**
   - **Amount**: **1000**
   - **Points**: **5**
9. Click **Save**.
10. To define the driver suspension rule, return to the DMN designer canvas, select the **Should the driver be suspended?** decision node, and click the **Edit** icon to open the DMN boxed expression designer.
11. Click **Select expression → Context**.
12. Click **ContextEntry-1**, enter **Total Points** as the **Name**, and select **number** from the **Data Type** drop-down menu.
13. Click the cell next to **Total Points**, select **Literal expression** from the context menu, and enter **Driver.Points + Fine.Points** as the expression.
14. In the cell below **Driver.Points + Fine.Points**, select **Literal Expression** from the context menu, and enter **if Total Points >= 20 then "Yes" else "No"**.
15. Click **Save**.
    You have defined how to calculate the fine and the context for deciding when to suspend the driver. You can navigate to the **traffic-violation** project page and click **Build** to build the example project and address any errors noted in the **Alerts** panel.

CHAPTER 6. TEST SCENARIOS

Test scenarios in Red Hat Decision Manager enable you to validate the functionality of business rules and business rule data (for rules-based test scenarios) or of DMN models (for DMN-based test scenarios) before deploying them into a production environment. With a test scenario, you use data from your project to set given conditions and expected results based on one or more defined business rules. When you run the scenario, the expected results and actual results of the rule instance are compared. If the expected results match the actual results, the test is successful. If the expected results do not match the actual results, then the test fails.

Red Hat Decision Manager currently supports both the new **Test Scenarios** designer and the former **Test Scenarios (Legacy)** designer. The default designer is the new test scenarios designer, which supports testing of both rules and DMN models and provides an enhanced overall user experience with test scenarios. If required, you can continue to use the legacy test scenarios designer, which supports rule-based test scenarios only.

You can run the defined test scenarios in a number of ways, for example, you can run available test scenarios at the project level or inside a specific test scenario asset. Test scenarios are independent and cannot affect or modify other test scenarios. You can run test scenarios at any time during project development in Business Central. You do not have to compile or deploy your decision service to run test scenarios.

You can import data objects from different packages to the same project package as the test scenario. Assets in the same package are imported by default. After you create the necessary data objects and the test scenario, you can use the **Data Objects** tab of the test scenarios designer to verify that all required data objects are listed or to import other existing data objects by adding a **New item**.

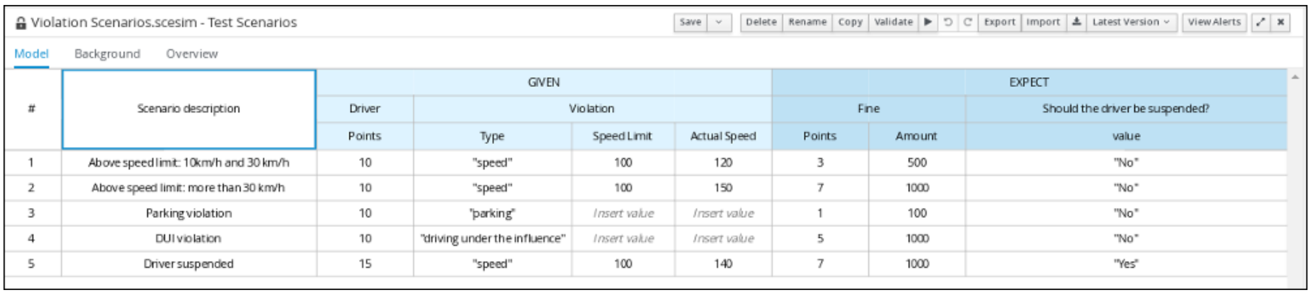
IMPORTANT

Throughout the test scenarios documentation, all references to *test scenarios* and the *test scenarios designer* are for the new version, unless explicitly noted as the legacy version.

6.1. TESTING THE TRAFFIC VIOLATIONS USING TEST SCENARIOS

Use the test scenarios designer in Business Central to test the DMN decision requirements diagrams (DRDs) and define decision logic for the traffic violations project.

Figure 6.1. Test scenario for the traffic violations example



#	Scenario description	GIVEN				EXPECT		
		Driver	Violation			Fine		Should the driver be suspended?
		Points	Type	Speed Limit	Actual Speed	Points	Amount	value
1	Above speed limit: 10km/h and 30 km/h	10	"speed"	100	120	3	500	"No"
2	Above speed limit: more than 30 km/h	10	"speed"	100	150	7	1000	"No"
3	Parking violation	10	"parking"	*Insert value*	*Insert value*	1	100	"No"
4	DUI violation	10	"driving under the influence"	*Insert value*	*Insert value*	5	1000	"No"
5	Driver suspended	15	"speed"	100	140	7	1000	"Yes"

Prerequisites

- You have successfully built the traffic violations project in Business Central.

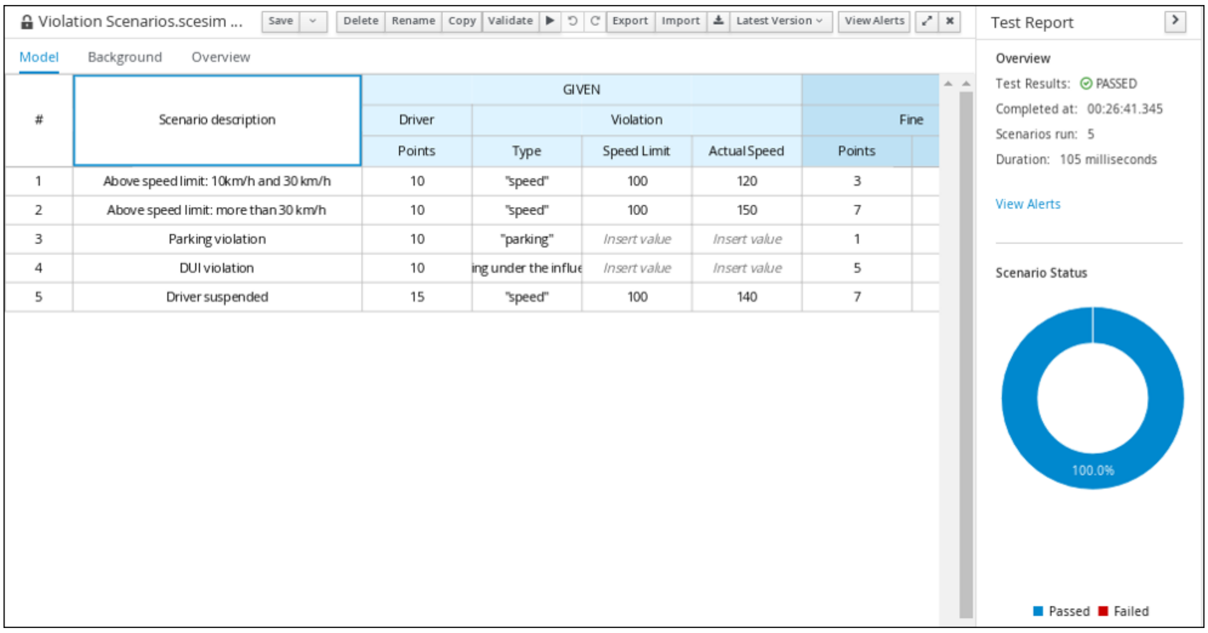
Procedure

1. On the **traffic-violation** project's home screen, click **Add Asset** to open the **Add Asset** screen.
2. Click **Test Scenario** to open the **Create new Test Scenario** dialog.
   a. Enter **Violation Scenarios** in the **Test Scenario** field.
   b. From the **Package** list, select **com.myspace.traffic_violation**.
   c. Select **DMN** as the **Source type**.
   d. From the **Choose a DMN asset** list, select the path to the DMN asset.
   e. Click **Ok** to open the **Violation Scenarios** test scenario in the **Test Scenarios** designer.
3. Under **Driver** column sub-header, right-click the **State**, **City**, **Age**, and **Name** value cells and select **Delete column** from the context menu options to remove them.
4. Under **Violation** column sub-header, right-click the **Date** and **Code** value cells and select **Delete column** to remove them.
5. Enter the following information in the first row of the test scenarios:
   - **Scenario description**: **Above speed limit: 10km/h and 30 km/h**
   - **Points** (under **Given** column header): **10**
   - **Type**: **"speed"**
   - **Speed Limit**: **100**
   - **Actual Speed**: **120**
   - **Points**: **3**
   - **Amount**: **500**
   - **Should the driver be suspended?**: **"No"**
     Right-click the first row and select **Insert row below** to add another row.
6. Enter the following information in the second row of the test scenarios:
   - **Scenario description**: **Above speed limit: more than 30 km/h**
   - **Points** (under **Given** column header): **10**
   - **Type**: **"speed"**
   - **Speed Limit**: **100**
   - **Actual Speed**: **150**
   - **Points**: **7**
   - **Amount**: **1000**
   - **Should the driver be suspended?**: **"No"**
     Right-click the second row and select **Insert row below** to add another row.

7. Enter the following information in the third row of the test scenarios:
   - **Scenario description**: **Parking violation**
   - **Points** (under **Given** column header): **10**
   - **Type**: **"parking"**
   - **Speed Limit**: leave blank
   - **Actual Speed**: leave blank
   - **Points**: **1**
   - **Amount**: **100**
   - **Should the driver be suspended?**: **"No"**
     Right-click the third row and select **Insert row below** to add another row.
8. Enter the following information in the fourth row of the test scenarios:
   - **Scenario description**: **DUI violation**
   - **Points** (under **Given** column header): **10**
   - **Type**: **"driving under the influence"**
   - **Speed Limit**: leave blank
   - **Actual Speed**: leave blank
   - **Points**: **5**
   - **Amount**: **1000**
   - **Should the driver be suspended?**: **"No"**
     Right-click the fourth row and select **Insert row below** to add another row.
9. Enter the following information in the fifth row of the test scenarios:
   - **Scenario description**: **Driver suspended**
   - **Points** (under **Given** column header): **15**
   - **Type**: **"speed"**
   - **Speed Limit**: **100**
   - **Actual Speed**: **140**
   - **Points**: **7**
   - **Amount**: **1000**
   - **Should the driver be suspended?**: **"Yes"**
10. Click **Save**.

11. Click the **Play** icon to check whether the test scenarios pass or fail.

Figure 6.2. Test scenario execution result for the traffic violations example



Violation Scenarios.scesim ...

Model | Background | Overview

#	Scenario description	GIVEN				
		Driver	Violation			Fine
		Points	Type	Speed Limit	Actual Speed	Points
1	Above speed limit: 10km/h and 30 km/h	10	"speed"	100	120	3
2	Above speed limit: more than 30 km/h	10	"speed"	100	150	7
3	Parking violation	10	"parking"	*Insert value*	*Insert value*	1
4	DUI violation	10	ing under the influe	*Insert value*	*Insert value*	5
5	Driver suspended	15	"speed"	100	140	7

Test Report

Overview

Test Results: ✓ PASSED

Completed at: 00:26:41.345

Scenarios run: 5

Duration: 105 milliseconds

View Alerts

Scenario Status

In case of failure, correct the errors and run the test scenarios again.

CHAPTER 7. DMN MODEL EXECUTION

You can create or import DMN files in your Red Hat Decision Manager project using Business Central or package the DMN files as part of your project knowledge JAR (KJAR) file without Business Central. After you implement your DMN files in your Red Hat Decision Manager project, you can execute the DMN decision service by deploying the KIE container that contains it to KIE Server for remote access and interacting with the container using the KIE Server REST API.

For information about including external DMN assets with your project packaging and deployment method, see *Packaging and deploying a Red Hat Decision Manager project* .

7.1. EXECUTING A DMN SERVICE USING THE KIE SERVER REST API

Directly interacting with the REST endpoints of KIE Server provides the most separation between the calling code and the decision logic definition. The calling code is completely free of direct dependencies, and you can implement it in an entirely different development platform such as **Node.js** or **.NET**. The examples in this section demonstrate Nix-style curl commands but provide relevant information to adapt to any REST client.

When you use a REST endpoint of KIE Server, the best practice is to define a domain object POJO Java class, annotated with standard KIE Server marshalling annotations. For example, the following code is using a domain object **Person** class that is annotated properly:

Example POJO Java class

```
@javax.xml.bind.annotation.XmlAccessorType(javax.xml.bind.annotation.XmlAccessType.FIELD)
public class Person implements java.io.Serializable {

    static final long serialVersionUID = 1L;

    private java.lang.String id;
    private java.lang.String name;

@javax.xml.bind.annotation.adapters.XmlJavaTypeAdapter(org.kie.internal.jaxb.LocalDateXmlAdapter.c
lass)
    private java.time.LocalDate dojoining;

    public Person() {
    }

    public java.lang.String getId() {
        return this.id;
    }

    public void setId(java.lang.String id) {
        this.id = id;
    }

    public java.lang.String getName() {
        return this.name;
    }

    public void setName(java.lang.String name) {
        this.name = name;
    }
    public java.time.LocalDate getDojoining() {
        return this.dojoining;
    }

    public void setDojoining(java.time.LocalDate dojoining) {
        this.dojoining = dojoining;
    }

    public Person(java.lang.String id, java.lang.String name,
            java.time.LocalDate dojoining) {
        this.id = id;
        this.name = name;
        this.dojoining = dojoining;
    }

}
```

For more information about the KIE Server REST API, see *Interacting with Red Hat Decision Manager using KIE APIs*.

Prerequisites

- KIE Server is installed and configured, including a known user name and credentials for a user with the **kie-server** role. For installation options, see *Planning a Red Hat Decision Manager installation*.
- You have built the DMN project as a KJAR artifact and deployed it to KIE Server. Ideally, you have built the DMN project as an executable model for more efficient execution:

  ```
  mvn clean install -DgenerateDMNModel=yes
  ```

  For more information about project packaging and deployment and executable models, see *Packaging and deploying a Red Hat Decision Manager project* .
- You have the ID of the KIE container containing the DMN model. If more than one model is present, you must also know the model namespace and model name of the relevant model.

Procedure

1. Determine the base URL for accessing the KIE Server REST API endpoints. This requires knowing the following values (with the default local deployment values as an example):
   - Host (**localhost**)
   - Port (**8080**)
   - Root context (**kie-server**)
   - Base REST path (**services/rest/**)

   Example base URL in local deployment for the traffic violations project:

   http://localhost:8080/kie-server/services/rest/server/containers/traffic-violation_1.0.0-SNAPSHOT

2. Determine user authentication requirements.
   When users are defined directly in the KIE Server configuration, HTTP Basic authentication is used and requires the user name and password. Successful requests require that the user have the **kie-server** role.

   The following example demonstrates how to add credentials to a curl request:

   ```
   curl -u username:password <request>
   ```

   If KIE Server is configured with Red Hat Single Sign-On, the request must include a bearer token:

   ```
   curl -H "Authorization: bearer $TOKEN" <request>
   ```

3. Specify the format of the request and response. The REST API endpoints work with both JSON and XML formats and are set using request headers:

   JSON

   ```
   curl -H "accept: application/json" -H "content-type: application/json"
   ```

   XML

   ```
   curl -H "accept: application/xml" -H "content-type: application/xml"
   ```

4. Optional: Query the container for a list of deployed decision models:
   [GET] server/containers/{containerId}/dmn

   Example curl request:

   ```
   curl -u wbadmin:wbadmin -H "accept: application/xml" -X GET "http://localhost:8080/kie-
   server/services/rest/server/containers/traffic-violation_1.0.0-SNAPSHOT/dmn"
   ```

   Sample XML output:

   ```
   <?xml version="1.0" encoding="UTF-8" standalone="yes"?>
   <response type="SUCCESS" msg="Ok models successfully retrieved from container 'traffic-
   violation_1.0.0-SNAPSHOT'">
     <dmn-model-info-list>
       <model>
         <model-namespace>https://github.com/kiegroup/drools/kie-dmn/_60b01f4d-e407-
   43f7-848e-258723b5fac8</model-namespace>
         <model-name>Traffic Violation</model-name>
         <model-id>_2CD7D1AA-BD84-4B43-AD21-B0342ADE655A</model-id>
         <decisions>
           <dmn-decision-info>
             <decision-id>_23428EE8-DC8B-4067-8E67-9D7C53EC975F</decision-id>
             <decision-name>Fine</decision-name>
           </dmn-decision-info>
           <dmn-decision-info>
             <decision-id>_B5EEE2B1-915C-44DC-BE43-C244DC066FD8</decision-id>
             <decision-name>Should the driver be suspended?</decision-name>
           </dmn-decision-info>
   ```

```
          </decisions>
          <inputs>
            <dmn-inputdata-info>
              <inputdata-id>_CEB959CD-3638-4A87-93BA-03CD0FB63AE3</inputdata-id>
              <inputdata-name>Violation</inputdata-name>
              <inputdata-typeref>
                <namespace-uri>https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-
E407-43F7-848E-258723B5FAC8</namespace-uri>
                <local-part>tViolation</local-part>
                <prefix></prefix>
              </inputdata-typeref>
            </dmn-inputdata-info>
            <dmn-inputdata-info>
              <inputdata-id>_B0E810E6-7596-430A-B5CF-67CE16863B6C</inputdata-id>
              <inputdata-name>Driver</inputdata-name>
              <inputdata-typeref>
                <namespace-uri>https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-
E407-43F7-848E-258723B5FAC8</namespace-uri>
                <local-part>tDriver</local-part>
                <prefix></prefix>
              </inputdata-typeref>
            </dmn-inputdata-info>
          </inputs>
          <itemdefinitions>
            <dmn-itemdefinition-info>
              <itemdefinition-id>_9C758F4A-7D72-4D0F-B63F-
2F5B8405980E</itemdefinition-id>
              <itemdefinition-name>tViolation</itemdefinition-name>
              <itemdefinition-itemcomponent>
                <dmn-itemdefinition-info>
                  <itemdefinition-id>_0B6FF1E2-ACE9-4FB3-876B-
5BB30B88009B</itemdefinition-id>
                  <itemdefinition-name>Code</itemdefinition-name>
                  <itemdefinition-typeref>
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e407-43f7-848e-258723b5fac8</namespace-uri>
                    <local-part>string</local-part>
                    <prefix></prefix>
                  </itemdefinition-typeref>
                  <itemdefinition-itemcomponent/>
                  <itemdefinition-iscollection>false</itemdefinition-iscollection>
                </dmn-itemdefinition-info>
                <dmn-itemdefinition-info>
                  <itemdefinition-id>_27A5DA18-3CA7-4C06-81B7-
CF7F2F050E29</itemdefinition-id>
                  <itemdefinition-name>date</itemdefinition-name>
                  <itemdefinition-typeref>
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E407-43F7-848E-258723B5FAC8</namespace-uri>
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                    <prefix></prefix>
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                  <itemdefinition-itemcomponent/>
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                <dmn-itemdefinition-info>
                <itemdefinition-id>_8961969A-8A80-4F12-B568-
346920C0F038</itemdefinition-id>
                <itemdefinition-name>type</itemdefinition-name>
                <itemdefinition-typeref>
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E407-43F7-848E-258723B5FAC8</namespace-uri>
                  <local-part>string</local-part>
                  <prefix></prefix>
                </itemdefinition-typeref>
                <itemdefinition-itemcomponent/>
                <itemdefinition-iscollection>false</itemdefinition-iscollection>
              </dmn-itemdefinition-info>
              <dmn-itemdefinition-info>
                <itemdefinition-id>_7450F12A-3E95-4D5E-8DCE-
2CB1FAC2BDD4</itemdefinition-id>
                <itemdefinition-name>speed limit</itemdefinition-name>
                <itemdefinition-typeref>
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e407-43f7-848e-258723b5fac8</namespace-uri>
                  <local-part>number</local-part>
                  <prefix></prefix>
                </itemdefinition-typeref>
                <itemdefinition-itemcomponent/>
                <itemdefinition-iscollection>false</itemdefinition-iscollection>
              </dmn-itemdefinition-info>
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765E5850429A</itemdefinition-id>
                <itemdefinition-name>Actual Speed</itemdefinition-name>
                <itemdefinition-typeref>
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E407-43F7-848E-258723B5FAC8</namespace-uri>
                  <local-part>number</local-part>
                  <prefix></prefix>
                </itemdefinition-typeref>
                <itemdefinition-itemcomponent/>
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            </itemdefinition-itemcomponent>
            <itemdefinition-iscollection>false</itemdefinition-iscollection>
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14FABE39A4A0</itemdefinition-id>
            <itemdefinition-name>tDriver</itemdefinition-name>
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2C757F40DFE8</itemdefinition-id>
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02493EAAC9D2</itemdefinition-id>
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                    <local-part>number</local-part>
                    <prefix></prefix>
                </itemdefinition-typeref>
                <itemdefinition-itemcomponent/>
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773C240FB9AD</itemdefinition-id>
                <itemdefinition-name>State</itemdefinition-name>
                <itemdefinition-typeref>
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E407-43F7-848E-258723B5FAC8</namespace-uri>
                    <local-part>string</local-part>
                    <prefix></prefix>
                </itemdefinition-typeref>
                <itemdefinition-itemcomponent/>
                <itemdefinition-iscollection>false</itemdefinition-iscollection>
            </dmn-itemdefinition-info>
            <dmn-itemdefinition-info>
                <itemdefinition-id>_3D4B49DD-700C-4925-99A7-
3B2B873F7800</itemdefinition-id>
                <itemdefinition-name>city</itemdefinition-name>
                <itemdefinition-typeref>
                    <namespace-uri>https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-
E407-43F7-848E-258723B5FAC8</namespace-uri>
                    <local-part>string</local-part>
                    <prefix></prefix>
                </itemdefinition-typeref>
                <itemdefinition-itemcomponent/>
                <itemdefinition-iscollection>false</itemdefinition-iscollection>
            </dmn-itemdefinition-info>
            <dmn-itemdefinition-info>
                <itemdefinition-id>_B37C49E8-B0D9-4B20-9DC6-
D655BB1CA7B1</itemdefinition-id>
                <itemdefinition-name>Points</itemdefinition-name>
                <itemdefinition-typeref>
                    <namespace-uri>https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-
E407-43F7-848E-258723B5FAC8</namespace-uri>
                    <local-part>number</local-part>
                    <prefix></prefix>
                </itemdefinition-typeref>
                <itemdefinition-itemcomponent/>
                <itemdefinition-iscollection>false</itemdefinition-iscollection>
            </dmn-itemdefinition-info>
        </itemdefinition-itemcomponent>
```

```
                    <itemdefinition-iscollection>false</itemdefinition-iscollection>
                </dmn-itemdefinition-info>
                <dmn-itemdefinition-info>
                    <itemdefinition-id>_A4077C7E-B57A-4DEE-9C65-
7769636316F3</itemdefinition-id>
                    <itemdefinition-name>tFine</itemdefinition-name>
                    <itemdefinition-itemcomponent>
                        <dmn-itemdefinition-info>
                            <itemdefinition-id>_79B152A8-DE83-4001-B88B-
52DFF0D73B2D</itemdefinition-id>
                            <itemdefinition-name>Amount</itemdefinition-name>
                            <itemdefinition-typeref>
                                <namespace-uri>https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-
E407-43F7-848E-258723B5FAC8</namespace-uri>
                                <local-part>number</local-part>
                                <prefix></prefix>
                            </itemdefinition-typeref>
                            <itemdefinition-itemcomponent/>
                            <itemdefinition-iscollection>false</itemdefinition-iscollection>
                        </dmn-itemdefinition-info>
                        <dmn-itemdefinition-info>
                            <itemdefinition-id>_D7CB5F9C-9D55-48C2-83EE-
D47045EC90D0</itemdefinition-id>
                            <itemdefinition-name>Points</itemdefinition-name>
                            <itemdefinition-typeref>
                                <namespace-uri>https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-
E407-43F7-848E-258723B5FAC8</namespace-uri>
                                <local-part>number</local-part>
                                <prefix></prefix>
                            </itemdefinition-typeref>
                            <itemdefinition-itemcomponent/>
                            <itemdefinition-iscollection>false</itemdefinition-iscollection>
                        </dmn-itemdefinition-info>
                    </itemdefinition-itemcomponent>
                    <itemdefinition-iscollection>false</itemdefinition-iscollection>
                </dmn-itemdefinition-info>
            </itemdefinitions>
            <decisionservices/>
        </model>
    </dmn-model-info-list>
</response>
```

Sample JSON output:

```
{
  "type" : "SUCCESS",
  "msg" : "OK models successfully retrieved from container 'Traffic-Violation_1.0.0-
SNAPSHOT'",
  "result" : {
    "dmn-model-info-list" : {
      "models" : [ {
        "model-namespace" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-
43F7-848E-258723B5FAC8",
        "model-name" : "Traffic Violation",
        "model-id" : "_2CD7D1AA-BD84-4B43-AD21-B0342ADE655A",
        "decisions" : [ {
```

```
        "decision-id" : "_23428EE8-DC8B-4067-8E67-9D7C53EC975F",
        "decision-name" : "Fine"
      }, {
        "decision-id" : "_B5EEE2B1-915C-44DC-BE43-C244DC066FD8",
        "decision-name" : "Should the driver be suspended?"
      } ],
      "inputs" : [ {
        "inputdata-id" : "_CEB959CD-3638-4A87-93BA-03CD0FB63AE3",
        "inputdata-name" : "Violation",
        "inputdata-typeRef" : {
          "namespace-uri" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-
43F7-848E-258723B5FAC8",
          "local-part" : "tViolation",
          "prefix" : ""
        }
      }, {
        "inputdata-id" : "_B0E810E6-7596-430A-B5CF-67CE16863B6C",
        "inputdata-name" : "Driver",
        "inputdata-typeRef" : {
          "namespace-uri" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-
43F7-848E-258723B5FAC8",
          "local-part" : "tDriver",
          "prefix" : ""
        }
      } ],
      "itemDefinitions" : [ {
        "itemdefinition-id" : "_13C7EFD8-B85C-43BF-94D3-14FABE39A4A0",
        "itemdefinition-name" : "tDriver",
        "itemdefinition-typeRef" : null,
        "itemdefinition-itemComponent" : [ {
          "itemdefinition-id" : "_EC11744C-4160-4549-9610-2C757F40DFE8",
          "itemdefinition-name" : "Name",
          "itemdefinition-typeRef" : {
            "namespace-uri" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-
43F7-848E-258723B5FAC8",
            "local-part" : "string",
            "prefix" : ""
          },
          "itemdefinition-itemComponent" : [ ],
          "itemdefinition-isCollection" : false
        }, {
          "itemdefinition-id" : "_E95BE3DB-4A51-4658-A166-02493EAAC9D2",
          "itemdefinition-name" : "Age",
          "itemdefinition-typeRef" : {
            "namespace-uri" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-
43F7-848E-258723B5FAC8",
            "local-part" : "number",
            "prefix" : ""
          },
          "itemdefinition-itemComponent" : [ ],
          "itemdefinition-isCollection" : false
        }, {
          "itemdefinition-id" : "_7B3023E2-BC44-4BF3-BF7E-773C240FB9AD",
          "itemdefinition-name" : "State",
          "itemdefinition-typeRef" : {
            "namespace-uri" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-
43F7-848E-258723B5FAC8",
              "local-part" : "string",
              "prefix" : ""
            },
            "itemdefinition-itemComponent" : [ ],
            "itemdefinition-isCollection" : false
          }, {
            "itemdefinition-id" : "_3D4B49DD-700C-4925-99A7-3B2B873F7800",
            "itemdefinition-name" : "City",
            "itemdefinition-typeRef" : {
              "namespace-uri" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-
43F7-848E-258723B5FAC8",
              "local-part" : "string",
              "prefix" : ""
            },
            "itemdefinition-itemComponent" : [ ],
            "itemdefinition-isCollection" : false
          }, {
            "itemdefinition-id" : "_B37C49E8-B0D9-4B20-9DC6-D655BB1CA7B1",
            "itemdefinition-name" : "Points",
            "itemdefinition-typeRef" : {
              "namespace-uri" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-
43F7-848E-258723B5FAC8",
              "local-part" : "number",
              "prefix" : ""
            },
            "itemdefinition-itemComponent" : [ ],
            "itemdefinition-isCollection" : false
          } ],
          "itemdefinition-isCollection" : false
        }, {
          "itemdefinition-id" : "_A4077C7E-B57A-4DEE-9C65-7769636316F3",
          "itemdefinition-name" : "tFine",
          "itemdefinition-typeRef" : null,
          "itemdefinition-itemComponent" : [ {
            "itemdefinition-id" : "_79B152A8-DE83-4001-B88B-52DFF0D73B2D",
            "itemdefinition-name" : "Amount",
            "itemdefinition-typeRef" : {
              "namespace-uri" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-
43F7-848E-258723B5FAC8",
              "local-part" : "number",
              "prefix" : ""
            },
            "itemdefinition-itemComponent" : [ ],
            "itemdefinition-isCollection" : false
          }, {
            "itemdefinition-id" : "_D7CB5F9C-9D55-48C2-83EE-D47045EC90D0",
            "itemdefinition-name" : "Points",
            "itemdefinition-typeRef" : {
              "namespace-uri" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-
43F7-848E-258723B5FAC8",
              "local-part" : "number",
              "prefix" : ""
            },
            "itemdefinition-itemComponent" : [ ],
            "itemdefinition-isCollection" : false
        } ],
        "itemdefinition-isCollection" : false
      }, {
        "itemdefinition-id" : "_9C758F4A-7D72-4D0F-B63F-2F5B8405980E",
        "itemdefinition-name" : "tViolation",
        "itemdefinition-typeRef" : null,
        "itemdefinition-itemComponent" : [ {
          "itemdefinition-id" : "_0B6FF1E2-ACE9-4FB3-876B-5BB30B88009B",
          "itemdefinition-name" : "Code",
          "itemdefinition-typeRef" : {
            "namespace-uri" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-
43F7-848E-258723B5FAC8",
            "local-part" : "string",
            "prefix" : ""
          },
          "itemdefinition-itemComponent" : [ ],
          "itemdefinition-isCollection" : false
        }, {
          "itemdefinition-id" : "_27A5DA18-3CA7-4C06-81B7-CF7F2F050E29",
          "itemdefinition-name" : "Date",
          "itemdefinition-typeRef" : {
            "namespace-uri" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-
43F7-848E-258723B5FAC8",
            "local-part" : "date",
            "prefix" : ""
          },
          "itemdefinition-itemComponent" : [ ],
          "itemdefinition-isCollection" : false
        }, {
          "itemdefinition-id" : "_8961969A-8A80-4F12-B568-346920C0F038",
          "itemdefinition-name" : "Type",
          "itemdefinition-typeRef" : {
            "namespace-uri" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-
43F7-848E-258723B5FAC8",
            "local-part" : "string",
            "prefix" : ""
          },
          "itemdefinition-itemComponent" : [ ],
          "itemdefinition-isCollection" : false
        }, {
          "itemdefinition-id" : "_7450F12A-3E95-4D5E-8DCE-2CB1FAC2BDD4",
          "itemdefinition-name" : "Speed Limit",
          "itemdefinition-typeRef" : {
            "namespace-uri" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-
43F7-848E-258723B5FAC8",
            "local-part" : "number",
            "prefix" : ""
          },
          "itemdefinition-itemComponent" : [ ],
          "itemdefinition-isCollection" : false
        }, {
          "itemdefinition-id" : "_0A9A6F26-6C14-414D-A9BF-765E5850429A",
          "itemdefinition-name" : "Actual Speed",
          "itemdefinition-typeRef" : {
            "namespace-uri" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-
43F7-848E-258723B5FAC8",
              "local-part" : "number",
              "prefix" : ""
            },
            "itemdefinition-itemComponent" : [ ],
            "itemdefinition-isCollection" : false
          } ],
          "itemdefinition-isCollection" : false
        } ],
        "decisionServices" : [ ]
      } ]
    }
  }
}
```

5. Execute the model:
   [POST] server/containers/{containerId}/dmn

   NOTE

   The attribute **model-namespace** is automatically generated and is different for every user. Ensure that the **model-namespace** and **model-name** attributes that you use match those of the deployed model.

   Example curl request:

```
curl -u wbadmin:wbadmin -H "accept: application/json" -H "content-type: application/json" -X POST "http://localhost:8080/kie-server/services/rest/server/containers/traffic-violation_1.0.0-SNAPSHOT/dmn" -d "{ \"model-namespace\" : \"https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-43F7-848E-258723B5FAC8\", \"model-name\" : \"Traffic Violation\", \"dmn-context\" : {\"Driver\" : {\"Points\" : 15}, \"Violation\" : {\"Type\" : \"speed\", \"Actual Speed\" : 135, \"Speed Limit\" : 100}}}"
```

   Example JSON request:

```
{
  "model-namespace" : "https://github.com/kiegroup/drools/kie-dmn/_60B01F4D-E407-43F7-848E-258723B5FAC8",
  "model-name" : "Traffic Violation",
  "dmn-context" :
  {
    "Driver" :
    {
      "Points" : 15
    },
   "Violation" :
    {
    "Type" : "speed",
    "Actual Speed" : 135,
    "Speed Limit" : 100
   }
  }
}
```

   Example XML request (JAXB format):

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<dmn-evaluation-context>
   <dmn-context xsi:type="jaxbListWrapper" xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance">
      <type>MAP</type>
      <element xsi:type="jaxbStringObjectPair" key="Violation">
         <value xsi:type="jaxbListWrapper">
            <type>MAP</type>
            <element xsi:type="jaxbStringObjectPair" key="Type">
               <value xsi:type="xs:string"
xmlns:xs="http://www.w3.org/2001/XMLSchema">speed</value>
            </element>
            <element xsi:type="jaxbStringObjectPair" key="Speed Limit">
               <value xsi:type="xs:decimal"
xmlns:xs="http://www.w3.org/2001/XMLSchema">100</value>
            </element>
            <element xsi:type="jaxbStringObjectPair" key="Actual Speed">
               <value xsi:type="xs:decimal"
xmlns:xs="http://www.w3.org/2001/XMLSchema">135</value>
            </element>
         </value>
      </element>
      <element xsi:type="jaxbStringObjectPair" key="Driver">
         <value xsi:type="jaxbListWrapper">
            <type>MAP</type>
            <element xsi:type="jaxbStringObjectPair" key="Points">
               <value xsi:type="xs:decimal"
xmlns:xs="http://www.w3.org/2001/XMLSchema">15</value>
            </element>
         </value>
      </element>
   </dmn-context>
</dmn-evaluation-context>
```

NOTE

Regardless of the request format, the request requires the following elements:

- Model namespace
- Model name
- Context object containing input values

Example JSON response:

```
{
  "type": "SUCCESS",
  "msg": "OK from container 'Traffic-Violation_1.0.0-SNAPSHOT'",
  "result": {
     "dmn-evaluation-result": {
        "messages": [],
        "model-namespace": "https://github.com/kiegroup/drools/kie-dmn/_7D8116DE-ADF5-
4560-A116-FE1A2EAFFF48",
        "model-name": "Traffic Violation",
            "decision-name": [],
            "dmn-context": {
                "Violation": {
                  "Type": "speed",
                  "Speed Limit": 100,
                  "Actual Speed": 135
                },
                "Should Driver be Suspended?": "Yes",
                  "Driver": {
                    "Points": 15
                  },
                  "Fine": {
                    "Points": 7,
                    "Amount": 1000
                  }
              },
        "decision-results": {
            "_E1AF5AC2-E259-455C-96E4-596E30D3BC86": {
                "messages": [],
                "decision-id": "_E1AF5AC2-E259-455C-96E4-596E30D3BC86",
                "decision-name": "Should the Driver be Suspended?",
                "result": "Yes",
                "status": "SUCCEEDED"
              },
            "_D7F02CE0-AF50-4505-AB80-C7D6DE257920": {
                "messages": [],
                "decision-id": "_D7F02CE0-AF50-4505-AB80-C7D6DE257920",
                "decision-name": "Fine",
                "result": {
                  "Points": 7,
                  "Amount": 1000
                },
            "status": "SUCCEEDED"
          }
        }
      }
    }
  }
```

Example XML (JAXB format) response:

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<response type="SUCCESS" msg="OK from container 'Traffic_1.0.0-SNAPSHOT'">
    <dmn-evaluation-result>
        <model-namespace>https://github.com/kiegroup/drools/kie-dmn/_A4BCA8B8-CF08-
433F-93B2-A2598F19ECFF</model-namespace>
        <model-name>Traffic Violation</model-name>
        <dmn-context xsi:type="jaxbListWrapper"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
            <type>MAP</type>
            <element xsi:type="jaxbStringObjectPair" key="Violation">
                <value xsi:type="jaxbListWrapper">
                    <type>MAP</type>
                    <element xsi:type="jaxbStringObjectPair" key="Type">
                        <value xsi:type="xs:string"
xmlns:xs="http://www.w3.org/2001/XMLSchema">speed</value>
```

```
                </element>
                <element xsi:type="jaxbStringObjectPair" key="Speed Limit">
                    <value xsi:type="xs:decimal"
xmlns:xs="http://www.w3.org/2001/XMLSchema">100</value>
                </element>
                <element xsi:type="jaxbStringObjectPair" key="Actual Speed">
                    <value xsi:type="xs:decimal"
xmlns:xs="http://www.w3.org/2001/XMLSchema">135</value>
                </element>
            </value>
        </element>
        <element xsi:type="jaxbStringObjectPair" key="Driver">
            <value xsi:type="jaxbListWrapper">
                <type>MAP</type>
                <element xsi:type="jaxbStringObjectPair" key="Points">
                    <value xsi:type="xs:decimal"
xmlns:xs="http://www.w3.org/2001/XMLSchema">15</value>
                </element>
            </value>
        </element>
        <element xsi:type="jaxbStringObjectPair" key="Fine">
            <value xsi:type="jaxbListWrapper">
                <type>MAP</type>
                <element xsi:type="jaxbStringObjectPair" key="Points">
                    <value xsi:type="xs:decimal"
xmlns:xs="http://www.w3.org/2001/XMLSchema">7</value>
                </element>
                <element xsi:type="jaxbStringObjectPair" key="Amount">
                    <value xsi:type="xs:decimal"
xmlns:xs="http://www.w3.org/2001/XMLSchema">1000</value>
                </element>
            </value>
        </element>
        <element xsi:type="jaxbStringObjectPair" key="Should the driver be suspended?">
            <value xsi:type="xs:string"
xmlns:xs="http://www.w3.org/2001/XMLSchema">Yes</value>
        </element>
    </dmn-context>
    <messages/>
    <decisionResults>
        <entry>
            <key>_4055D956-1C47-479C-B3F4-BAEB61F1C929</key>
            <value>
                <decision-id>_4055D956-1C47-479C-B3F4-BAEB61F1C929</decision-id>
                <decision-name>Fine</decision-name>
                <result xsi:type="jaxbListWrapper"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
                    <type>MAP</type>
                    <element xsi:type="jaxbStringObjectPair" key="Points">
                        <value xsi:type="xs:decimal"
xmlns:xs="http://www.w3.org/2001/XMLSchema">7</value>
                    </element>
                    <element xsi:type="jaxbStringObjectPair" key="Amount">
                        <value xsi:type="xs:decimal"
xmlns:xs="http://www.w3.org/2001/XMLSchema">1000</value>
                    </element>
```

```
          </result>
          <messages/>
          <status>SUCCEEDED</status>
        </value>
      </entry>
      <entry>
        <key>_8A408366-D8E9-4626-ABF3-5F69AA01F880</key>
        <value>
          <decision-id>_8A408366-D8E9-4626-ABF3-5F69AA01F880</decision-id>
          <decision-name>Should the driver be suspended?</decision-name>
          <result xsi:type="xs:string" xmlns:xs="http://www.w3.org/2001/XMLSchema"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">Yes</result>
          <messages/>
          <status>SUCCEEDED</status>
        </value>
      </entry>
    </decisionResults>
  </dmn-evaluation-result>
</response>
```

CHAPTER 8. ADDITIONAL RESOURCES

- *Designing a decision service using DMN models*
- *Testing a decision service using test scenarios*
- *Managing projects in Business Central*
- *Interacting with Red Hat Decision Manager using KIE APIs*

PART II. GETTING STARTED WITH RED HAT BUILD OF OPTAPLANNER

As a business rules developer, you can use Red Hat build of OptaPlanner to find the optimal solution to planning problems based on a set of limited resources and under specific constraints.

Use this document to start developing solvers with OptaPlanner.

CHAPTER 9. INTRODUCTION TO RED HAT BUILD OF OPTAPLANNER

OptaPlanner is a lightweight, embeddable planning engine that optimizes planning problems. It helps normal Java programmers solve planning problems efficiently, and it combines optimization heuristics and metaheuristics with very efficient score calculations.

For example, OptaPlanner helps solve various use cases:

- *Employee/Patient Rosters*: It helps create time tables for nurses and keeps track of patient bed management.
- *Educational Timetables*: It helps schedule lessons, courses, exams, and conference presentations.
- *Shop Schedules*: It tracks car assembly lines, machine queue planning, and workforce task planning.
- *Cutting Stock*: It minimizes waste by reducing the consumption of resources such as paper and steel.

Every organization faces planning problems; that is, they provide products and services with a limited set of constrained resources (employees, assets, time, and money).

OptaPlanner is open source software under the Apache Software License 2.0. It is 100% pure Java and runs on most Java virtual machines.

9.1. PLANNING PROBLEMS

A *planning problem* has an optimal goal, based on limited resources and under specific constraints. Optimal goals can be any number of things, such as:

- Maximized profits - the optimal goal results in the highest possible profit.
- Minimized ecological footprint - the optimal goal has the least amount of environmental impact.
- Maximized satisfaction for employees or customers - the optimal goal prioritizes the needs of employees or customers.

The ability to achieve these goals relies on the number of resources available. For example, the following resources might be limited:

- The number of people
- Amount of time
- Budget
- Physical assets, for example, machinery, vehicles, computers, buildings, and so on

You must also take into account the specific constraints related to these resources, such as the number of hours a person works, their ability to use certain machines, or compatibility between pieces of equipment.

Red Hat build of OptaPlanner helps Java programmers solve constraint satisfaction problems efficiently. It combines optimization heuristics and metaheuristics with efficient score calculation.

9.2. NP-COMPLETENESS IN PLANNING PROBLEMS

The provided use cases are *probably* NP-complete or NP-hard, which means the following statements apply:

- It is easy to verify a given solution to a problem in reasonable time.
- There is no simple way to find the optimal solution of a problem in reasonable time.

The implication is that solving your problem is probably harder than you anticipated, because the two common techniques do not suffice:

- A brute force algorithm (even a more advanced variant) takes too long.
- A quick algorithm, for example in the bin packing problem, *putting in the largest items first* returns a solution that is far from optimal.

By using advanced optimization algorithms, OptaPlanner finds a good solution in reasonable time for such planning problems.

9.3. SOLUTIONS TO PLANNING PROBLEMS

A planning problem has a number of solutions.

Several categories of solutions are:

Possible solution

A possible solution is any solution, whether or not it breaks any number of constraints. Planning problems often have an incredibly large number of possible solutions. Many of those solutions are not useful.

Feasible solution

A feasible solution is a solution that does not break any (negative) hard constraints. The number of feasible solutions are relative to the number of possible solutions. Sometimes there are no feasible solutions. Every feasible solution is a possible solution.

Optimal solution

An optimal solution is a solution with the highest score. Planning problems usually have a few optimal solutions. They always have at least one optimal solution, even in the case that there are no feasible solutions and the optimal solution is not feasible.

Best solution found

The best solution is the solution with the highest score found by an implementation in a given amount of time. The best solution found is likely to be feasible and, given enough time, it’s an optimal solution.

Counterintuitively, the number of possible solutions is huge (if calculated correctly), even with a small data set.

In the examples provided in the **planner-engine** distribution folder, most instances have a large number of possible solutions. As there is no guaranteed way to find the optimal solution, any implementation is forced to evaluate at least a subset of all those possible solutions.

OptaPlanner supports several optimization algorithms to efficiently wade through that incredibly large number of possible solutions.

Depending on the use case, some optimization algorithms perform better than others, but it is impossible to know in advance. Using OptaPlanner, you can switch the optimization algorithm by changing the solver configuration in a few lines of XML or code.

9.4. CONSTRAINTS ON PLANNING PROBLEMS

Usually, a planning problem has minimum two levels of constraints:

- A *(negative) hard constraint* must not be broken.
  For example, one teacher can not teach two different lessons at the same time.
- A *(negative) soft constraint* should not be broken if it can be avoided.
  For example, Teacher A does not like to teach on Friday afternoons.

Some problems also have positive constraints:

- A *positive soft constraint (or reward)* should be fulfilled if possible.
  For example, Teacher B likes to teach on Monday mornings.

Some basic problems only have hard constraints. Some problems have three or more levels of constraints, for example, hard, medium, and soft constraints.

These constraints define the *score calculation* (otherwise known as the *fitness function*) of a planning problem. Each solution of a planning problem is graded with a score. With OptaPlanner, score constraints are written in an object oriented language such as Java, or in Drools rules.

This type of code is flexible and scalable.

CHAPTER 10. EXAMPLES PROVIDED WITH RED HAT BUILD OF OPTAPLANNER

Several Red Hat build of OptaPlanner examples are shipped with Red Hat Decision Manager. You can review the code for examples and modify it as necessary to suit your needs.

NOTE

Red Hat does not provide support for the example code included in the Red Hat Decision Manager distribution.

Some of the OptaPlanner examples solve problems that are presented in academic contests. The **Contest** column in the following table lists the contests. It also identifies an example as being either *realistic* or *unrealistic* for the purpose of a contest. A *realistic contest* is an official, independent contest that meets the following standards:

- Clearly defined real-world use cases
- Real-world constraints
- Multiple real-world datasets
- Reproducible results within a specific time limit on specific hardware
- Serious participation from the academic and/or enterprise Operations Research community.

Realistic contests provide an objective comparison of OptaPlanner with competitive software and academic research.

Table 10.1. Examples overview

Example	Domain	Size	Contest	Directory name
N queens	1 entity class (1 variable)	Entity ⇐ **256** Value ⇐ **256** Search space ⇐ **10^616**	Pointless (cheatable)	**nqueens**
Cloud balancing	1 entity class (1 variable)	Entity ⇐ **2400** Value ⇐ **800** Search space ⇐ **10^6967**	No (Defined by us)	**cloudbalancing**
Traveling salesman	1 entity class (1 chained variable)	Entity ⇐ **980** Value ⇐ **980** Search space ⇐ **10^2504**	Unrealistic TSP web	**tsp**

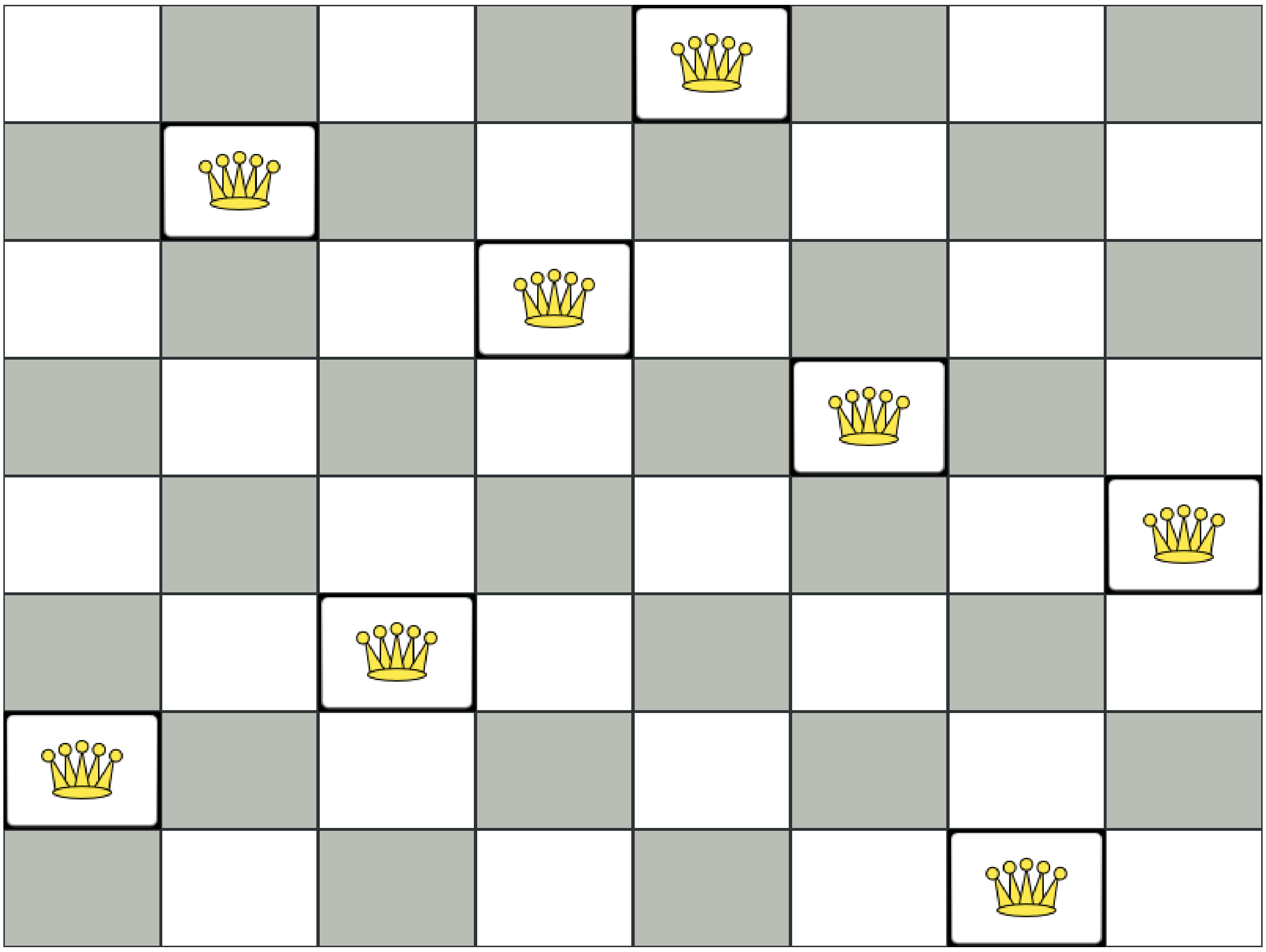
Example	Domain	Size	Contest	Directory name
Tennis club scheduling	1 entity class (1 variable)	Entity ⇐ **72** Value ⇐ **7** Search space ⇐ **10^60**	No (Defined by us)	**tennis**
Meeting scheduling	1 entity class (2 variables)	Entity ⇐ **10** Value ⇐ **320** and ⇐ **5** Search space ⇐ **10^320**	No (Defined by us)	**meetingscheduling**
Course timetabling	1 entity class (2 variables)	Entity ⇐ **434** Value ⇐ **25** and ⇐ **20** Search space ⇐ **10^1171**	Realistic ITC 2007 track 3	**curriculumCourse**
Machine reassignment	1 entity class (1 variable)	Entity ⇐ **50000** Value ⇐ **5000** Search space ⇐ **10^184948**	Nearly realistic ROADEF 2012	**machineReassignment**
Vehicle routing	1 entity class (1 chained variable) 1 shadow entity class (1 automatic shadow variable)	Entity ⇐ **2740** Value ⇐ **2795** Search space ⇐ **10^8380**	Unrealistic VRP web	**vehiclerouting**
Vehicle routing with time windows	All of Vehicle routing (1 shadow variable)	Entity ⇐ **2740** Value ⇐ **2795** Search space ⇐ **10^8380**	Unrealistic VRP web	**vehiclerouting**
Project job scheduling	1 entity class (2 variables) (1 shadow variable)	Entity ⇐ **640** Value ⇐ **?** and ⇐ **?** Search space ⇐ **?**	Nearly realistic MISTA 2013	**projectjobscheduling**

Example	Domain	Size	Contest	Directory name
Task assigning	1 entity class (1 chained variable) (1 shadow variable) 1 shadow entity class (1 automatic shadow variable)	Entity ⇐ **500** Value ⇐ **520** Search space ⇐ **10^1168**	No Defined by us	**taskassigning**
Exam timetabling	2 entity classes (same hierarchy) (2 variables)	Entity ⇐ **1096** Value ⇐ **80** and ⇐ **49** Search space ⇐ **10^3374**	Realistic ITC 2007 track 1	**examination**
Nurse rostering	1 entity class (1 variable)	Entity ⇐ **752** Value ⇐ **50** Search space ⇐ **10^1277**	Realistic INRC 2010	**nurserostering**
Traveling tournament	1 entity class (1 variable)	Entity ⇐ **1560** Value ⇐ **78** Search space ⇐ **10^2301**	Unrealistic TTP	**travelingtournament**
Cheap time scheduling	1 entity class (2 variables)	Entity ⇐ **500** Value ⇐ **100** and ⇐ **288** Search space ⇐ **10^20078**	Nearly realistic ICON Energy	**cheaptimescheduling**
Investment	1 entity class (1 variable)	Entity ⇐ **11** Value = **1000** Search space ⇐ **10^4**	No Defined by us	**investment**
Conference scheduling	1 entity class (2 variables)	Entity ⇐ **216** Value ⇐ **18** and ⇐ **20** Search space ⇐ **10^552**	No Defined by us	**conferencescheduling**

Example	Domain	Size	Contest	Directory name
Rock tour	1 entity class (1 chained variable) (4 shadow variables) 1 shadow entity class (1 automatic shadow variable)	Entity ⇐ **47** Value ⇐ **48** Search space ⇐ **10^59**	No Defined by us	**rocktour**
Flight crew scheduling	1 entity class (1 variable) 1 shadow entity class (1 automatic shadow variable)	Entity ⇐ **4375** Value ⇐ **750** Search space ⇐ **10^12578**	No Defined by us	**flightcrewscheduling**

10.1. N QUEENS

Place *n* queens on a *n* sized chessboard so that no two queens can attack each other. The most common *n* queens puzzle is the eight queens puzzle, with *n = 8*:



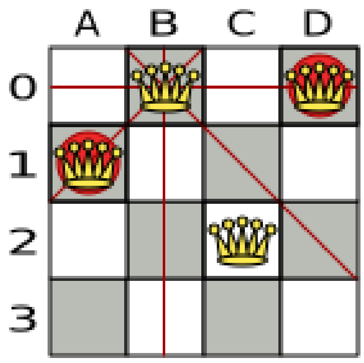
Constraints:

- Use a chessboard of *n* columns and *n* rows.
- Place *n* queens on the chessboard.
- No two queens can attack each other. A queen can attack any other queen on the same horizontal, vertical, or diagonal line.

This documentation heavily uses the four queens puzzle as the primary example.

A proposed solution could be:

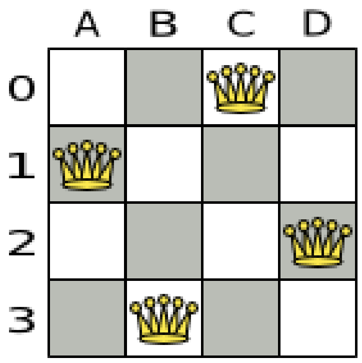
Figure 10.1. A wrong solution for the Four queens puzzle



The above solution is wrong because queens **A1** and **B0** can attack each other (so can queens **B0** and **D0**). Removing queen **B0** would respect the "no two queens can attack each other" constraint, but would break the "place *n* queens" constraint.

Below is a correct solution:

Figure 10.2. A correct solution for the Four queens puzzle



All the constraints have been met, so the solution is correct.

Note that most *n* queens puzzles have multiple correct solutions. We will focus on finding a single correct solution for a given *n*, not on finding the number of possible correct solutions for a given *n*.

Problem size

```
4queens   has   4 queens with a search space of    256.
8queens   has   8 queens with a search space of   10^7.
16queens  has  16 queens with a search space of  10^19.
```

```
32queens  has  32 queens with a search space of  10^48.
64queens  has  64 queens with a search space of 10^115.
256queens has 256 queens with a search space of 10^616.
```

The implementation of the *n* queens example has not been optimized because it functions as a beginner example. Nevertheless, it can easily handle 64 queens. With a few changes it has been shown to easily handle 5000 queens and more.

10.1.1. Domain model for N queens

This example uses the domain model to solve the four queens problem.

- **Creating a Domain Model**
  A good domain model will make it easier to understand and solve your planning problem.

  This is the domain model for the *n* queens example:

  ```
  public class Column {

      private int index;

      // ... getters and setters
  }
  ```

  ```
  public class Row {

      private int index;

      // ... getters and setters
  }
  ```

  ```
  public class Queen {

      private Column column;
      private Row row;

      public int getAscendingDiagonalIndex() {...}
      public int getDescendingDiagonalIndex() {...}

      // ... getters and setters
  }
  ```

- **Calculating the Search Space.**
  A **Queen** instance has a **Column** (for example: 0 is column A, 1 is column B, ...) and a **Row** (its row, for example: 0 is row 0, 1 is row 1, ...).

  The ascending diagonal line and the descending diagonal line can be calculated based on the column and the row.

  The column and row indexes start from the upper left corner of the chessboard.

  ```
  public class NQueens {

      private int n;
  ```

```
    private List<Column> columnList;
    private List<Row> rowList;

    private List<Queen> queenList;

    private SimpleScore score;

    // ... getters and setters
}
```

- Finding the Solution
  A single **NQueens** instance contains a list of all **Queen** instances. It is the **Solution** implementation which will be supplied to, solved by, and retrieved from the Solver.

Notice that in the four queens example, NQueens's **getN()** method will always return four.

Figure 10.3. A solution for Four Queens

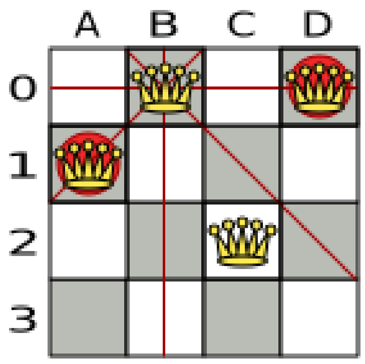


Table 10.2. Details of the solution in the domain model

	columnIndex	rowIndex	ascendingDiagonalIndex (columnIndex + rowIndex)	descendingDiagonalIndex (columnIndex - rowIndex)
A1	0	1	**1 (**)**	-1
B0	1	**0 (*)**	**1 (**)**	1
C2	2	2	4	0
D0	3	**0 (*)**	3	3

When two queens share the same column, row or diagonal line, such as (*) and (**), they can attack each other.

10.2. CLOUD BALANCING

For information about this example, see *Red Hat build of OptaPlanner quick start guides* .

10.3. TRAVELING SALESMAN (TSP - TRAVELING SALESMAN PROBLEM)

Given a list of cities, find the shortest tour for a salesman that visits each city exactly once.

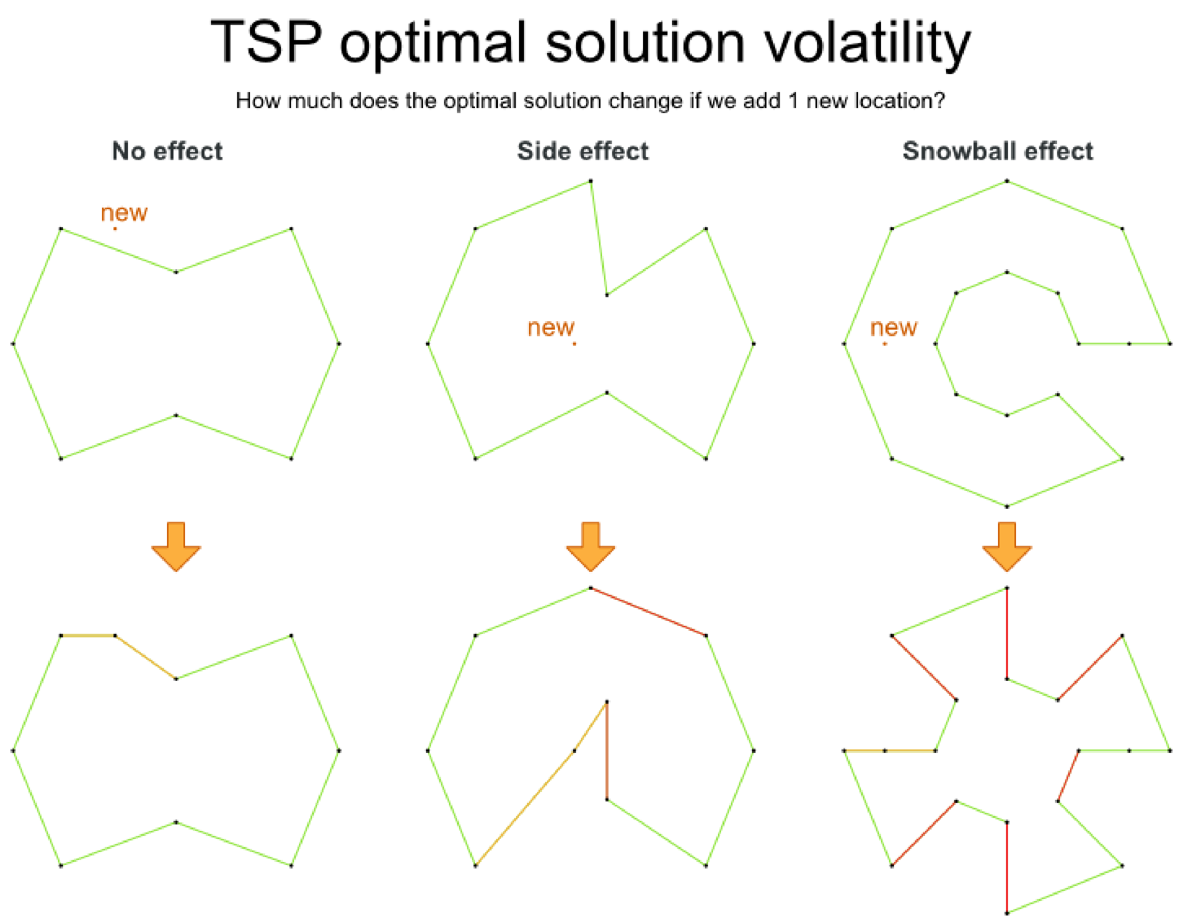
The problem is defined by Wikipedia. It is one of the most intensively studied problems in computational mathematics. Yet, in the real world, it is often only part of a planning problem, along with other constraints, such as employee shift rostering constraints.

Problem size

```
dj38     has  38 cities with a search space of   10^43.
europe40 has  40 cities with a search space of   10^46.
st70     has  70 cities with a search space of   10^98.
pcb442   has 442 cities with a search space of  10^976.
lu980    has 980 cities with a search space of 10^2504.
```

Problem difficulty

Despite TSP's simple definition, the problem is surprisingly hard to solve. Because it is an NP-hard problem (like most planning problems), the optimal solution for a specific problem dataset can change a lot when that problem dataset is slightly altered:


TSP optimal solution volatility
How much does the optimal solution change if we add 1 new location?
No effect
Side effect
Snowball effect
new
new
new

10.4. TENNIS CLUB SCHEDULING

Every week the tennis club has four teams playing round robin against each other. Assign those four spots to the teams fairly.

Hard constraints:

- Conflict: A team can only play once per day.
- Unavailability: Some teams are unavailable on some dates.

Medium constraints:

- Fair assignment: All teams should play an (almost) equal number of times.

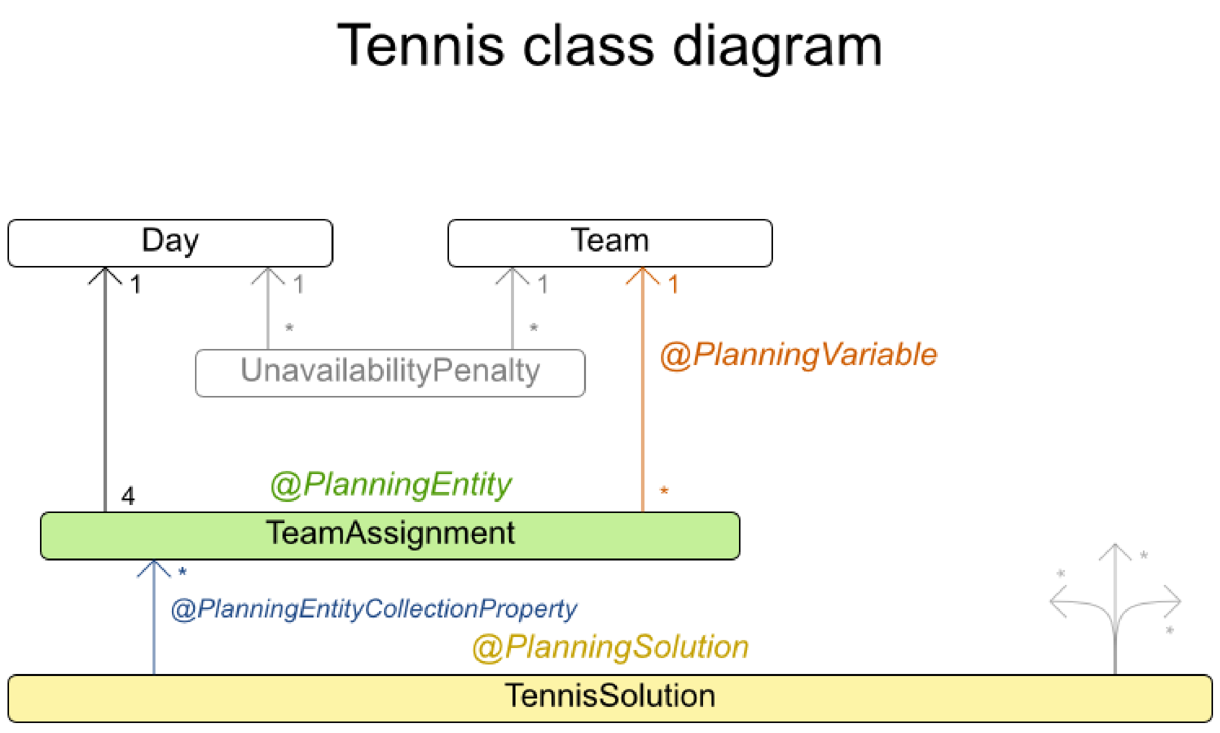
Soft constraints:

- Evenly confrontation: Each team should play against every other team an equal number of times.

Problem size

> munich-7teams has 7 teams, 18 days, 12 unavailabilityPenalties and 72 teamAssignments with a search space of 10^60.

Figure 10.4. Domain model



10.5. MEETING SCHEDULING

Assign each meeting to a starting time and a room. Meetings have different durations.

Hard constraints:

- Room conflict: two meetings must not use the same room at the same time.

- Required attendance: A person cannot have two required meetings at the same time.
- Required room capacity: A meeting must not be in a room that doesn't fit all of the meeting's attendees.
- Start and end on same day: A meeting shouldn't be scheduled over multiple days.

Medium constraints:

- Preferred attendance: A person cannot have two preferred meetings at the same time, nor a preferred and a required meeting at the same time.

Soft constraints:

- Sooner rather than later: Schedule all meetings as soon as possible.
- A break between meetings: Any two meetings should have at least one time grain break between them.
- Overlapping meetings: To minimize the number of meetings in parallel so people don't have to choose one meeting over the other.
- Assign larger rooms first: If a larger room is available any meeting should be assigned to that room in order to accommodate as many people as possible even if they haven't signed up to that meeting.
- Room stability: If a person has two consecutive meetings with two or less time grains break between them they better be in the same room.

Problem size

```
50meetings-160timegrains-5rooms  has  50 meetings, 160 timeGrains and 5 rooms with a search
space of 10^145.
100meetings-320timegrains-5rooms has 100 meetings, 320 timeGrains and 5 rooms with a search
space of 10^320.
200meetings-640timegrains-5rooms has 200 meetings, 640 timeGrains and 5 rooms with a search
space of 10^701.
400meetings-1280timegrains-5rooms has 400 meetings, 1280 timeGrains and 5 rooms with a search
space of 10^1522.
800meetings-2560timegrains-5rooms has 800 meetings, 2560 timeGrains and 5 rooms with a search
space of 10^3285.
```

10.6. COURSE TIMETABLING (ITC 2007 TRACK 3 - CURRICULUM COURSE SCHEDULING)

Schedule each lecture into a timeslot and into a room.

Hard constraints:

- Teacher conflict: A teacher must not have two lectures in the same period.
- Curriculum conflict: A curriculum must not have two lectures in the same period.
- Room occupancy: Two lectures must not be in the same room in the same period.

- Unavailable period (specified per dataset): A specific lecture must not be assigned to a specific period.

Soft constraints:

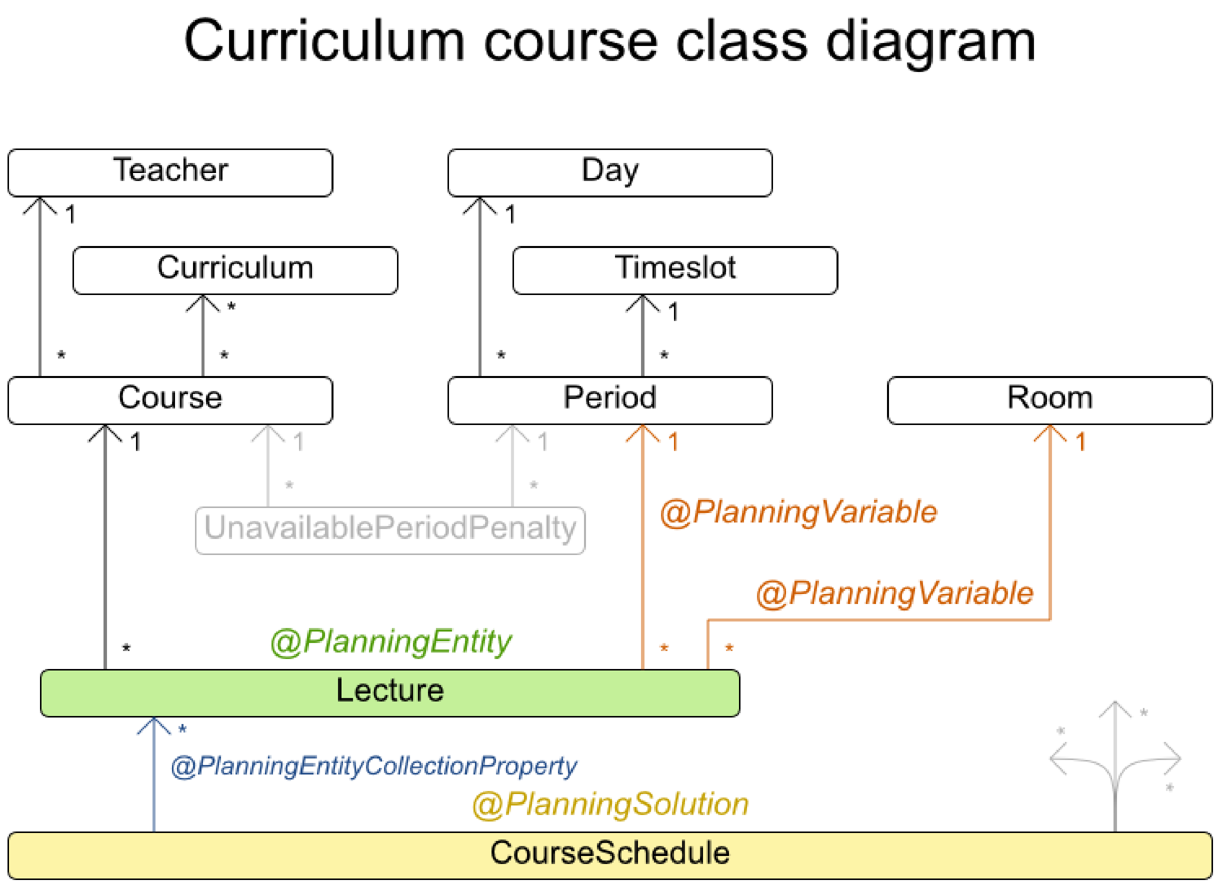
- Room capacity: A room's capacity should not be less than the number of students in its lecture.
- Minimum working days: Lectures of the same course should be spread out into a minimum number of days.
- Curriculum compactness: Lectures belonging to the same curriculum should be adjacent to each other (so in consecutive periods).
- Room stability: Lectures of the same course should be assigned to the same room.

The problem is defined by the International Timetabling Competition 2007 track 3 .

Problem size

```
comp01 has 24 teachers,  14 curricula,  30 courses, 160 lectures, 30 periods,  6 rooms and   53 unavailable period constraints with a search space of  10^360.
comp02 has 71 teachers,  70 curricula,  82 courses, 283 lectures, 25 periods, 16 rooms and  513 unavailable period constraints with a search space of  10^736.
comp03 has 61 teachers,  68 curricula,  72 courses, 251 lectures, 25 periods, 16 rooms and  382 unavailable period constraints with a search space of  10^653.
comp04 has 70 teachers,  57 curricula,  79 courses, 286 lectures, 25 periods, 18 rooms and  396 unavailable period constraints with a search space of  10^758.
comp05 has 47 teachers, 139 curricula,  54 courses, 152 lectures, 36 periods,  9 rooms and  771 unavailable period constraints with a search space of  10^381.
comp06 has 87 teachers,  70 curricula, 108 courses, 361 lectures, 25 periods, 18 rooms and  632 unavailable period constraints with a search space of  10^957.
comp07 has 99 teachers,  77 curricula, 131 courses, 434 lectures, 25 periods, 20 rooms and  667 unavailable period constraints with a search space of 10^1171.
comp08 has 76 teachers,  61 curricula,  86 courses, 324 lectures, 25 periods, 18 rooms and  478 unavailable period constraints with a search space of  10^859.
comp09 has 68 teachers,  75 curricula,  76 courses, 279 lectures, 25 periods, 18 rooms and  405 unavailable period constraints with a search space of  10^740.
comp10 has 88 teachers,  67 curricula, 115 courses, 370 lectures, 25 periods, 18 rooms and  694 unavailable period constraints with a search space of  10^981.
comp11 has 24 teachers,  13 curricula,  30 courses, 162 lectures, 45 periods,  5 rooms and   94 unavailable period constraints with a search space of  10^381.
comp12 has 74 teachers, 150 curricula,  88 courses, 218 lectures, 36 periods, 11 rooms and 1368 unavailable period constraints with a search space of  10^566.
comp13 has 77 teachers,  66 curricula,  82 courses, 308 lectures, 25 periods, 19 rooms and  468 unavailable period constraints with a search space of  10^824.
comp14 has 68 teachers,  60 curricula,  85 courses, 275 lectures, 25 periods, 17 rooms and  486 unavailable period constraints with a search space of  10^722.
```

Figure 10.5. Domain model



10.7. MACHINE REASSIGNMENT (GOOGLE ROADEF 2012)

Assign each process to a machine. All processes already have an original (unoptimized) assignment. Each process requires an amount of each resource (such as CPU or RAM). This is a more complex version of the Cloud Balancing example.

Hard constraints:

- Maximum capacity: The maximum capacity for each resource for each machine must not be exceeded.
- Conflict: Processes of the same service must run on distinct machines.
- Spread: Processes of the same service must be spread out across locations.
- Dependency: The processes of a service depending on another service must run in the neighborhood of a process of the other service.
- Transient usage: Some resources are transient and count towards the maximum capacity of both the original machine as the newly assigned machine.

Soft constraints:

- Load: The safety capacity for each resource for each machine should not be exceeded.

- Balance: Leave room for future assignments by balancing the available resources on each machine.
- Process move cost: A process has a move cost.
- Service move cost: A service has a move cost.
- Machine move cost: Moving a process from machine A to machine B has another A-B specific move cost.

The problem is defined by the Google ROADEF/EURO Challenge 2012 .

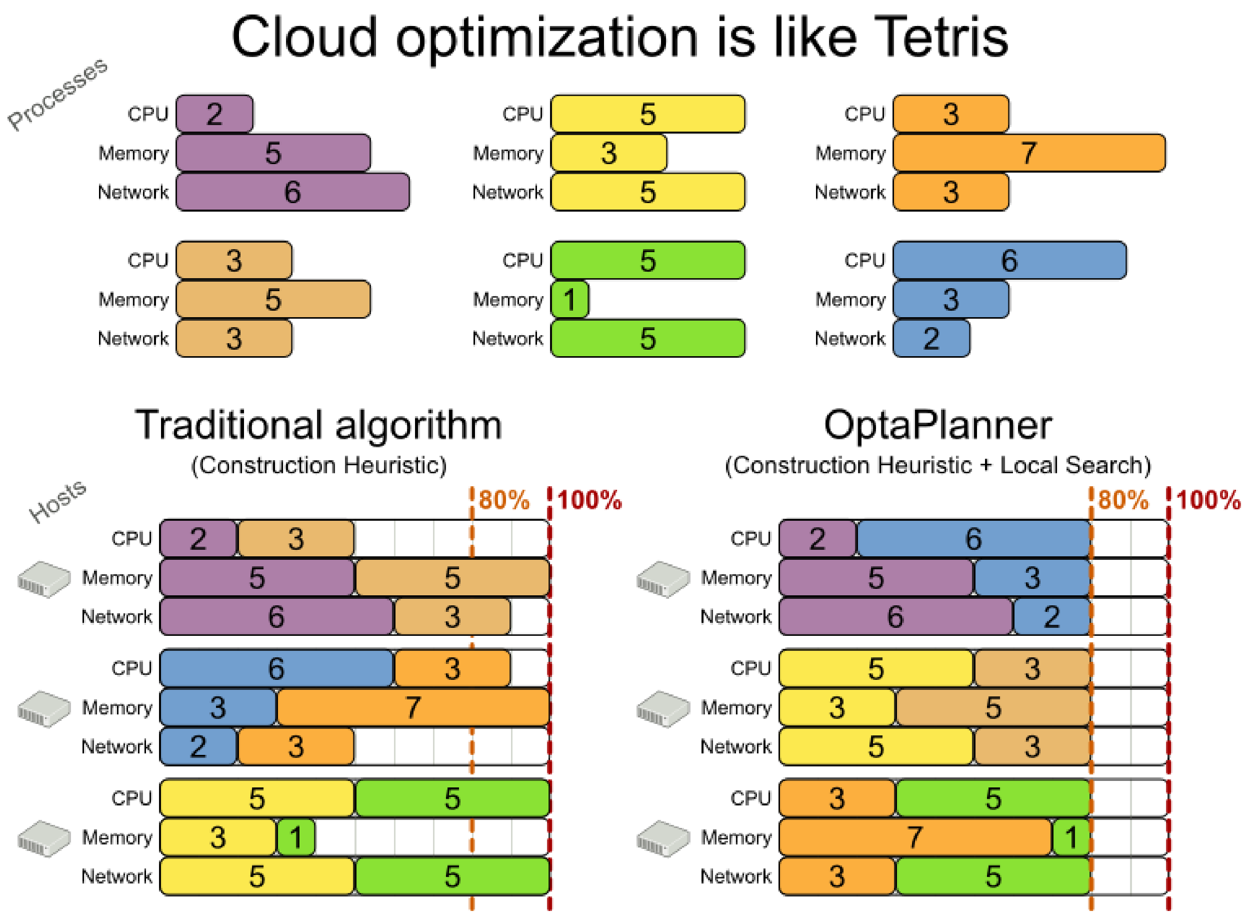
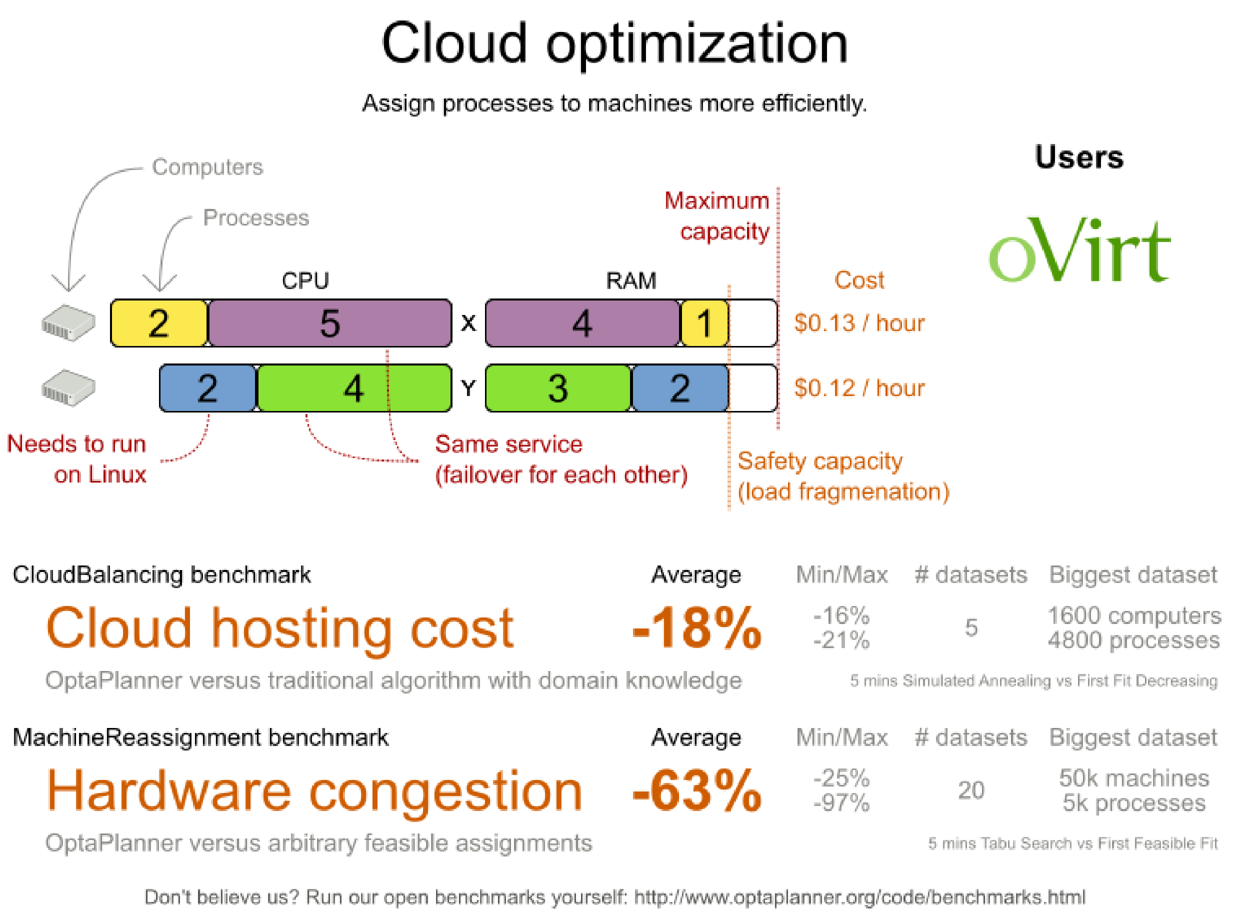


Figure 10.6. Value proposition

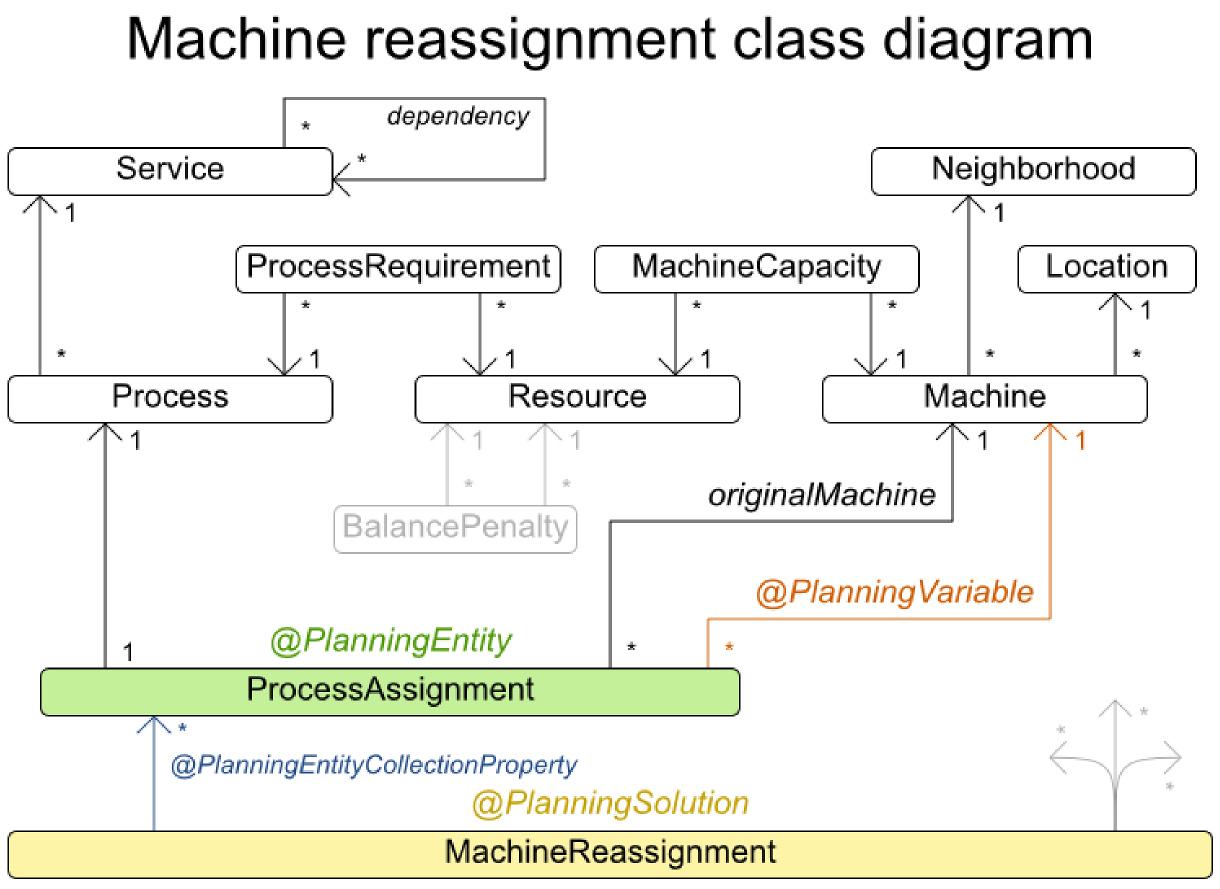

Cloud optimization
Assign processes to machines more efficiently.
Users
oVirt
Computers
Processes
CPU
RAM
Maximum capacity
Cost
2
5
X
4
1
$0.13 / hour
2
4
Y
3
2
$0.12 / hour
Needs to run on Linux
Same service (failover for each other)
Safety capacity (load fragmentation)
CloudBalancing benchmark
Average
Min/Max
# datasets
Biggest dataset
Cloud hosting cost
-18%
-16% -21%
5
1600 computers 4800 processes
OptaPlanner versus traditional algorithm with domain knowledge
5 mins Simulated Annealing vs First Fit Decreasing
MachineReassignment benchmark
Average
Min/Max
# datasets
Biggest dataset
Hardware congestion
-63%
-25% -97%
20
50k machines 5k processes
OptaPlanner versus arbitrary feasible assignments
5 mins Tabu Search vs First Feasible Fit
Don't believe us? Run our open benchmarks yourself: http://www.optaplanner.org/code/benchmarks.html

Problem size

```
model_a1_1 has  2 resources,  1 neighborhoods,  4 locations,   4 machines,   79 services,  100
processes and 1 balancePenalties with a search space of    10^60.
model_a1_2 has  4 resources,  2 neighborhoods,  4 locations, 100 machines,  980 services, 1000
processes and 0 balancePenalties with a search space of  10^2000.
model_a1_3 has  3 resources,  5 neighborhoods, 25 locations, 100 machines,  216 services, 1000
processes and 0 balancePenalties with a search space of  10^2000.
model_a1_4 has  3 resources, 50 neighborhoods, 50 locations,  50 machines,  142 services, 1000
processes and 1 balancePenalties with a search space of  10^1698.
model_a1_5 has  4 resources,  2 neighborhoods,  4 locations,  12 machines,  981 services, 1000
processes and 1 balancePenalties with a search space of  10^1079.
model_a2_1 has  3 resources,  1 neighborhoods,  1 locations, 100 machines, 1000 services, 1000
processes and 0 balancePenalties with a search space of  10^2000.
model_a2_2 has 12 resources,  5 neighborhoods, 25 locations, 100 machines,  170 services, 1000
processes and 0 balancePenalties with a search space of  10^2000.
model_a2_3 has 12 resources,  5 neighborhoods, 25 locations, 100 machines,  129 services, 1000
processes and 0 balancePenalties with a search space of  10^2000.
model_a2_4 has 12 resources,  5 neighborhoods, 25 locations,  50 machines,  180 services, 1000
processes and 1 balancePenalties with a search space of  10^1698.
model_a2_5 has 12 resources,  5 neighborhoods, 25 locations,  50 machines,  153 services, 1000
processes and 0 balancePenalties with a search space of  10^1698.
model_b_1  has 12 resources,  5 neighborhoods, 10 locations, 100 machines, 2512 services, 5000
processes and 0 balancePenalties with a search space of 10^10000.
model_b_2  has 12 resources,  5 neighborhoods, 10 locations, 100 machines, 2462 services, 5000
processes and 1 balancePenalties with a search space of 10^10000.
```

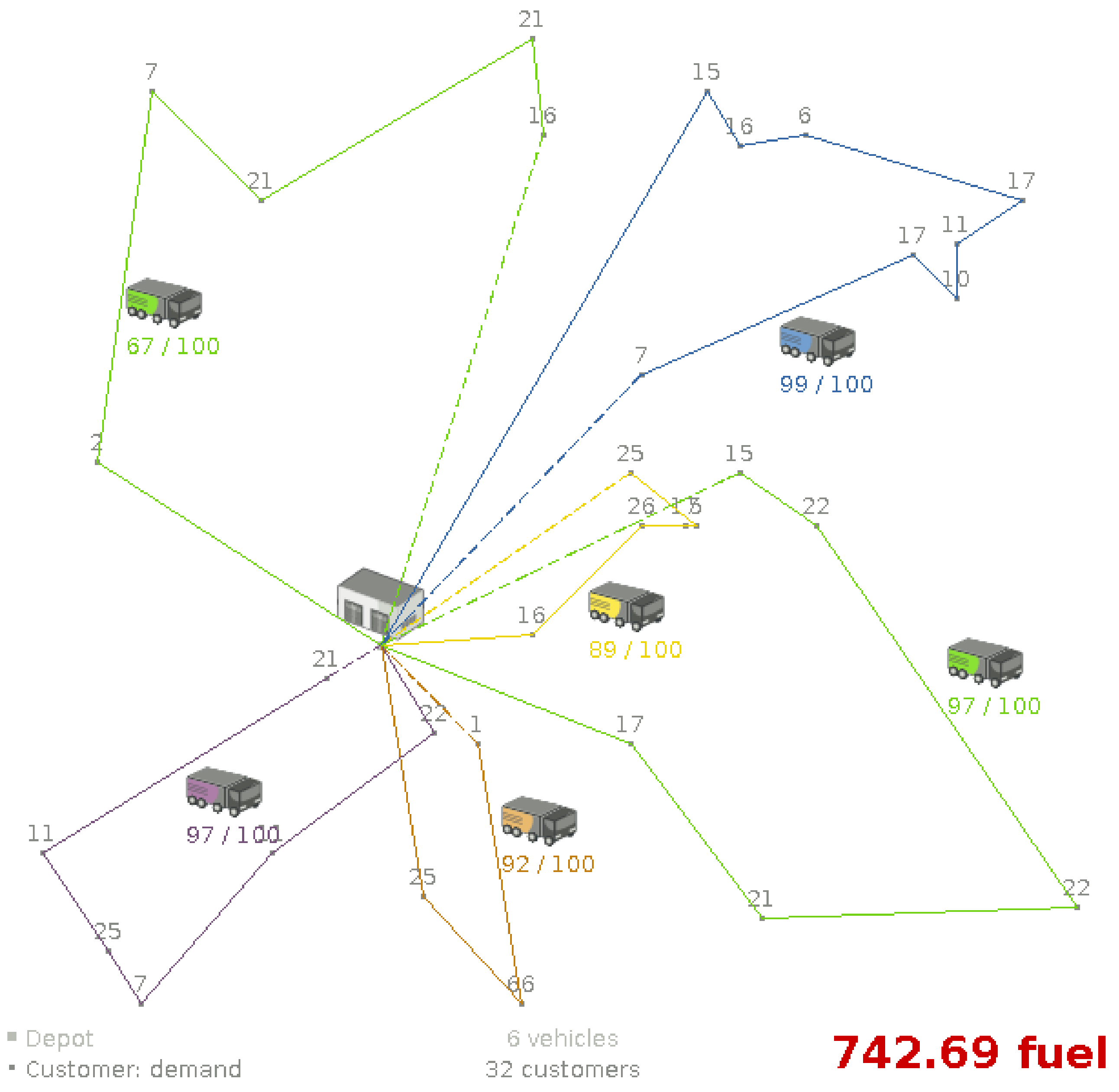
```
model_b_3  has  6 resources,  5 neighborhoods,  10 locations,  100 machines, 15025 services, 20000
processes and 0 balancePenalties with a search space of  10^40000.
model_b_4  has  6 resources,  5 neighborhoods,  50 locations,  500 machines,  1732 services, 20000
processes and 1 balancePenalties with a search space of  10^53979.
model_b_5  has  6 resources,  5 neighborhoods,  10 locations,  100 machines, 35082 services, 40000
processes and 0 balancePenalties with a search space of  10^80000.
model_b_6  has  6 resources,  5 neighborhoods,  50 locations,  200 machines, 14680 services, 40000
processes and 1 balancePenalties with a search space of  10^92041.
model_b_7  has  6 resources,  5 neighborhoods,  50 locations, 4000 machines, 15050 services,
40000 processes and 1 balancePenalties with a search space of 10^144082.
model_b_8  has  3 resources,  5 neighborhoods,  10 locations,  100 machines, 45030 services, 50000
processes and 0 balancePenalties with a search space of 10^100000.
model_b_9  has  3 resources,  5 neighborhoods, 100 locations, 1000 machines,  4609 services,
50000 processes and 1 balancePenalties with a search space of 10^150000.
model_b_10 has  3 resources,  5 neighborhoods, 100 locations, 5000 machines,  4896 services,
50000 processes and 1 balancePenalties with a search space of 10^184948.
```

Figure 10.7. Domain model



10.8. VEHICLE ROUTING

Using a fleet of vehicles, pick up the objects of each customer and bring them to the depot. Each vehicle can service multiple customers, but it has a limited capacity.



Besides the basic case (CVRP), there is also a variant with time windows (CVRPTW).

Hard constraints:

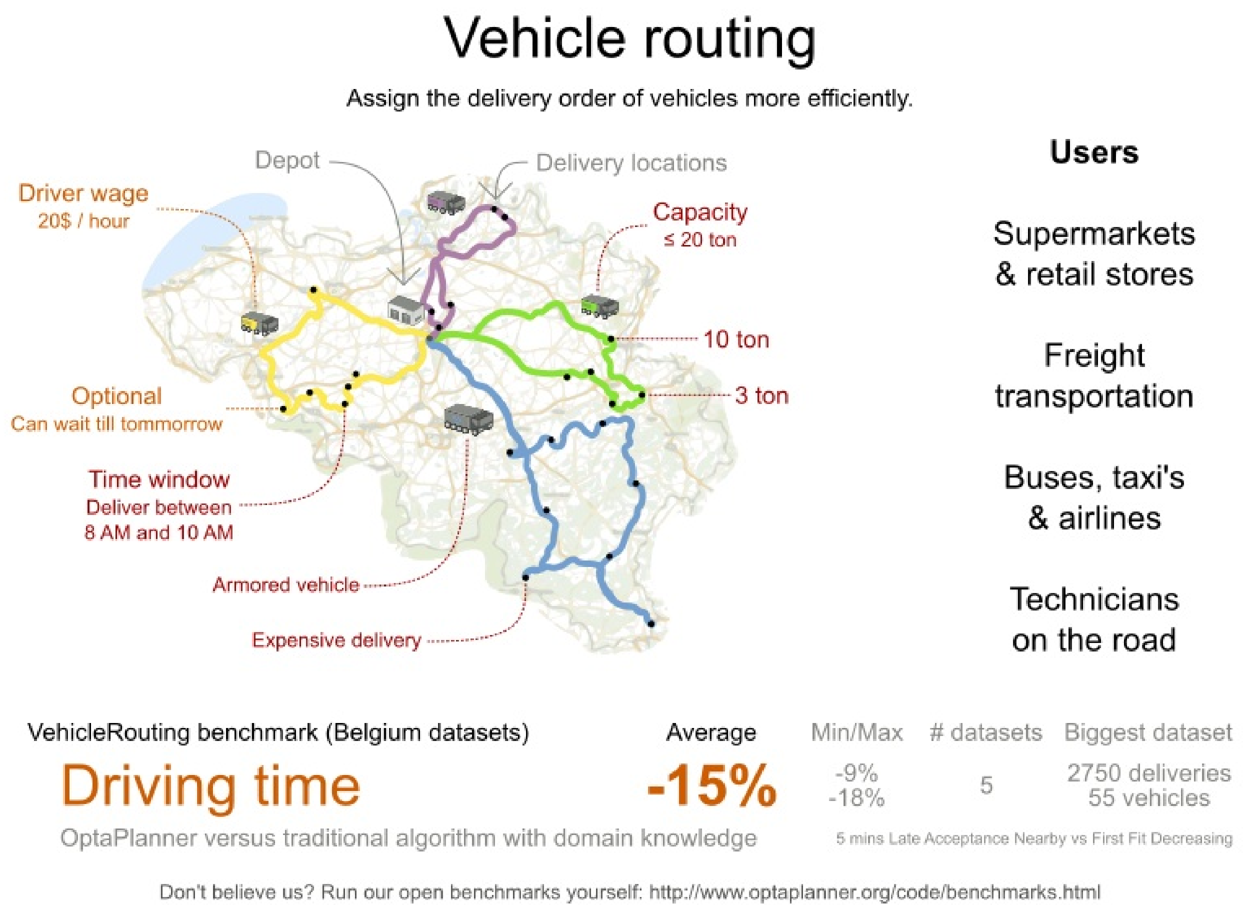
- Vehicle capacity: a vehicle cannot carry more items then its capacity.
- Time windows (only in CVRPTW):
  - Travel time: Traveling from one location to another takes time.
  - Customer service duration: a vehicle must stay at the customer for the length of the service duration.
  - Customer ready time: a vehicle may arrive before the customer’s ready time, but it must wait until the ready time before servicing.
  - Customer due time: a vehicle must arrive on time, before the customer’s due time.

Soft constraints:

- Total distance: minimize the total distance driven (fuel consumption) of all vehicles.

The capacitated vehicle routing problem (CVRP) and its time-windowed variant (CVRPTW) are defined by the VRP web.

Figure 10.8. Value proposition



Problem size

CVRP instances (without time windows):

```
belgium-n50-k10            has  1 depots, 10 vehicles and   49 customers with a search space of
10^74.
belgium-n100-k10           has  1 depots, 10 vehicles and   99 customers with a search space of
10^170.
belgium-n500-k20           has  1 depots, 20 vehicles and  499 customers with a search space of
10^1168.
belgium-n1000-k20          has  1 depots, 20 vehicles and  999 customers with a search space of
10^2607.
belgium-n2750-k55          has  1 depots, 55 vehicles and 2749 customers with a search space of
10^8380.
belgium-road-km-n50-k10    has  1 depots, 10 vehicles and   49 customers with a search space of
10^74.
belgium-road-km-n100-k10   has  1 depots, 10 vehicles and   99 customers with a search space of
10^170.
belgium-road-km-n500-k20   has  1 depots, 20 vehicles and  499 customers with a search space of
10^1168.
belgium-road-km-n1000-k20  has  1 depots, 20 vehicles and  999 customers with a search space of
10^2607.
belgium-road-km-n2750-k55  has  1 depots, 55 vehicles and 2749 customers with a search space of
```

```
10^8380.
belgium-road-time-n50-k10   has  1 depots, 10 vehicles and   49 customers with a search space of
10^74.
belgium-road-time-n100-k10  has  1 depots, 10 vehicles and   99 customers with a search space of
10^170.
belgium-road-time-n500-k20  has  1 depots, 20 vehicles and  499 customers with a search space of
10^1168.
belgium-road-time-n1000-k20 has  1 depots, 20 vehicles and  999 customers with a search space of
10^2607.
belgium-road-time-n2750-k55 has  1 depots, 55 vehicles and 2749 customers with a search space of
10^8380.
belgium-d2-n50-k10          has  2 depots, 10 vehicles and   48 customers with a search space of
10^74.
belgium-d3-n100-k10         has  3 depots, 10 vehicles and   97 customers with a search space of
10^170.
belgium-d5-n500-k20         has  5 depots, 20 vehicles and  495 customers with a search space of
10^1168.
belgium-d8-n1000-k20        has  8 depots, 20 vehicles and  992 customers with a search space of
10^2607.
belgium-d10-n2750-k55       has 10 depots, 55 vehicles and 2740 customers with a search space of
10^8380.

A-n32-k5  has 1 depots,  5 vehicles and  31 customers with a search space of  10^40.
A-n33-k5  has 1 depots,  5 vehicles and  32 customers with a search space of  10^41.
A-n33-k6  has 1 depots,  6 vehicles and  32 customers with a search space of  10^42.
A-n34-k5  has 1 depots,  5 vehicles and  33 customers with a search space of  10^43.
A-n36-k5  has 1 depots,  5 vehicles and  35 customers with a search space of  10^46.
A-n37-k5  has 1 depots,  5 vehicles and  36 customers with a search space of  10^48.
A-n37-k6  has 1 depots,  6 vehicles and  36 customers with a search space of  10^49.
A-n38-k5  has 1 depots,  5 vehicles and  37 customers with a search space of  10^49.
A-n39-k5  has 1 depots,  5 vehicles and  38 customers with a search space of  10^51.
A-n39-k6  has 1 depots,  6 vehicles and  38 customers with a search space of  10^52.
A-n44-k7  has 1 depots,  7 vehicles and  43 customers with a search space of  10^61.
A-n45-k6  has 1 depots,  6 vehicles and  44 customers with a search space of  10^62.
A-n45-k7  has 1 depots,  7 vehicles and  44 customers with a search space of  10^63.
A-n46-k7  has 1 depots,  7 vehicles and  45 customers with a search space of  10^65.
A-n48-k7  has 1 depots,  7 vehicles and  47 customers with a search space of  10^68.
A-n53-k7  has 1 depots,  7 vehicles and  52 customers with a search space of  10^77.
A-n54-k7  has 1 depots,  7 vehicles and  53 customers with a search space of  10^79.
A-n55-k9  has 1 depots,  9 vehicles and  54 customers with a search space of  10^82.
A-n60-k9  has 1 depots,  9 vehicles and  59 customers with a search space of  10^91.
A-n61-k9  has 1 depots,  9 vehicles and  60 customers with a search space of  10^93.
A-n62-k8  has 1 depots,  8 vehicles and  61 customers with a search space of  10^94.
A-n63-k9  has 1 depots,  9 vehicles and  62 customers with a search space of  10^97.
A-n63-k10 has 1 depots, 10 vehicles and  62 customers with a search space of  10^98.
A-n64-k9  has 1 depots,  9 vehicles and  63 customers with a search space of  10^99.
A-n65-k9  has 1 depots,  9 vehicles and  64 customers with a search space of 10^101.
A-n69-k9  has 1 depots,  9 vehicles and  68 customers with a search space of 10^108.
A-n80-k10 has 1 depots, 10 vehicles and  79 customers with a search space of 10^130.
F-n45-k4  has 1 depots,  4 vehicles and  44 customers with a search space of  10^60.
F-n72-k4  has 1 depots,  4 vehicles and  71 customers with a search space of 10^108.
F-n135-k7 has 1 depots,  7 vehicles and 134 customers with a search space of 10^240.
```

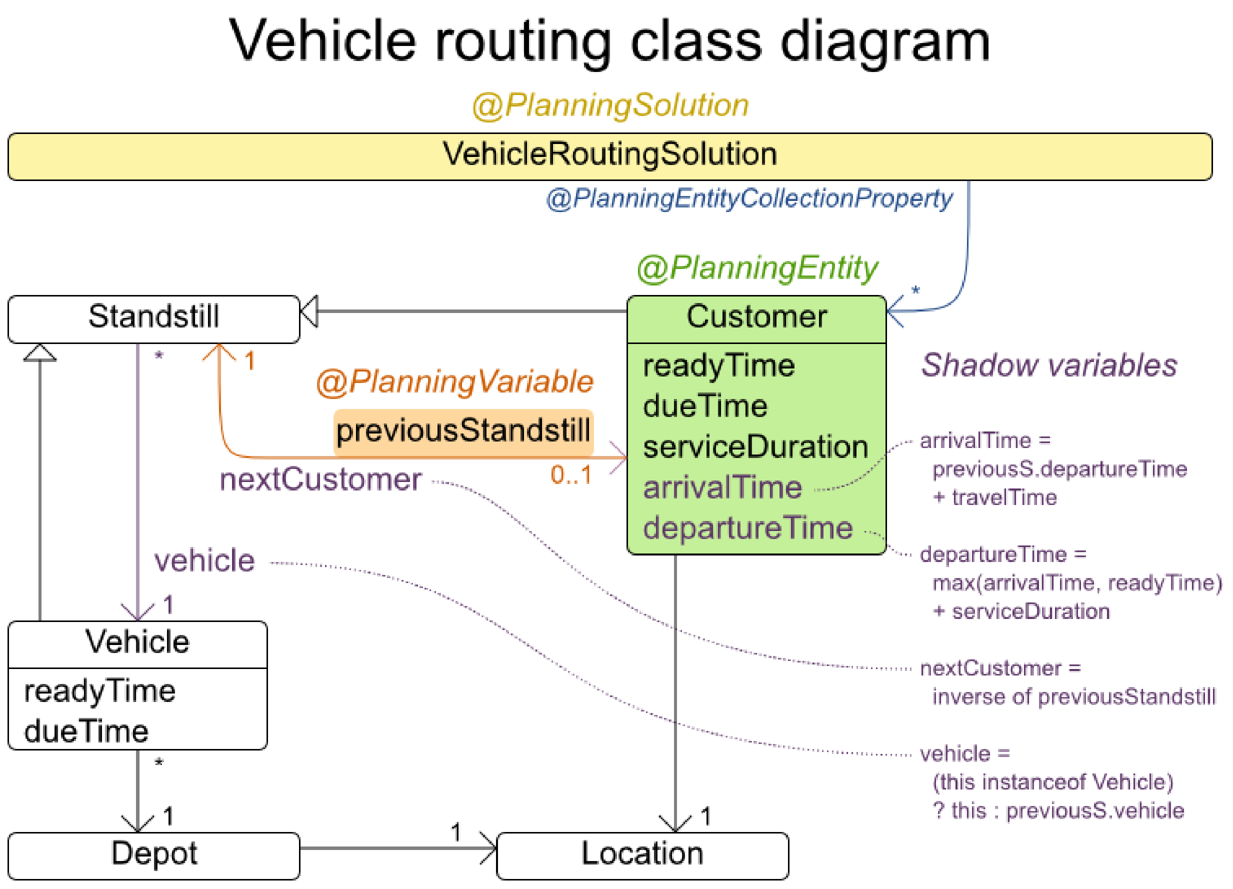
CVRPTW instances (with time windows):

```
belgium-tw-d2-n50-k10    has  2 depots, 10 vehicles and   48 customers with a search space of
```

```
10^74.
belgium-tw-d3-n100-k10   has  3 depots, 10 vehicles and   97 customers with a search space of
10^170.
belgium-tw-d5-n500-k20   has  5 depots, 20 vehicles and  495 customers with a search space of
10^1168.
belgium-tw-d8-n1000-k20  has  8 depots, 20 vehicles and  992 customers with a search space of
10^2607.
belgium-tw-d10-n2750-k55 has 10 depots, 55 vehicles and 2740 customers with a search space of
10^8380.
belgium-tw-n50-k10       has  1 depots, 10 vehicles and   49 customers with a search space of
10^74.
belgium-tw-n100-k10      has  1 depots, 10 vehicles and   99 customers with a search space of
10^170.
belgium-tw-n500-k20      has  1 depots, 20 vehicles and  499 customers with a search space of
10^1168.
belgium-tw-n1000-k20     has  1 depots, 20 vehicles and  999 customers with a search space of
10^2607.
belgium-tw-n2750-k55     has  1 depots, 55 vehicles and 2749 customers with a search space of
10^8380.

Solomon_025_C101       has 1 depots,  25 vehicles and   25 customers with a search space of
10^40.
Solomon_025_C201       has 1 depots,  25 vehicles and   25 customers with a search space of
10^40.
Solomon_025_R101       has 1 depots,  25 vehicles and   25 customers with a search space of
10^40.
Solomon_025_R201       has 1 depots,  25 vehicles and   25 customers with a search space of
10^40.
Solomon_025_RC101      has 1 depots,  25 vehicles and   25 customers with a search space of
10^40.
Solomon_025_RC201      has 1 depots,  25 vehicles and   25 customers with a search space of
10^40.
Solomon_100_C101       has 1 depots,  25 vehicles and  100 customers with a search space of
10^185.
Solomon_100_C201       has 1 depots,  25 vehicles and  100 customers with a search space of
10^185.
Solomon_100_R101       has 1 depots,  25 vehicles and  100 customers with a search space of
10^185.
Solomon_100_R201       has 1 depots,  25 vehicles and  100 customers with a search space of
10^185.
Solomon_100_RC101      has 1 depots,  25 vehicles and  100 customers with a search space of
10^185.
Solomon_100_RC201      has 1 depots,  25 vehicles and  100 customers with a search space of
10^185.
Homberger_0200_C1_2_1  has 1 depots,  50 vehicles and  200 customers with a search space of
10^429.
Homberger_0200_C2_2_1  has 1 depots,  50 vehicles and  200 customers with a search space of
10^429.
Homberger_0200_R1_2_1  has 1 depots,  50 vehicles and  200 customers with a search space of
10^429.
Homberger_0200_R2_2_1  has 1 depots,  50 vehicles and  200 customers with a search space of
10^429.
Homberger_0200_RC1_2_1 has 1 depots,  50 vehicles and  200 customers with a search space of
10^429.
Homberger_0200_RC2_2_1 has 1 depots,  50 vehicles and  200 customers with a search space of
10^429.
```

```
Homberger_0400_C1_4_1  has 1 depots, 100 vehicles and  400 customers with a search space of 10^978.
Homberger_0400_C2_4_1  has 1 depots, 100 vehicles and  400 customers with a search space of 10^978.
Homberger_0400_R1_4_1  has 1 depots, 100 vehicles and  400 customers with a search space of 10^978.
Homberger_0400_R2_4_1  has 1 depots, 100 vehicles and  400 customers with a search space of 10^978.
Homberger_0400_RC1_4_1 has 1 depots, 100 vehicles and  400 customers with a search space of 10^978.
Homberger_0400_RC2_4_1 has 1 depots, 100 vehicles and  400 customers with a search space of 10^978.
Homberger_0600_C1_6_1  has 1 depots, 150 vehicles and  600 customers with a search space of 10^1571.
Homberger_0600_C2_6_1  has 1 depots, 150 vehicles and  600 customers with a search space of 10^1571.
Homberger_0600_R1_6_1  has 1 depots, 150 vehicles and  600 customers with a search space of 10^1571.
Homberger_0600_R2_6_1  has 1 depots, 150 vehicles and  600 customers with a search space of 10^1571.
Homberger_0600_RC1_6_1 has 1 depots, 150 vehicles and  600 customers with a search space of 10^1571.
Homberger_0600_RC2_6_1 has 1 depots, 150 vehicles and  600 customers with a search space of 10^1571.
Homberger_0800_C1_8_1  has 1 depots, 200 vehicles and  800 customers with a search space of 10^2195.
Homberger_0800_C2_8_1  has 1 depots, 200 vehicles and  800 customers with a search space of 10^2195.
Homberger_0800_R1_8_1  has 1 depots, 200 vehicles and  800 customers with a search space of 10^2195.
Homberger_0800_R2_8_1  has 1 depots, 200 vehicles and  800 customers with a search space of 10^2195.
Homberger_0800_RC1_8_1 has 1 depots, 200 vehicles and  800 customers with a search space of 10^2195.
Homberger_0800_RC2_8_1 has 1 depots, 200 vehicles and  800 customers with a search space of 10^2195.
Homberger_1000_C110_1  has 1 depots, 250 vehicles and 1000 customers with a search space of 10^2840.
Homberger_1000_C210_1  has 1 depots, 250 vehicles and 1000 customers with a search space of 10^2840.
Homberger_1000_R110_1  has 1 depots, 250 vehicles and 1000 customers with a search space of 10^2840.
Homberger_1000_R210_1  has 1 depots, 250 vehicles and 1000 customers with a search space of 10^2840.
Homberger_1000_RC110_1 has 1 depots, 250 vehicles and 1000 customers with a search space of 10^2840.
Homberger_1000_RC210_1 has 1 depots, 250 vehicles and 1000 customers with a search space of 10^2840.
```

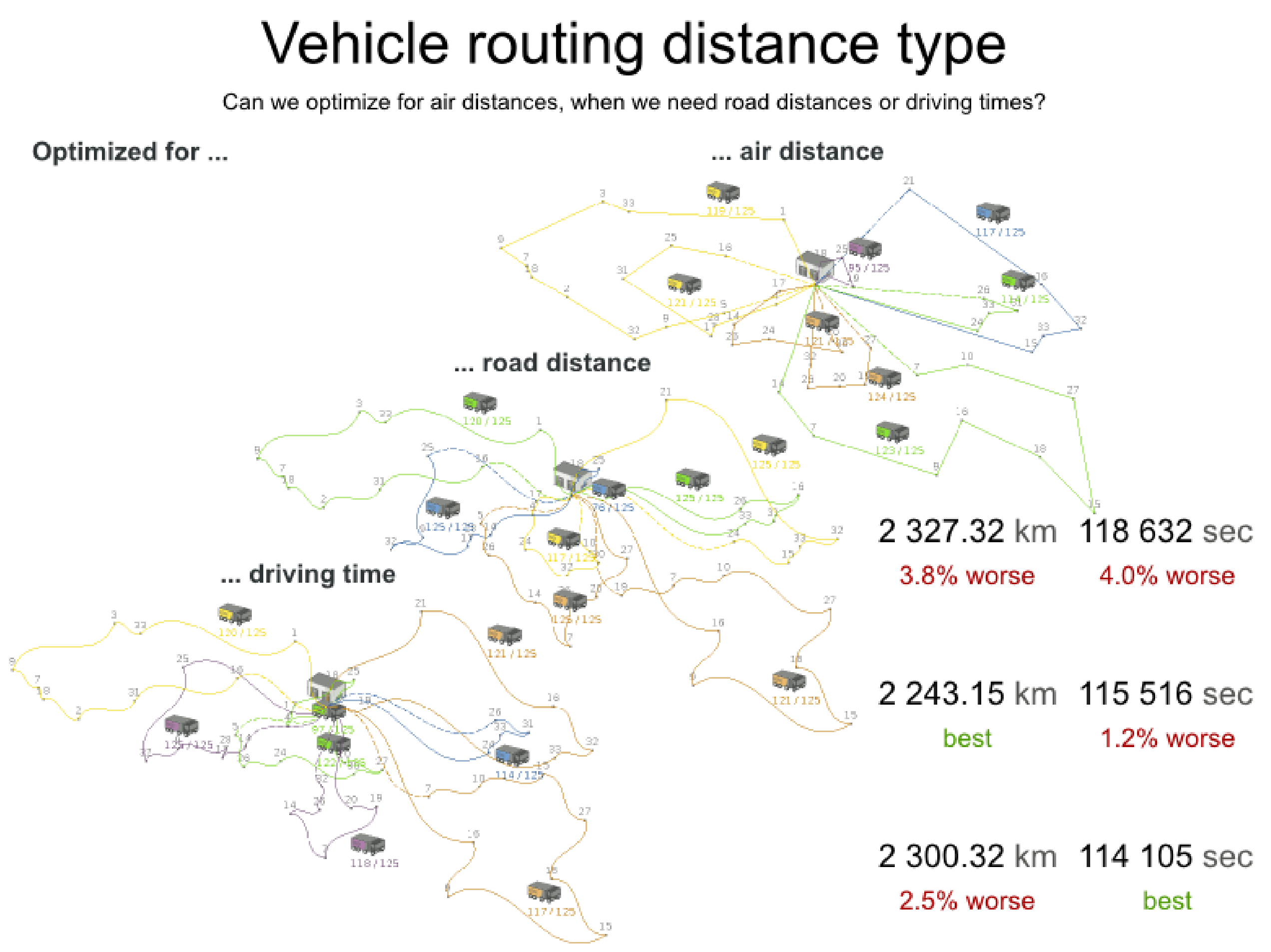
10.8.1. Domain model for Vehicle routing


Vehicle routing class diagram
@PlanningSolution
VehicleRoutingSolution
@PlanningEntityCollectionProperty
@PlanningEntity
Standstill
Customer
readyTime
dueTime
serviceDuration
arrivalTime
departureTime
@PlanningVariable
previousStandstill
0..1
nextCustomer
vehicle
Shadow variables
arrivalTime = previousS.departureTime + travelTime
departureTime = max(arrivalTime, readyTime) + serviceDuration
nextCustomer = inverse of previousStandstill
vehicle = (this instanceof Vehicle) ? this : previousS.vehicle
Vehicle
readyTime
dueTime
Depot
Location
1
*

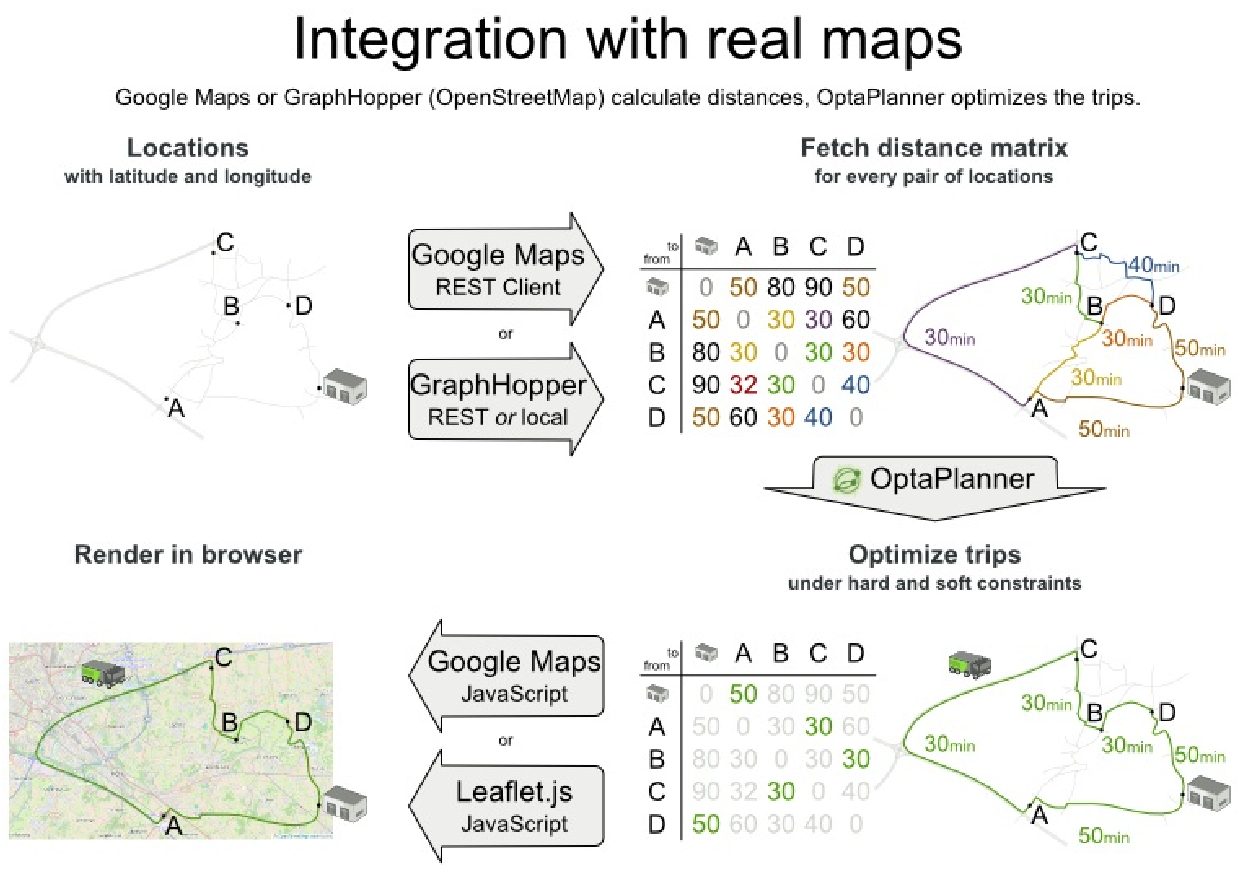
The vehicle routing with timewindows domain model makes heavily use of the shadow variable feature. This allows it to express its constraints more naturally, because properties such as **arrivalTime** and **departureTime**, are directly available on the domain model.

Road Distances Instead of Air Distances

In the real world, vehicles cannot follow a straight line from location to location: they have to use roads and highways. From a business point of view, this matters a lot:



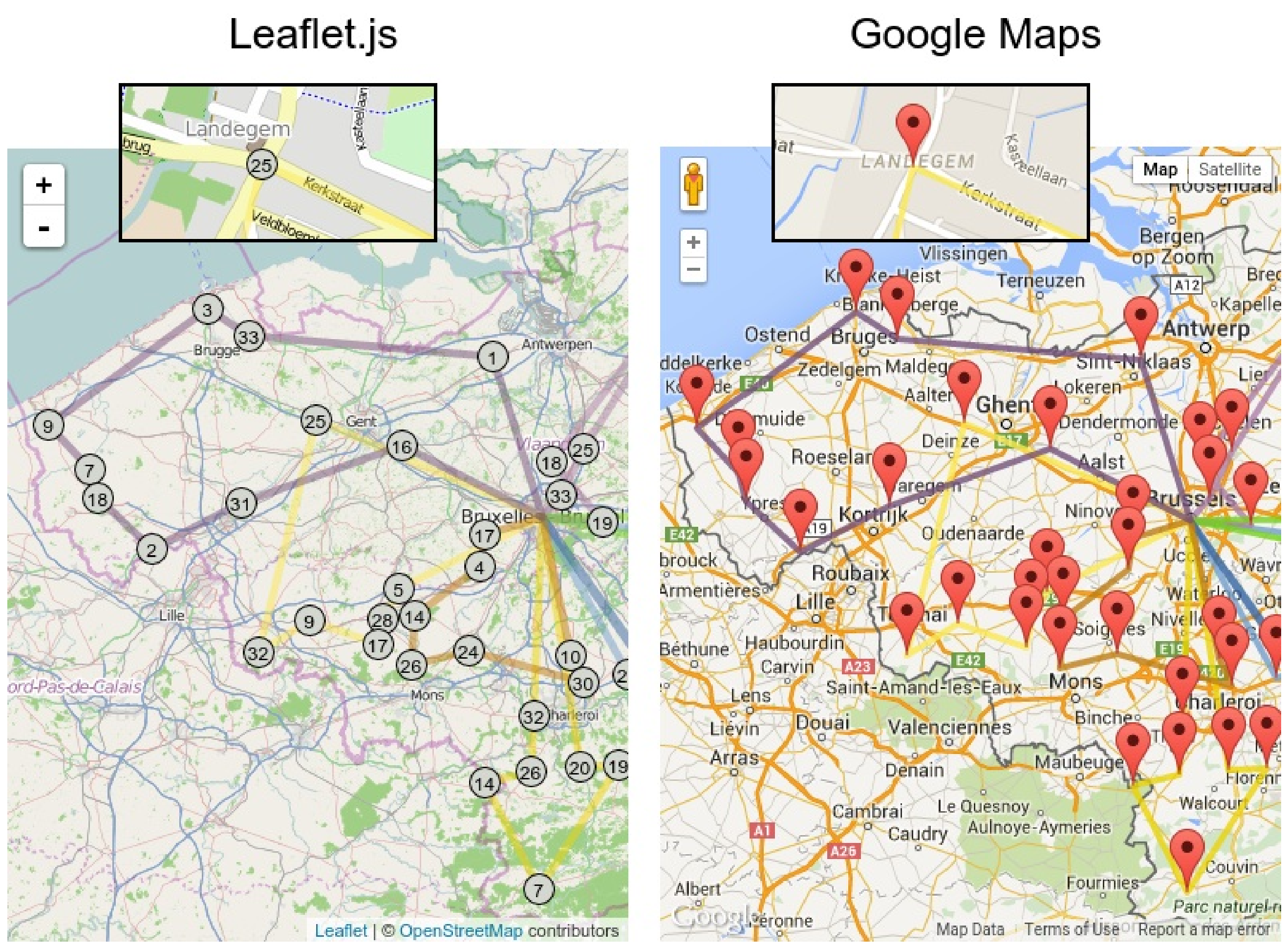
For the optimization algorithm, this does not matter much, as long as the distance between two points can be looked up (and are preferably precalculated). The road cost does not even need to be a distance, it can also be travel time, fuel cost, or a weighted function of those. There are several technologies available to precalculate road costs, such as GraphHopper (embeddable, offline Java engine), Open MapQuest (web service) and Google Maps Client API (web service).



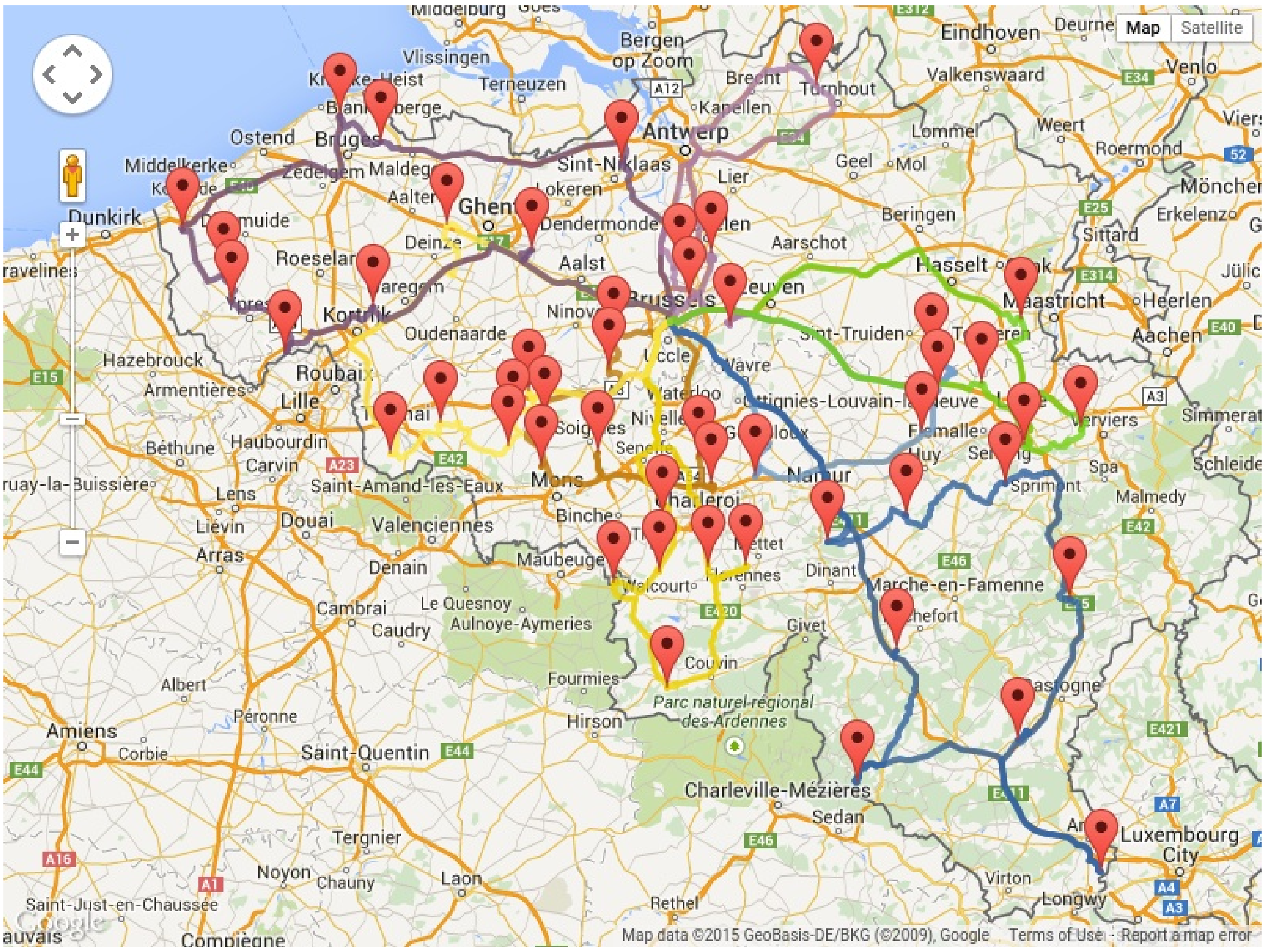
to / from	🏭	A	B	C	D
🏭	0	50	80	90	50
A	50	0	30	30	60
B	80	30	0	30	30
C	90	32	30	0	40
D	50	60	30	40	0

to / from	🏭	A	B	C	D
🏭	0	50	80	90	50
A	50	0	30	30	60
B	80	30	0	30	30
C	90	32	30	0	40
D	50	60	30	40	0

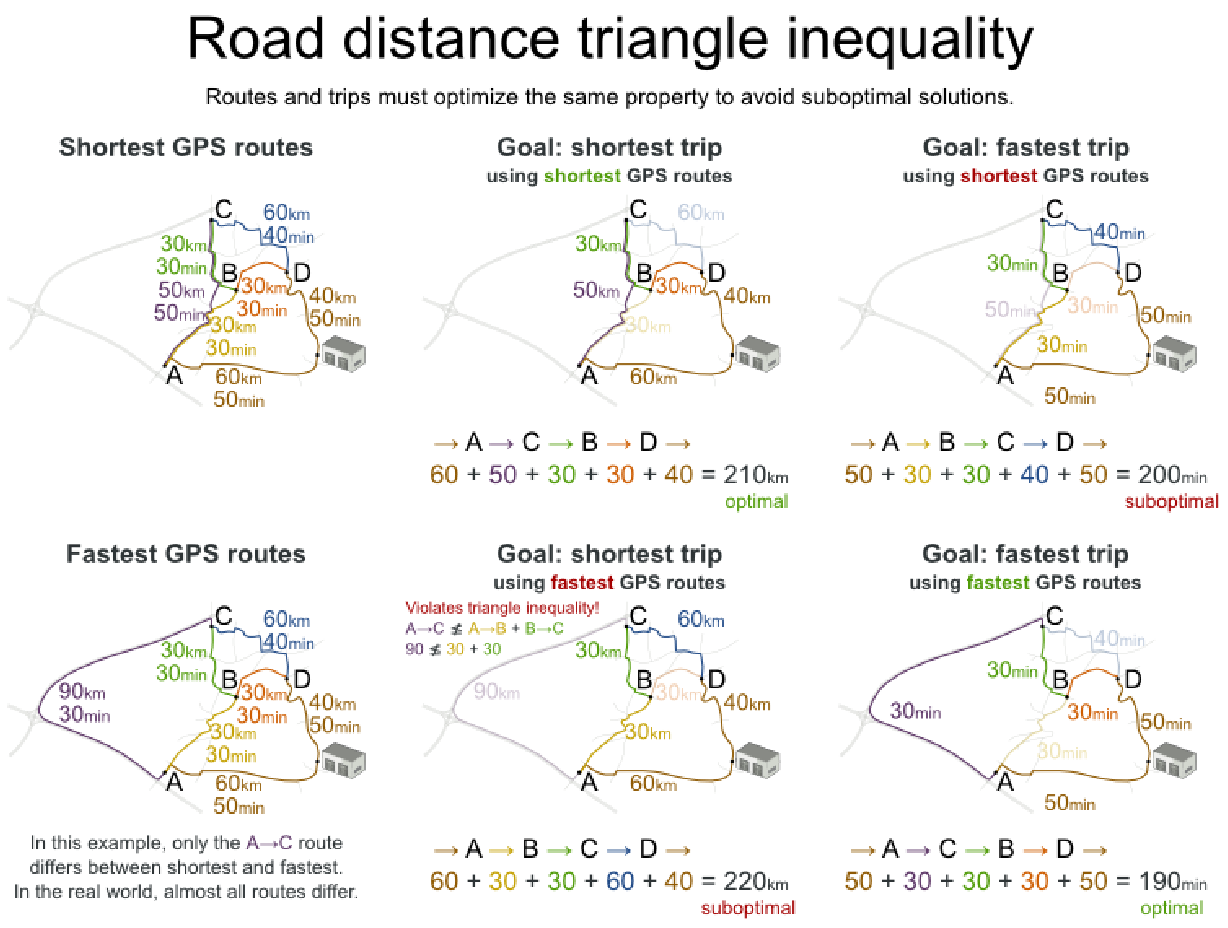
There are also several technologies to render it, such as Leaflet and Google Maps for developers.



It is even possible to render the actual road routes with GraphHopper or Google Map Directions, but because of route overlaps on highways, it can become harder to see the standstill order:



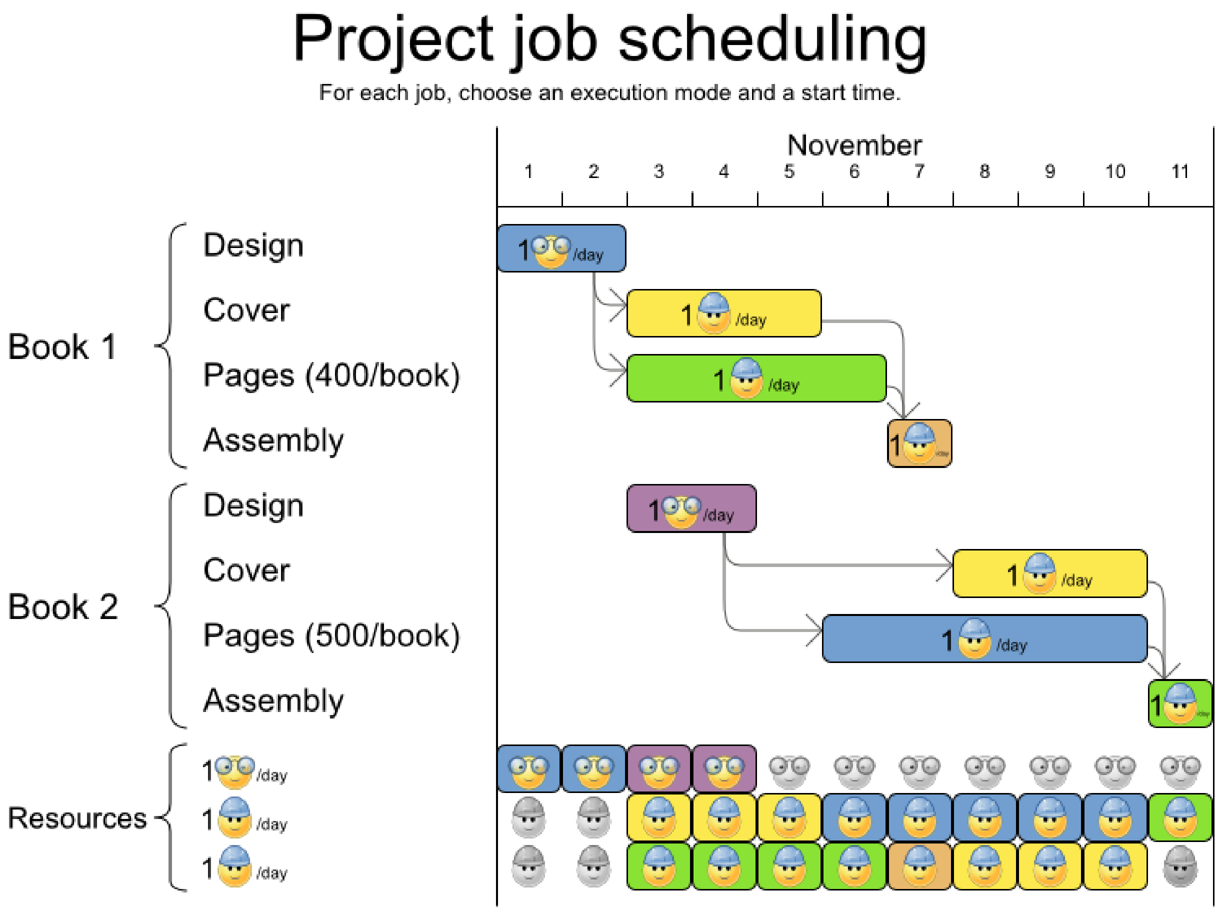
Take special care that the road costs between two points use the same optimization criteria as the one used in Planner. For example, GraphHopper etc will by default return the fastest route, not the shortest route. Don't use the km (or miles) distances of the fastest GPS routes to optimize the shortest trip in Planner: this leads to a suboptimal solution as shown below:


Road distance triangle inequality
Routes and trips must optimize the same property to avoid suboptimal solutions.
Shortest GPS routes
Goal: shortest trip
using shortest GPS routes
→ A → C → B → D →
60 + 50 + 30 + 30 + 40 = 210km
optimal
Goal: fastest trip
using shortest GPS routes
→ A → B → C → D →
50 + 30 + 30 + 40 + 50 = 200min
suboptimal
Fastest GPS routes
In this example, only the A→C route differs between shortest and fastest.
In the real world, almost all routes differ.
Goal: shortest trip
using fastest GPS routes
Violates triangle inequality!
A→C ≰ A→B + B→C
90 ≰ 30 + 30
→ A → B → C → D →
60 + 30 + 30 + 60 + 40 = 220km
suboptimal
Goal: fastest trip
using fastest GPS routes
→ A → C → B → D →
50 + 30 + 30 + 30 + 50 = 190min
optimal

Contrary to popular belief, most users do not want the shortest route: they want the fastest route instead. They prefer highways over normal roads. They prefer normal roads over dirt roads. In the real world, the fastest and shortest route are rarely the same.

10.9. PROJECT JOB SCHEDULING

Schedule all jobs in time and execution mode to minimize project delays. Each job is part of a project. A job can be executed in different ways: each way is an execution mode that implies a different duration but also different resource usages. This is a form of flexible *job shop scheduling*.



Hard constraints:

- Job precedence: a job can only start when all its predecessor jobs are finished.
- Resource capacity: do not use more resources than available.
  - Resources are local (shared between jobs of the same project) or global (shared between all jobs)
  - Resources are renewable (capacity available per day) or nonrenewable (capacity available for all days)

Medium constraints:

- Total project delay: minimize the duration (makespan) of each project.

Soft constraints:

- Total makespan: minimize the duration of the whole multi-project schedule.

The problem is defined by the MISTA 2013 challenge.

Problem size

> Schedule A-1 has 2 projects, 24 jobs,   64 execution modes, 7 resources and 150 resource requirements.
> Schedule A-2 has 2 projects, 44 jobs, 124 execution modes, 7 resources and 420 resource requirements.

```
Schedule A-3  has  2 projects,  64 jobs,  184 execution modes,  7 resources and  630 resource
requirements.
Schedule A-4  has  5 projects,  60 jobs,  160 execution modes, 16 resources and  390 resource
requirements.
Schedule A-5  has  5 projects, 110 jobs,  310 execution modes, 16 resources and  900 resource
requirements.
Schedule A-6  has  5 projects, 160 jobs,  460 execution modes, 16 resources and 1440 resource
requirements.
Schedule A-7  has 10 projects, 120 jobs,  320 execution modes, 22 resources and  900 resource
requirements.
Schedule A-8  has 10 projects, 220 jobs,  620 execution modes, 22 resources and 1860 resource
requirements.
Schedule A-9  has 10 projects, 320 jobs,  920 execution modes, 31 resources and 2880 resource
requirements.
Schedule A-10 has 10 projects, 320 jobs,  920 execution modes, 31 resources and 2970 resource
requirements.
Schedule B-1  has 10 projects, 120 jobs,  320 execution modes, 31 resources and  900 resource
requirements.
Schedule B-2  has 10 projects, 220 jobs,  620 execution modes, 22 resources and 1740 resource
requirements.
Schedule B-3  has 10 projects, 320 jobs,  920 execution modes, 31 resources and 3060 resource
requirements.
Schedule B-4  has 15 projects, 180 jobs,  480 execution modes, 46 resources and 1530 resource
requirements.
Schedule B-5  has 15 projects, 330 jobs,  930 execution modes, 46 resources and 2760 resource
requirements.
Schedule B-6  has 15 projects, 480 jobs, 1380 execution modes, 46 resources and 4500 resource
requirements.
Schedule B-7  has 20 projects, 240 jobs,  640 execution modes, 61 resources and 1710 resource
requirements.
Schedule B-8  has 20 projects, 440 jobs, 1240 execution modes, 42 resources and 3180 resource
requirements.
Schedule B-9  has 20 projects, 640 jobs, 1840 execution modes, 61 resources and 5940 resource
requirements.
Schedule B-10 has 20 projects, 460 jobs, 1300 execution modes, 42 resources and 4260 resource
requirements.
```

10.10. TASK ASSIGNING

Assign each task to a spot in an employee's queue. Each task has a duration which is affected by the employee's affinity level with the task's customer.

Hard constraints:

- Skill: Each task requires one or more skills. The employee must possess all these skills.

Soft level 0 constraints:

- Critical tasks: Complete critical tasks first, sooner than major and minor tasks.

Soft level 1 constraints:

- Minimize makespan: Reduce the time to complete all tasks.
  - Start with the longest working employee first, then the second longest working employee and so forth, to create fairness and load balancing.

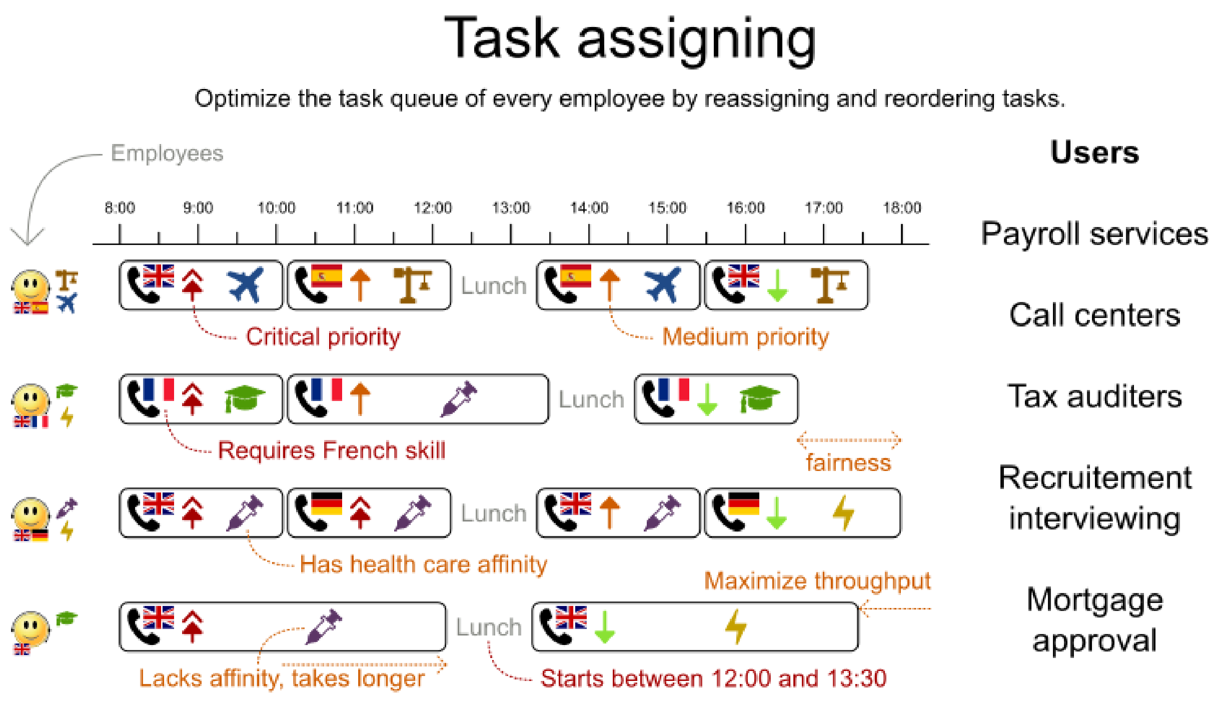
Soft level 2 constraints:

- Major tasks: Complete major tasks as soon as possible, sooner than minor tasks.

Soft level 3 constraints:

- Minor tasks: Complete minor tasks as soon as possible.

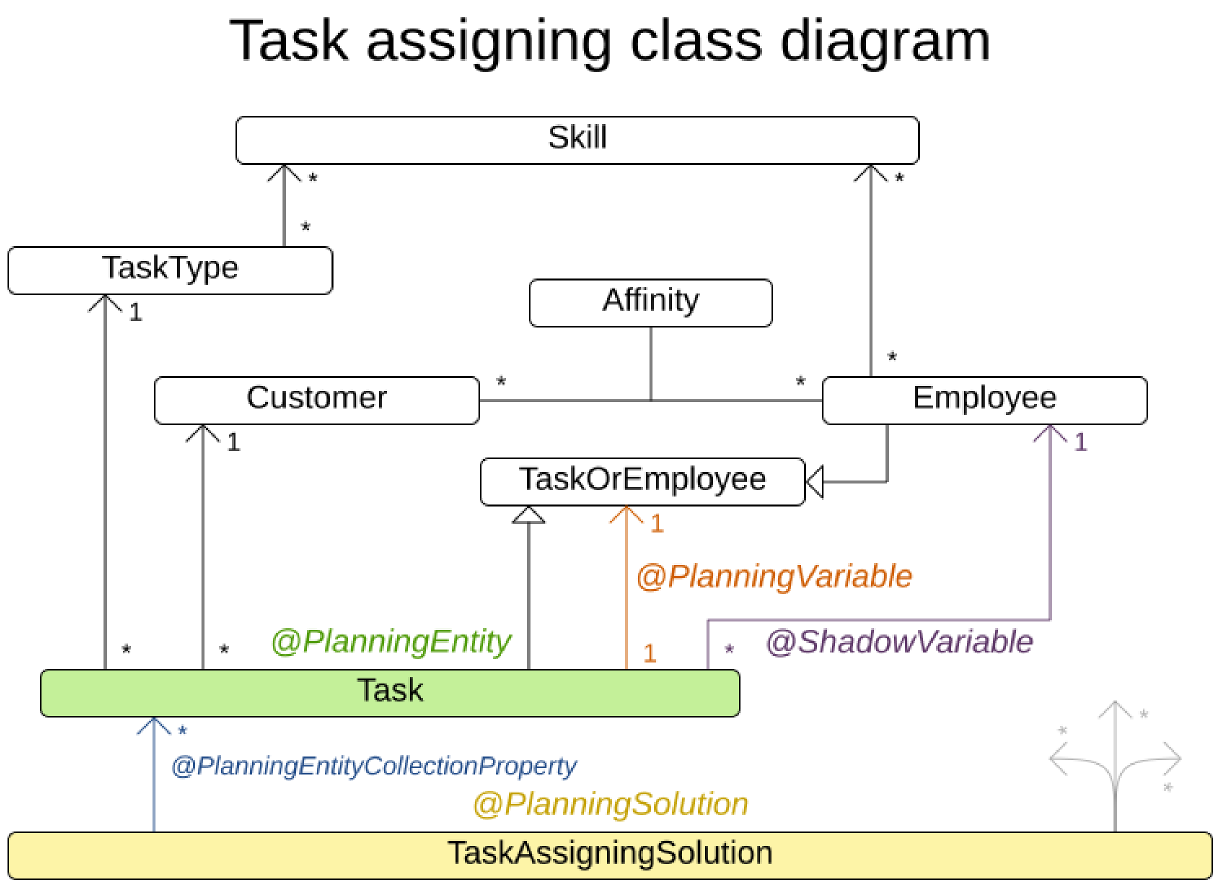
Figure 10.9. Value proposition



Problem size

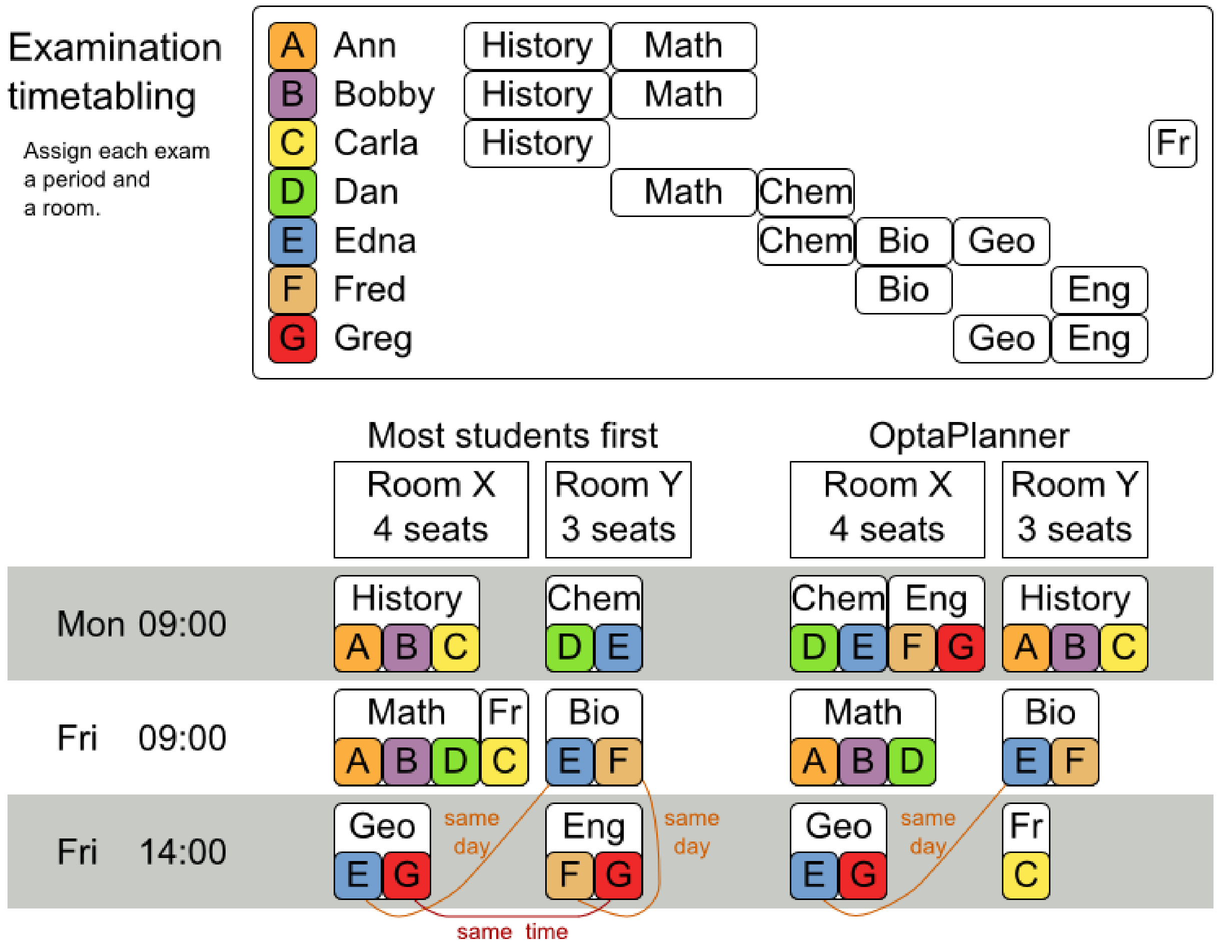
```
24tasks-8employees   has  24 tasks, 6 skills,  8 employees,   4 task types and  4 customers with a
search space of   10^30.
50tasks-5employees   has  50 tasks, 5 skills,  5 employees,  10 task types and 10 customers with a
search space of   10^69.
100tasks-5employees  has 100 tasks, 5 skills,  5 employees,  20 task types and 15 customers with a
search space of  10^164.
500tasks-20employees has 500 tasks, 6 skills, 20 employees, 100 task types and 60 customers with
a search space of 10^1168.
```

Figure 10.10. Domain model



10.11. EXAM TIMETABLING (ITC 2007 TRACK 1 - EXAMINATION)

Schedule each exam into a period and into a room. Multiple exams can share the same room during the same period.



Hard constraints:

- Exam conflict: Two exams that share students must not occur in the same period.
- Room capacity: A room's seating capacity must suffice at all times.
- Period duration: A period's duration must suffice for all of its exams.
- Period related hard constraints (specified per dataset):
  - Coincidence: Two specified exams must use the same period (but possibly another room).
  - Exclusion: Two specified exams must not use the same period.
  - After: A specified exam must occur in a period after another specified exam's period.
- Room related hard constraints (specified per dataset):
  - Exclusive: One specified exam should not have to share its room with any other exam.

Soft constraints (each of which has a parametrized penalty):

- The same student should not have two exams in a row.
- The same student should not have two exams on the same day.
- Period spread: Two exams that share students should be a number of periods apart.
- Mixed durations: Two exams that share a room should not have different durations.

- Front load: Large exams should be scheduled earlier in the schedule.
- Period penalty (specified per dataset): Some periods have a penalty when used.
- Room penalty (specified per dataset): Some rooms have a penalty when used.

It uses large test data sets of real-life universities.

The problem is defined by the International Timetabling Competition 2007 track 1. Geoffrey De Smet finished 4th in that competition with a very early version of Planner. Many improvements have been made since then.

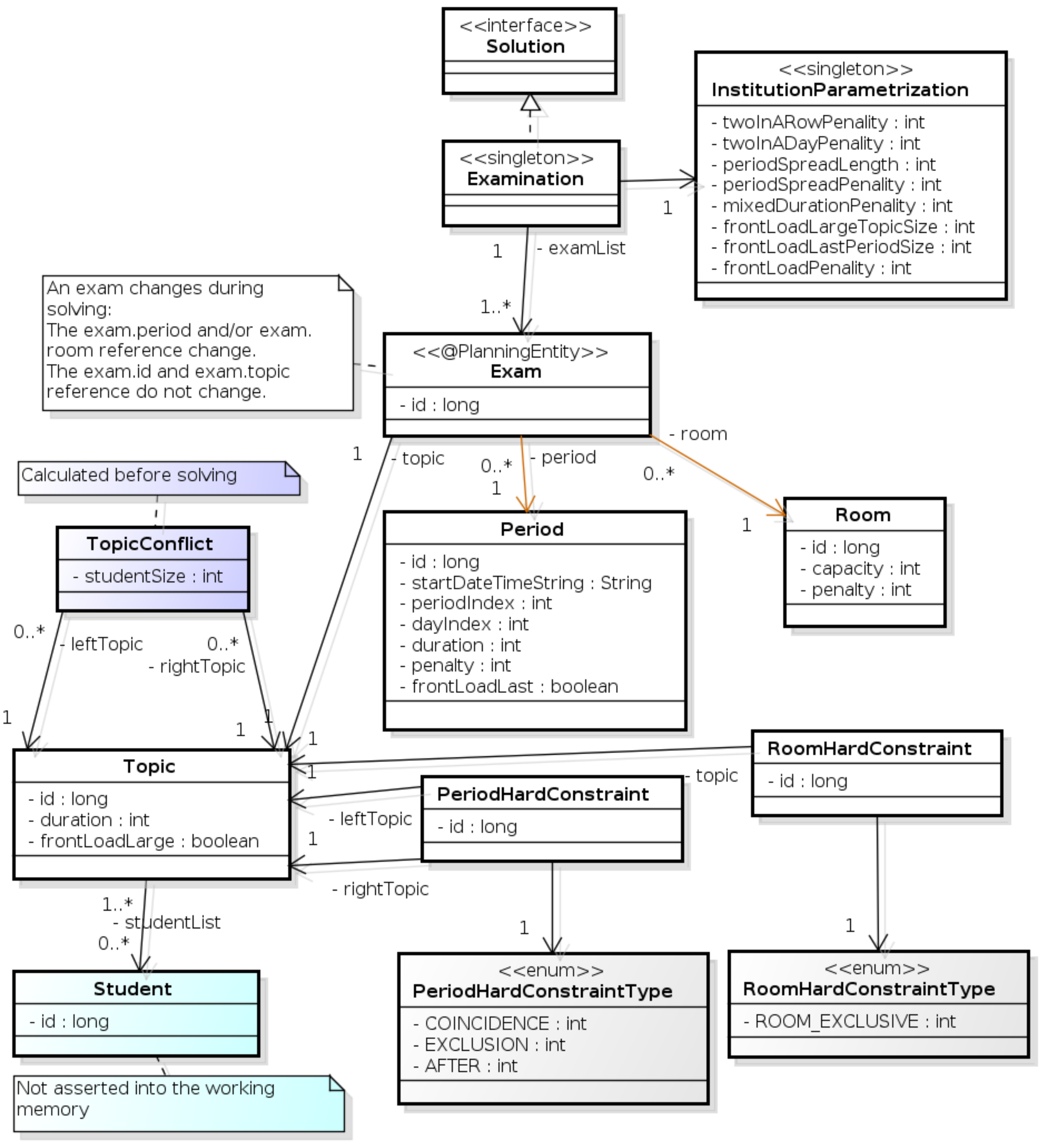
Problem Size

```
exam_comp_set1 has  7883 students,  607 exams, 54 periods,  7 rooms,  12 period constraints and
0 room constraints with a search space of 10^1564.
exam_comp_set2 has 12484 students,  870 exams, 40 periods, 49 rooms,  12 period constraints and
2 room constraints with a search space of 10^2864.
exam_comp_set3 has 16365 students,  934 exams, 36 periods, 48 rooms, 168 period constraints and
15 room constraints with a search space of 10^3023.
exam_comp_set4 has  4421 students,  273 exams, 21 periods,  1 rooms,  40 period constraints and
0 room constraints with a search space of  10^360.
exam_comp_set5 has  8719 students, 1018 exams, 42 periods,  3 rooms,  27 period constraints and
0 room constraints with a search space of 10^2138.
exam_comp_set6 has  7909 students,  242 exams, 16 periods,  8 rooms,  22 period constraints and
0 room constraints with a search space of  10^509.
exam_comp_set7 has 13795 students, 1096 exams, 80 periods, 15 rooms,  28 period constraints and
0 room constraints with a search space of 10^3374.
exam_comp_set8 has  7718 students,  598 exams, 80 periods,  8 rooms,  20 period constraints and
1 room constraints with a search space of 10^1678.
```

10.11.1. Domain model for Exam timetabling

The following diagram shows the main examination domain classes:

Figure 10.11. Examination domain class diagram

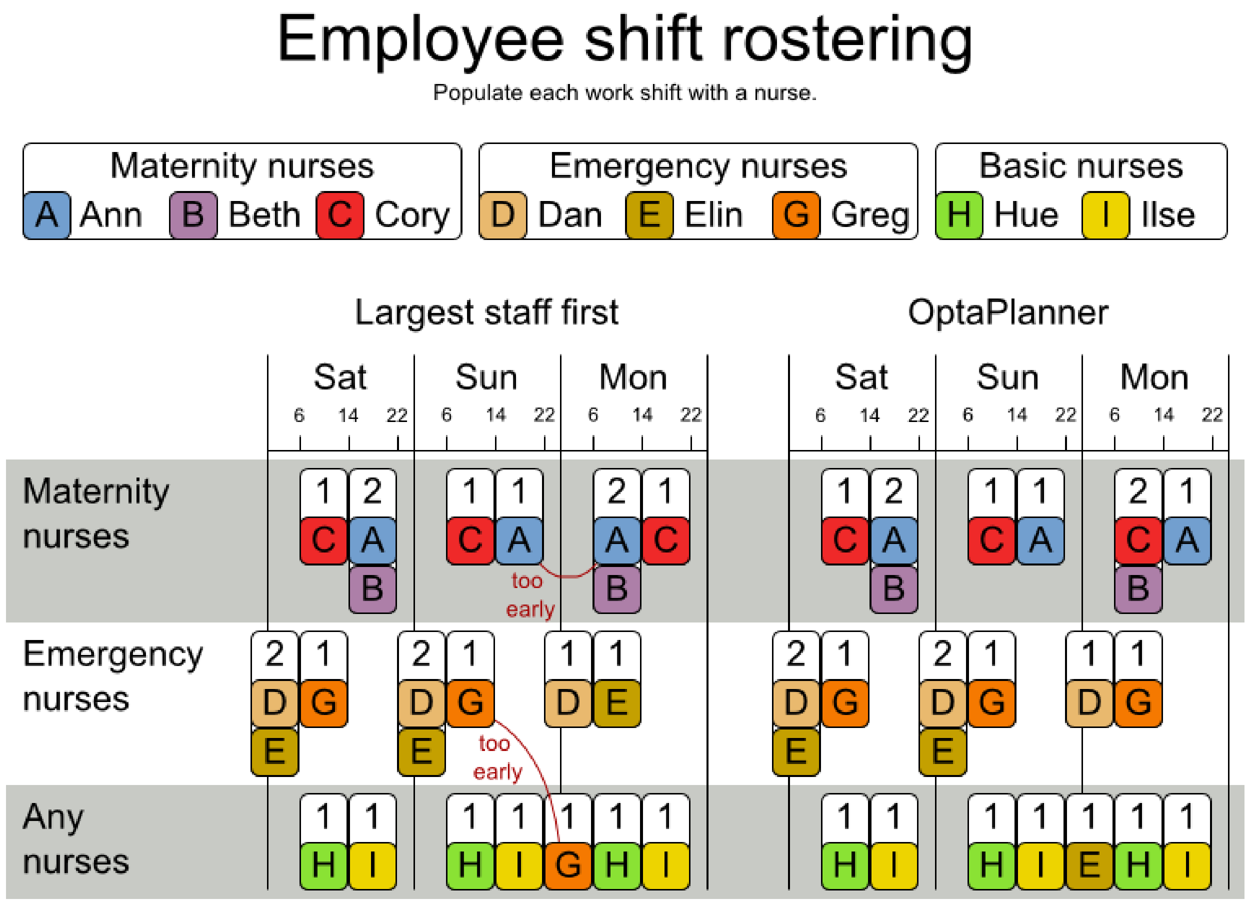


<<interface>> Solution
<<singleton>> InstitutionParametrization
- twoInARowPenality : int
- twoInADayPenality : int
- periodSpreadLength : int
- periodSpreadPenality : int
- mixedDurationPenality : int
- frontLoadLargeTopicSize : int
- frontLoadLastPeriodSize : int
- frontLoadPenality : int
<<singleton>> Examination
1
1
- examList
1..*
An exam changes during solving: The exam.period and/or exam.room reference change. The exam.id and exam.topic reference do not change.
<<@PlanningEntity>> Exam
- id : long
- room
0..*
1
- topic
0..*
- period
1
Calculated before solving
Period
- id : long
- startDateTimeString : String
- periodIndex : int
- dayIndex : int
- duration : int
- penalty : int
- frontLoadLast : boolean
Room
- id : long
- capacity : int
- penalty : int
1
TopicConflict
- studentSize : int
0..*
- leftTopic
0..*
- rightTopic
1
1
1
1
Topic
- id : long
- duration : int
- frontLoadLarge : boolean
1
RoomHardConstraint
- id : long
- topic
PeriodHardConstraint
- id : long
- leftTopic
1
- rightTopic
1..*
- studentList
0..*
Student
- id : long
Not asserted into the working memory
1
1
<<enum>> PeriodHardConstraintType
- COINCIDENCE : int
- EXCLUSION : int
- AFTER : int
<<enum>> RoomHardConstraintType
- ROOM_EXCLUSIVE : int

Notice that we’ve split up the exam concept into an **Exam** class and a **Topic** class. The **Exam** instances change during solving (this is the planning entity class), when their period or room property changes. The **Topic**, **Period** and **Room** instances never change during solving (these are problem facts, just like some other classes).

10.12. NURSE ROSTERING (INRC 2010)

For each shift, assign a nurse to work that shift.



Hard constraints:

- **No unassigned shifts** (built-in): Every shift need to be assigned to an employee.
- **Shift conflict**: An employee can have only one shift per day.

Soft constraints:

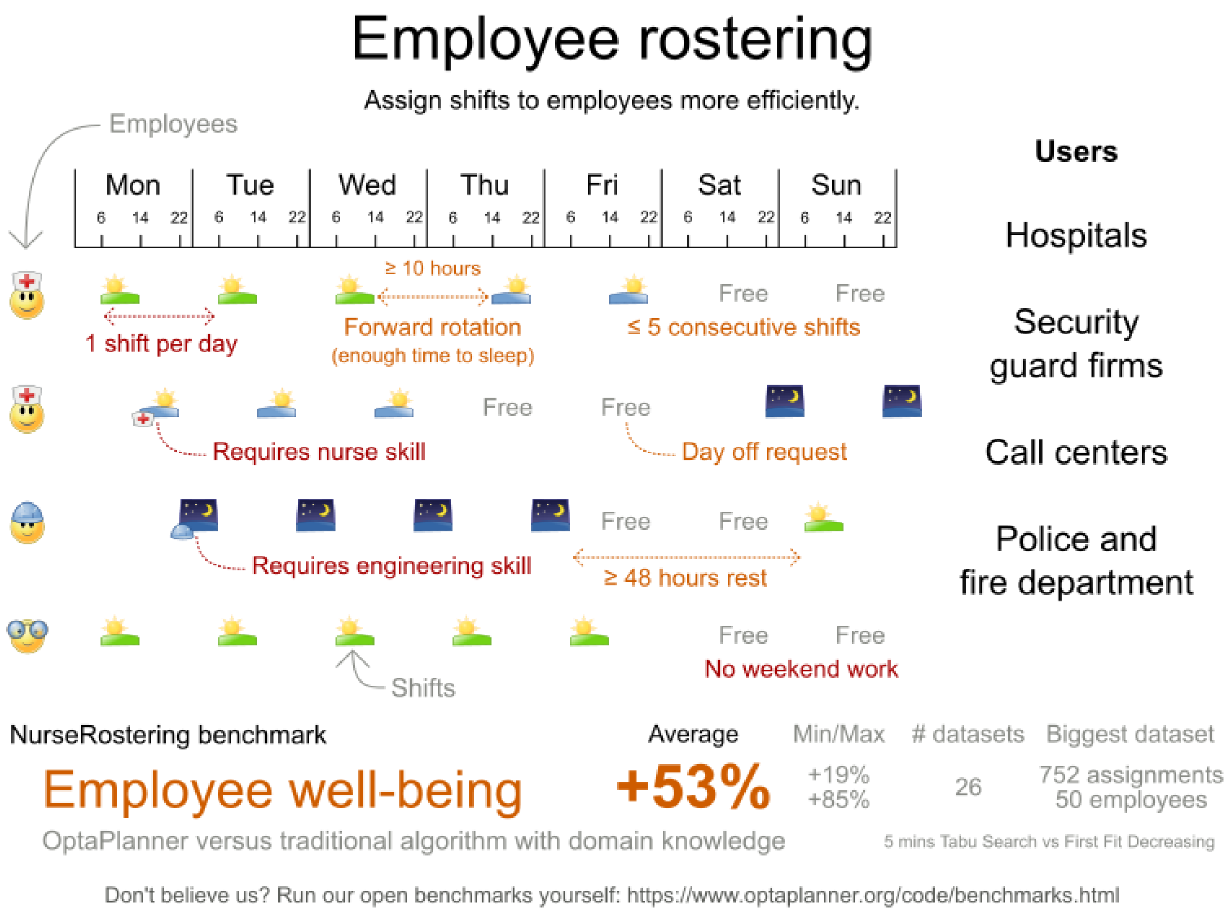
- Contract obligations. The business frequently violates these, so they decided to define these as soft constraints instead of hard constraints.
  - **Minimum and maximum assignments**: Each employee needs to work more than x shifts and less than y shifts (depending on their contract).
  - **Minimum and maximum consecutive working days**: Each employee needs to work between x and y days in a row (depending on their contract).
  - **Minimum and maximum consecutive free days**: Each employee needs to be free between x and y days in a row (depending on their contract).
  - **Minimum and maximum consecutive working weekends**: Each employee needs to work between x and y weekends in a row (depending on their contract).
  - **Complete weekends**: Each employee needs to work every day in a weekend or not at all.
  - **Identical shift types during weekend**: Each weekend shift for the same weekend of the same employee must be the same shift type.

- **Unwanted patterns**: A combination of unwanted shift types in a row. For example: a late shift followed by an early shift followed by a late shift.

- Employee wishes:
    - **Day on request**: An employee wants to work on a specific day.
    - **Day off request**: An employee does not want to work on a specific day.
    - **Shift on request**: An employee wants to be assigned to a specific shift.
    - **Shift off request**: An employee does not want to be assigned to a specific shift.
- **Alternative skill**: An employee assigned to a skill should have a proficiency in every skill required by that shift.

The problem is defined by the International Nurse Rostering Competition 2010 .

Figure 10.12. Value proposition



Problem size

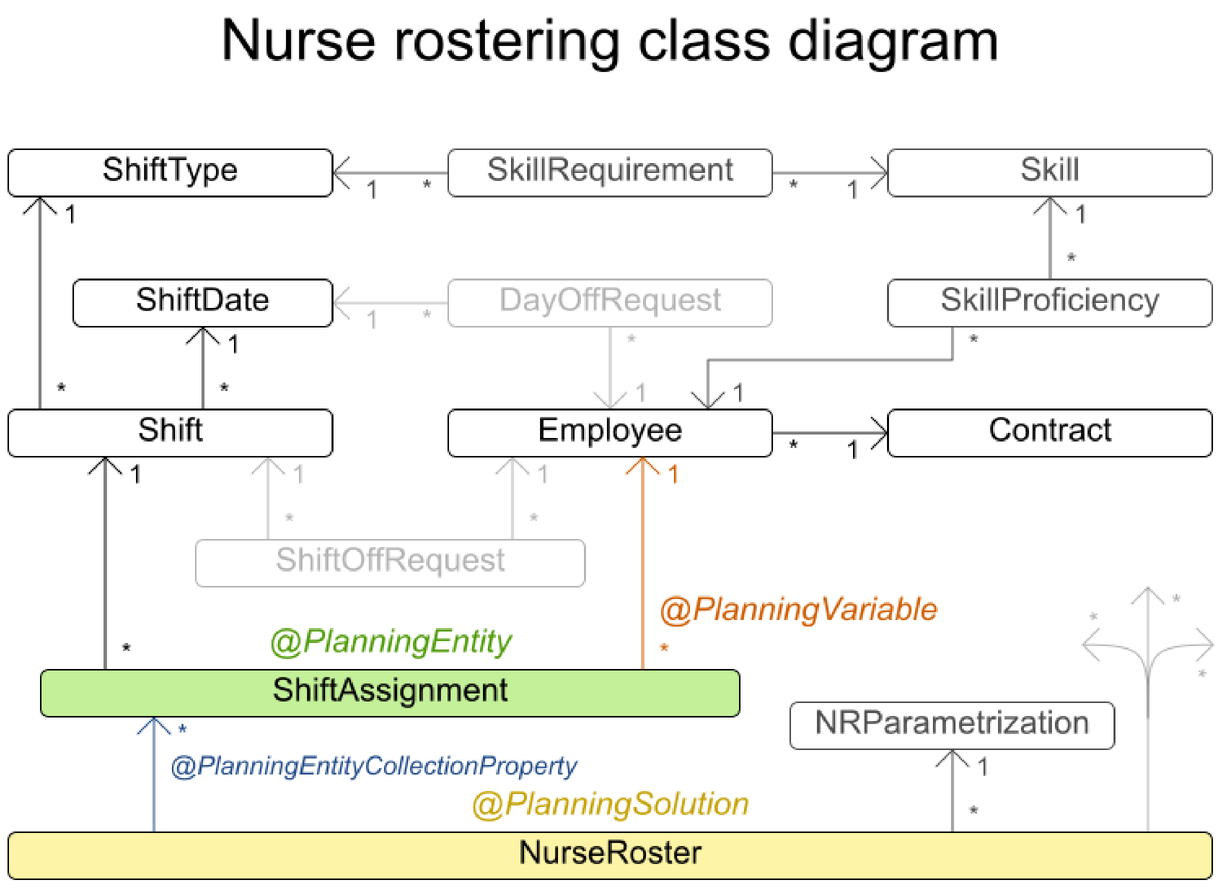
There are three dataset types:

- sprint: must be solved in seconds.
- medium: must be solved in minutes.
- long: must be solved in hours.

```
toy1          has 1 skills, 3 shiftTypes, 2 patterns, 1 contracts,  6 employees,  7 shiftDates,  35
shiftAssignments and   0 requests with a search space of   10^27.
toy2          has 1 skills, 3 shiftTypes, 3 patterns, 2 contracts, 20 employees, 28 shiftDates, 180
shiftAssignments and 140 requests with a search space of  10^234.

sprint01      has 1 skills, 4 shiftTypes, 3 patterns, 4 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint02      has 1 skills, 4 shiftTypes, 3 patterns, 4 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint03      has 1 skills, 4 shiftTypes, 3 patterns, 4 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint04      has 1 skills, 4 shiftTypes, 3 patterns, 4 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint05      has 1 skills, 4 shiftTypes, 3 patterns, 4 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint06      has 1 skills, 4 shiftTypes, 3 patterns, 4 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint07      has 1 skills, 4 shiftTypes, 3 patterns, 4 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint08      has 1 skills, 4 shiftTypes, 3 patterns, 4 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint09      has 1 skills, 4 shiftTypes, 3 patterns, 4 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint10      has 1 skills, 4 shiftTypes, 3 patterns, 4 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint_hint01 has 1 skills, 4 shiftTypes, 8 patterns, 3 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint_hint02 has 1 skills, 4 shiftTypes, 0 patterns, 3 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint_hint03 has 1 skills, 4 shiftTypes, 8 patterns, 3 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint_late01 has 1 skills, 4 shiftTypes, 8 patterns, 3 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint_late02 has 1 skills, 3 shiftTypes, 4 patterns, 3 contracts, 10 employees, 28 shiftDates, 144
shiftAssignments and 139 requests with a search space of  10^144.
sprint_late03 has 1 skills, 4 shiftTypes, 8 patterns, 3 contracts, 10 employees, 28 shiftDates, 160
shiftAssignments and 150 requests with a search space of  10^160.
sprint_late04 has 1 skills, 4 shiftTypes, 8 patterns, 3 contracts, 10 employees, 28 shiftDates, 160
shiftAssignments and 150 requests with a search space of  10^160.
sprint_late05 has 1 skills, 4 shiftTypes, 8 patterns, 3 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint_late06 has 1 skills, 4 shiftTypes, 0 patterns, 3 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint_late07 has 1 skills, 4 shiftTypes, 0 patterns, 3 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.
sprint_late08 has 1 skills, 4 shiftTypes, 0 patterns, 3 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and   0 requests with a search space of  10^152.
sprint_late09 has 1 skills, 4 shiftTypes, 0 patterns, 3 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and   0 requests with a search space of  10^152.
sprint_late10 has 1 skills, 4 shiftTypes, 0 patterns, 3 contracts, 10 employees, 28 shiftDates, 152
shiftAssignments and 150 requests with a search space of  10^152.

medium01      has 1 skills, 4 shiftTypes, 0 patterns, 4 contracts, 31 employees, 28 shiftDates, 608
shiftAssignments and 403 requests with a search space of  10^906.
medium02      has 1 skills, 4 shiftTypes, 0 patterns, 4 contracts, 31 employees, 28 shiftDates, 608
shiftAssignments and 403 requests with a search space of  10^906.
```

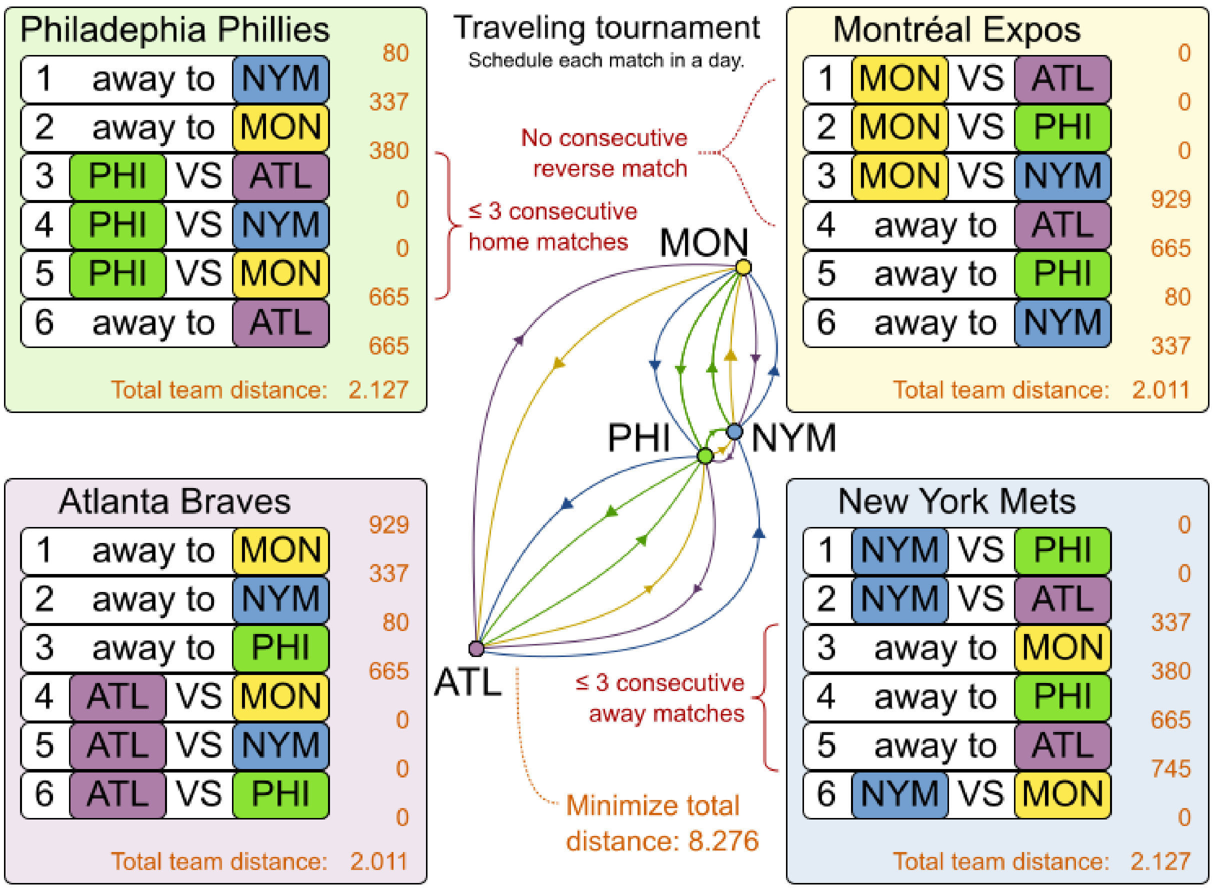
```
medium03      has 1 skills, 4 shiftTypes, 0 patterns, 4 contracts, 31 employees, 28 shiftDates, 608
shiftAssignments and 403 requests with a search space of  10^906.
medium04      has 1 skills, 4 shiftTypes, 0 patterns, 4 contracts, 31 employees, 28 shiftDates, 608
shiftAssignments and 403 requests with a search space of  10^906.
medium05      has 1 skills, 4 shiftTypes, 0 patterns, 4 contracts, 31 employees, 28 shiftDates, 608
shiftAssignments and 403 requests with a search space of  10^906.
medium_hint01 has 1 skills, 4 shiftTypes, 7 patterns, 4 contracts, 30 employees, 28 shiftDates, 428
shiftAssignments and 390 requests with a search space of  10^632.
medium_hint02 has 1 skills, 4 shiftTypes, 7 patterns, 3 contracts, 30 employees, 28 shiftDates, 428
shiftAssignments and 390 requests with a search space of  10^632.
medium_hint03 has 1 skills, 4 shiftTypes, 7 patterns, 4 contracts, 30 employees, 28 shiftDates, 428
shiftAssignments and 390 requests with a search space of  10^632.
medium_late01 has 1 skills, 4 shiftTypes, 7 patterns, 4 contracts, 30 employees, 28 shiftDates, 424
shiftAssignments and 390 requests with a search space of  10^626.
medium_late02 has 1 skills, 4 shiftTypes, 7 patterns, 3 contracts, 30 employees, 28 shiftDates, 428
shiftAssignments and 390 requests with a search space of  10^632.
medium_late03 has 1 skills, 4 shiftTypes, 0 patterns, 4 contracts, 30 employees, 28 shiftDates, 428
shiftAssignments and 390 requests with a search space of  10^632.
medium_late04 has 1 skills, 4 shiftTypes, 7 patterns, 3 contracts, 30 employees, 28 shiftDates, 416
shiftAssignments and 390 requests with a search space of  10^614.
medium_late05 has 2 skills, 5 shiftTypes, 7 patterns, 4 contracts, 30 employees, 28 shiftDates, 452
shiftAssignments and 390 requests with a search space of  10^667.

long01        has 2 skills, 5 shiftTypes, 3 patterns, 3 contracts, 49 employees, 28 shiftDates, 740
shiftAssignments and 735 requests with a search space of 10^1250.
long02        has 2 skills, 5 shiftTypes, 3 patterns, 3 contracts, 49 employees, 28 shiftDates, 740
shiftAssignments and 735 requests with a search space of 10^1250.
long03        has 2 skills, 5 shiftTypes, 3 patterns, 3 contracts, 49 employees, 28 shiftDates, 740
shiftAssignments and 735 requests with a search space of 10^1250.
long04        has 2 skills, 5 shiftTypes, 3 patterns, 3 contracts, 49 employees, 28 shiftDates, 740
shiftAssignments and 735 requests with a search space of 10^1250.
long05        has 2 skills, 5 shiftTypes, 3 patterns, 3 contracts, 49 employees, 28 shiftDates, 740
shiftAssignments and 735 requests with a search space of 10^1250.
long_hint01   has 2 skills, 5 shiftTypes, 9 patterns, 3 contracts, 50 employees, 28 shiftDates, 740
shiftAssignments and   0 requests with a search space of 10^1257.
long_hint02   has 2 skills, 5 shiftTypes, 7 patterns, 3 contracts, 50 employees, 28 shiftDates, 740
shiftAssignments and   0 requests with a search space of 10^1257.
long_hint03   has 2 skills, 5 shiftTypes, 7 patterns, 3 contracts, 50 employees, 28 shiftDates, 740
shiftAssignments and   0 requests with a search space of 10^1257.
long_late01   has 2 skills, 5 shiftTypes, 9 patterns, 3 contracts, 50 employees, 28 shiftDates, 752
shiftAssignments and   0 requests with a search space of 10^1277.
long_late02   has 2 skills, 5 shiftTypes, 9 patterns, 4 contracts, 50 employees, 28 shiftDates, 752
shiftAssignments and   0 requests with a search space of 10^1277.
long_late03   has 2 skills, 5 shiftTypes, 9 patterns, 3 contracts, 50 employees, 28 shiftDates, 752
shiftAssignments and   0 requests with a search space of 10^1277.
long_late04   has 2 skills, 5 shiftTypes, 9 patterns, 4 contracts, 50 employees, 28 shiftDates, 752
shiftAssignments and   0 requests with a search space of 10^1277.
long_late05   has 2 skills, 5 shiftTypes, 9 patterns, 3 contracts, 50 employees, 28 shiftDates, 740
shiftAssignments and   0 requests with a search space of 10^1257.
```

Figure 10.13. Domain model



10.13. TRAVELING TOURNAMENT PROBLEM (TTP)

Schedule matches between *n* teams.



Hard constraints:

- Each team plays twice against every other team: once home and once away.
- Each team has exactly one match on each timeslot.
- No team must have more than three consecutive home or three consecutive away matches.
- No repeaters: no two consecutive matches of the same two opposing teams.

Soft constraints:

- Minimize the total distance traveled by all teams.

The problem is defined on Michael Trick's website (which contains the world records too) .

Problem size

```
1-nl04     has  6 days,  4 teams and   12 matches with a search space of    10^5.
1-nl06     has 10 days,  6 teams and   30 matches with a search space of   10^19.
1-nl08     has 14 days,  8 teams and   56 matches with a search space of   10^43.
1-nl10     has 18 days, 10 teams and   90 matches with a search space of   10^79.
1-nl12     has 22 days, 12 teams and  132 matches with a search space of  10^126.
1-nl14     has 26 days, 14 teams and  182 matches with a search space of  10^186.
1-nl16     has 30 days, 16 teams and  240 matches with a search space of  10^259.
2-bra24     has 46 days, 24 teams and  552 matches with a search space of  10^692.
3-nfl16    has 30 days, 16 teams and  240 matches with a search space of  10^259.
3-nfl18    has 34 days, 18 teams and  306 matches with a search space of  10^346.
```

```
3-nfl20    has 38 days, 20 teams and  380 matches with a search space of  10^447.
3-nfl22    has 42 days, 22 teams and  462 matches with a search space of  10^562.
3-nfl24    has 46 days, 24 teams and  552 matches with a search space of  10^692.
3-nfl26    has 50 days, 26 teams and  650 matches with a search space of  10^838.
3-nfl28    has 54 days, 28 teams and  756 matches with a search space of  10^999.
3-nfl30    has 58 days, 30 teams and  870 matches with a search space of 10^1175.
3-nfl32    has 62 days, 32 teams and  992 matches with a search space of 10^1367.
4-super04  has  6 days,  4 teams and   12 matches with a search space of    10^5.
4-super06  has 10 days,  6 teams and   30 matches with a search space of   10^19.
4-super08  has 14 days,  8 teams and   56 matches with a search space of   10^43.
4-super10  has 18 days, 10 teams and   90 matches with a search space of   10^79.
4-super12  has 22 days, 12 teams and  132 matches with a search space of  10^126.
4-super14  has 26 days, 14 teams and  182 matches with a search space of  10^186.
5-galaxy04 has  6 days,  4 teams and   12 matches with a search space of    10^5.
5-galaxy06 has 10 days,  6 teams and   30 matches with a search space of   10^19.
5-galaxy08 has 14 days,  8 teams and   56 matches with a search space of   10^43.
5-galaxy10 has 18 days, 10 teams and   90 matches with a search space of   10^79.
5-galaxy12 has 22 days, 12 teams and  132 matches with a search space of  10^126.
5-galaxy14 has 26 days, 14 teams and  182 matches with a search space of  10^186.
5-galaxy16 has 30 days, 16 teams and  240 matches with a search space of  10^259.
5-galaxy18 has 34 days, 18 teams and  306 matches with a search space of  10^346.
5-galaxy20 has 38 days, 20 teams and  380 matches with a search space of  10^447.
5-galaxy22 has 42 days, 22 teams and  462 matches with a search space of  10^562.
5-galaxy24 has 46 days, 24 teams and  552 matches with a search space of  10^692.
5-galaxy26 has 50 days, 26 teams and  650 matches with a search space of  10^838.
5-galaxy28 has 54 days, 28 teams and  756 matches with a search space of  10^999.
5-galaxy30 has 58 days, 30 teams and  870 matches with a search space of 10^1175.
5-galaxy32 has 62 days, 32 teams and  992 matches with a search space of 10^1367.
5-galaxy34 has 66 days, 34 teams and 1122 matches with a search space of 10^1576.
5-galaxy36 has 70 days, 36 teams and 1260 matches with a search space of 10^1801.
5-galaxy38 has 74 days, 38 teams and 1406 matches with a search space of 10^2042.
5-galaxy40 has 78 days, 40 teams and 1560 matches with a search space of 10^2301.
```

10.14. CHEAP TIME SCHEDULING

Schedule all tasks in time and on a machine to minimize power cost. Power prices differs in time. This is a form of *job shop scheduling*.

Hard constraints:

- Start time limits: Each task must start between its earliest start and latest start limit.
- Maximum capacity: The maximum capacity for each resource for each machine must not be exceeded.
- Startup and shutdown: Each machine must be active in the periods during which it has assigned tasks. Between tasks it is allowed to be idle to avoid startup and shutdown costs.

Medium constraints:

- Power cost: Minimize the total power cost of the whole schedule.
  - Machine power cost: Each active or idle machine consumes power, which infers a power cost (depending on the power price during that time).

   - Task power cost: Each task consumes power too, which infers a power cost (depending on the power price during its time).
   - Machine startup and shutdown cost: Every time a machine starts up or shuts down, an extra cost is inflicted.

Soft constraints (addendum to the original problem definition):

- Start early: Prefer starting a task sooner rather than later.

The problem is defined by the ICON challenge.

Problem size

```
sample01   has 3 resources,   2 machines, 288 periods and   25 tasks with a search space of
10^53.
sample02   has 3 resources,   2 machines, 288 periods and   50 tasks with a search space of
10^114.
sample03   has 3 resources,   2 machines, 288 periods and  100 tasks with a search space of
10^226.
sample04   has 3 resources,   5 machines, 288 periods and  100 tasks with a search space of
10^266.
sample05   has 3 resources,   2 machines, 288 periods and  250 tasks with a search space of
10^584.
sample06   has 3 resources,   5 machines, 288 periods and  250 tasks with a search space of
10^673.
sample07   has 3 resources,   2 machines, 288 periods and 1000 tasks with a search space of
10^2388.
sample08   has 3 resources,   5 machines, 288 periods and 1000 tasks with a search space of
10^2748.
sample09   has 4 resources,  20 machines, 288 periods and 2000 tasks with a search space of
10^6668.
instance00 has 1 resources,  10 machines, 288 periods and  200 tasks with a search space of
10^595.
instance01 has 1 resources,  10 machines, 288 periods and  200 tasks with a search space of
10^599.
instance02 has 1 resources,  10 machines, 288 periods and  200 tasks with a search space of
10^599.
instance03 has 1 resources,  10 machines, 288 periods and  200 tasks with a search space of
10^591.
instance04 has 1 resources,  10 machines, 288 periods and  200 tasks with a search space of
10^590.
instance05 has 2 resources,  25 machines, 288 periods and  200 tasks with a search space of
10^667.
instance06 has 2 resources,  25 machines, 288 periods and  200 tasks with a search space of
10^660.
instance07 has 2 resources,  25 machines, 288 periods and  200 tasks with a search space of
10^662.
instance08 has 2 resources,  25 machines, 288 periods and  200 tasks with a search space of
10^651.
instance09 has 2 resources,  25 machines, 288 periods and  200 tasks with a search space of
10^659.
instance10 has 2 resources,  20 machines, 288 periods and  500 tasks with a search space of
10^1657.
instance11 has 2 resources,  20 machines, 288 periods and  500 tasks with a search space of
10^1644.
```

```
instance12 has 2 resources,  20 machines, 288 periods and  500 tasks with a search space of
10^1637.
instance13 has 2 resources,  20 machines, 288 periods and  500 tasks with a search space of
10^1659.
instance14 has 2 resources,  20 machines, 288 periods and  500 tasks with a search space of
10^1643.
instance15 has 3 resources,  40 machines, 288 periods and  500 tasks with a search space of
10^1782.
instance16 has 3 resources,  40 machines, 288 periods and  500 tasks with a search space of
10^1778.
instance17 has 3 resources,  40 machines, 288 periods and  500 tasks with a search space of
10^1764.
instance18 has 3 resources,  40 machines, 288 periods and  500 tasks with a search space of
10^1769.
instance19 has 3 resources,  40 machines, 288 periods and  500 tasks with a search space of
10^1778.
instance20 has 3 resources,  50 machines, 288 periods and 1000 tasks with a search space of
10^3689.
instance21 has 3 resources,  50 machines, 288 periods and 1000 tasks with a search space of
10^3678.
instance22 has 3 resources,  50 machines, 288 periods and 1000 tasks with a search space of
10^3706.
instance23 has 3 resources,  50 machines, 288 periods and 1000 tasks with a search space of
10^3676.
instance24 has 3 resources,  50 machines, 288 periods and 1000 tasks with a search space of
10^3681.
instance25 has 3 resources,  60 machines, 288 periods and 1000 tasks with a search space of
10^3774.
instance26 has 3 resources,  60 machines, 288 periods and 1000 tasks with a search space of
10^3737.
instance27 has 3 resources,  60 machines, 288 periods and 1000 tasks with a search space of
10^3744.
instance28 has 3 resources,  60 machines, 288 periods and 1000 tasks with a search space of
10^3731.
instance29 has 3 resources,  60 machines, 288 periods and 1000 tasks with a search space of
10^3746.
instance30 has 4 resources,  70 machines, 288 periods and 2000 tasks with a search space of
10^7718.
instance31 has 4 resources,  70 machines, 288 periods and 2000 tasks with a search space of
10^7740.
instance32 has 4 resources,  70 machines, 288 periods and 2000 tasks with a search space of
10^7686.
instance33 has 4 resources,  70 machines, 288 periods and 2000 tasks with a search space of
10^7672.
instance34 has 4 resources,  70 machines, 288 periods and 2000 tasks with a search space of
10^7695.
instance35 has 4 resources,  80 machines, 288 periods and 2000 tasks with a search space of
10^7807.
instance36 has 4 resources,  80 machines, 288 periods and 2000 tasks with a search space of
10^7814.
instance37 has 4 resources,  80 machines, 288 periods and 2000 tasks with a search space of
10^7764.
instance38 has 4 resources,  80 machines, 288 periods and 2000 tasks with a search space of
10^7736.
instance39 has 4 resources,  80 machines, 288 periods and 2000 tasks with a search space of
10^7783.
```

```
instance40 has 4 resources,  90 machines, 288 periods and 4000 tasks with a search space of
10^15976.
instance41 has 4 resources,  90 machines, 288 periods and 4000 tasks with a search space of
10^15935.
instance42 has 4 resources,  90 machines, 288 periods and 4000 tasks with a search space of
10^15887.
instance43 has 4 resources,  90 machines, 288 periods and 4000 tasks with a search space of
10^15896.
instance44 has 4 resources,  90 machines, 288 periods and 4000 tasks with a search space of
10^15885.
instance45 has 4 resources, 100 machines, 288 periods and 5000 tasks with a search space of
10^20173.
instance46 has 4 resources, 100 machines, 288 periods and 5000 tasks with a search space of
10^20132.
instance47 has 4 resources, 100 machines, 288 periods and 5000 tasks with a search space of
10^20126.
instance48 has 4 resources, 100 machines, 288 periods and 5000 tasks with a search space of
10^20110.
instance49 has 4 resources, 100 machines, 288 periods and 5000 tasks with a search space of
10^20078.
```

10.15. INVESTMENT ASSET CLASS ALLOCATION (PORTFOLIO OPTIMIZATION)

Decide the relative quantity to invest in each asset class.

Hard constraints:

- Risk maximum: the total standard deviation must not be higher than the standard deviation maximum.
  - Total standard deviation calculation takes asset class correlations into account by applying Markowitz Portfolio Theory.
- Region maximum: Each region has a quantity maximum.
- Sector maximum: Each sector has a quantity maximum.

Soft constraints:

- Maximize expected return.

Problem size

```
de_smet_1 has 1 regions, 3 sectors and 11 asset classes with a search space of 10^4.
irrinki_1 has 2 regions, 3 sectors and 6 asset classes with a search space of 10^3.
```

Larger datasets have not been created or tested yet, but should not pose a problem. A good source of data is this Asset Correlation website.

10.16. CONFERENCE SCHEDULING

Assign each conference talk to a timeslot and a room. Timeslots can overlap. Read/write to/from an ***.xlsx** file that can be edited with LibreOffice or Excel too.

Hard constraints:

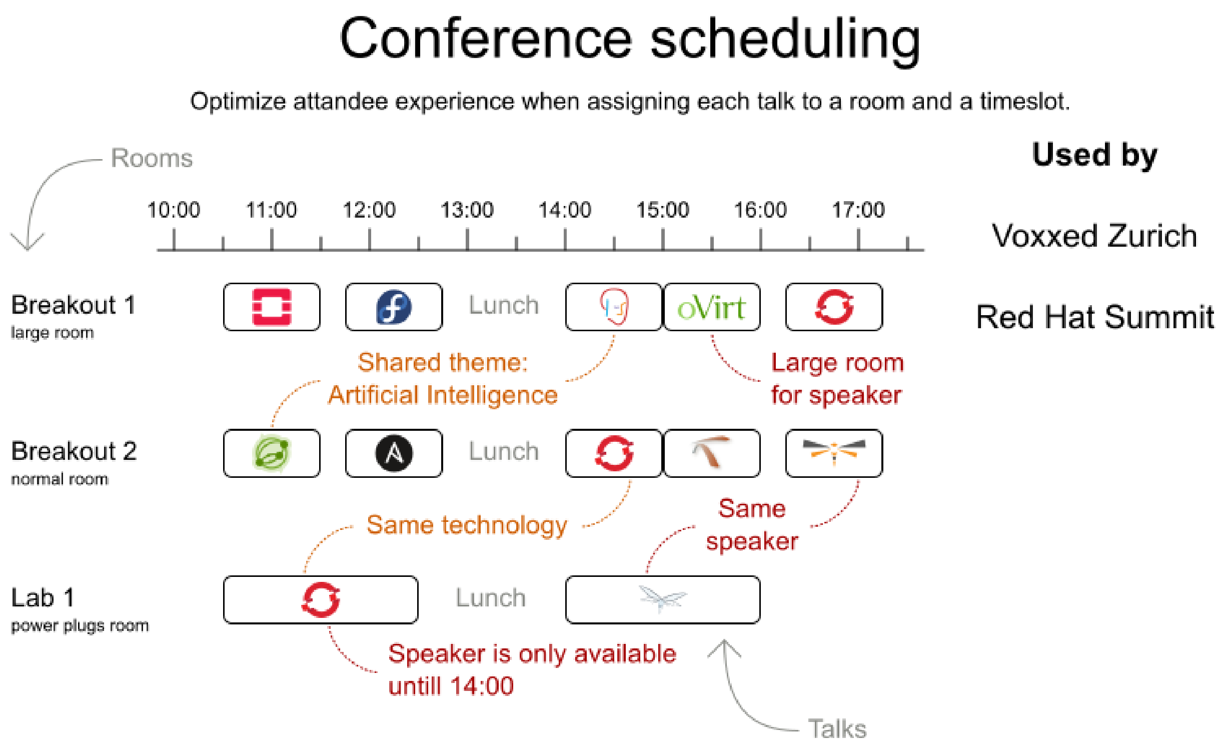
- Talk type of timeslot: The type of a talk must match the timeslot's talk type.
- Room unavailable timeslots: A talk's room must be available during the talk's timeslot.
- Room conflict: Two talks can't use the same room during overlapping timeslots.
- Speaker unavailable timeslots: Every talk's speaker must be available during the talk's timeslot.
- Speaker conflict: Two talks can't share a speaker during overlapping timeslots.
- Generic purpose timeslot and room tags
  - Speaker required timeslot tag: If a speaker has a required timeslot tag, then all his/her talks must be assigned to a timeslot with that tag.
  - Speaker prohibited timeslot tag: If a speaker has a prohibited timeslot tag, then all his/her talks cannot be assigned to a timeslot with that tag.
  - Talk required timeslot tag: If a talk has a required timeslot tag, then it must be assigned to a timeslot with that tag.
  - Talk prohibited timeslot tag: If a talk has a prohibited timeslot tag, then it cannot be assigned to a timeslot with that tag.
  - Speaker required room tag: If a speaker has a required room tag, then all his/her talks must be assigned to a room with that tag.
  - Speaker prohibited room tag: If a speaker has a prohibited room tag, then all his/her talks cannot be assigned to a room with that tag.
  - Talk required room tag: If a talk has a required room tag, then it must be assigned to a room with that tag.
  - Talk prohibited room tag: If a talk has a prohibited room tag, then it cannot be assigned to a room with that tag.
- Talk mutually-exclusive-talks tag: Talks that share such a tag must not be scheduled in overlapping timeslots.
- Talk prerequisite talks: A talk must be scheduled after all its prerequisite talks.

Soft constraints:

- Theme track conflict: Minimize the number of talks that share a same theme tag during overlapping timeslots.
- Sector conflict: Minimize the number of talks that share a same sector tag during overlapping timeslots.
- Content audience level flow violation: For every content tag, schedule the introductory talks before the advanced talks.
- Audience level diversity: For every timeslot, maximize the number of talks with a different audience level.
- Language diversity: For every timeslot, maximize the number of talks with a different language.

- Generic purpose timeslot and room tags
  - Speaker preferred timeslot tag: If a speaker has a preferred timeslot tag, then all his/her talks should be assigned to a timeslot with that tag.
  - Speaker undesired timeslot tag: If a speaker has an undesired timeslot tag, then all his/her talks should not be assigned to a timeslot with that tag.
  - Talk preferred timeslot tag: If a talk has a preferred timeslot tag, then it should be assigned to a timeslot with that tag.
  - Talk undesired timeslot tag: If a talk has an undesired timeslot tag, then it should not be assigned to a timeslot with that tag.
  - Speaker preferred room tag: If a speaker has a preferred room tag, then all his/her talks should be assigned to a room with that tag.
  - Speaker undesired room tag: If a speaker has an undesired room tag, then all his/her talks should not be assigned to a room with that tag.
  - Talk preferred room tag: If a talk has a preferred room tag, then it should be assigned to a room with that tag.
  - Talk undesired room tag: If a talk has an undesired room tag, then it should not be assigned to a room with that tag.
- Same day talks: All talks that share a same theme tag or content tag should be scheduled in the minimum number of days (ideally in the same day).

Figure 10.14. Value proposition



Problem size

> 18talks-6timeslots-5rooms   has 18 talks, 6 timeslots and 5 rooms with a search space of 10^26.
> 36talks-12timeslots-5rooms   has 36 talks, 12 timeslots and 5 rooms with a search space of 10^64.
> 72talks-12timeslots-10rooms has 72 talks, 12 timeslots and 10 rooms with a search space of 10^149.
> 108talks-18timeslots-10rooms has 108 talks, 18 timeslots and 10 rooms with a search space of 10^243.
> 216talks-18timeslots-20rooms has 216 talks, 18 timeslots and 20 rooms with a search space of 10^552.

10.17. ROCK TOUR

Drive the rock bus from show to show, but schedule shows only on available days.

Hard constraints:

- Schedule every required show.
- Schedule as many shows as possible.

Medium constraints:

- Maximize revenue opportunity.

- Minimize driving time.
- Visit sooner than later.

Soft constraints:

- Avoid long driving times.

Problem size

> 47shows has 47 shows with a search space of 10^59.

10.18. FLIGHT CREW SCHEDULING

Assign flights to pilots and flight attendants.

Hard constraints:

- Required skill: each flight assignment has a required skill. For example, flight AB0001 requires 2 pilots and 3 flight attendants.
- Flight conflict: each employee can only attend one flight at the same time
- Transfer between two flights: between two flights, an employee must be able to transfer from the arrival airport to the departure airport. For example, Ann arrives in Brussels at 10:00 and departs in Amsterdam at 15:00.
- Employee unavailability: the employee must be available on the day of the flight. For example, Ann is on PTO on 1-Feb.

Soft constraints:

- First assignment departing from home
- Last assignment arriving at home
- Load balance flight duration total per employee

Problem size

> 175flights-7days-Europe has 2 skills, 50 airports, 150 employees, 175 flights and 875 flight assignments with a search space of 10^1904.
> 700flights-28days-Europe has 2 skills, 50 airports, 150 employees, 700 flights and 3500 flight assignments with a search space of 10^7616.
> 875flights-7days-Europe has 2 skills, 50 airports, 750 employees, 875 flights and 4375 flight assignments with a search space of 10^12578.
> 175flights-7days-US   has 2 skills, 48 airports, 150 employees, 175 flights and 875 flight assignments with a search space of 10^1904.

CHAPTER 11. DOWNLOADING RED HAT BUILD OF OPTAPLANNER EXAMPLES

You can download the Red Hat build of OptaPlanner examples as a part of the Red Hat Decision Manager add-ons package available on the Red Hat Customer Portal.

Procedure

1. Navigate to the Software Downloads page in the Red Hat Customer Portal (login required), and select the product and version from the drop-down options:
    - Product: Decision Manager
    - Version: 7.11
2. Download **Red Hat Decision Manager 7.11 Add Ons**.
3. Extract the **rhdm-7.11.0-add-ons.zip** file. The extracted **add-ons** folder contains the **rhdm-7.11.0-planner-engine.zip** file.
4. Extract the **rhdm-7.11.0-planner-engine.zip** file.

Result

The extracted **rhdm-7.11.0-planner-engine** directory contains example source code under the following subdirectories:

- **examples/sources/src/main/java/org/optaplanner/examples**
- **examples/sources/src/main/resources/org/optaplanner/examples**

11.1. RUNNING OPTAPLANNER EXAMPLES

Red Hat build of OptaPlanner includes several examples that demonstrate a variety of planning use cases. Download and use the examples to explore different types of planning solutions.

Prerequisites

- You have downloaded and extracted the examples as described in Chapter 11, *Downloading Red Hat build of OptaPlanner examples*.

Procedure

1. To run the examples, in the **rhdm-7.11.0-planner-engine/examples** directory enter one of the following commands:
   Linux or Mac:

   ```
   $ ./runExamples.sh
   ```

   Windows:

   ```
   $ runExamples.bat
   ```

   The OptaPlanner Examples window opens.

2. Select an example to run that example.

> NOTE
>
> Red Hat build of OptaPlanner has no GUI dependencies. It runs just as well on a server or a mobile JVM as it does on the desktop.

11.2. RUNNING THE RED HAT BUILD OF OPTAPLANNER EXAMPLES IN AN IDE (INTELLIJ, ECLIPSE, OR NETBEANS)

If you use an integrated development environment (IDE), such as IntelliJ, Eclipse, or Netbeans, you can run your downloaded OptaPlanner examples within your development environment.

Prerequisites

- You have downloaded and extracted the OptaPlanner examples as described in Chapter 11, *Downloading Red Hat build of OptaPlanner examples* .

Procedure

1. Open the OptaPlanner examples as a new project:
   a. For IntelliJ or Netbeans, open **examples/sources/pom.xml** as the new project. The Maven integration guides you through the rest of the installation. Skip the rest of the steps in this procedure.
   b. For Eclipse, open a new project for the /**examples/binaries** directory, located under the **rhdm-7.11.0-planner-engine** directory.
2. Add all the JAR files that are in the **binaries** directory to the classpath, except for the **examples/binaries/optaplanner-examples-7.52.0.Final-redhat-00007.jar** file.
3. Add the Java source directory **src/main/java** and the Java resources directory **src/main/resources**, located under the **rhdm-7.11.0-planner-engine/examples/sources/** directory.
4. Create a run configuration:
   - Main class: **org.optaplanner.examples.app.OptaPlannerExamplesApp**
   - VM parameters (optional): **-Xmx512M -server -Dorg.optaplanner.examples.dataDir=examples/sources/data**
   - Working directory: **examples/sources**
5. Run the run configuration.

CHAPTER 12. GETTING STARTED WITH OPTAPLANNER IN BUSINESS CENTRAL: AN EMPLOYEE ROSTERING EXAMPLE

You can build and deploy the **employee-rostering** sample project in Business Central. The project demonstrates how to create each of the Business Central assets required to solve the shift rostering planning problem and use Red Hat build of OptaPlanner to find the best possible solution.

You can deploy the preconfigured **employee-rostering** project in Business Central. Alternatively, you can create the project yourself using Business Central.

NOTE

The **employee-rostering** sample project in Business Central does not include a data set. You must supply a data set in XML format using a REST API call.

12.1. DEPLOYING THE EMPLOYEE ROSTERING SAMPLE PROJECT IN BUSINESS CENTRAL

Business Central includes a number of sample projects that you can use to get familiar with the product and its features. The employee rostering sample project is designed and created to demonstrate the shift rostering use case for Red Hat build of OptaPlanner. Use the following procedure to deploy and run the employee rostering sample in Business Central.

Prerequisites

- Red Hat Decision Manager has been downloaded and installed. For installation options, see *Planning a Red Hat Decision Manager installation* .
- You have started the KIE Server and logged in to Business Central with a user that has **admin** permissions.

Procedure

1. In Business Central, click **Menu** → **Design** → **Projects**.
2. In the preconfigured **MySpace** space, click **Try Samples**.
3. Select **employee-rostering** from the list of sample projects and click **Ok** in the upper-right corner to import the project.
4. After the asset list has complied, click **Build & Deploy** to deploy the employee rostering example.

The rest of this document explains each of the project assets and their configuration.

12.2. RE-CREATING THE EMPLOYEE ROSTERING SAMPLE PROJECT

The employee rostering sample project is a preconfigured project available in Business Central. You can learn about how to deploy this project in Section 12.1, “Deploying the employee rostering sample project in Business Central”.

You can create the employee rostering example "from scratch". You can use the workflow in this example to create a similar project of your own in Business Central.

12.2.1. Setting up the employee rostering project

To start developing a solver in Business Central, you must set up the project.

Prerequisites

- Red Hat Decision Manager has been downloaded and installed.
- You have deployed Business Central and logged in with a user that has the **admin** role.

Procedure

1. Create a new project in Business Central by clicking **Menu → Design → Projects → Add Project**.
2. In the **Add Project** window, fill out the following fields:
    - Name: **employee-rostering**
    - **Description**(optional): Employee rostering problem optimization using OptaPlanner. Assigns employees to shifts based on their skill.

    Optionally, click **Configure Advanced Options** to populate the **Group ID**, **Artifact ID**, and **Version** information.

    - Group ID: **employeerostering**
    - Artifact ID: **employeerostering**
    - Version: **1.0.0-SNAPSHOT**
3. Click **Add** to add the project to the Business Central project repository.

12.2.2. Problem facts and planning entities

Each of the domain classes in the employee rostering planning problem is categorized as one of the following:

- An unrelated class: not used by any of the score constraints. From a planning standpoint, this data is obsolete.
- A *problem fact* class: used by the score constraints, but does not change during planning (as long as the problem stays the same), for example, **Shift** and **Employee**. All the properties of a problem fact class are problem properties.
- A *planning entity* class: used by the score constraints and changes during planning, for example, **ShiftAssignment**. The properties that change during planning are *planning variables*. The other properties are problem properties.
  Ask yourself the following questions:
- *What class changes during planning?*
- *Which class has variables that I want the **Solver** to change?*
  That class is a planning entity.

A planning entity class needs to be annotated with the **@PlanningEntity** annotation, or defined in Business Central using the Red Hat build of OptaPlanner dock in the domain designer.

Each planning entity class has one or more *planning variables*, and must also have one or more defining properties.

Most use cases have only one planning entity class, and only one planning variable per planning entity class.

12.2.3. Creating the data model for the employee rostering project

Use this section to create the data objects required to run the employee rostering sample project in Business Central.

Prerequisites

- You have completed the project setup described in Section 12.2.1, "Setting up the employee rostering project".

Procedure

1. With your new project, either click **Data Object** in the project perspective, or click **Add Asset → Data Object** to create a new data object.
2. Name the first data object **Timeslot**, and select **employeerostering.employeerostering** as the **Package**.
   Click **Ok**.
3. In the **Data Objects** perspective, click **+add field** to add fields to the **Timeslot** data object.
4. In the **id** field, type **endTime**.
5. Click the drop-down menu next to **Type** and select **LocalDateTime**.
6. Click **Create and continue** to add another field.
7. Add another field with the **id startTime** and **Type LocalDateTime**.
8. Click **Create**.
9. Click **Save** in the upper-right corner to save the **Timeslot** data object.
10. Click the **x** in the upper-right corner to close the **Data Objects** perspective and return to the **Assets** menu.
11. Using the previous steps, create the following data objects and their attributes:

Table 12.1. Skill

id	Type
name	**String**

Table 12.2. Employee

id	Type
name	**String**
skills	**employeerostering.employeerostering.Skill[List]**

Table 12.3. Shift

id	Type
requiredSkill	**employeerostering.employeerostering.Skill**
timeslot	**employeerostering.employeerostering.Timeslot**

Table 12.4. DayOffRequest

id	Type
date	**LocalDate**
employee	**employeerostering.employeerostering.Employee**

Table 12.5. ShiftAssignment

id	Type
employee	**employeerostering.employeerostering.Employee**
shift	**employeerostering.employeerostering.Shift**

For more examples of creating data objects, see *Getting started with decision services* .

12.2.3.1. Creating the employee roster planning entity

In order to solve the employee rostering planning problem, you must create a planning entity and a solver. The planning entity is defined in the domain designer using the attributes available in the Red Hat build of OptaPlanner dock.

Use the following procedure to define the **ShiftAssignment** data object as the planning entity for the employee rostering example.

Prerequisites

- You have created the relevant data objects and planning entity required to run the employee rostering example by completing the procedures in Section 12.2.3, “Creating the data model for the employee rostering project”.

Procedure

1. From the project **Assets** menu, open the **ShiftAssignment** data object.
2. In the **Data Objects** perspective, open the OptaPlanner dock by clicking the on the right.
3. Select **Planning Entity**.
4. Select **employee** from the list of fields under the **ShiftAssignment** data object.
5. In the OptaPlanner dock, select **Planning Variable**.
   In the **Value Range Id** input field, type **employeeRange**. This adds the **@ValueRangeProvider** annotation to the planning entity, which you can view by clicking the **Source** tab in the designer.

   The value range of a planning variable is defined with the **@ValueRangeProvider** annotation. A **@ValueRangeProvider** annotation always has a property **id**, which is referenced by the **@PlanningVariable** property **valueRangeProviderRefs**.
6. Close the dock and click **Save** to save the data object.

12.2.3.2. Creating the employee roster planning solution

The employee roster problem relies on a defined planning solution. The planning solution is defined in the domain designer using the attributes available in the Red Hat build of OptaPlanner dock.

Prerequisites

- You have created the relevant data objects and planning entity required to run the employee rostering example by completing the procedures in Section 12.2.3, “Creating the data model for the employee rostering project” and Section 12.2.3.1, “Creating the employee roster planning entity”.

Procedure

1. Create a new data object with the identifier **EmployeeRoster**.
2. Create the following fields:

   Table 12.6. EmployeeRoster

id	Type
dayOffRequestList	**employeerostering.employeerostering.DayOffRequest[List]**
shiftAssignmentList	**employeerostering.employeerostering.ShiftAssignment[List]**

id	Type
shiftList	**employeerostering.employeerostering.Shift[List]**
skillList	**employeerostering.employeerostering.Skill[List]**
timeslotList	**employeerostering.employeerostering.Timeslot[List]**

3. In the **Data Objects** perspective, open the OptaPlanner dock by clicking the on the right.
4. Select **Planning Solution**.
5. Leave the default **Hard soft score** as the **Solution Score Type**. This automatically generates a **score** field in the **EmployeeRoster** data object with the solution score as the type.
6. Add a new field with the following attributes:

id	Type
employeeList	**employeerostering.employeerostering.Employee[List]**

7. With the **employeeList** field selected, open the OptaPlanner dock and select the **Planning Value Range Provider** box.
   In the **id** field, type **employeeRange**. Close the dock.
8. Click **Save** in the upper-right corner to save the asset.

12.2.4. Employee rostering constraints

Employee rostering is a planning problem. All planning problems include constraints that must be satisfied in order to find an optimal solution.

The employee rostering sample project in Business Central includes the following hard and soft constraints:

Hard constraint

- Employees are only assigned one shift per day.
- All shifts that require a particular employee skill are assigned an employee with that particular skill.

Soft constraints

- All employees are assigned a shift.

- If an employee requests a day off, their shift is reassigned to another employee.

Hard and soft constraints are defined in Business Central using either the free-form DRL designer, or using guided rules.

12.2.4.1. DRL (Drools Rule Language) rules

DRL (Drools Rule Language) rules are business rules that you define directly in **.drl** text files. These DRL files are the source in which all other rule assets in Business Central are ultimately rendered. You can create and manage DRL files within the Business Central interface, or create them externally as part of a Maven or Java project using Red Hat CodeReady Studio or another integrated development environment (IDE). A DRL file can contain one or more rules that define at a minimum the rule conditions (**when**) and actions (**then**). The DRL designer in Business Central provides syntax highlighting for Java, DRL, and XML.

DRL files consist of the following components:

Components in a DRL file

```
package

import

function  // Optional

query  // Optional

declare   // Optional

global   // Optional

rule "rule name"
    // Attributes
    when
        // Conditions
    then
        // Actions
end

rule "rule2 name"

...
```

The following example DRL rule determines the age limit in a loan application decision service:

Example rule for loan application age limit

```
rule "Underage"
  salience 15
  agenda-group "applicationGroup"
  when
    $application : LoanApplication()
    Applicant( age < 21 )
  then
```

```
    $application.setApproved( false );
    $application.setExplanation( "Underage" );
end
```

A DRL file can contain single or multiple rules, queries, and functions, and can define resource declarations such as imports, globals, and attributes that are assigned and used by your rules and queries. The DRL package must be listed at the top of a DRL file and the rules are typically listed last. All other DRL components can follow any order.

Each rule must have a unique name within the rule package. If you use the same rule name more than once in any DRL file in the package, the rules fail to compile. Always enclose rule names with double quotation marks (**rule "rule name"**) to prevent possible compilation errors, especially if you use spaces in rule names.

All data objects related to a DRL rule must be in the same project package as the DRL file in Business Central. Assets in the same package are imported by default. Existing assets in other packages can be imported with the DRL rule.

12.2.4.2. Defining constraints for employee rostering using the DRL designer

You can create constraint definitions for the employee rostering example using the free-form DRL designer in Business Central.

Use this procedure to create a *hard constraint* where no employee is assigned a shift that begins less than 10 hours after their previous shift ended.

Procedure

1. In Business Central, go to **Menu** → **Design** → **Projects** and click the project name.
2. Click **Add Asset** → **DRL file**.
3. In the **DRL file** name field, type **ComplexScoreRules**.
4. Select the **employeerostering.employeerostering** package.
5. Click **+Ok** to create the DRL file.
6. In the **Model** tab of the DRL designer, define the **Employee10HourShiftSpace** rule as a DRL file:

```
package employeerostering.employeerostering;

rule "Employee10HourShiftSpace"
    when
        $shiftAssignment : ShiftAssignment( $employee : employee != null, $shiftEndDateTime :
shift.timeslot.endTime)
        ShiftAssignment( this != $shiftAssignment, $employee == employee, $shiftEndDateTime
<= shift.timeslot.endTime,
                $shiftEndDateTime.until(shift.timeslot.startTime,
java.time.temporal.ChronoUnit.HOURS) <10)
    then
        scoreHolder.addHardConstraintMatch(kcontext, -1);
end
```

7. Click **Save** to save the DRL file.

For more information about creating DRL files, see *Designing a decision service using DRL rules* .

12.2.5. Creating rules for employee rostering using guided rules

You can create rules that define hard and soft constraints for employee rostering using the guided rules designer in Business Central.

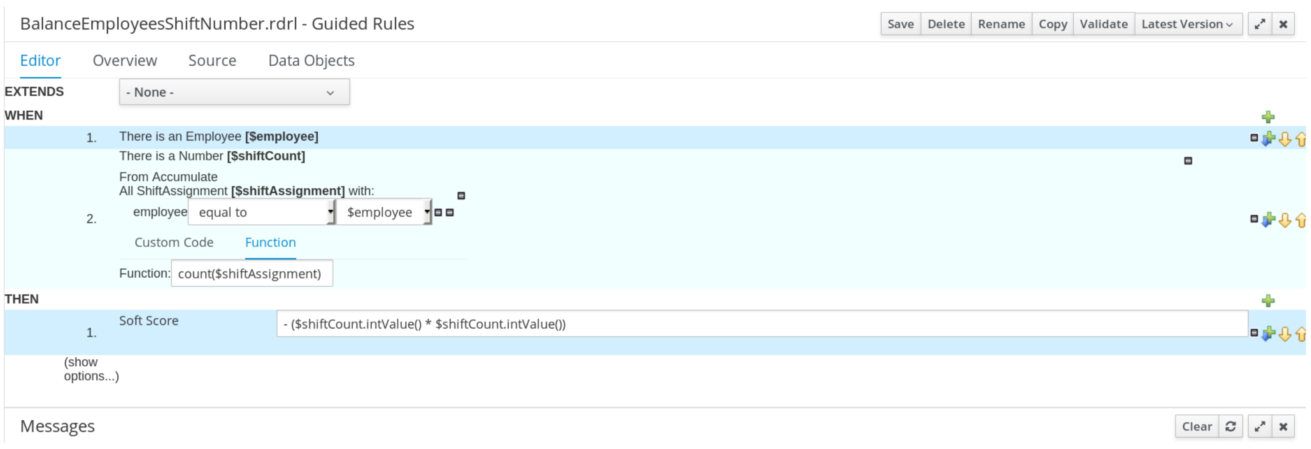
12.2.5.1. Guided rules

Guided rules are business rules that you create in a UI-based guided rules designer in Business Central that leads you through the rule-creation process. The guided rules designer provides fields and options for acceptable input based on the data objects for the rule being defined. The guided rules that you define are compiled into Drools Rule Language (DRL) rules as with all other rule assets.

All data objects related to a guided rule must be in the same project package as the guided rule. Assets in the same package are imported by default. After you create the necessary data objects and the guided rule, you can use the **Data Objects** tab of the guided rules designer to verify that all required data objects are listed or to import other existing data objects by adding a **New item**.

12.2.5.2. Creating a guided rule to balance employee shift numbers

The **BalanceEmployeesShiftNumber** guided rule creates a soft constraint that ensures shifts are assigned to employees in a way that is balanced as evenly as possible. It does this by creating a score penalty that increases when shift distribution is less even. The score formula, implemented by the rule, incentivizes the Solver to distribute shifts in a more balanced way.



EXTENDS - None -

WHEN

1. There is an Employee **[$employee]**

2. There is a Number **[$shiftCount]**
From Accumulate
All ShiftAssignment **[$shiftAssignment]** with:
employee equal to $employee
Custom Code Function
Function: count($shiftAssignment)

THEN

1. Soft Score - ($shiftCount.intValue() * $shiftCount.intValue())

(show options...)

Procedure

1. In Business Central, go to **Menu** → **Design** → **Projects** and click the project name.

2. Click **Add Asset** → **Guided Rule**.

3. Enter **BalanceEmployeesShiftNumber** as the **Guided Rule** name and select the **employeerostering.employeerostering** **Package**.

4. Click **Ok** to create the rule asset.

5. Add a **WHEN** condition by clicking the + in the **WHEN** field.

6. Select **Employee** in the **Add a condition to the rule**window. Click **+Ok**.

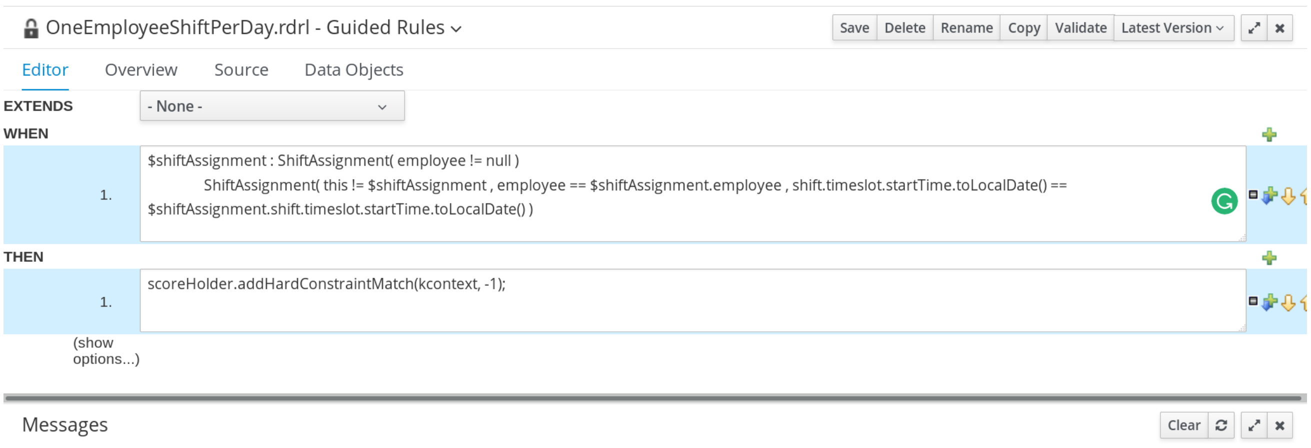
7. Click the **Employee** condition to modify the constraints and add the variable name **$employee**.

8. Add the **WHEN** condition **From Accumulate**.
    a. Above the **From Accumulate** condition, click **click to add pattern** and select **Number** as the fact type from the drop-down list.
    b. Add the variable name **$shiftCount** to the **Number** condition.
    c. Below the **From Accumulate** condition, click **click to add pattern** and select the **ShiftAssignment** fact type from the drop-down list.
    d. Add the variable name **$shiftAssignment** to the **ShiftAssignment** fact type.
    e. Click the **ShiftAssignment** condition again and from the **Add a restriction on a field** drop-down list, select **employee**.
    f. Select **equal to** from the drop-down list next to the **employee** constraint.
    g. Click the ✎ icon next to the drop-down button to add a variable, and click **Bound variable** in the **Field value** window.
    h. Select **$employee** from the drop-down list.
    i. In the **Function** box type **count($shiftAssignment)**.
9. Add the **THEN** condition by clicking the ➕ in the **THEN** field.
10. Select **Modify Soft Score** in the **Add a new action** window. Click **+Ok**.
    a. Type the following expression into the box: **-($shiftCount.intValue()*$shiftCount.intValue())**
11. Click **Validate** in the upper-right corner to check all rule conditions are valid. If the rule validation fails, address any problems described in the error message, review all components in the rule, and try again to validate the rule until the rule passes.
12. Click **Save** to save the rule.

For more information about creating guided rules, see *Designing a decision service using guided rules* .

12.2.5.3. Creating a guided rule for no more than one shift per day

The **OneEmployeeShiftPerDay** guided rule creates a hard constraint that employees are not assigned more than one shift per day. In the employee rostering example, this constraint is created using the guided rule designer.



```
$shiftAssignment : ShiftAssignment( employee != null )
        ShiftAssignment( this != $shiftAssignment , employee == $shiftAssignment.employee , shift.timeslot.startTime.toLocalDate() ==
$shiftAssignment.shift.timeslot.startTime.toLocalDate() )
```

```
scoreHolder.addHardConstraintMatch(kcontext, -1);
```

Procedure

1. In Business Central, go to **Menu** → **Design** → **Projects** and click the project name.
2. Click **Add Asset** → **Guided Rule**.
3. Enter **OneEmployeeShiftPerDay** as the **Guided Rule** name and select the **employeerostering.employeerostering** Package.
4. Click **Ok** to create the rule asset.
5. Add a **WHEN** condition by clicking the ✚ in the **WHEN** field.
6. Select **Free form DRL** from the **Add a condition to the rule**window.
7. In the free form DRL box, type the following condition:

   ```
   $shiftAssignment : ShiftAssignment( employee != null )
     ShiftAssignment( this != $shiftAssignment , employee == $shiftAssignment.employee ,
   shift.timeslot.startTime.toLocalDate() ==
   $shiftAssignment.shift.timeslot.startTime.toLocalDate() )
   ```

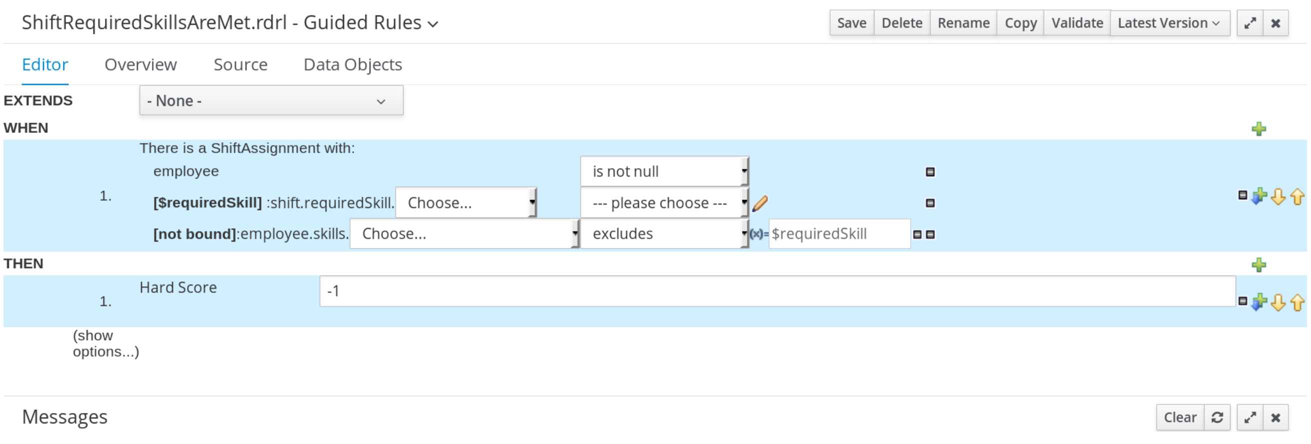
   This condition states that a shift cannot be assigned to an employee that already has another shift assignment on the same day.
8. Add the **THEN** condition by clicking the ✚ in the **THEN** field.
9. Select **Add free form DRL**from the **Add a new action**window.
10. In the free form DRL box, type the following condition:

    ```
    scoreHolder.addHardConstraintMatch(kcontext, -1);
    ```
11. Click **Validate** in the upper-right corner to check all rule conditions are valid. If the rule validation fails, address any problems described in the error message, review all components in the rule, and try again to validate the rule until the rule passes.
12. Click **Save** to save the rule.

For more information about creating guided rules, see *Designing a decision service using guided rules* .

12.2.5.4. Creating a guided rule to match skills to shift requirements

The **ShiftReqiredSkillsAreMet** guided rule creates a hard constraint that ensures all shifts are assigned an employee with the correct set of skills. In the employee rostering example, this constraint is created using the guided rule designer.



EXTENDS - None -
WHEN
1. There is a ShiftAssignment with:
employee is not null
[$requiredSkill] :shift.requiredSkill. Choose... --- please choose ---
[not bound]:employee.skills. Choose... excludes $requiredSkill
THEN
1. Hard Score -1
(show options...)

Procedure

1. In Business Central, go to **Menu → Design → Projects** and click the project name.
2. Click **Add Asset → Guided Rule**.
3. Enter **ShiftReqiredSkillsAreMet** as the **Guided Rule** name and select the **employeerostering.employeerostering Package**.
4. Click **Ok** to create the rule asset.
5. Add a **WHEN** condition by clicking the ✚ in the **WHEN** field.
6. Select **ShiftAssignment** in the **Add a condition to the rule**window. Click **+Ok**.
7. Click the **ShiftAssignment** condition, and select **employee** from the **Add a restriction on a field** drop-down list.
8. In the designer, click the drop-down list next to **employee** and select **is not null**.
9. Click the **ShiftAssignment** condition, and click **Expression editor**.
    a. In the designer, click **[not bound]** to open the **Expression editor**, and bind the expression to the variable **$requiredSkill**. Click **Set**.
    b. In the designer, next to **$requiredSkill**, select **shift** from the first drop-down list, then **requiredSkill** from the next drop-down list.
10. Click the **ShiftAssignment** condition, and click **Expression editor**.
    a. In the designer, next to **[not bound]**, select **employee** from the first drop-down list, then **skills** from the next drop-down list.
    b. Leave the next drop-down list as **Choose**.
    c. In the next drop-down box, change **please choose** to **excludes**.
    d. Click the ✎ icon next to **excludes**, and in the **Field value** window, click the **New formula** button.

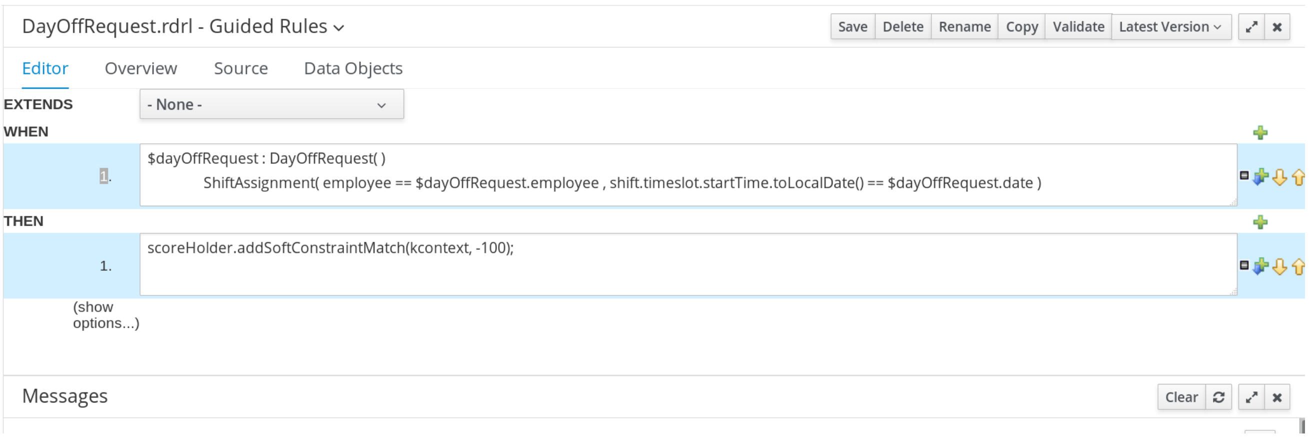
  e. Type **$requiredSkill** into the formula box.

11. Add the **THEN** condition by clicking the ✚ in the **THEN** field.
12. Select **Modify Hard Score** in the **Add a new action** window. Click **+Ok**.
13. Type **-1** into the score actions box.
14. Click **Validate** in the upper-right corner to check all rule conditions are valid. If the rule validation fails, address any problems described in the error message, review all components in the rule, and try again to validate the rule until the rule passes.
15. Click **Save** to save the rule.

For more information about creating guided rules, see *Designing a decision service using guided rules* .

12.2.5.5. Creating a guided rule to manage day off requests

The **DayOffRequest** guided rule creates a soft constraint. This constraint allows a shift to be reassigned to another employee in the event the employee who was originally assigned the shift is no longer able to work that day. In the employee rostering example, this constraint is created using the guided rule designer.


DayOffRequest.rdrl - Guided Rules

Save | Delete | Rename | Copy | Validate | Latest Version

Editor | Overview | Source | Data Objects

EXTENDS - None -

WHEN

1.
```
$dayOffRequest : DayOffRequest( )
        ShiftAssignment( employee == $dayOffRequest.employee , shift.timeslot.startTime.toLocalDate() == $dayOffRequest.date )
```

THEN

1.
```
scoreHolder.addSoftConstraintMatch(kcontext, -100);
```

(show options...)

Messages

Clear

Procedure

1. In Business Central, go to **Menu** → **Design** → **Projects** and click the project name.
2. Click **Add Asset** → **Guided Rule**.
3. Enter **DayOffRequest** as the **Guided Rule** name and select the **employeerostering.employeerostering** Package.
4. Click **Ok** to create the rule asset.
5. Add a **WHEN** condition by clicking the ✚ in the **WHEN** field.
6. Select **Free form DRL** from the **Add a condition to the rule** window.
7. In the free form DRL box, type the following condition:

```
$dayOffRequest : DayOffRequest( )
  ShiftAssignment( employee == $dayOffRequest.employee ,
shift.timeslot.startTime.toLocalDate() == $dayOffRequest.date )
```

This condition states if a shift is assigned to an employee who has made a day off request, the employee can be unassigned the shift on that day.

8. Add the **THEN** condition by clicking the ✚ in the **THEN** field.

9. Select **Add free form DRL** from the **Add a new action** window.

10. In the free form DRL box, type the following condition:

```
scoreHolder.addSoftConstraintMatch(kcontext, -100);
```

11. Click **Validate** in the upper-right corner to check all rule conditions are valid. If the rule validation fails, address any problems described in the error message, review all components in the rule, and try again to validate the rule until the rule passes.

12. Click **Save** to save the rule.

For more information about creating guided rules, see *Designing a decision service using guided rules* .

12.2.6. Creating a solver configuration for employee rostering

You can create and edit Solver configurations in Business Central. The Solver configuration designer creates a solver configuration that can be run after the project is deployed.

Prerequisites

- Red Hat Decision Manager has been downloaded and installed.
- You have created and configured all of the relevant assets for the employee rostering example.

Procedure

1. In Business Central, click **Menu** → **Projects**, and click your project to open it.

2. In the **Assets** perspective, click **Add Asset** → **Solver configuration**

3. In the **Create new Solver configuration** window, type the name **EmployeeRosteringSolverConfig** for your Solver and click **Ok**.
   This opens the **Solver configuration** designer.

4. In the **Score Director Factory** configuration section, define a KIE base that contains scoring rule definitions. The employee rostering sample project uses **defaultKieBase**.

   a. Select one of the KIE sessions defined within the KIE base. The employee rostering sample project uses **defaultKieSession**.

5. Click **Validate** in the upper-right corner to check the **Score Director Factory** configuration is correct. If validation fails, address any problems described in the error message, and try again to validate until the configuration passes.

6. Click **Save** to save the Solver configuration.

12.2.7. Configuring Solver termination for the employee rostering project

You can configure the Solver to terminate after a specified amount of time. By default, the planning engine is given an unlimited time period to solve a problem instance.

The employee rostering sample project is set up to run for 30 seconds.

Prerequisites

- You have created all relevant assets for the employee rostering project and created the **EmployeeRosteringSolverConfig** solver configuration in Business Central as described in Section 12.2.6, "Creating a solver configuration for employee rostering" .

Procedure

1. Open the **EmployeeRosteringSolverConfig** from the **Assets** perspective. This will open the **Solver configuration** designer.
2. In the **Termination** section, click **Add** to create new termination element within the selected logical group.
3. Select the **Time spent** termination type from the drop-down list. This is added as an input field in the termination configuration.
4. Use the arrows next to the time elements to adjust the amount of time spent to 30 seconds.
5. Click **Validate** in the upper-right corner to check the **Score Director Factory** configuration is correct. If validation fails, address any problems described in the error message, and try again to validate until the configuration passes.
6. Click **Save** to save the Solver configuration.

12.3. ACCESSING THE SOLVER USING THE REST API

After deploying or re-creating the sample solver, you can access it using the REST API.

You must register a solver instance using the REST API. Then you can supply data sets and retrieve optimized solutions.

Prerequisites

- The employee rostering project is set up and deployed according to the previous sections in this document. You can either deploy the sample project, as described in Section 12.1, "Deploying the employee rostering sample project in Business Central", or re-create the project, as described in Section 12.2, "Re-creating the employee rostering sample project".

12.3.1. Registering the Solver using the REST API

You must register the solver instance using the REST API before you can use the solver.

Each solver instance is capable of optimizing one planning problem at a time.

Procedure

1. Create a HTTP request using the following header:

```
authorization: admin:admin
X-KIE-ContentType: xstream
content-type: application/xml
```

2. Register the Solver using the following request:

   PUT

   http://localhost:8080/kie-server/services/rest/server/containers/employeerostering_1.0.0-SNAPSHOT/solvers/EmployeeRosteringSolver

   Request body

   ```
   <solver-instance>
     <solver-config-file>employeerostering/employeerostering/EmployeeRosteringSolverConfig.solver.xml</solver-config-file>
   </solver-instance>
   ```

12.3.2. Calling the Solver using the REST API

After registering the solver instance, you can use the REST API to submit a data set to the solver and to retrieve an optimized solution.

Procedure

1. Create a HTTP request using the following header:

   ```
   authorization: admin:admin
   X-KIE-ContentType: xstream
   content-type: application/xml
   ```

2. Submit a request to the Solver with a data set, as in the following example:

   POST

   http://localhost:8080/kie-server/services/rest/server/containers/employeerostering_1.0.0-SNAPSHOT/solvers/EmployeeRosteringSolver/state/solving

   Request body

   ```
   <employeerostering.employeerostering.EmployeeRoster>
     <employeeList>
       <employeerostering.employeerostering.Employee>
         <name>John</name>
         <skills>
           <employeerostering.employeerostering.Skill>
             <name>reading</name>
           </employeerostering.employeerostering.Skill>
         </skills>
       </employeerostering.employeerostering.Employee>
       <employeerostering.employeerostering.Employee>
         <name>Mary</name>
         <skills>
   ```

```
        <employeerostering.employeerostering.Skill>
          <name>writing</name>
        </employeerostering.employeerostering.Skill>
      </skills>
    </employeerostering.employeerostering.Employee>
    <employeerostering.employeerostering.Employee>
      <name>Petr</name>
      <skills>
        <employeerostering.employeerostering.Skill>
          <name>speaking</name>
        </employeerostering.employeerostering.Skill>
      </skills>
    </employeerostering.employeerostering.Employee>
  </employeeList>
  <shiftList>
    <employeerostering.employeerostering.Shift>
      <timeslot>
        <startTime>2017-01-01T00:00:00</startTime>
        <endTime>2017-01-01T01:00:00</endTime>
      </timeslot>
      <requiredSkill
reference="../../../employeeList/employeerostering.employeerostering.Employee/skills/emplo
yeerostering.employeerostering.Skill"/>
    </employeerostering.employeerostering.Shift>
    <employeerostering.employeerostering.Shift>
      <timeslot reference="../../employeerostering.employeerostering.Shift/timeslot"/>
      <requiredSkill
reference="../../../employeeList/employeerostering.employeerostering.Employee[3]/skills/emp
loyeerostering.employeerostering.Skill"/>
    </employeerostering.employeerostering.Shift>
    <employeerostering.employeerostering.Shift>
      <timeslot reference="../../employeerostering.employeerostering.Shift/timeslot"/>
      <requiredSkill
reference="../../../employeeList/employeerostering.employeerostering.Employee[2]/skills/emp
loyeerostering.employeerostering.Skill"/>
    </employeerostering.employeerostering.Shift>
  </shiftList>
  <skillList>
    <employeerostering.employeerostering.Skill
reference="../../employeeList/employeerostering.employeerostering.Employee/skills/employe
erostering.employeerostering.Skill"/>
    <employeerostering.employeerostering.Skill
reference="../../employeeList/employeerostering.employeerostering.Employee[3]/skills/emplo
yeerostering.employeerostering.Skill"/>
    <employeerostering.employeerostering.Skill
reference="../../employeeList/employeerostering.employeerostering.Employee[2]/skills/emplo
yeerostering.employeerostering.Skill"/>
  </skillList>
  <timeslotList>
    <employeerostering.employeerostering.Timeslot
reference="../../shiftList/employeerostering.employeerostering.Shift/timeslot"/>
  </timeslotList>
  <dayOffRequestList/>
  <shiftAssignmentList>
    <employeerostering.employeerostering.ShiftAssignment>
      <shift reference="../../../shiftList/employeerostering.employeerostering.Shift"/>
    </employeerostering.employeerostering.ShiftAssignment>
    <employeerostering.employeerostering.ShiftAssignment>
      <shift reference="../../../shiftList/employeerostering.employeerostering.Shift[3]"/>
    </employeerostering.employeerostering.ShiftAssignment>
    <employeerostering.employeerostering.ShiftAssignment>
      <shift reference="../../../shiftList/employeerostering.employeerostering.Shift[2]"/>
    </employeerostering.employeerostering.ShiftAssignment>
  </shiftAssignmentList>
</employeerostering.employeerostering.EmployeeRoster>
```

3. Request the best solution to the planning problem:

   GET

   http://localhost:8080/kie-server/services/rest/server/containers/employeerostering_1.0.0-SNAPSHOT/solvers/EmployeeRosteringSolver/bestsolution

   Example response

```
<solver-instance>
  <container-id>employee-rostering</container-id>
  <solver-id>solver1</solver-id>
  <solver-config-
file>employeerostering/employeerostering/EmployeeRosteringSolverConfig.solver.xml</s
olver-config-file>
  <status>NOT_SOLVING</status>
  <score
scoreClass="org.optaplanner.core.api.score.buildin.hardsoft.HardSoftScore">0hard/0soft<
/score>
  <best-solution class="employeerostering.employeerostering.EmployeeRoster">
    <employeeList>
      <employeerostering.employeerostering.Employee>
        <name>John</name>
        <skills>
          <employeerostering.employeerostering.Skill>
            <name>reading</name>
          </employeerostering.employeerostering.Skill>
        </skills>
      </employeerostering.employeerostering.Employee>
      <employeerostering.employeerostering.Employee>
        <name>Mary</name>
        <skills>
          <employeerostering.employeerostering.Skill>
            <name>writing</name>
          </employeerostering.employeerostering.Skill>
        </skills>
      </employeerostering.employeerostering.Employee>
      <employeerostering.employeerostering.Employee>
        <name>Petr</name>
        <skills>
          <employeerostering.employeerostering.Skill>
            <name>speaking</name>
          </employeerostering.employeerostering.Skill>
        </skills>
      </employeerostering.employeerostering.Employee>
    </employeeList>
    <shiftList>
      <employeerostering.employeerostering.Shift>
        <timeslot>
          <startTime>2017-01-01T00:00:00</startTime>
          <endTime>2017-01-01T01:00:00</endTime>
        </timeslot>
        <requiredSkill
reference="../../../employeeList/employeerostering.employeerostering.Employee/skills/emplo
yeerostering.employeerostering.Skill"/>
      </employeerostering.employeerostering.Shift>
      <employeerostering.employeerostering.Shift>
        <timeslot reference="../../employeerostering.employeerostering.Shift/timeslot"/>
        <requiredSkill
reference="../../../employeeList/employeerostering.employeerostering.Employee[3]/skills/emp
loyeerostering.employeerostering.Skill"/>
      </employeerostering.employeerostering.Shift>
      <employeerostering.employeerostering.Shift>
        <timeslot reference="../../employeerostering.employeerostering.Shift/timeslot"/>
        <requiredSkill
reference="../../../employeeList/employeerostering.employeerostering.Employee[2]/skills/emp
loyeerostering.employeerostering.Skill"/>
      </employeerostering.employeerostering.Shift>
    </shiftList>
    <skillList>
      <employeerostering.employeerostering.Skill
reference="../../employeeList/employeerostering.employeerostering.Employee/skills/employe
erostering.employeerostering.Skill"/>
      <employeerostering.employeerostering.Skill
reference="../../employeeList/employeerostering.employeerostering.Employee[3]/skills/emplo
yeerostering.employeerostering.Skill"/>
      <employeerostering.employeerostering.Skill
reference="../../employeeList/employeerostering.employeerostering.Employee[2]/skills/emplo
yeerostering.employeerostering.Skill"/>
    </skillList>
    <timeslotList>
      <employeerostering.employeerostering.Timeslot
reference="../../shiftList/employeerostering.employeerostering.Shift/timeslot"/>
    </timeslotList>
    <dayOffRequestList/>
    <shiftAssignmentList/>
    <score>0hard/0soft</score>
  </best-solution>
</solver-instance>
```

CHAPTER 13. GETTING STARTED WITH OPTAPLANNER AND QUARKUS

You can use the **https://code.quarkus.redhat.com** website to generate a Red Hat build of OptaPlanner Quarkus Maven project and automatically add and configure the extensions that you want to use in your application. You can then download the Quarkus Maven repository or use the online Maven repository with your project.

13.1. APACHE MAVEN AND RED HAT BUILD OF QUARKUS

Apache Maven is a distributed build automation tool used in Java application development to create, manage, and build software projects. Maven uses standard configuration files called Project Object Model (POM) files to define projects and manage the build process. POM files describe the module and component dependencies, build order, and targets for the resulting project packaging and output using an XML file. This ensures that the project is built in a correct and uniform manner.

Maven repositories

A Maven repository stores Java libraries, plug-ins, and other build artifacts. The default public repository is the Maven 2 Central Repository, but repositories can be private and internal within a company to share common artifacts among development teams. Repositories are also available from third parties.

You can use the online Maven repository with your Quarkus projects or you can download the Red Hat build of Quarkus Maven repository.

Maven plug-ins

Maven plug-ins are defined parts of a POM file that achieve one or more goals. Quarkus applications use the following Maven plug-ins:

- Quarkus Maven plug-in (**quarkus-maven-plugin**): Enables Maven to create Quarkus projects, supports the generation of uber-JAR files, and provides a development mode.
- Maven Surefire plug-in (**maven-surefire-plugin**): Used during the test phase of the build lifecycle to execute unit tests on your application. The plug-in generates text and XML files that contain the test reports.

13.2. CONFIGURING THE MAVEN SETTINGS.XML FILE FOR THE ONLINE REPOSITORY

You can use the online Maven repository with your Maven project by configuring your user **settings.xml** file. This is the recommended approach. Maven settings used with a repository manager or repository on a shared server provide better control and manageability of projects.

NOTE

When you configure the repository by modifying the Maven **settings.xml** file, the changes apply to all of your Maven projects.

Procedure

1. Open the Maven **~/.m2/settings.xml** file in a text editor or integrated development environment (IDE).

> **NOTE**
>
> If there is not a **settings.xml** file in the ~/**.m2**/ directory, copy the **settings.xml** file from the **$MAVEN_HOME**/**.m2**/**conf**/ directory into the ~/**.m2**/ directory.

2. Add the following lines to the **<profiles>** element of the **settings.xml** file:

```
<!-- Configure the Maven repository -->
<profile>
  <id>red-hat-enterprise-maven-repository</id>
  <repositories>
    <repository>
      <id>red-hat-enterprise-maven-repository</id>
      <url>https://maven.repository.redhat.com/ga/</url>
      <releases>
        <enabled>true</enabled>
      </releases>
      <snapshots>
        <enabled>false</enabled>
      </snapshots>
    </repository>
  </repositories>
  <pluginRepositories>
    <pluginRepository>
      <id>red-hat-enterprise-maven-repository</id>
      <url>https://maven.repository.redhat.com/ga/</url>
      <releases>
        <enabled>true</enabled>
      </releases>
      <snapshots>
        <enabled>false</enabled>
      </snapshots>
    </pluginRepository>
  </pluginRepositories>
</profile>
```

3. Add the following lines to the **<activeProfiles>** element of the **settings.xml** file and save the file.

```
<activeProfile>red-hat-enterprise-maven-repository</activeProfile>
```

13.3. DOWNLOADING AND CONFIGURING THE QUARKUS MAVEN REPOSITORY

If you do not want to use the online Maven repository, you can download and configure the Quarkus Maven repository to create a Quarkus application with Maven. The Quarkus Maven repository contains many of the requirements that Java developers typically use to build their applications. This procedure describes how to edit the **settings.xml** file to configure the Quarkus Maven repository.

> **NOTE**
>
> When you configure the repository by modifying the Maven **settings.xml** file, the changes apply to all of your Maven projects.

Procedure

1. Download the Red Hat build of Quarkus Maven repository ZIP file from the Software Downloads page of the Red Hat Customer Portal (login required).
2. Expand the downloaded archive.
3. Change directory to the **~/.m2/** directory and open the Maven **settings.xml** file in a text editor or integrated development environment (IDE).
4. Add the following lines to the **<profiles>** element of the **settings.xml** file, where ***QUARKUS_MAVEN_REPOSITORY*** is the path of the Quarkus Maven repository that you downloaded. The format of ***QUARKUS_MAVEN_REPOSITORY*** must be **file://$PATH**, for example **file:///home/userX/rh-quarkus-1.11.6.GA-maven-repository/maven-repository**.

```
<!-- Configure the Quarkus Maven repository -->
<profile>
  <id>red-hat-enterprise-maven-repository</id>
  <repositories>
    <repository>
      <id>red-hat-enterprise-maven-repository</id>
      <url>QUARKUS_MAVEN_REPOSITORY</url>
      <releases>
        <enabled>true</enabled>
      </releases>
      <snapshots>
        <enabled>false</enabled>
      </snapshots>
    </repository>
  </repositories>
  <pluginRepositories>
    <pluginRepository>
      <id>red-hat-enterprise-maven-repository</id>
      <url>QUARKUS_MAVEN_REPOSITORY</url>
      <releases>
        <enabled>true</enabled>
      </releases>
      <snapshots>
        <enabled>false</enabled>
      </snapshots>
    </pluginRepository>
  </pluginRepositories>
</profile>
```

5. Add the following lines to the **<activeProfiles>** element of the **settings.xml** file and save the file.

```
<activeProfile>red-hat-enterprise-maven-repository</activeProfile>
```

IMPORTANT

If your Maven repository contains outdated artifacts, you might encounter one of the following Maven error messages when you build or deploy your project, where ***ARTIFACT_NAME*** is the name of a missing artifact and ***PROJECT_NAME*** is the name of the project you are trying to build:

- **Missing artifact *PROJECT_NAME***
- **[ERROR] Failed to execute goal on project *ARTIFACT_NAME*; Could not resolve dependencies for *PROJECT_NAME***

To resolve the issue, delete the cached version of your local repository located in the **~/.m2/repository** directory to force a download of the latest Maven artifacts.

13.4. CREATING A RED HAT BUILD OF QUARKUS MAVEN PROJECT USING CODE.QUARKUS.REDHAT.COM

You can use the **code.quarkus.redhat.com** website to generate a Red Hat build of OptaPlanner Quarkus Maven project and automatically add and configure the extensions that you want to use in your application. In addition, **code.quarkus.redhat.com** automatically manages the configuration parameters required to compile your project into a native executable.

This section walks you through the process of generating an OptaPlanner Maven project and includes the following topics:

- Specifying basic details about your application.
- Choosing the extensions that you want to include in your project.
- Generating a downloadable archive with your project files.
- Using the custom commands for compiling and starting your application.

Prerequisites

- You have a web browser.

Procedure

1. Open **https://code.quarkus.redhat.com** in your web browser:
2. Specify details about your project:
3. Enter a group name for your project. The format of the name follows the Java package naming convention, for example, **com.example**.
4. Enter a name that you want to use for Maven artifacts generated from your project, for example **code-with-quarkus**.
5. Select **Build Tool** > **Maven** to specify that you want to create a Maven project. The build tool that you choose determines the items:
   - The directory structure of your generated project
   - The format of configuration files used in your generated project

- The custom build script and command for compiling and starting your application that **code.quarkus.redhat.com** displays for you after you generate your project

  > **NOTE**
  >
  > Red Hat provides support for using **code.quarkus.redhat.com** to create OptaPlanner Maven projects only. Generating Gradle projects is not supported by Red Hat.

6. Enter a version to be used in artifacts generated from your project. The default value of this field is **1.0.0-SNAPSHOT**. Using semantic versioning is recommended, but you can use a different type of versioning if you prefer.
7. Enter the package name of artifacts that the build tool generates when you package your project.
   According to the Java package naming conventions the package name should match the group name that you use for your project, but you can specify a different name.

   > **NOTE**
   >
   > The **code.quarkus.redhat.com** website automatically uses the latest release of OptaPlanner. You can manually change the BOM version in the **pom.xml** file after you generate your project.

8. Select the following extensions to include as dependencies:
   - RESTEasy JAX-RS (quarkus-resteasy)
   - RESTEasy Jackson (quarkus-resteasy-jackson)
   - OptaPlanner AI constraint solver(optaplanner-quarkus)
   - OptaPlanner Jackson (optaplanner-quarkus-jackson)
     Red Hat provides different levels of support for individual extensions on the list, which are indicated by labels next to the name of each extension:
     - *SUPPORTED* extensions are fully supported by Red Hat for use in enterprise applications in production environments.
     - *TECH-PREVIEW* extensions are subject to limited support by Red Hat in production environments under the Technology Preview Features Support Scope .
     - *DEV-SUPPORT* extensions are not supported by Red Hat for use in production environments, but the core functionalities that they provide are supported by Red Hat developers for use in developing new applications.
     - *DEPRECATED* extension are planned to be replaced with a newer technology or implementation that provides the same functionality.
       Unlabeled extensions are not supported by Red Hat for use in production environments.
9. Select *Generate your application* to confirm your choices and display the overlay screen with the download link for the archive that contains your generated project. The overlay screen also shows the custom command that you can use to compile and start your application.
10. Select **Download the ZIP** to save the archive with the generated project files to your system.

11. Extract the contents of the archive.

12. Navigate to the directory that contains your extracted project files:

    ```
    cd <directory_name>
    ```

13. Compile and start your application in development mode:

    ```
    ./mvnw compile quarkus:dev
    ```

PART III. GETTING STARTED WITH KOGITO MICROSERVICES IN RED HAT DECISION MANAGER

As a business rules developer, you can use Kogito business automation to build cloud-native applications that adapt to your business domain and tooling.

Prerequisites

- JDK 11 or later is installed.
- Apache Maven 3.6.2 or later is installed.

CHAPTER 14. KOGITO MICROSERVICES IN RED HAT DECISION MANAGER

Kogito is a cloud-native business automation technology for building cloud-ready business applications. The name *Kogito* derives from the Latin "Cogito", as in "Cogito, ergo sum" ("I think, therefore I am"), and is pronounced **['koː.d͡ʒi.to]** (*KO-jee-to*). The letter *K* refers to Kubernetes, the base for Red Hat OpenShift Container Platform as the target cloud platform for Red Hat Decision Manager, and to the Knowledge Is Everything (KIE) open source business automation project from which Kogito originates.

Kogito in Red Hat Decision Manager is optimized for a hybrid cloud environment and adapts to your domain and tooling needs. The core objective of Kogito microservices is to help you mold a set of decisions into your own domain-specific cloud-native set of services.

IMPORTANT

In Red Hat Decision Manager 7.11 version, Kogito support is limited to decision services, including Decision Model and Notation (DMN), Drools Rule Language (DRL), and Predictive Model Markup Language (PMML). This support will be improved and extended to Business Process Modeling Notation (BPMN) in a future release.

When you use Kogito, you are building a cloud-native application as a set of independent domain-specific microservices to achieve some business value. The decisions that you use to describe the target behavior are executed as part of the microservices that you create. The resulting microservices are highly distributed and scalable with no centralized orchestration service, and the runtime that your microservice uses is optimized for what is required.

As a business rules developer, you can use Kogito microservices in Red Hat Decision Manager to build cloud-native applications that adapt to your business domain and tooling.

14.1. CLOUD-FIRST PRIORITY

Kogito microservices are designed to run and scale on a cloud infrastructure. You can use Kogito microservices in Red Hat Decision Manager with the latest cloud-based technologies, such as Quarkus, to increase start times and instant scaling on container application platforms, such as Red Hat OpenShift Container Platform.

For example, Kogito microservices are compatible with the following technologies:

- **Red Hat OpenShift Container Platform** is based on Kubernetes, and is the target platform for building and managing containerized applications.
- **Quarkus** is a native Java stack for Kubernetes that you can use to build applications, using the Kogito microservices.
- **Spring Boot** is an application framework that you can use to configure Spring Framework with Red Hat Decision Manager.

14.2. KOGITO MICROSERVICES ON QUARKUS AND SPRING BOOT

The primary Java frameworks that Kogito microservices support are Quarkus and Spring Boot.

Quarkus is a Kubernetes-native Java framework with a container-first approach to building Java applications, especially for Java virtual machines (JVMs) such as OpenJDK HotSpot. Quarkus optimizes Java specifically for Kubernetes by reducing the size of both the Java application and container image footprint, eliminating some of the Java programming workload from previous generations, and reducing the amount of memory required to run those images.

For Kogito microservices, Quarkus is the preferred framework for optimal Kubernetes compatibility and enhanced developer features, such as live reload in development mode for advanced debugging.

Spring Boot is a Java-based framework for building standalone production-ready Spring applications. Spring Boot enables you to develop Spring applications with minimal configurations and without an entire Spring configuration setup.

For Kogito microservices, Spring Boot is supported for developers who need to use Red Hat Decision Manager in an existing Spring Framework environment.

CHAPTER 15. DMN MODELERS FOR KOGITO MICROSERVICES

Red Hat Decision Manager provides extensions or applications that you can use to design Decision Model and Notation (DMN) decision models for your Kogito microservices using graphical modelers.

The following DMN modelers are available in the Business Modeler Hub desktop application:

- **VSCode extension**: Enables you to view and design DMN models in Visual Studio Code (VSCode). The VSCode extension requires VSCode 1.46.0 or later.
  To install the VSCode extension directly in VSCode, select the **Extensions** menu option in VSCode and search for and install the **Red Hat Business Automation Bundle**extension.

- **Business Modeler standalone editors** Enable you to view and design DMN models embedded in your web applications. To download the necessary files, you can either use the NPM artifacts from the Kogito tooling repository or download the JavaScript files directly for the DMN standalone editor library at **https://kiegroup.github.io/kogito-online/standalone/dmn/index.js**.

15.1. INSTALLING THE RED HAT DECISION MANAGER VSCODE EXTENSION BUNDLE

Red Hat Decision Manager provides a **Red Hat Business Automation Bundle**VSCode extension that enables you to design Decision Model and Notation (DMN) decision models, Business Process Model and Notation (BPMN) 2.0 business processes, and test scenarios directly in VSCode. VSCode is the preferred integrated development environment (IDE) for developing new business applications. Red Hat Decision Manager also provides individual **DMN Editor** and **BPMN Editor** VSCode extensions for DMN or BPMN support only, if needed.

IMPORTANT

The editors in the VSCode are partially compatible with the editors in the Business Central, and several Business Central features are not supported in the VSCode.

Prerequisites

- The latest stable version of VSCode is installed.

Procedure

1. In your VSCode IDE, select the **Extensions** menu option and search for **Red Hat Business Automation Bundle** for DMN, BPMN, and test scenario file support.
   For DMN or BPMN file support only, you can also search for the individual **DMN Editor** or **BPMN Editor** extensions.

2. When the **Red Hat Business Automation Bundle**extension appears in VSCode, select it and click **Install**.

3. For optimal VSCode editor behavior, after the extension installation is complete, reload or close and re-launch your instance of VSCode.

After you install the VSCode extension bundle, any **.dmn**, **.bpmn**, or **.bpmn2** files that you open or create in VSCode are automatically displayed as graphical models. Additionally, any **.scesim** files that you open or create are automatically displayed as tabular test scenario models for testing the functionality of your business decisions.

If the DMN, BPMN, or test scenario modelers open only the XML source of a DMN, BPMN, or test scenario file and displays an error message, review the reported errors and the model file to ensure that all elements are correctly defined.

NOTE

For new DMN or BPMN models, you can also enter **dmn.new** or **bpmn.new** in a web browser to design your DMN or BPMN model in the online modeler. When you finish creating your model, you can click **Download** in the online modeler page to import your DMN or BPMN file into your Red Hat Decision Manager project in VSCode.

15.2. CONFIGURING THE RED HAT DECISION MANAGER STANDALONE EDITORS

Red Hat Decision Manager provides standalone editors that are distributed in a self-contained library providing an all-in-one JavaScript file for each editor. The JavaScript file uses a comprehensive API to set and control the editor.

You can install the standalone editors in three ways:

- Download each JavaScript file manually
- Use the NPM package

Procedure

1. Install the standalone editors using one of the following methods:
   Download each JavaScript file manually: For this method, follow these steps:

   a. Download the JavaScript files.

   b. Add the downloaded Javascript files to your hosted application.

   c. Add the following **<script>** tag to your HTML page:

   Script tag for your HTML page for the DMN editor

   ```
   <script src="https://<YOUR_PAGE>/dmn/index.js"></script>
   ```

   Script tag for your HTML page for the BPMN editor

   ```
   <script src="https://<YOUR_PAGE>/bpmn/index.js"></script>
   ```

   Use the NPM package: For this method, follow these steps:

   a. Add the NPM package to your **package.json** file:

   Adding the NPM package

   ```
   npm install @redhat/kogito-tooling-kie-editors-standalone
   ```

   b. Import each editor library to your TypeScript file:

Importing each editor

```
import * as DmnEditor from "@redhat/kogito-tooling-kie-editors-standalone/dist/dmn"
import * as BpmnEditor from "@redhat/kogito-tooling-kie-editors-standalone/dist/bpmn"
```

2. After you install the standalone editors, open the required editor by using the provided editor API, as shown in the following example for opening a DMN editor. The API is the same for each editor.

Opening the DMN standalone editor

```
const editor = DmnEditor.open({
  container: document.getElementById("dmn-editor-container"),
  initialContent: Promise.resolve(""),
  readOnly: false,
  origin: "",
  resources: new Map([
    [
      "MyIncludedModel.dmn",
      {
        contentType: "text",
        content: Promise.resolve("")
      }
    ]
  ])
});
```

Use the following parameters with the editor API:

Table 15.1. Example parameters

Parameter	Description
container	HTML element in which the editor is appended.
initialContent	Promise to a DMN model content. This parameter can be empty, as shown in the following examples: • **Promise.resolve("")** • **Promise.resolve("<DIAGRAM_CONTENT_DIRECTLY_HERE>")** • **fetch("MyDmnModel.dmn").then(content ⇒ content.text())**
readOnly (Optional)	Enables you to allow changes in the editor. Set to **false** (default) to allow content editing and **true** for read-only mode in editor.
origin (Optional)	Origin of the repository. The default value is **window.location.origin**.

Parameter	Description
resources (Optional)	Map of resources for the editor. For example, this parameter is used to provide included models for the DMN editor or work item definitions for the BPMN editor. Each entry in the map contains a resource name and an object that consists of **content-type** (**text** or **binary**) and **content** (similar to the **initialContent** parameter).

The returned object contains the methods that are required to manipulate the editor.

Table 15.2. Returned object methods

Method	Description
getContent(): Promise<string>	Returns a promise containing the editor content.
setContent(content: string): void	Sets the content of the editor.
getPreview(): Promise<string>	Returns a promise containing an SVG string of the current diagram.
subscribeToContentChanges(callback: (isDirty: boolean) ⇒ void): (isDirty: boolean) ⇒ void	Sets a callback to be called when the content changes in the editor and returns the same callback to be used for unsubscription.
unsubscribeToContentChanges(callback: (isDirty: boolean) ⇒ void): void	Unsubscribes the passed callback when the content changes in the editor.
markAsSaved(): void	Resets the editor state that indicates that the content in the editor is saved. Also, it activates the subscribed callbacks related to content change.
undo(): void	Undoes the last change in the editor. Also, it activates the subscribed callbacks related to content change.
redo(): void	Redoes the last undone change in the editor. Also, it activates the subscribed callbacks related to content change.
close(): void	Closes the editor.

Method	Description
getElementPosition(selector: string): Promise<Rect>	Provides an alternative to extend the standard query selector when an element lives inside a canvas or a video component. The **selector** parameter must follow the **<PROVIDER>:::<SELECT>** format, such as **Canvas:::MySquare** or **Video:::PresenterHand**. This method returns a **Rect** representing the element position.
envelopeApi: MessageBusClientApi<KogitoEditorEnvelopeApi>	This is an advanced editor API. For more information about advanced editor API, see MessageBusClientApi and KogitoEditorEnvelopeApi.

CHAPTER 16. CREATING A MAVEN PROJECT FOR A KOGITO MICROSERVICE

Before you can begin developing Kogito microservices, you need to create a Maven project where you can build your assets and any other related resources for your application.

Procedure

1. In a command terminal, navigate to a local folder where you want to store the new project.
2. Enter the following command to generate a project within a defined folder:

On Quarkus

```
$ mvn archetype:generate \
    -DarchetypeGroupId=org.kie.kogito \
    -DarchetypeArtifactId=kogito-quarkus-dm-archetype \
    -DgroupId=org.acme -DartifactId=sample-kogito \
    -DarchetypeVersion=1.5.0.redhat-00002 \
    -Dversion=1.0-SNAPSHOT
```

On Spring Boot

```
$ mvn archetype:generate \
    -DarchetypeGroupId=org.kie.kogito \
    -DarchetypeArtifactId=kogito-springboot-dm-archetype \
    -DgroupId=org.acme -DartifactId=sample-kogito \
    -DarchetypeVersion=1.5.0.redhat-00002 \
    -Dversion=1.0-SNAPSHOT
```

This command generates a **sample-kogito** Maven project and imports the extension for all required dependencies and configurations to prepare your application for business automation.

If you want to enable PMML execution for your project, add the following dependency to the **pom.xml** file in the Maven project that contains your Kogito microservices:

Dependency to enable PMML execution

```
<dependency>
  <groupId>org.kie.kogito</groupId>
  <artifactId>kogito-pmml</artifactId>
</dependency>
<dependency>
  <groupId>org.jpmml</groupId>
  <artifactId>pmml-model</artifactId>
</dependency>
```

On Quarkus, if you plan to run your application on OpenShift, you must also import the Quarkus **smallrye-health** extension for the liveness and readiness probes, as shown in the following example:

SmallRye Health extension for Quarkus applications on OpenShift

```
$ mvn quarkus:add-extension -Dextensions="smallrye-health"
```

This command generates the following dependency in the **pom.xml** file of your Red Hat Decision Manager project on Quarkus:

SmallRye Heath dependency for Quarkus applications on OpenShift

```
<dependency>
  <groupId>io.quarkus</groupId>
  <artifactId>quarkus-smallrye-health</artifactId>
</dependency>
```

3. Open or import the project in your VSCode IDE to view the contents.

CHAPTER 17. EXAMPLE APPLICATIONS WITH KOGITO MICROSERVICES

Kogito microservices include example applications in the **rhdm-7.11.0-decision-services-quickstarts.zip** file. These example applications contain various types of services on Quarkus or Spring Boot to help you develop your own applications. The services use one or more Decision Model and Notation (DMN) decision models, Drools Rule Language (DRL) rule units, Predictive Model Markup Language (PMML) models, or Java classes to define the service logic.

For information about each example application and instructions for using them, see the **README** file in the relevant application folder.

The following list describes some of the examples provided with Kogito microservices:

Decision services

- **dmn-quarkus-example** and **dmn-springboot-example**: A decision service (on Quarkus or Spring Boot) that uses DMN to determine driver penalty and suspension based on traffic violations.
- **rules-quarkus-helloworld**: A Hello World decision service on Quarkus with a single DRL rule unit.
- **ruleunit-quarkus-example** and **ruleunit-springboot-example**: A decision service (on Quarkus or Spring Boot) that uses DRL with rule units to validate a loan application and that exposes REST operations to view application status.
- **dmn-pmml-quarkus-example** and **dmn-pmml-springboot-example**: A decision service (on Quarkus or Spring Boot) that uses DMN and PMML to determine driver penalty and suspension based on traffic violations.
- **dmn-drools-quarkus-metrics** and **dmn-drools-springboot-metrics**: A decision service (on Quarkus or Spring Boot) that enables and consumes the runtime metrics monitoring feature in Kogito.
- **pmml-quarkus-example** and **pmml-springboot-example**: A decision service (on Quarkus or Spring Boot) that uses PMML.

For more information about using DMN, DRL, and PMML models in Red Hat Decision Manager, see *Designing a decision service using DMN models* , *Designing a decision service using DRL rules* , and *Designing a decision service using PMML models* .

CHAPTER 18. DESIGNING THE APPLICATION LOGIC FOR A KOGITO MICROSERVICE USING DMN

After you create your project, you can create or import Decision Model and Notation (DMN) decision models and Drools Rule Language (DRL) business rules in the **src/main/resources** folder of your project. You can also include Java classes in the **src/main/java** folder of your project that act as Java services or provide implementations that you call from your decisions.

The example for this procedure is a basic Kogito microservice that provides a REST endpoint **/persons**. This endpoint is automatically generated based on an example **PersonDecisions.dmn** DMN model to make decisions based on the data being processed.

The business decision contains the decision logic of the Red Hat Decision Manager service. You can define business rules and decisions in different ways, such as with DMN models or DRL rules. The example for this procedure uses a DMN model.

Prerequisites

- You have created a project. For more information about creating a Maven project, see Chapter 16, *Creating a Maven project for a Kogito microservice* .

Procedure

1. In the Maven project that you generated for your Red Hat Decision Manager service, navigate to the **src/main/java/org/acme** folder and add the following **Person.java** file:

   ### Example person Java object

```
package org.acme;

import java.io.Serializable;

public class Person {

 private String name;
 private int age;
 private boolean adult;

 public String getName() {
  return name;
 }

 public void setName(String name) {
  this.name = name;
 }

 public int getAge() {
  return age;
 }

 public void setAge(int age) {
  this.age = age;
 }

 public boolean isAdult() {
    return adult;
  }

  public void setAdult(boolean adult) {
    this.adult = adult;
  }

  @Override
  public String toString() {
    return "Person [name=" + name + ", age=" + age + ", adult=" + adult + "]";
  }

}
```

This example Java object sets and retrieves a person's name, age, and adult status.

2. Navigate to the **src/main/resources** folder and add the following **PersonDecisions.dmn** DMN decision model:

Figure 18.1. Example **PersonDecisions** DMN decision requirements diagram (DRD)

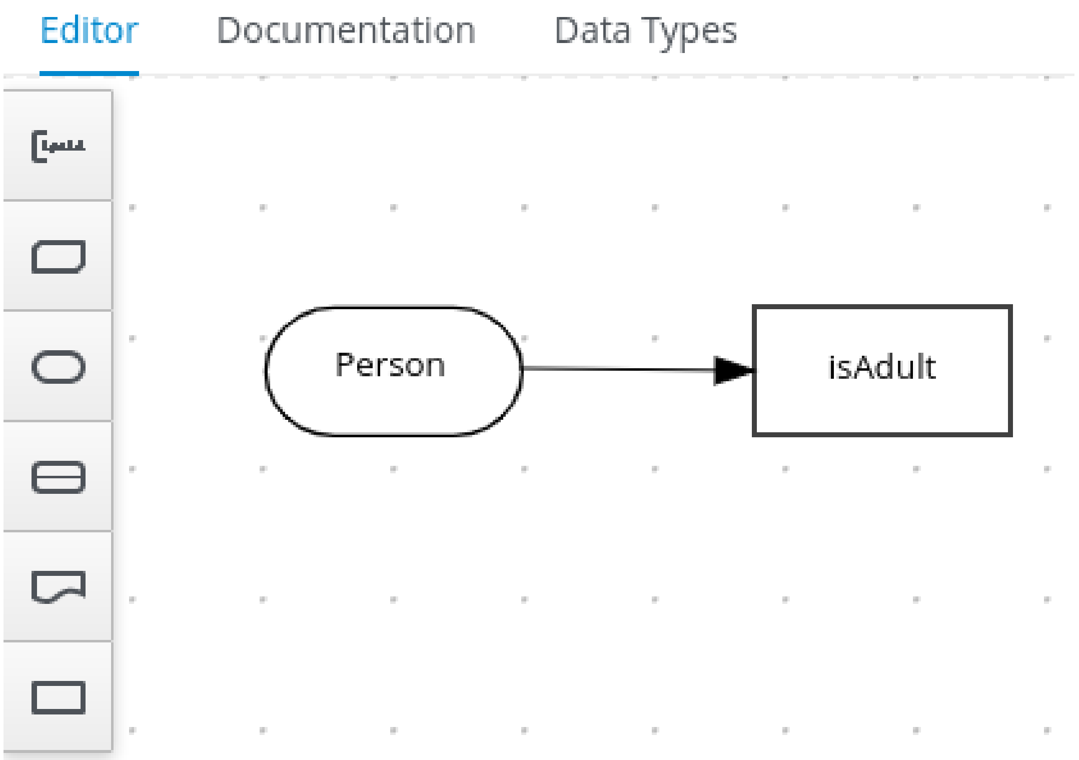
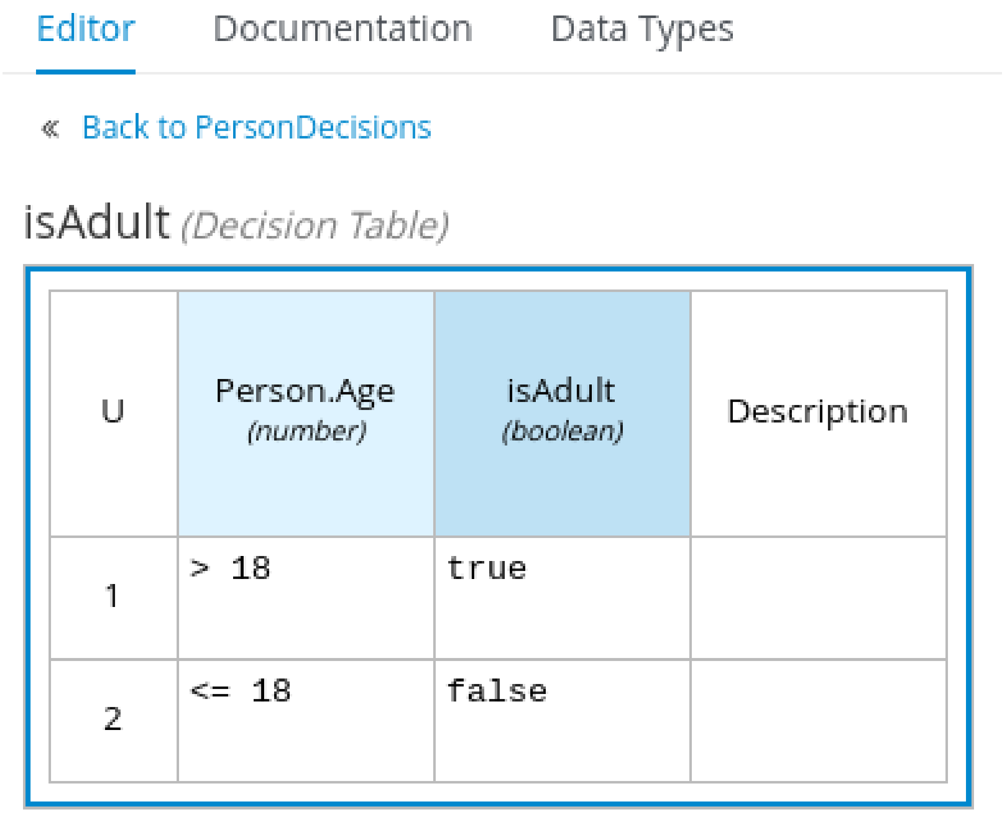


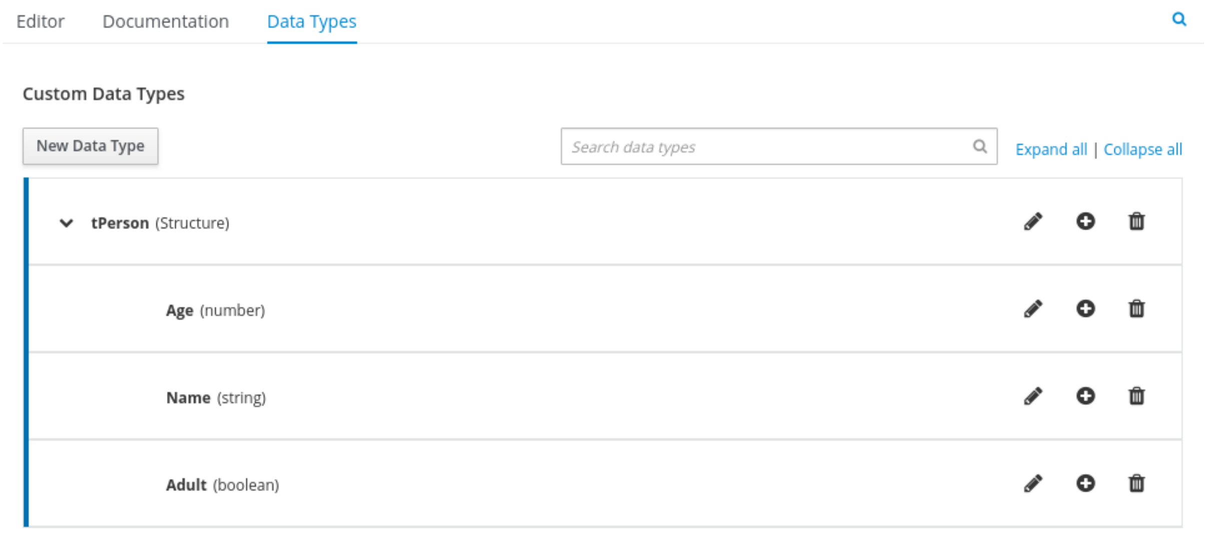
Figure 18.2. Example DMN boxed expression for**isAdult** decision



isAdult *(Decision Table)*

U	Person.Age *(number)*	isAdult *(boolean)*	Description
1	`> 18`	`true`	
2	`<= 18`	`false`	

Figure 18.3. Example DMN data types



Custom Data Types

- **tPerson** (Structure)
  - **Age** (number)
  - **Name** (string)
  - **Adult** (boolean)

This example DMN model consists of a basic DMN input node and a decision node defined by a DMN decision table with a custom structured data type.

In VSCode, you can add the **Red Hat Business Automation Bundle**VSCode extension to design the decision requirements diagram (DRD), boxed expression, and data types with the DMN modeler.

To create this example DMN model quickly, you can copy the following **PersonDecisions.dmn** file content:

Example DMN file

```
<dmn:definitions xmlns:dmn="http://www.omg.org/spec/DMN/20180521/MODEL/"
xmlns="https://kiegroup.org/dmn/_52CEF9FD-9943-4A89-96D5-6F66810CA4C1"
xmlns:di="http://www.omg.org/spec/DMN/20180521/DI/"
xmlns:kie="http://www.drools.org/kie/dmn/1.2"
xmlns:dmndi="http://www.omg.org/spec/DMN/20180521/DMNDI/"
xmlns:dc="http://www.omg.org/spec/DMN/20180521/DC/"
xmlns:feel="http://www.omg.org/spec/DMN/20180521/FEEL/" id="_84B432F5-87E7-43B1-
9101-1BAFE3D18FC5" name="PersonDecisions"
typeLanguage="http://www.omg.org/spec/DMN/20180521/FEEL/"
namespace="https://kiegroup.org/dmn/_52CEF9FD-9943-4A89-96D5-6F66810CA4C1">
  <dmn:extensionElements/>
  <dmn:itemDefinition id="_DEF2C3A7-F3A9-4ABA-8D0A-C823E4EB43AB" name="tPerson"
isCollection="false">
    <dmn:itemComponent id="_DB46DB27-0752-433F-ABE3-FC9E3BDECC97" name="Age"
isCollection="false">
      <dmn:typeRef>number</dmn:typeRef>
    </dmn:itemComponent>
    <dmn:itemComponent id="_8C6D865F-E9C8-43B0-AB4D-3F2075A4ECA6" name="Name"
isCollection="false">
      <dmn:typeRef>string</dmn:typeRef>
    </dmn:itemComponent>
    <dmn:itemComponent id="_9033704B-4E1C-42D3-AC5E-0D94107303A1" name="Adult"
isCollection="false">
      <dmn:typeRef>boolean</dmn:typeRef>
    </dmn:itemComponent>
  </dmn:itemDefinition>
  <dmn:inputData id="_F9685B74-0C69-4982-B3B6-B04A14D79EDB" name="Person">
    <dmn:extensionElements/>
    <dmn:variable id="_0E345A3C-BB1F-4FB2-B00F-C5691FD1D36C" name="Person"
typeRef="tPerson"/>
  </dmn:inputData>
  <dmn:decision id="_0D2BD7A9-ACA1-49BE-97AD-19699E0C9852" name="isAdult">
    <dmn:extensionElements/>
    <dmn:variable id="_54CD509F-452F-40E5-941C-AFB2667D4D45" name="isAdult"
typeRef="boolean"/>
    <dmn:informationRequirement id="_2F819B03-36B7-4DEB-AED6-2B46AE3ADB75">
      <dmn:requiredInput href="#_F9685B74-0C69-4982-B3B6-B04A14D79EDB"/>
    </dmn:informationRequirement>
    <dmn:decisionTable id="_58370567-05DE-4EC0-AC2D-A23803C1EAAE"
hitPolicy="UNIQUE" preferredOrientation="Rule-as-Row">
      <dmn:input id="_ADEF36CD-286A-454A-ABD8-9CF96014021B">
        <dmn:inputExpression id="_4930C2E5-7401-46DD-8329-EAC523BFA492"
typeRef="number">
          <dmn:text>Person.Age</dmn:text>
        </dmn:inputExpression>
      </dmn:input>
      <dmn:output id="_9867E9A3-CBF6-4D66-9804-D2206F6B4F86" typeRef="boolean"/>
      <dmn:rule id="_59D6BFF0-35B4-4B7E-8D7B-E31CB0DB8242">
        <dmn:inputEntry id="_7DC55D63-234F-497B-A12A-93DA358C0136">
          <dmn:text>&gt; 18</dmn:text>
        </dmn:inputEntry>
        <dmn:outputEntry id="_B3BB5B97-05B9-464A-AB39-58A33A9C7C00">
          <dmn:text>true</dmn:text>
        </dmn:outputEntry>
      </dmn:rule>
      <dmn:rule id="_8FCD63FE-8AD8-4F56-AD12-923E87AFD1B1">
```

```
        <dmn:inputEntry id="_B4EF7F13-E486-46CB-B14E-1D21647258D9">
          <dmn:text>&lt;= 18</dmn:text>
        </dmn:inputEntry>
        <dmn:outputEntry id="_F3A9EC8E-A96B-42A0-BF87-9FB1F2FDB15A">
          <dmn:text>false</dmn:text>
        </dmn:outputEntry>
      </dmn:rule>
    </dmn:decisionTable>
  </dmn:decision>
  <dmndi:DMNDI>
    <dmndi:DMNDiagram>
      <di:extension>
        <kie:ComponentsWidthsExtension>
          <kie:ComponentWidths dmnElementRef="_58370567-05DE-4EC0-AC2D-
A23803C1EAAE">
            <kie:width>50</kie:width>
            <kie:width>100</kie:width>
            <kie:width>100</kie:width>
            <kie:width>100</kie:width>
          </kie:ComponentWidths>
        </kie:ComponentsWidthsExtension>
      </di:extension>
      <dmndi:DMNShape id="dmnshape-_F9685B74-0C69-4982-B3B6-B04A14D79EDB"
dmnElementRef="_F9685B74-0C69-4982-B3B6-B04A14D79EDB" isCollapsed="false">
        <dmndi:DMNStyle>
          <dmndi:FillColor red="255" green="255" blue="255"/>
          <dmndi:StrokeColor red="0" green="0" blue="0"/>
          <dmndi:FontColor red="0" green="0" blue="0"/>
        </dmndi:DMNStyle>
        <dc:Bounds x="404" y="464" width="100" height="50"/>
        <dmndi:DMNLabel/>
      </dmndi:DMNShape>
      <dmndi:DMNShape id="dmnshape-_0D2BD7A9-ACA1-49BE-97AD-19699E0C9852"
dmnElementRef="_0D2BD7A9-ACA1-49BE-97AD-19699E0C9852" isCollapsed="false">
        <dmndi:DMNStyle>
          <dmndi:FillColor red="255" green="255" blue="255"/>
          <dmndi:StrokeColor red="0" green="0" blue="0"/>
          <dmndi:FontColor red="0" green="0" blue="0"/>
        </dmndi:DMNStyle>
        <dc:Bounds x="404" y="311" width="100" height="50"/>
        <dmndi:DMNLabel/>
      </dmndi:DMNShape>
      <dmndi:DMNEdge id="dmnedge-_2F819B03-36B7-4DEB-AED6-2B46AE3ADB75"
dmnElementRef="_2F819B03-36B7-4DEB-AED6-2B46AE3ADB75">
        <di:waypoint x="504" y="489"/>
        <di:waypoint x="404" y="336"/>
      </dmndi:DMNEdge>
    </dmndi:DMNDiagram>
  </dmndi:DMNDI>
</dmn:definitions>
```

To create this example DMN model in VSCode using the DMN modeler, follow these steps:

a. Open the empty **PersonDecisions.dmn** file, click the **Properties** icon in the upper-right corner of the DMN modeler, and confirm that the DMN model **Name** is set to **PersonDecisions**.

b. In the left palette, select **DMN Input Data**, drag the node to the canvas, and double-click the node to name it **Person**.

c. In the left palette, drag the **DMN Decision** node to the canvas, double-click the node to name it **isAdult**, and link to it from the input node.

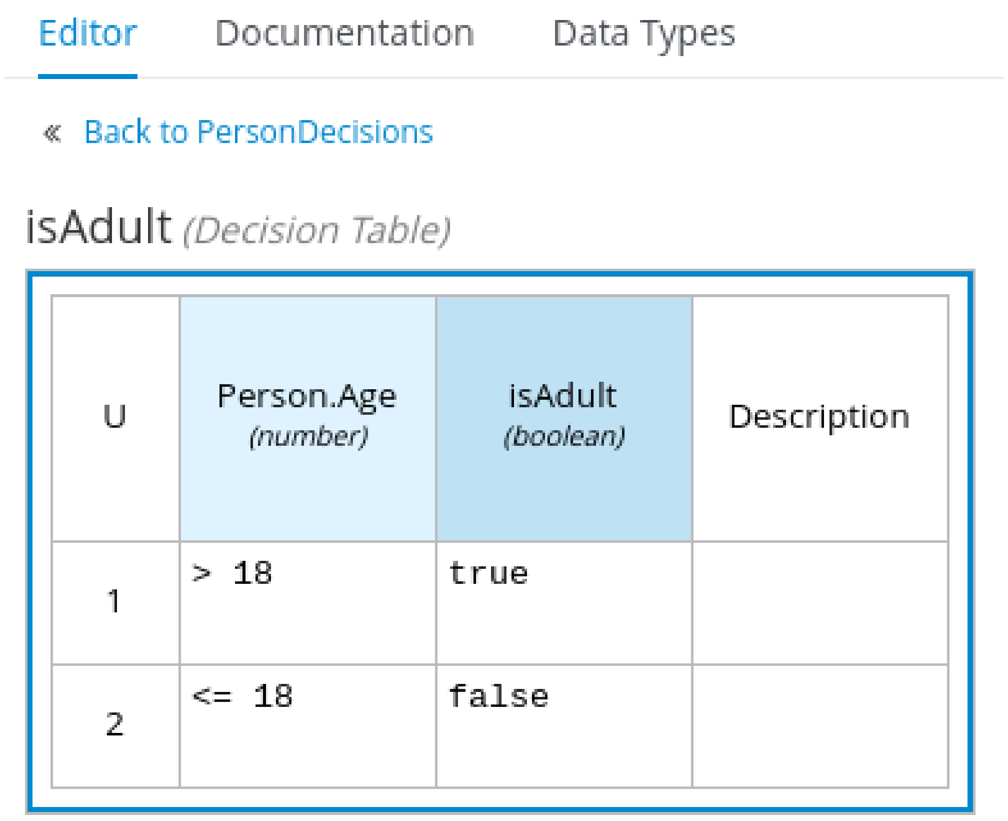
d. Select the decision node to display the node options and click the **Edit** icon to open the DMN boxed expression editor to define the decision logic for the node.

e. Click the *undefined expression* field and select **Decision Table**.

f. Click the upper-left corner of the decision table to set the hit policy to **Unique**.

g. Set the input and output columns so that the input source **Person.Age** with type **number** determines the age limit and the output target **isAdult** with type **boolean** determines adult status:

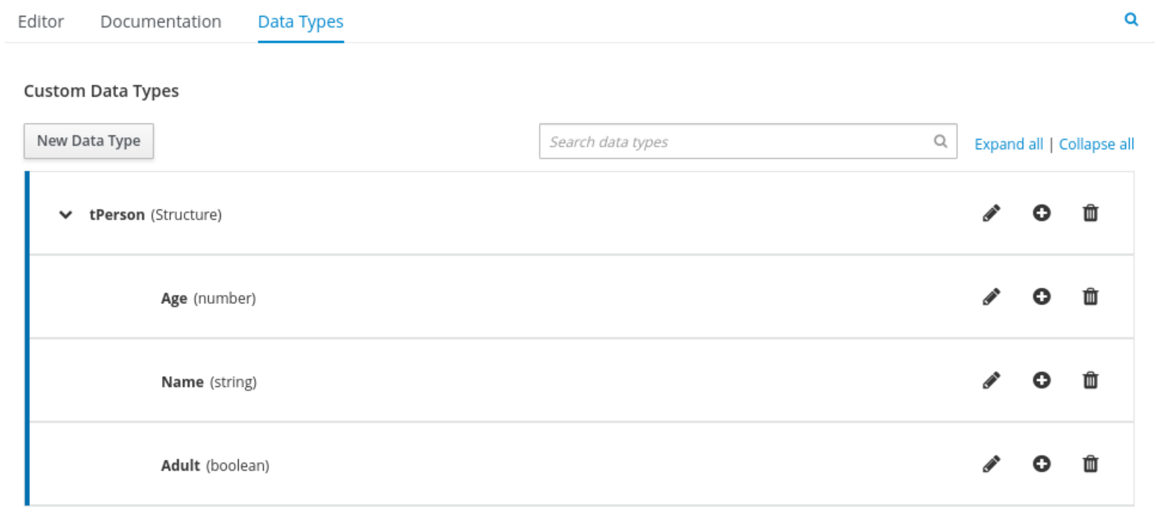
Figure 18.4. Example DMN decision table forisAdult decision



U	Person.Age *(number)*	isAdult *(boolean)*	Description
1	> 18	true	
2	<= 18	false	

h. In the upper tab options, select the **Data Types** tab and add the following **tPerson** structured data type and nested data types:

Figure 18.5. Example DMN data types



tPerson (Structure)
Age (number)
Name (string)
Adult (boolean)

i. After you define the data types, select the **Editor** tab to return to the DMN modeler canvas.

j. Select the **Person** input node, click the **Properties** icon, and under **Information item**, set the **Data type** to **tPerson**.

k. Select the **isAdult** decision node, click the **Properties** icon, and under **Information item**, confirm that the **Data type** is still set to **boolean**. You previously set this data type when you created the decision table.

l. Save the DMN decision file.

18.1. USING DRL RULE UNITS AS AN ALTERNATIVE DECISION SERVICE

You can also use a Drools Rule Language (DRL) file implemented as a rule unit to define this example decision service, as an alternative to using Decision Model and Notation (DMN).

A DRL rule unit is a module for rules and a unit of execution. A rule unit collects a set of rules with the declaration of the type of facts that the rules act on. A rule unit also serves as a unique namespace for each group of rules. A single rule base can contain multiple rule units. You typically store all the rules for a unit in the same file as the unit declaration so that the unit is self-contained. For more information about rule units, see *Designing a decision service using DRL rules* .

Prerequisites

- You have created a project. For more information about creating a Maven project, see Chapter 16, *Creating a Maven project for a Kogito microservice* .

Procedure

1. In the **src/main/resources** folder of your example project, instead of using a DMN file, add the following **PersonRules.drl** file:

Example PersonRules DRL file

```
package org.acme
unit PersonRules;

import org.acme.Person;
```

```
rule isAdult
 when
  $person: /person[ age > 18 ]
 then
    modify($person) {
     setAdult(true)
    };
 end

 query persons
  $p : /person[ adult ]
  end
```

This example rule determines that any person who is older than 18 is classified as an adult. The rule file also declares that the rule belongs to the rule unit **PersonRules**. When you build the project, the rule unit is generated and associated with the DRL file.

The rule also defines the condition using OOPath notation. OOPath is an object-oriented syntax extension to XPath for navigating through related elements while handling collections and filtering constraints.

You can also rewrite the same rule condition in a more explicit form using the traditional rule pattern syntax, as shown in the following example:

Example **PersonRules** DRL file using traditional notation

```
package org.acme
unit PersonRules;

import org.acme.Person;

rule isAdult
 when
  $person: Person(age > 18) from person
 then
    modify($person) {
     setAdult(true)
    };
 end

 query persons
  $p : /person[ adult ]
  end
```

CHAPTER 19. RUNNING A KOGITO MICROSERVICE

After you design the business decisions for your Kogito microservice, you can run your Quarkus or Spring Boot application in one of the following modes:

- **Development mode**: For local testing. On Quarkus, development mode also offers live reload of your decisions in your running applications for advanced debugging.
- **JVM mode**: For compatibility with a Java virtual machine (JVM).

Procedure

In a command terminal, navigate to the project that contains your Kogito microservice and enter one of the following commands, depending on your preferred run mode and application environment:

- For development mode:

  On Quarkus

  ```
  $ mvn clean compile quarkus:dev
  ```

  On Sprint Boot

  ```
  $ mvn clean compile spring-boot:run
  ```

- For JVM mode:

  On Quarkus and Spring Boot

  ```
  $ mvn clean package
  $ java -jar target/sample-kogito-1.0-SNAPSHOT-runner.jar
  ```

CHAPTER 20. INTERACTING WITH A RUNNING KOGITO MICROSERVICE

After your Kogito microservice is running, you can send REST API requests to interact with your application and execute your microservices according to how you set up the application.

This example tests the **/persons** REST API endpoint that is automatically generated the decisions in the **PersonDecisions.dmn** file (or the rules in the **PersonRules.drl** file if you used a DRL rule unit).

For this example, use a REST client, curl utility, or the Swagger UI configured for the application (such as **http://localhost:8080/q/swagger-ui** or **http://localhost:8080/swagger-ui.html**) to send API requests with the following components:

- URL: **http://localhost:8080/persons**
- **HTTP headers**: For **POST** requests only:
  - **accept**: **application/json**
  - **content-type**: **application/json**
- **HTTP methods**: **GET**, **POST**, or **DELETE**

Example POST request body to add an adult (JSON)

```
{
  "person": {
    "name": "John Quark",
    "age": 20
  }
}
```

Example curl command to add an adult

```
curl -X POST http://localhost:8080/persons -H 'content-type: application/json' -H 'accept:
application/json' -d '{"person": {"name":"John Quark", "age": 20}}'
```

Example response (JSON)

```
{
  "id": "3af806dd-8819-4734-a934-728f4c819682",
  "person": {
    "name": "John Quark",
    "age": 20,
    "adult": false
  },
  "isAdult": true
}
```

This example procedure uses curl commands for convenience.

Procedure

In a command terminal window that is separate from your running application, navigate to the project that contains your Kogito microservice and use any of the following curl commands with JSON requests to interact with your running microservice:

> **NOTE**
>
> On Spring Boot, you might need to modify how your application exposes API endpoints in order for these example requests to function. For more information, see the **README** file included in the example Spring Boot project that you created for this tutorial.

- Add an adult person:

  Example request

  ```
  curl -X POST http://localhost:8080/persons -H 'content-type: application/json' -H 'accept:
  application/json' -d '{"person": {"name":"John Quark", "age": 20}}'
  ```

  Example response

  ```
  {"id":"3af806dd-8819-4734-a934-728f4c819682","person":{"name":"John
  Quark","age":20,"adult":false},"isAdult":true}
  ```

- Add an underage person:

  Example request

  ```
  curl -X POST http://localhost:8080/persons -H 'content-type: application/json' -H 'accept:
  application/json' -d '{"person": {"name":"Jenny Quark", "age": 15}}'
  ```

  Example response

  ```
  {"id":"8eef502b-012b-4628-acb7-73418a089c08","person":{"name":"Jenny
  Quark","age":15,"adult":false},"isAdult":false}
  ```

- Complete the evaluation using the returned UUIDs:

  Example request

  ```
  curl -X POST http://localhost:8080/persons/8eef502b-012b-4628-acb7-
  73418a089c08/ChildrenHandling/cdec4241-d676-47de-8c55-4ee4f9598bac -H 'content-type:
  application/json' -H 'accept: application/json' -d '{}'
  ```

CHAPTER 21. DEPLOYING KOGITO MICROSERVICES ON RED HAT OPENSHIFT CONTAINER PLATFORM

As a business rules developer, you can deploy Kogito microservices on Red Hat OpenShift Container Platform for cloud implementation. The Red Hat Decision Manager Kogito Operator automates many of the deployment steps for you or guides you through the deployment process.

Prerequisites

- Red Hat OpenShift Container Platform 4.6 or 4.7 is installed.
- The OpenShift project for the deployment is created.

21.1. KOGITO ON RED HAT OPENSHIFT CONTAINER PLATFORM

You can deploy Kogito microservices on Red Hat OpenShift Container Platform for cloud implementation. In this architecture, Kogito microservices are deployed as OpenShift pods that you can scale up and down individually to provide as few or as many containers as required for a particular service.

To help you deploy your Kogito microservices on OpenShift, Red Hat Decision Manager provides **Red Hat Process Automation Manager Kogito Operator**. This operator guides you through the deployment process. The operator is based on the Operator SDK and automates many of the deployment steps for you. For example, when you provide the operator with a link to the Git repository that contains your application, the operator automatically configures the components required to build your project from source and deploys the resulting services.

To install the Red Hat Process Automation Manager Kogito Operator in OpenShift web console, go to **Operators → OperatorHub** in the left menu, search for and select **RHPAM Kogito Operator**, and follow the on-screen instructions to install the latest operator version.

21.2. OPENSHIFT DEPLOYMENT OPTIONS WITH THE RED HAT DECISION MANAGER KOGITO OPERATOR

After you create your Kogito microservices as part of a business application, you can use the Red Hat OpenShift Container Platform web console to deploy your microservices. The Red Hat Decision Manager Kogito Operator page in the OpenShift web console guides you through the deployment process.

The Red Hat Process Automation Manager Kogito Operator supports the following options for building and deploying Kogito microservices on Red Hat OpenShift Container Platform:

- Git source build and deployment
- Binary build and deployment
- Custom image build and deployment
- File build and deployment

21.2.1. Deploying Kogito microservices on OpenShift using Git source build and OpenShift web console

The Red Hat Process Automation Manager Kogito Operator uses the following custom resources to deploy domain-specific microservices (the microservices that you develop):

- **KogitoBuild** builds an application using the Git URL or other sources and produces a runtime image.
- **KogitoRuntime** starts the runtime image and configures it as per your requirements.

In most use cases, you can use the standard runtime build and deployment method to deploy Kogito microservices on OpenShift from a Git repository source, as shown in the following procedure.

NOTE

If you are developing or testing your Kogito microservice locally, you can use the binary build, custom image build, or file build option to build and deploy from a local source instead of from a Git repository.

Prerequisites

- The Red Hat Process Automation Manager Kogito Operator is installed.
- The application with your Kogito microservices is in a Git repository that is reachable from your OpenShift environment.
- You have access to the OpenShift web console with the necessary permissions to create and edit **KogitoBuild** and **KogitoRuntime**.
- (Quarkus only) The **pom.xml** file of your project contains the following dependency for the Quarkus **smallrye-health** extension. This extension enables the liveness and readiness probes that are required for Quarkus-based projects on OpenShift.

  SmallRye Health dependency for Quarkus applications on OpenShift

  ```
  <dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-smallrye-health</artifactId>
  </dependency>
  ```

Procedure

1. Go to **Operators → Installed Operators** and select **RHPAM Kogito Operator**.
2. To create the Kogito build definition, on the operator page, select the **Kogito Build** tab and click **Create KogitoBuild**.
3. In the application window, use **Form View** or **YAML View** to configure the build definition.
   At a minimum, define the application configurations shown in the following example YAML file:

   Example YAML definition for a Quarkus application with Kogito build

   ```
   apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this service
   kind: KogitoBuild  # Application type
   metadata:
     name: example-quarkus  # Application name
   spec:
   ```

```
  type: RemoteSource
  gitSource:
    uri: 'https://github.com/kiegroup/kogito-examples'  # Git repository containing application (uses default branch)
    contextDir: dmn-quarkus-example  # Git folder location of application
```

Example YAML definition for a Spring Boot application with Kogito build

```
apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this service
kind: KogitoBuild  # Application type
metadata:
  name: example-springboot  # Application name
spec:
  runtime: springboot
  type: RemoteSource
  gitSource:
    uri: 'https://github.com/kiegroup/kogito-examples'  # Git repository containing application (uses default branch)
    contextDir: dmn-springboot-example  # Git folder location of application
```

> **NOTE**
>
> If you configured an internal Maven repository, you can use it as a Maven mirror service and specify the Maven mirror URL in your Kogito build definition to shorten build time substantially:
>
> ```
> spec:
>   mavenMirrorURL: http://nexus3-nexus.apps-crc.testing/repository/maven-public/
> ```
>
> For more information about internal Maven repositories, see the Apache Maven documentation.

4. After you define your application data, click **Create** to generate the Kogito build.
   Your application is listed in the **KogitoBuilds** page. You can select the application name to view or modify application settings and YAML details.

5. To create the Kogito microservice definition, on the operator page, select the **Kogito Runtime** tab and click **Create KogitoRuntime**.

6. In the application window, use **Form View** or **YAML View** to configure the microservice definition.
   At a minimum, define the application configurations shown in the following example YAML file:

Example YAML definition for a Quarkus application with Kogito microservices

```
apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this microservice
kind: KogitoRuntime  # Application type
metadata:
  name: example-quarkus  # Application name
```

Example YAML definition for a Spring Boot application with Kogito microservices

```
apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this microservice
kind: KogitoRuntime  # Application type
metadata:
  name: example-springboot  # Application name
spec:
  runtime: springboot
```

> **NOTE**
>
> In this case, the application is built from Git and deployed using KogitoRuntime. You must ensure that the application name is same in **KogitoBuild** and **KogitoRuntime**.

7. After you define your application data, click **Create** to generate the Kogito microservice.
   Your application is listed in the Kogito microservice page. You can select the application name to view or modify application settings and the contents of the YAML file.

8. In the left menu of the web console, go to **Builds → Builds** to view the status of your application build.
   You can select a specific build to view build details.

> **NOTE**
>
> For every Kogito microservice that you create for OpenShift deployment, two builds are generated and listed in the **Builds** page in the web console: a traditional runtime build and a Source-to-Image (S2I) build with the suffix **-builder**. The S2I mechanism builds the application in an OpenShift build and then passes the built application to the next OpenShift build to be packaged into the runtime container image. The Kogito S2I build configuration also enables you to build the project directly from a Git repository on the OpenShift platform.

9. After the application build is complete, go to **Workloads → Deployments** to view the application deployments, pod status, and other details.

10. After your Kogito microservice is deployed, in the left menu of the web console, go to **Networking → Routes** to view the access link to the deployed application.
    You can select the application name to view or modify route settings.

    With the application route, you can integrate your Kogito microservices with your business automation solutions as needed.

21.2.2. Deploying Kogito microservices on OpenShift using binary build and OpenShift web console

OpenShift builds can require extensive amounts of time. As a faster alternative for building and deploying your Kogito microservices on OpenShift, you can use a binary build.

The operator uses the following custom resources to deploy domain-specific microservices (the microservices that you develop):

- **KogitoBuild** processes an uploaded application and produces a runtime image.
- **KogitoRuntime** starts the runtime image and configures it as per your requirements.

Prerequisites

- The Red Hat Process Automation Manager Kogito Operator is installed.
- The **oc** OpenShift CLI is installed and you are logged in to the relevant OpenShift cluster. For **oc** installation and login instructions, see the OpenShift documentation.
- You have access to the OpenShift web console with the necessary permissions to create and edit **KogitoBuild** and **KogitoRuntime**.
- (Quarkus only) The **pom.xml** file of your project contains the following dependency for the Quarkus **smallrye-health** extension. This extension enables the liveness and readiness probes that are required for Quarkus-based projects on OpenShift.

  SmallRye Health dependency for Quarkus applications on OpenShift

  ```
  <dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-smallrye-health</artifactId>
  </dependency>
  ```

Procedure

1. Build an application locally.
2. Go to **Operators → Installed Operators** and select **RHPAM Kogito Operator**.
3. To create the Kogito build definition, on the operator page, select the **Kogito Build** tab and click **Create KogitoBuild**.
4. In the application window, use **Form View** or **YAML View** to configure the build definition.
   At a minimum, define the application configurations shown in the following example YAML file:

   Example YAML definition for a Quarkus application with Kogito build

   ```
   apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this service
   kind: KogitoBuild  # Application type
   metadata:
     name: example-quarkus  # Application name
   spec:
     type: Binary
   ```

   Example YAML definition for a Spring Boot application with Kogito build

   ```
   apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this service
   kind: KogitoBuild  # Application type
   metadata:
     name: example-springboot  # Application name
   spec:
     runtime: springboot
     type: Binary
   ```

5. After you define your application data, click **Create** to generate the Kogito build.

Your application is listed in the **KogitoBuilds** page. You can select the application name to view or modify application settings and YAML details.

6. Upload the built binary using the following command:

```
$ oc start-build example-quarkus --from-dir=target/ -n namespace
```

- **from-dir** is equals to the **target** folder path of the built application.
- **namespace** is the namespace where **KogitoBuild** is created.

7. To create the Kogito microservice definition, on the operator page, select the **Kogito Runtime** tab and click **Create KogitoRuntime**.

8. In the application window, use **Form View** or **YAML View** to configure the microservice definition.
At a minimum, define the application configurations shown in the following example YAML file:

Example YAML definition for a Quarkus application with Kogito microservices

```
apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this microservice
kind: KogitoRuntime  # Application type
metadata:
  name: example-quarkus  # Application name
```

Example YAML definition for a Spring Boot application with Kogito microservices

```
apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this microservice
kind: KogitoRuntime  # Application type
metadata:
  name: example-springboot  # Application name
spec:
  runtime: springboot
```

NOTE

In this case, the application is built locally and deployed using KogitoRuntime. You must ensure that the application name is same in **KogitoBuild** and **KogitoRuntime**.

9. After you define your application data, click **Create** to generate the Kogito microservice.
Your application is listed in the Kogito microservice page. You can select the application name to view or modify application settings and the contents of the YAML file.

10. In the left menu of the web console, go to **Builds → Builds** to view the status of your application build.
You can select a specific build to view build details.

11. After the application build is complete, go to **Workloads → Deployments** to view the application deployments, pod status, and other details.

12. After your Kogito microservice is deployed, in the left menu of the web console, go to **Networking → Routes** to view the access link to the deployed application.
You can select the application name to view or modify route settings.

With the application route, you can integrate your Kogito microservices with your business automation solutions as needed.

21.2.3. Deploying Kogito microservices on OpenShift using custom image build and OpenShift web console

You can use custom image build as an alternative for building and deploying your Kogito microservices on OpenShift.

The operator uses the following custom resources to deploy domain-specific microservices (the microservices that you develop):

- **KogitoRuntime** starts the runtime image and configures it as per your requirements.

Prerequisites

- The Red Hat Process Automation Manager Kogito Operator is installed.
- You have access to the OpenShift web console with the necessary permissions to create and edit **KogitoRuntime**.
- (Quarkus only) The **pom.xml** file of your project contains the following dependency for the Quarkus **smallrye-health** extension. This extension enables the liveness and readiness probes that are required for Quarkus-based projects on OpenShift.

  SmallRye Health dependency for Quarkus applications on OpenShift

  ```
  <dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-smallrye-health</artifactId>
  </dependency>
  ```

Procedure

1. Build an application locally.
2. Create **Containerfile** in the project root folder with the following content:

   Example Containerfile for a Quarkus application

   ```
   FROM registry.redhat.io/rhpam-7/rhpam-kogito-runtime-jvm-rhel8:7.11.0

   ENV RUNTIME_TYPE quarkus

   COPY target/quarkus-app/lib/ $KOGITO_HOME/bin/lib/
   COPY target/quarkus-app/*.jar $KOGITO_HOME/bin
   COPY target/quarkus-app/app/ $KOGITO_HOME/bin/app/
   COPY target/quarkus-app/quarkus/ $KOGITO_HOME/bin/quarkus/
   ```

   Example Containerfile for a Spring Boot application

   ```
   FROM registry.redhat.io/rhpam-7/rhpam-kogito-runtime-jvm-rhel8:7.11.0

   ENV RUNTIME_TYPE springboot
   ```

```
COPY target/<application-jar-file> $KOGITO_HOME/bin
```

- **application-jar-file** is the name of the JAR file of the application.

3. Build the Kogito image using the following command:

```
podman build --tag <final-image-name> -f <Container-file>
```

In the previous command, **final-image-name** is the name of the Kogito image and **Container-file** is name of the **Containerfile** that you created in the previous step.

4. Optionally, test the built image using the following command:

```
podman run --rm -it -p 8080:8080 <final-image-name>
```

5. Push the built Kogito image to an image registry using the following command:

```
podman push <final-image-name>
```

6. Go to **Operators → Installed Operators** and select **RHPAM Kogito Operator**.

7. To create the Kogito microservice definition, on the operator page, select the **Kogito Runtime** tab and click **Create KogitoRuntime**.

8. In the application window, use **Form View** or **YAML View** to configure the microservice definition.
At a minimum, define the application configurations shown in the following example YAML file:

Example YAML definition for a Quarkus application with Kogito microservices

```
apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this microservice
kind: KogitoRuntime # Application type
metadata:
  name: example-quarkus # Application name
spec:
  image: <final-image-name> # Kogito image name
  insecureImageRegistry: true # Can be omitted when image is pushed into secured registry
with valid certificate
```

Example YAML definition for a Spring Boot application with Kogito microservices

```
apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this microservice
kind: KogitoRuntime # Application type
metadata:
  name: example-springboot # Application name
spec:
  image: <final-image-name> # Kogito image name
  insecureImageRegistry: true # Can be omitted when image is pushed into secured registry
with valid certificate
  runtime: springboot
```

9. After you define your application data, click **Create** to generate the Kogito microservice.

Your application is listed in the Kogito microservice page. You can select the application name to view or modify application settings and the contents of the YAML file.

10. After the application build is complete, go to **Workloads → Deployments** to view the application deployments, pod status, and other details.

11. After your Kogito microservice is deployed, in the left menu of the web console, go to **Networking → Routes** to view the access link to the deployed application.
    You can select the application name to view or modify route settings.

    With the application route, you can integrate your Kogito microservices with your business automation solutions as needed.

21.2.4. Deploying Kogito microservices on OpenShift using file build and OpenShift web console

You can build and deploy your Kogito microservices from a single file, such as a Decision Model and Notation (DMN), Drools Rule Language (DRL), or properties file, or from a directory with multiple files. You can specify a single file from your local file system path or specify a file directory from a local file system path only. When you upload the file or directory to an OpenShift cluster, a new Source-to-Image (S2I) build is automatically triggered.

The operator uses the following custom resources to deploy domain-specific microservices (the microservices that you develop):

- **KogitoBuild** generates an application from a file and produces a runtime image.

- **KogitoRuntime** starts the runtime image and configures it as per your requirements.

Prerequisites

- The Red Hat Process Automation Manager Kogito Operator is installed.

- The **oc** OpenShift CLI is installed and you are logged in to the relevant OpenShift cluster. For **oc** installation and login instructions, see the OpenShift documentation.

- You have access to the OpenShift web console with the necessary permissions to create and edit **KogitoBuild** and **KogitoRuntime**.

Procedure

1. Go to **Operators → Installed Operators** and select **RHPAM Kogito Operator**.

2. To create the Kogito build definition, on the operator page, select the **Kogito Build** tab and click **Create KogitoBuild**.

3. In the application window, use **Form View** or **YAML View** to configure the build definition.
   At a minimum, define the application configurations shown in the following example YAML file:

   Example YAML definition for a Quarkus application with Kogito build

```
apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this service
kind: KogitoBuild  # Application type
metadata:
  name: example-quarkus  # Application name
spec:
  type: LocalSource
```

Example YAML definition for a Spring Boot application with Kogito build

```
apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this service
kind: KogitoBuild  # Application type
metadata:
  name: example-springboot  # Application name
spec:
  runtime: springboot
  type: LocalSource
```

NOTE

If you configured an internal Maven repository, you can use it as a Maven mirror service and specify the Maven mirror URL in your Kogito build definition to shorten build time substantially:

```
spec:
  mavenMirrorURL: http://nexus3-nexus.apps-crc.testing/repository/maven-
public/
```

For more information about internal Maven repositories, see the Apache Maven documentation.

4. After you define your application data, click **Create** to generate the Kogito build.
   Your application is listed in the **KogitoBuilds** page. You can select the application name to view or modify application settings and YAML details.

5. Upload the file asset using the following command:

   ```
   $ oc start-build example-quarkus-builder --from-file=<file-asset-path> -n namespace
   ```

   - **file-asset-path** is the path of the file asset that you want to upload.
   - **namespace** is the namespace where **KogitoBuild** is created.

6. To create the Kogito microservice definition, on the operator page, select the **Kogito Runtime** tab and click **Create KogitoRuntime**.

7. In the application window, use **Form View** or **YAML View** to configure the microservice definition.
   At a minimum, define the application configurations shown in the following example YAML file:

Example YAML definition for a Quarkus application with Kogito microservices

```
apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this microservice
kind: KogitoRuntime  # Application type
metadata:
  name: example-quarkus  # Application name
```

Example YAML definition for a Spring Boot application with Kogito microservices

```
apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this microservice
kind: KogitoRuntime  # Application type
metadata:
  name: example-springboot  # Application name
spec:
  runtime: springboot
```

NOTE

In this case, the application is built from a file and deployed using KogitoRuntime. You must ensure that the application name is same in **KogitoBuild** and **KogitoRuntime**.

8. After you define your application data, click **Create** to generate the Kogito microservice. Your application is listed in the Kogito microservice page. You can select the application name to view or modify application settings and the contents of the YAML file.

9. In the left menu of the web console, go to **Builds → Builds** to view the status of your application build.
   You can select a specific build to view build details.

   NOTE

   For every Kogito microservice that you create for OpenShift deployment, two builds are generated and listed in the **Builds** page in the web console: a traditional runtime build and a Source-to-Image (S2I) build with the suffix **-builder**. The S2I mechanism builds the application in an OpenShift build and then passes the built application to the next OpenShift build to be packaged into the runtime container image.

10. After the application build is complete, go to **Workloads → Deployments** to view the application deployments, pod status, and other details.

11. After your Kogito microservice is deployed, in the left menu of the web console, go to **Networking → Routes** to view the access link to the deployed application.
    You can select the application name to view or modify route settings.

    With the application route, you can integrate your Kogito microservices with your business automation solutions as needed.

21.3. PROBES FOR KOGITO MICROSERVICES ON RED HAT OPENSHIFT CONTAINER PLATFORM

The probes in Red Hat OpenShift Container Platform verify that an application is working or it needs to be restarted. For Kogito microservices on Quarkus and Spring Boot, probes interact with the application using an HTTP request, defaulting to the endpoints that are exposed by an extension. Therefore, to run your Kogito microservices on Red Hat OpenShift Container Platform, you must import the extensions to provide application availability information for the liveness, readiness, and startup probes.

21.3.1. Adding health check extension for Quarkus-based Kogito microservices on Red Hat OpenShift Container Platform

You can add the health check extension for the Quarkus-based Kogito services on Red Hat OpenShift Container Platform.

Procedure

In a command terminal, navigate to the **pom.xml** file of your project and add the following dependency for the Quarkus **smallrye-health** extension:

SmallRye Health dependency for Quarkus applications on Red Hat OpenShift Container Platform

```xml
<dependencies>
  <dependency>
    <groupId>io.quarkus</groupId>
    <artifactId>quarkus-smallrye-health</artifactId>
  </dependency>
</dependencies>
```

21.3.2. Adding health check extension for Spring Boot-based Kogito microservices on Red Hat OpenShift Container Platform

You can add the health check extension for the Spring Boot-based Kogito microservices on Red Hat OpenShift Container Platform.

Procedure

In a command terminal, navigate to the **pom.xml** file of your project and add the following Spring Boot actuator dependency:

Spring Boot actuator dependency for Spring Boot applications on Red Hat OpenShift Container Platform

```xml
<dependencies>
  <dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-actuator</artifactId>
  </dependency>
</dependencies>
```

21.3.3. Setting custom probes for Kogito microservices on Red Hat OpenShift Container Platform

You can also configure the custom endpoints for the liveness, readiness, and startup probes.

Procedure

1. Define the probes in the **KogitoRuntime** YAML file of your project, as shown in the following example:

Example Kogito microservice custom resource with custom probe endpoints

```
apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this service
kind: KogitoRuntime
metadata:
  name: process-quarkus-example # Application name
spec:
  replicas: 1
  probes:
    livenessProbe:
      httpGet:
        path: /probes/live # Liveness endpoint
        port: 8080
    readinessProbe:
      httpGet:
        path: /probes/ready # Readiness endpoint
        port: 8080
    startupProbe:
      tcpSocket:
        port: 8080
```

21.4. RED HAT PROCESS AUTOMATION MANAGER KOGITO OPERATOR INTERACTION WITH PROMETHEUS AND GRAFANA

Kogito in Red Hat Decision Manager provides a **monitoring-prometheus-addon** add-on that enables Prometheus metrics monitoring for Kogito microservices and generates Grafana dashboards that consume the default metrics exported by the add-on. The RHPAM Kogito Operator uses the Prometheus Operator to expose the metrics from your project for Prometheus to scrape. Due to this dependency, the Prometheus Operator must be installed in the same namespace as your project.

If you want to enable the Prometheus metrics monitoring for your Kogito microservices, add the following dependency to the **pom.xml** file in your project, depending on the framework you are using:

Dependency for Prometheus Quarkus add-on

```
<dependency>
    <groupId>org.kie.kogito</groupId>
    <artifactId>monitoring-prometheus-quarkus-addon</artifactId>
</dependency>
```

Dependency for Prometheus Spring Boot add-on

```
<dependency>
    <groupId>org.kie.kogito</groupId>
    <artifactId>monitoring-prometheus-springboot-addon</artifactId>
</dependency>
```

When you deploy a Kogito microservice that uses the **monitoring-prometheus-addon** add-on and the Prometheus Operator is installed, the Red Hat Process Automation Manager Kogito Operator creates a **ServiceMonitor** custom resource to expose the metrics for Prometheus, as shown in the following example:

Example **ServiceMonitor** resource for Prometheus

```
apiVersion: monitoring.coreos.com/v1
```

```
kind: ServiceMonitor
metadata:
  labels:
    app: onboarding-service
  name: onboarding-service
  namespace: kogito
spec:
  endpoints:
  - path: /metrics
    targetPort: 8080
    scheme: http
  namespaceSelector:
    matchNames:
    - kogito
  selector:
    matchLabels:
      app: onboarding-service
```

You must manually configure your **Prometheus** custom resource that is managed by the Prometheus Operator to select the **ServiceMonitor** resource:

Example Prometheus resource

```
apiVersion: monitoring.coreos.com/v1
kind: Prometheus
metadata:
  name: prometheus
spec:
  serviceAccountName: prometheus
  serviceMonitorSelector:
    matchLabels:
      app: dmn-drools-quarkus-metrics-service
```

After you configure your Prometheus resource with the **ServiceMonitor** resource, you can see the endpoint scraped by Prometheus in the **Targets** page in the Prometheus web console. The metrics exposed by the Red Hat Decision Manager service appear in the **Graph** view.

The Red Hat Process Automation Manager Kogito Operator also creates a **GrafanaDashboard** custom resource defined by the Grafana Operator for each of the Grafana dashboards generated by the add-on. The **app** label for the dashboards is the name of the deployed Kogito microservice. You must set the **dashboardLabelSelector** property of the **Grafana** custom resource according to the relevant Kogito microservice.

Example Grafana resource

```
apiVersion: integreatly.org/v1alpha1
kind: Grafana
metadata:
  name: example-grafana
spec:
  ingress:
    enabled: true
  config:
    auth:
      disable_signout_menu: true
    auth.anonymous:
      enabled: true
    log:
      level: warn
      mode: console
    security:
      admin_password: secret
      admin_user: root
  dashboardLabelSelector:
    - matchExpressions:
        - key: app
          operator: In
          values:
            - my-kogito-application
```

21.5. KOGITO MICROSERVICE DEPLOYMENT TROUBLESHOOTING

Use the information in this section to troubleshoot issues that you might encounter when using the operator to deploy Kogito microservices. The following information is updated as new issues and workarounds are discovered.

No builds are running

If you do not see any builds running nor any resources created in the relevant namespace, enter the following commands to retrieve running pods and to view the operator log for the pod:

View Kogito Operator log for a specified pod

```
// Retrieves running pods
$ oc get pods

NAME                                  READY   STATUS      RESTARTS   AGE
kogito-operator-6d7b6d4466-9ng8t   1/1     Running     0          26m

// Opens Kogito Operator log for the pod
$ oc logs -f kogito-operator-6d7b6d4466-9ng8t
```

Verify KogitoRuntime status

If you create, for example, **KogitoRuntime** application with a non-existing image using the following YAML definition:

Example YAML definition for a KogitoRuntime application

```
apiVersion: rhpam.kiegroup.org/v1 # Kogito API for this microservice
kind: KogitoRuntime # Application type
metadata:
  name: example # Application name
spec:
  image: 'not-existing-image:latest'
  replicas: 1
```

You can verify the status of the **KogitoRuntime** application using the **oc describe KogitoRuntime example** command in the bash console. When you run the **oc describe KogitoRuntime example** command in the bash console, you receive the following output:

Example KogitoRuntime status

```
[user@localhost ~]$ oc describe KogitoRuntime example
Name:         example
Namespace:    username-test
Labels:       <none>
Annotations:  <none>
API Version:  rhpam.kiegroup.org/v1
Kind:         KogitoRuntime
Metadata:
  Creation Timestamp:  2021-05-20T07:19:41Z
  Generation:          1
  Managed Fields:
    API Version:  rhpam.kiegroup.org/v1
    Fields Type:  FieldsV1
    fieldsV1:
      f:spec:
        .:
        f:image:
        f:replicas:
    Manager:      Mozilla
    Operation:    Update
    Time:         2021-05-20T07:19:41Z
    API Version:  rhpam.kiegroup.org/v1
    Fields Type:  FieldsV1
    fieldsV1:
      f:spec:
        f:monitoring:
        f:probes:
          .:
          f:livenessProbe:
          f:readinessProbe:
        f:resources:
        f:runtime:
      f:status:
        .:
        f:cloudEvents:
        f:conditions:
    Manager:         main
    Operation:       Update
    Time:            2021-05-20T07:19:45Z
  Resource Version:  272185
  Self Link:         /apis/rhpam.kiegroup.org/v1/namespaces/ksuta-test/kogitoruntimes/example
  UID:               edbe0bf1-554e-4523-9421-d074070df982
Spec:
  Image:     not-existing-image:latest
  Replicas:  1
Status:
  Cloud Events:
  Conditions:
    Last Transition Time:  2021-05-20T07:19:44Z
    Message:
    Reason:                NoPodAvailable
    Status:                False
    Type:                  Deployed
    Last Transition Time:  2021-05-20T07:19:44Z
    Message:
    Reason:               RequestedReplicasNotEqualToAvailableReplicas
    Status:               True
    Type:                 Provisioning
    Last Transition Time:  2021-05-20T07:19:45Z
    Message:               you may not have access to the container image "quay.io/kiegroup/not-
existing-image:latest"
    Reason:               ImageStreamNotReadyReason
    Status:               True
    Type:                 Failed
```

At the end of the output, you can see the **KogitoRuntime** status with a relevant message.

CHAPTER 22. ADDITIONAL RESOURCES

- *Designing a decision service using DMN models*
- *Designing a decision service using DRL rules*
- *Designing a decision service using PMML models*

APPENDIX A. VERSIONING INFORMATION

Documentation last updated on Thursday, June 17, 2021.

APPENDIX B. CONTACT INFORMATION

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