Institute of Systems Science

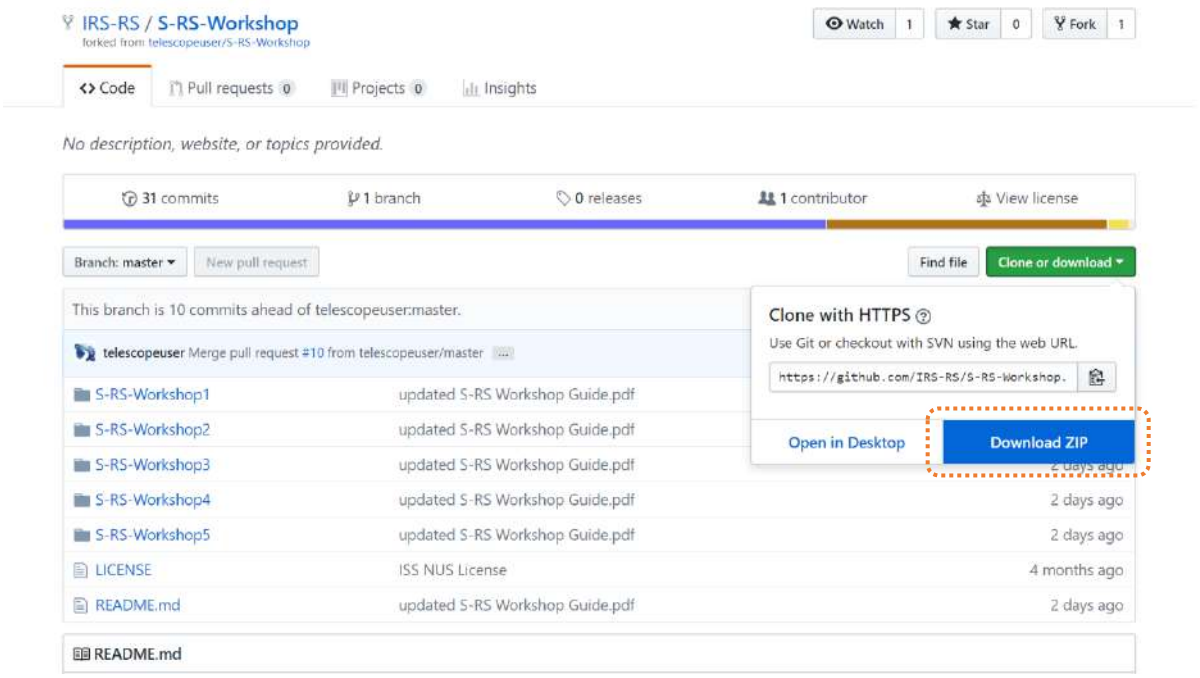
National University of Singapore

GRADUATE CERTIFICATE
INTELLIGENT REASONING SYSTEMS

Workshop Project Guide (1/5)

Subject: Reasoning Systems

Institute of Systems Science, 25 Heng Mui Keng Terrace, Singapore 119615



Workshops & References https://github.com/IRS-RS/S-RS-Workshop

Virtual Machine Workstation http://bit.ly/iss-vm

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WORKSHOP SEARCH REPRESENTATION

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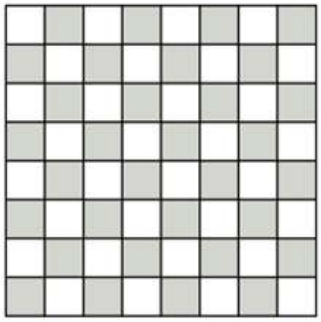
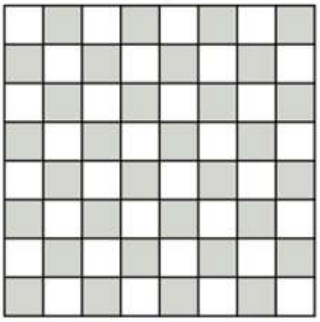
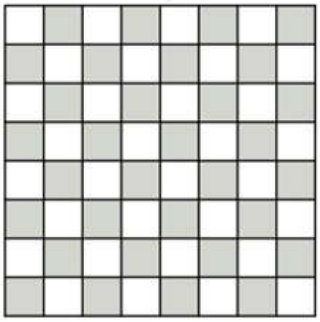
  - Optimizing Vehicle Route Planning (VRP)
  - Optimizing Europe Travelling Sales Person (TSP)

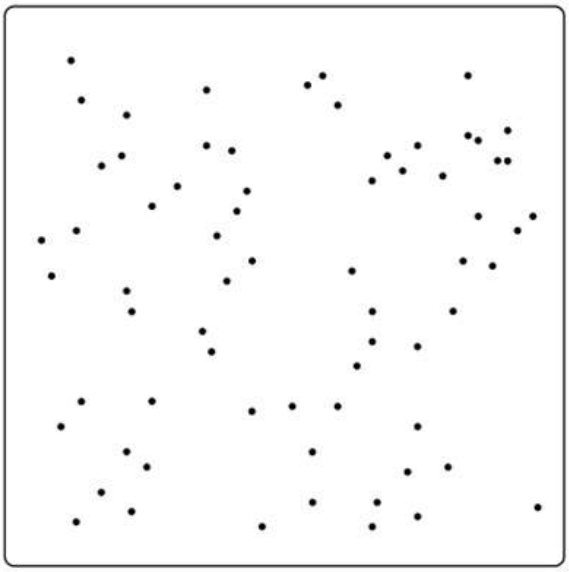
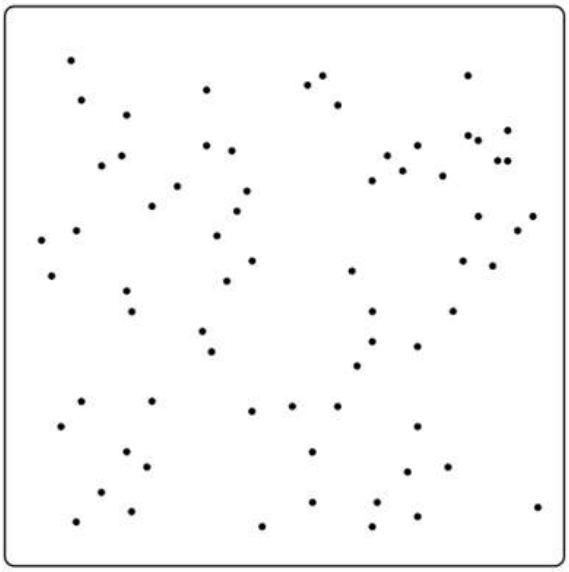
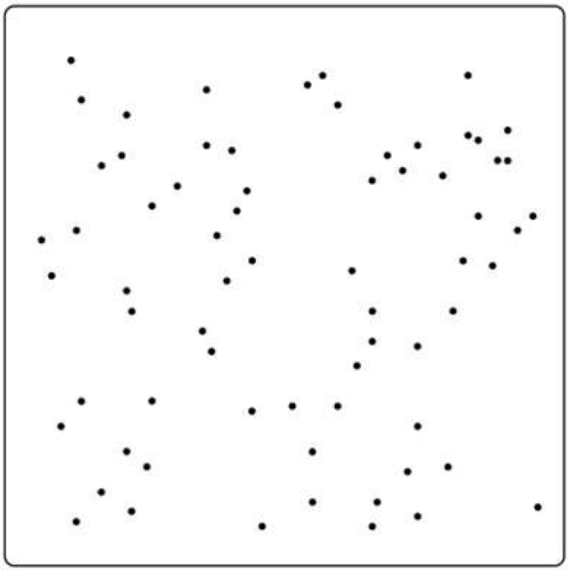
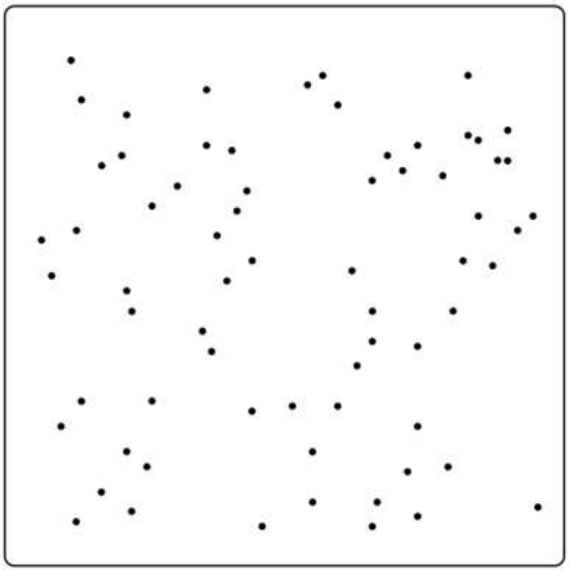
1.1. Search Modelling & Representation

1.1.1. Pen & Paper Planning

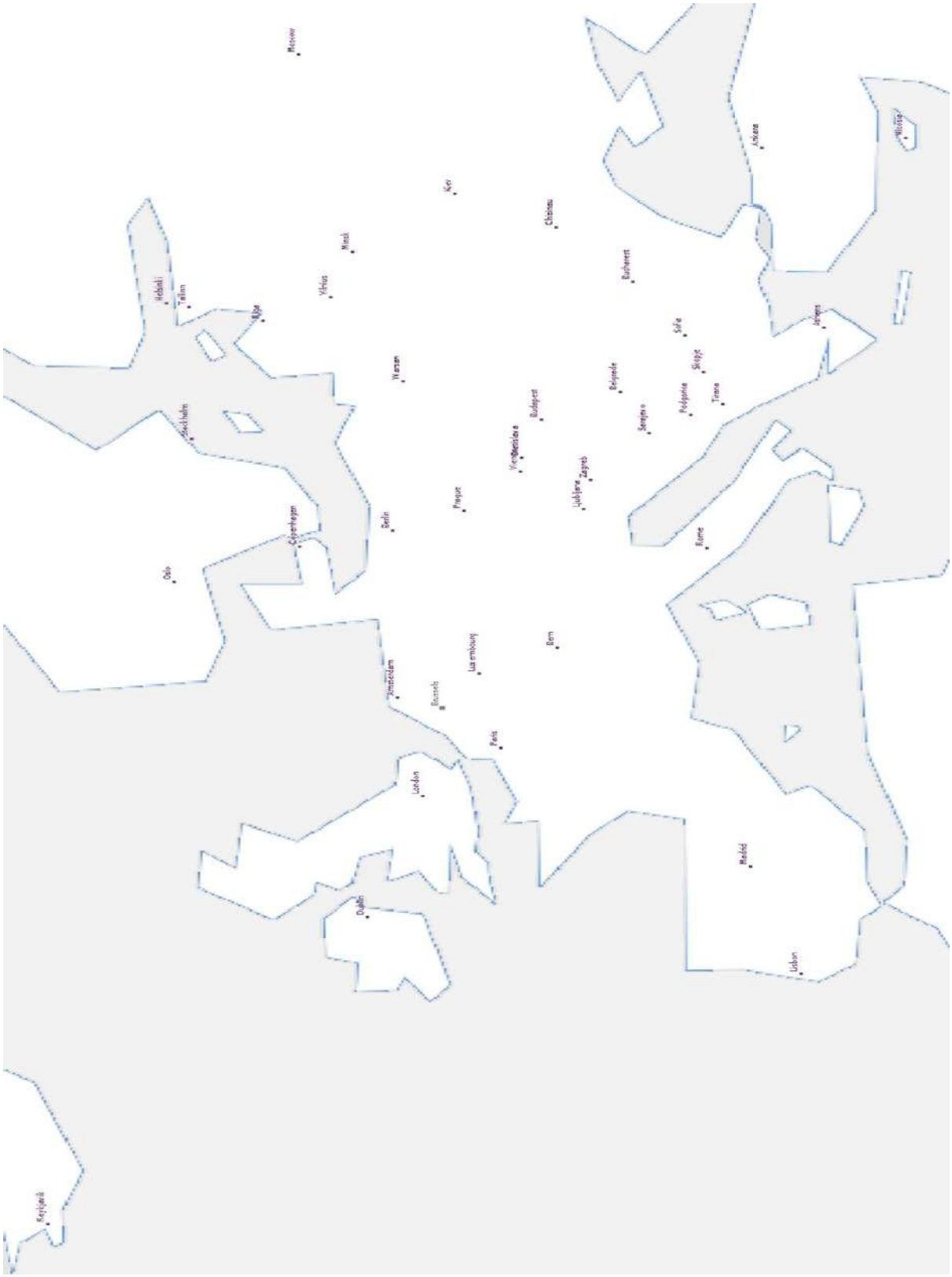
1) Place 8 queens on this chessboard so no 2 queens can attack each other.

2) Draw the shortest line that connects all dots and returns to its origin.

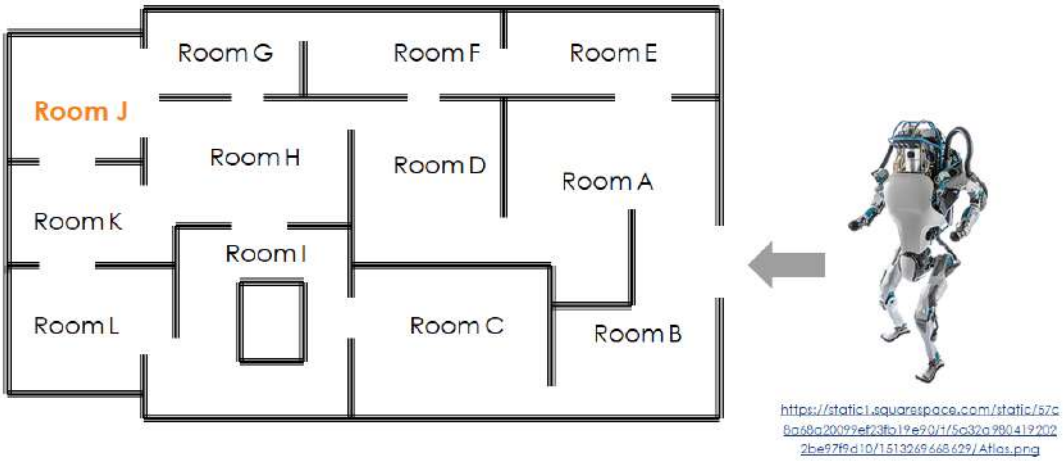





Plan a Europe round trip (shortest total path preferred)



1.1.2. Robot Navigation

- **Robotics: How to rapidly navigate to Room J ?**



https://static1.squarespace.com/static/57c8a68a20099ef23ffa19e9/t/5a32a9804192022be97f9d10/1513269668629/Atlas.png

Design and draft robot navigation search representation here:

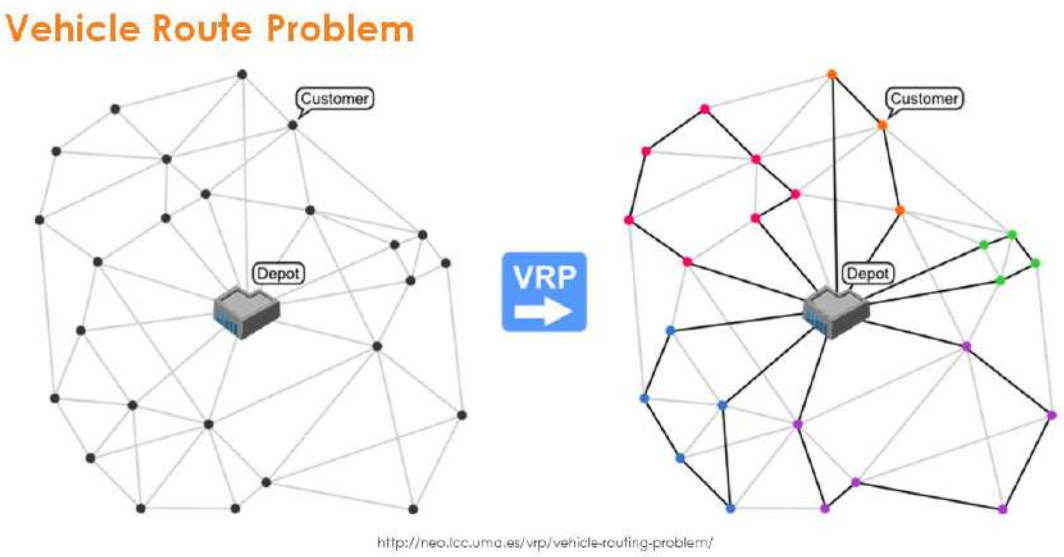
Write down DFS search order:

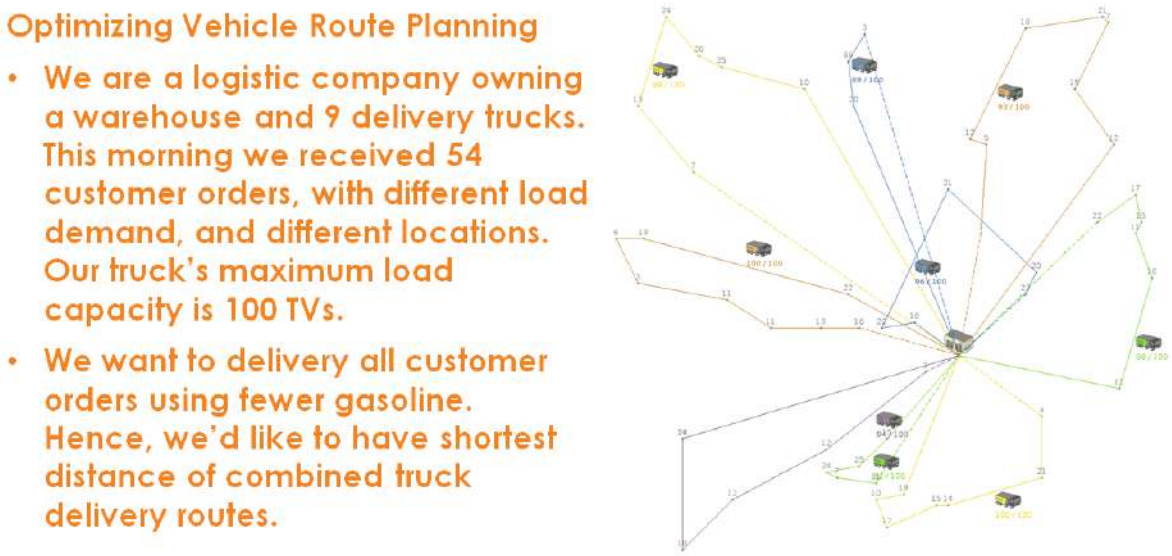
Write down BFS search order:

Construct reasonable heuristics, then design heuristic search strategy to enhance above DFS/BFS brute force search:

1.1.3. Vehicle Route Planning (VRP)

Form groups: 4-6 learners per group.



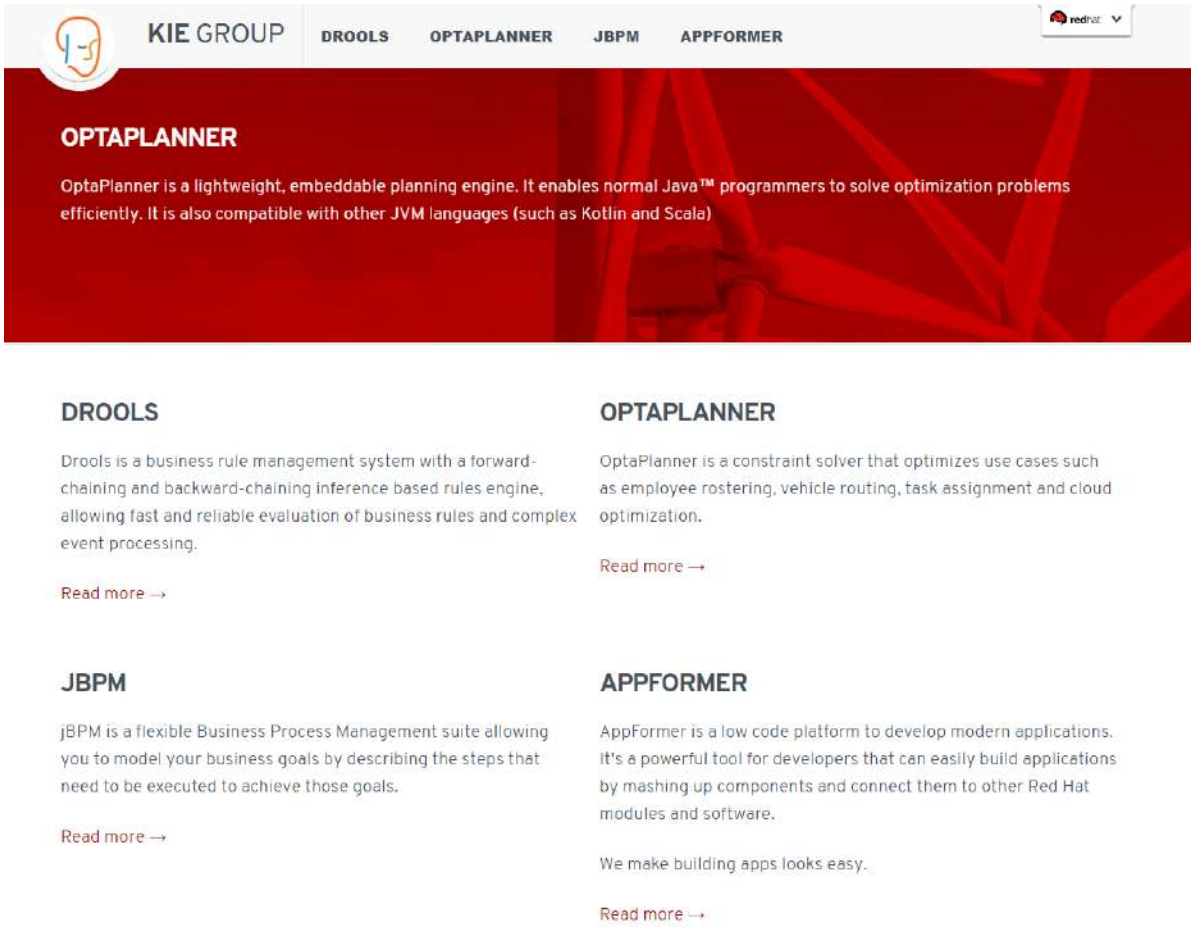


Try to draw/plan the route for 9 trucks:

Design and draft VRP search representation here:

Strategy to avoid looping (revisiting same customer):

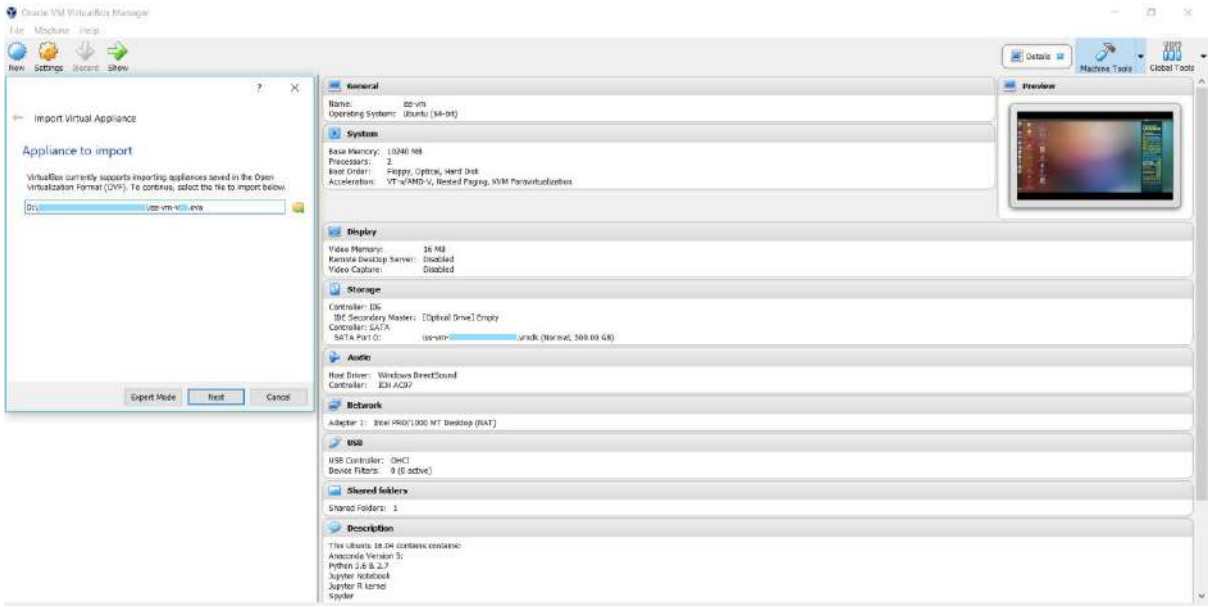
1.2. KIE OptaPlanner Tutorial



KIE / Business Central	http://www.kiegroup.org/
KIE OptaPlanner	https://www.optaplanner.org/

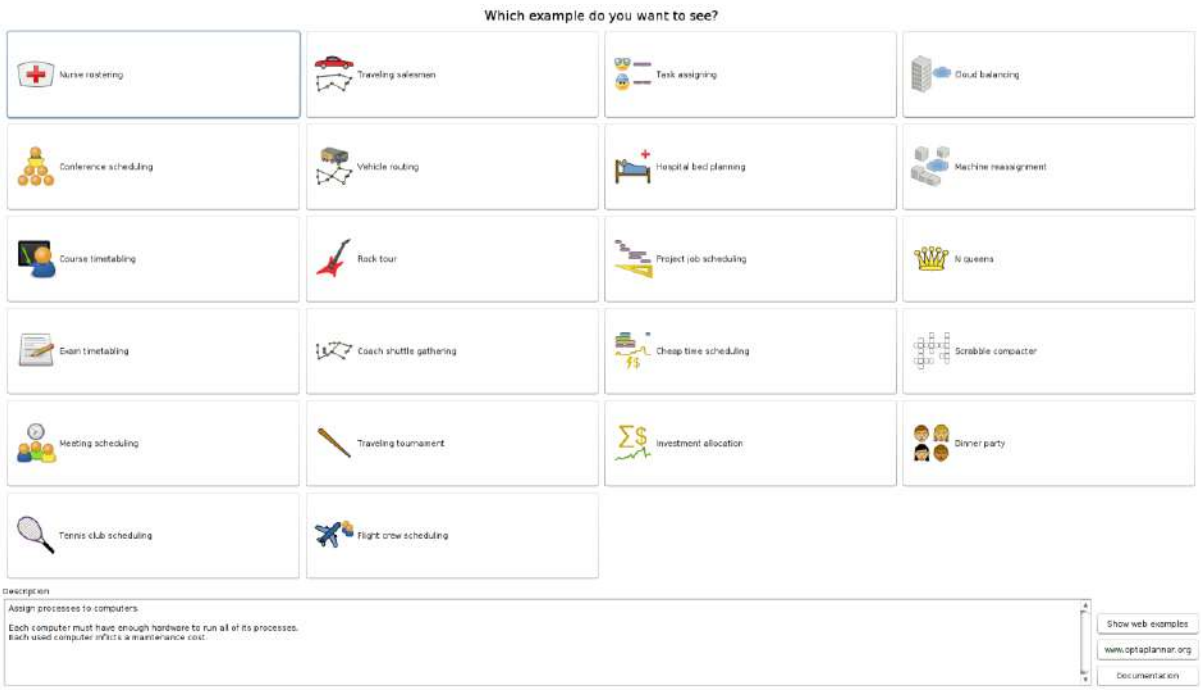
1.2.1. OptaPlanner Example Solutions in Graphic User Interface

1) Start computer → Oracle VM Virtual Box → iss-vm virtual machine



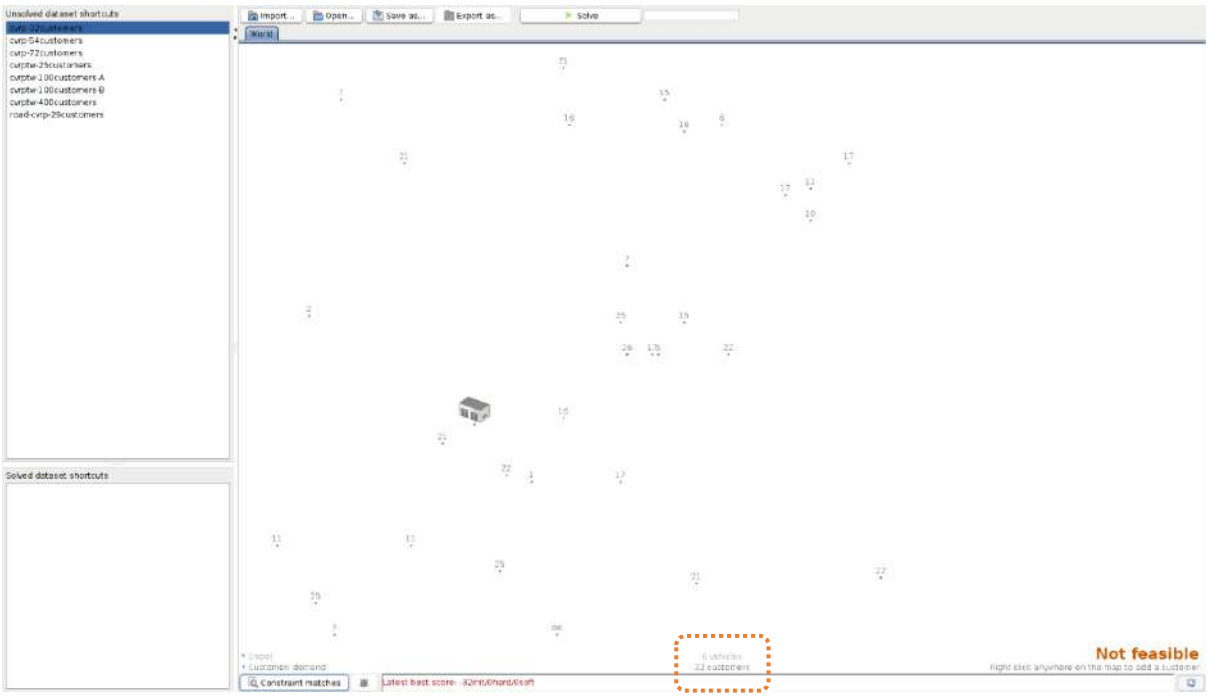
http://bit.ly/iss-vm

2) From desktop, start **Solution KIE Solver** (It takes a while to start).

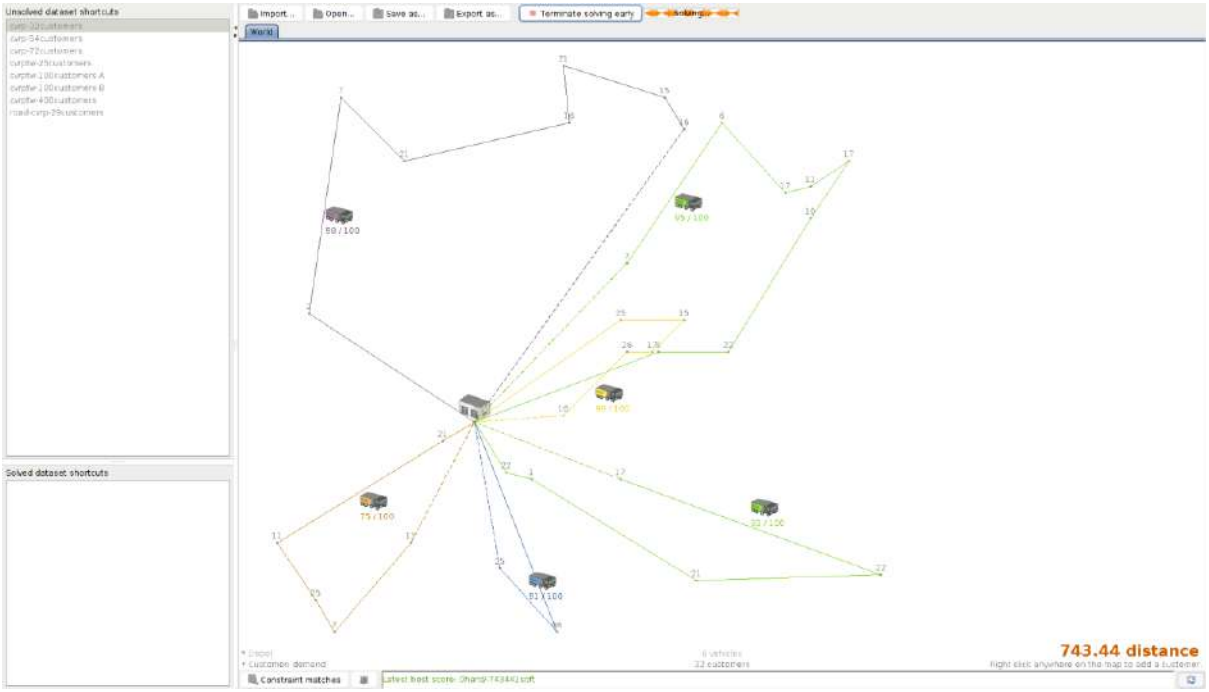


3) Start to explore **Vehicle routing** (VRP).

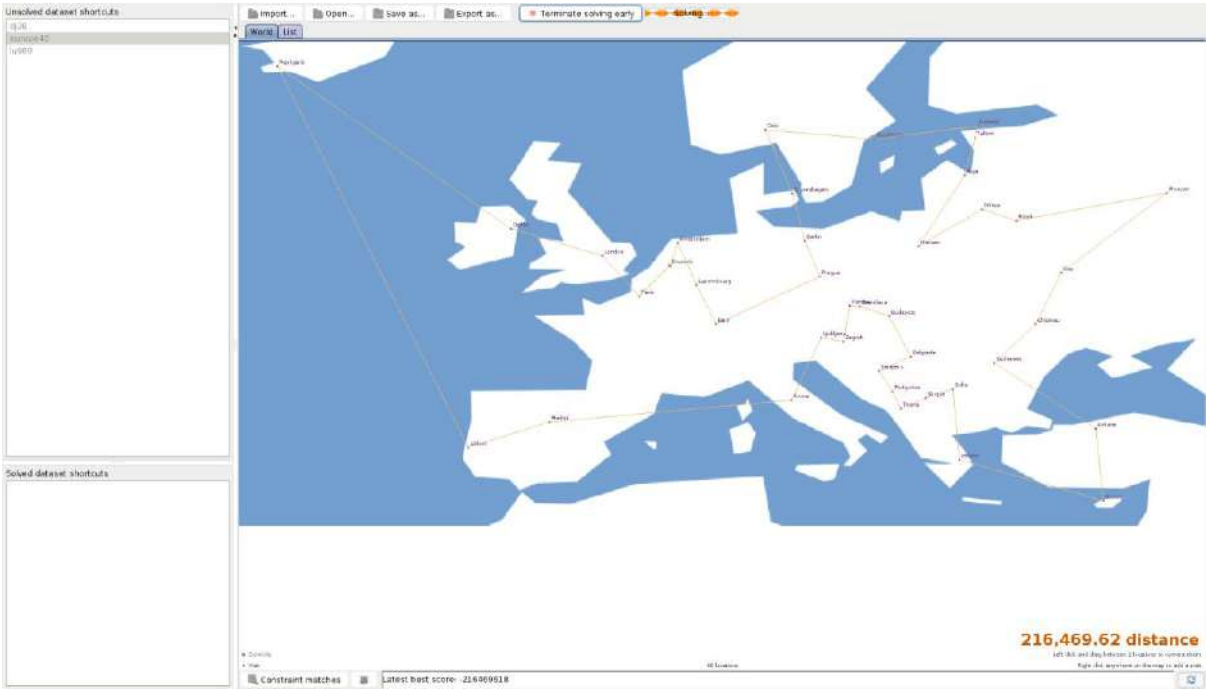
Based on below geospatial map, use pen & paper to plan the **6** trucks' route for **32** customer orders:



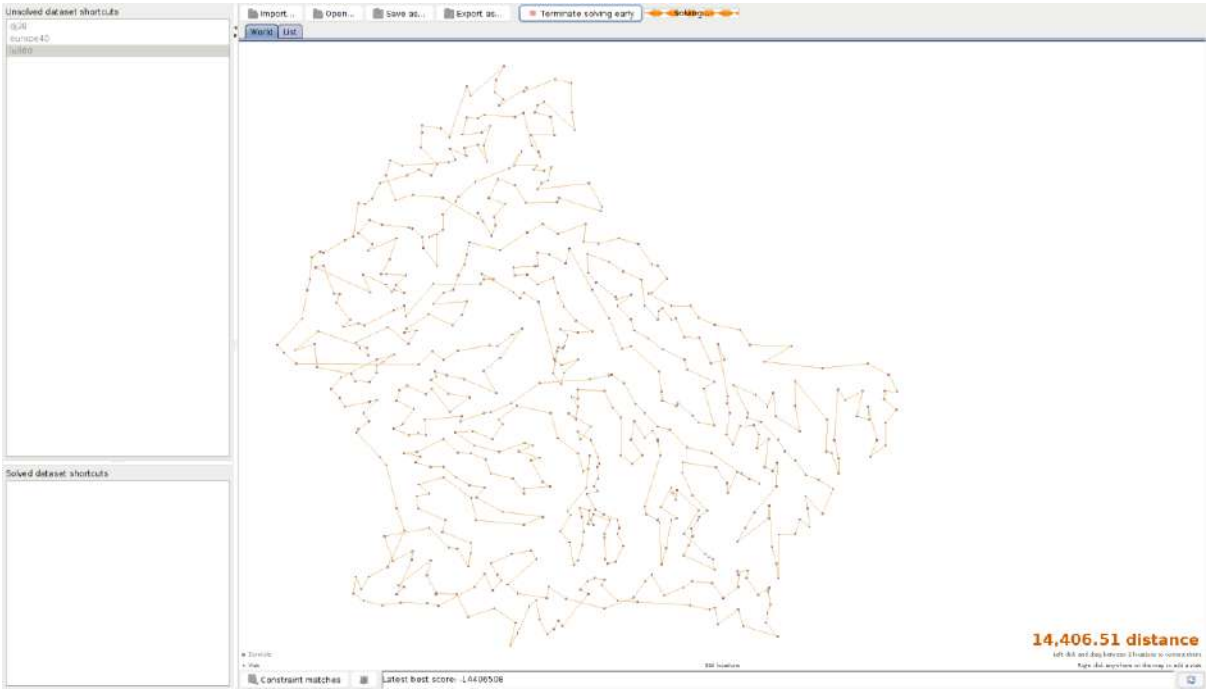
Run the OptaPlanner to view the solution, then compare with above pen & paper solution, which one could be better?



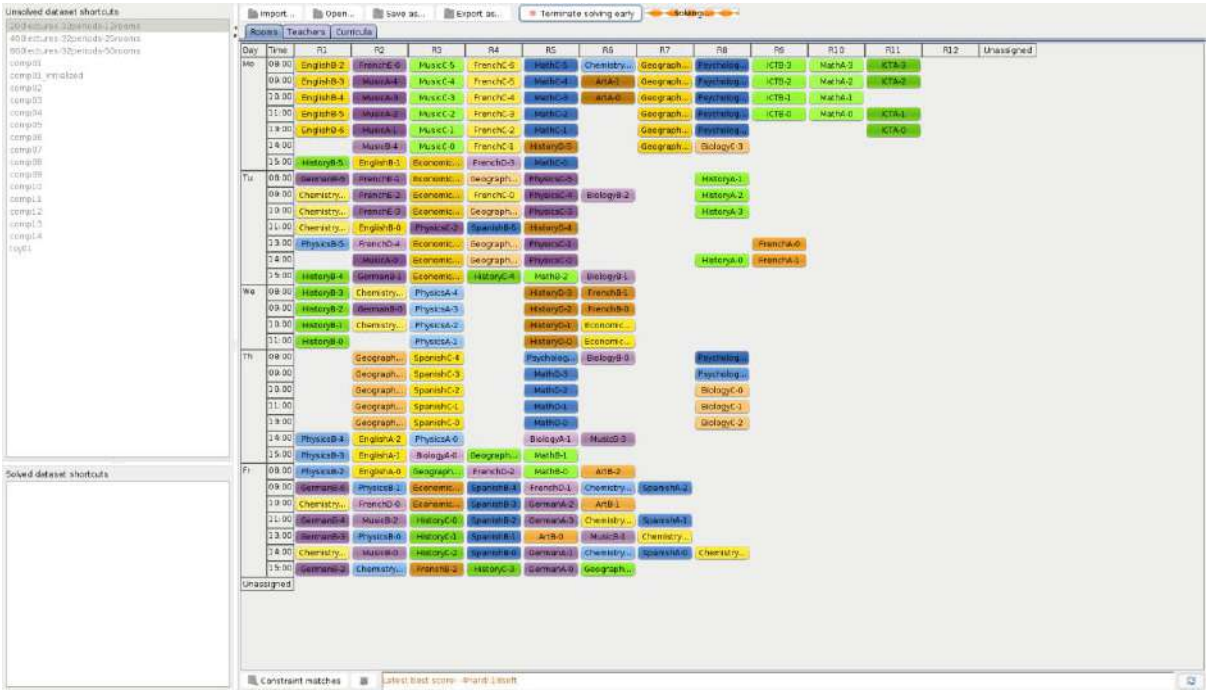
4) Start to explore **Travelling salesman** (TSP).



Plan a Europe round trip seems enjoyable, but what about visiting more places like below: to find a shortest travel route?

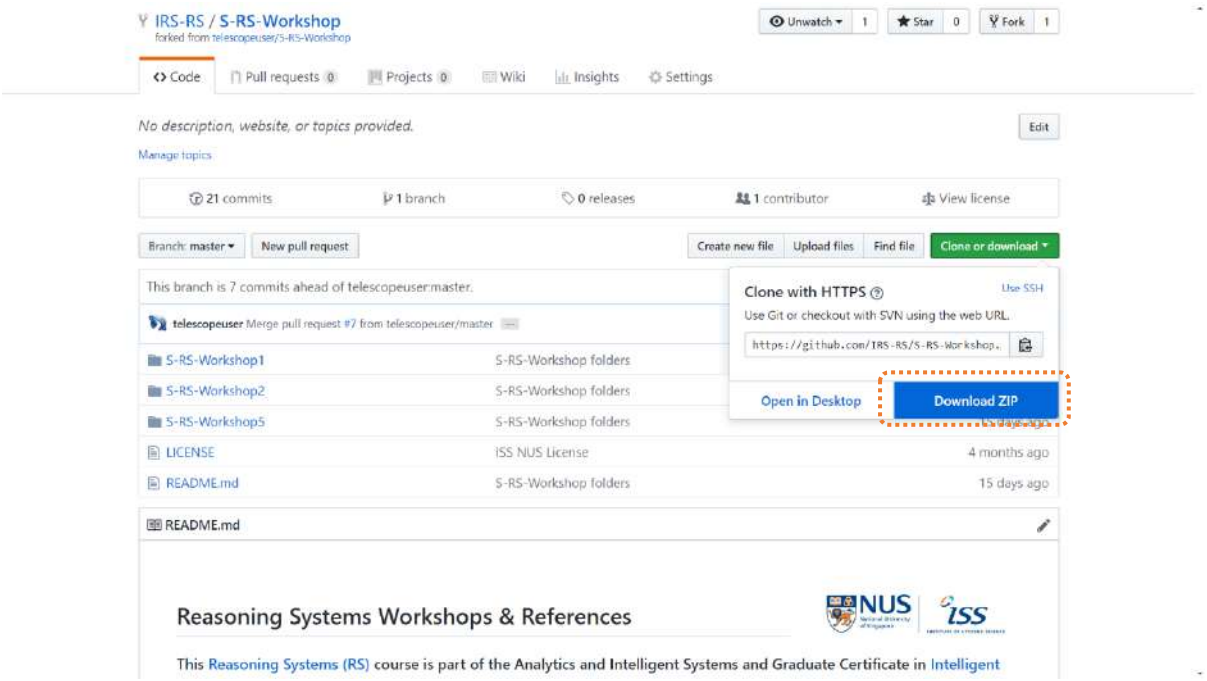


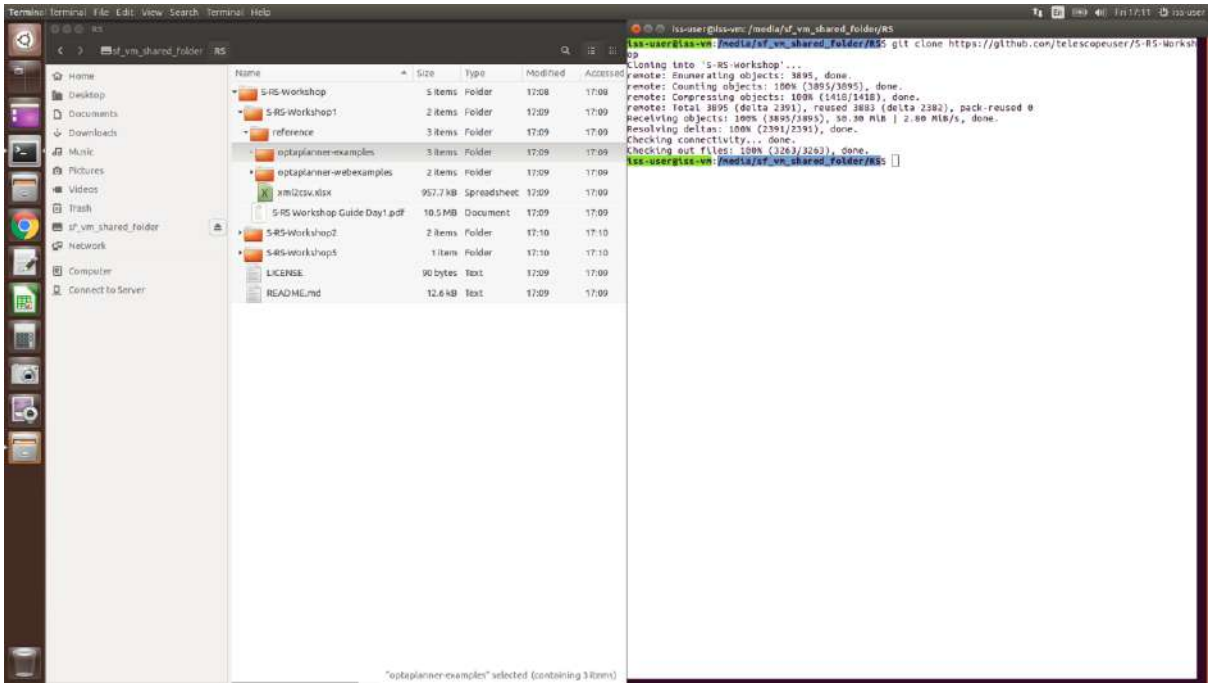
5) Explore other example solutions of your interest, e.g. are you inspired to design a course scheduler for NUS ISS courses/classrooms/lecturers/…?



1.2.2. OptaPlanner Example Solutions in Integrated Develop Environment

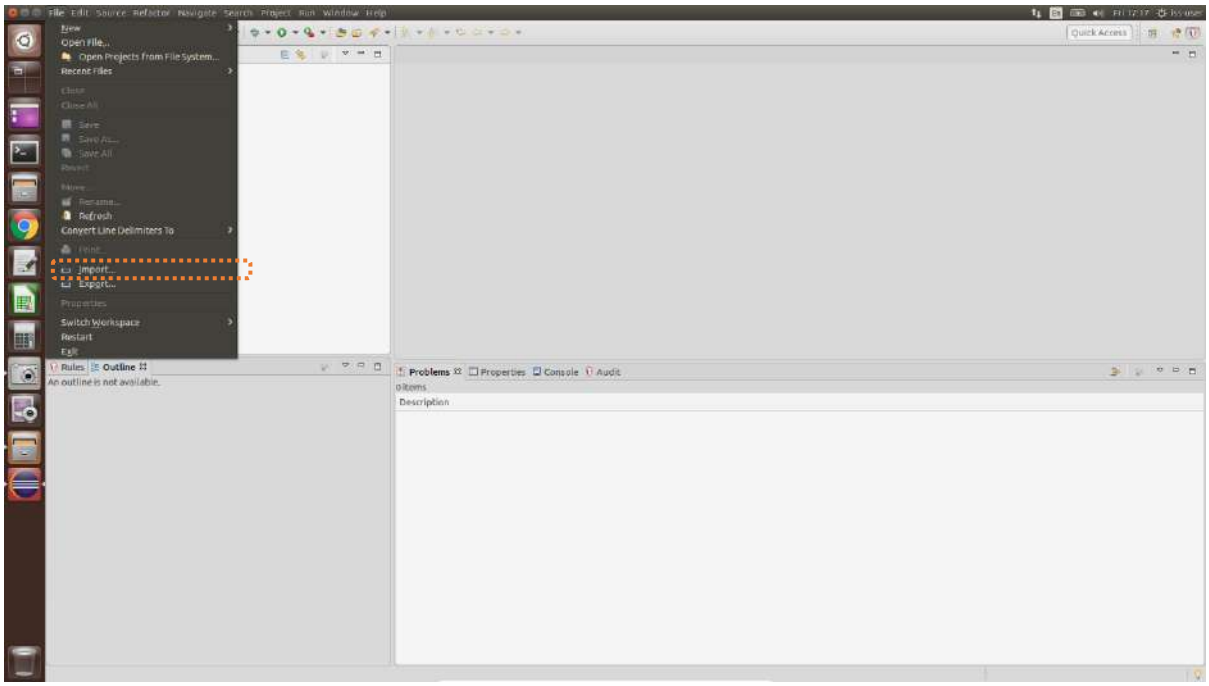
1) Download workshop materials from Github
   https://github.com/telescopeuser/S-RS-Workshop



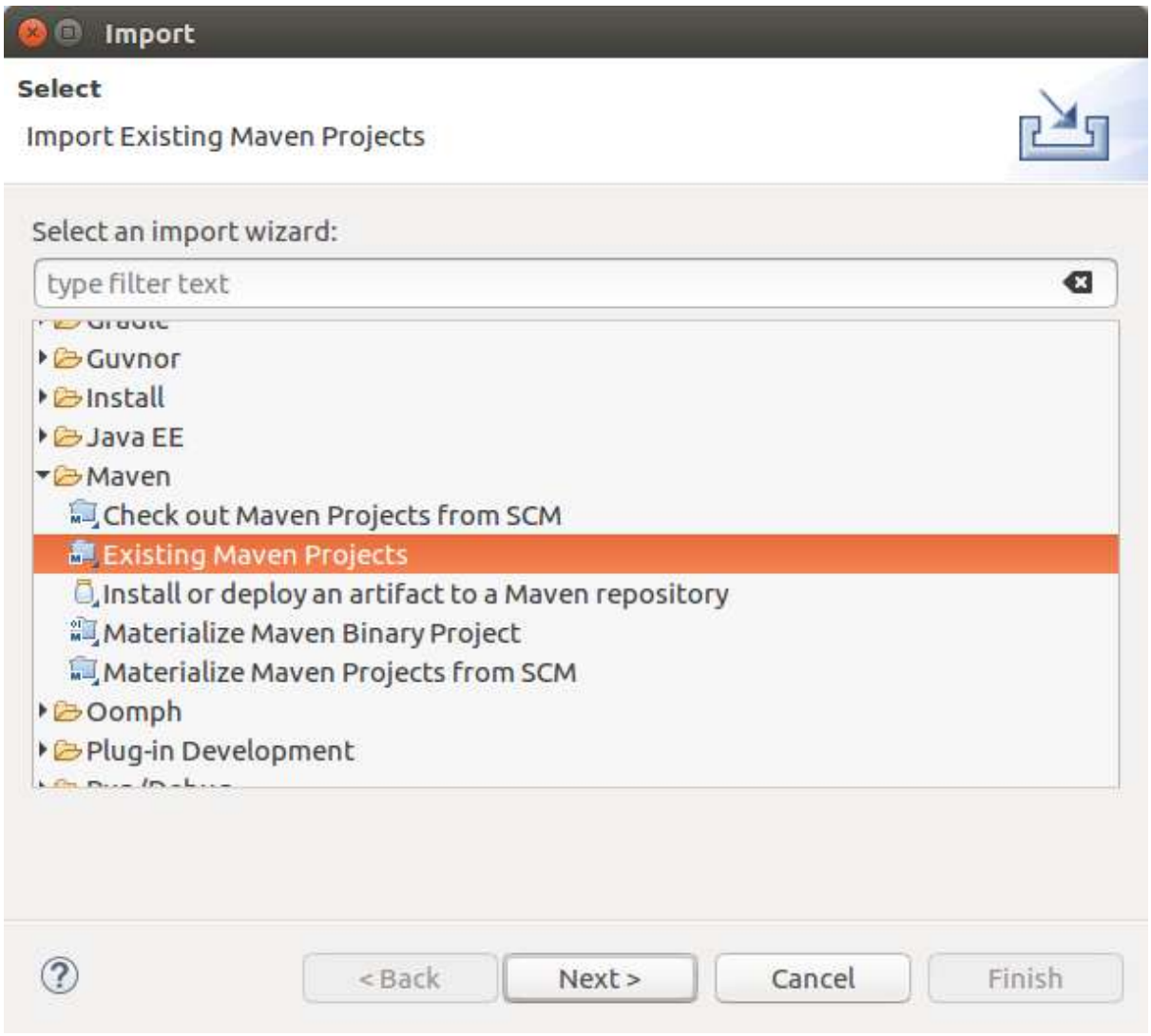


2) From desktop, Start **Tool Eclipse**.

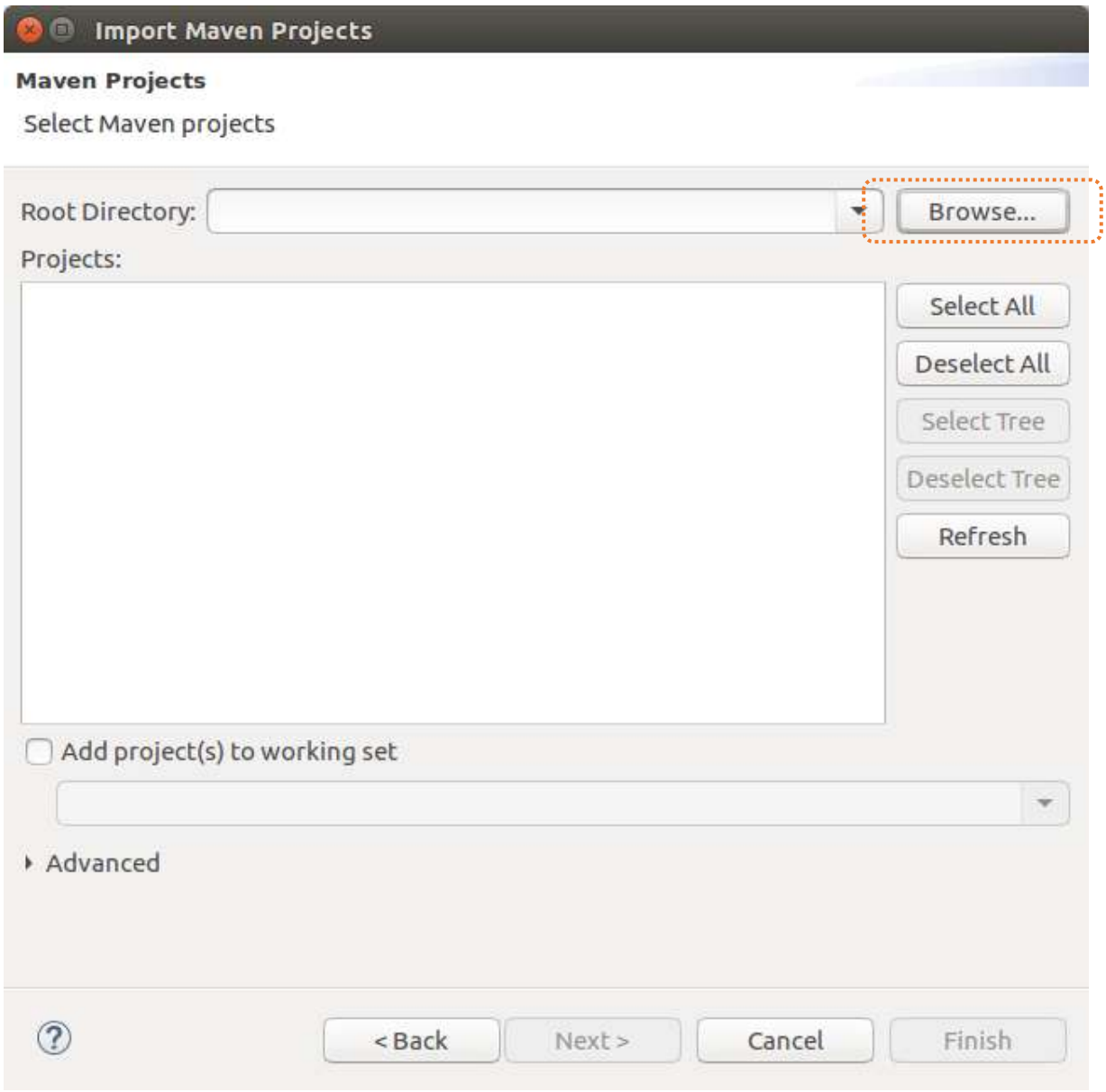
3) Select **Import…**



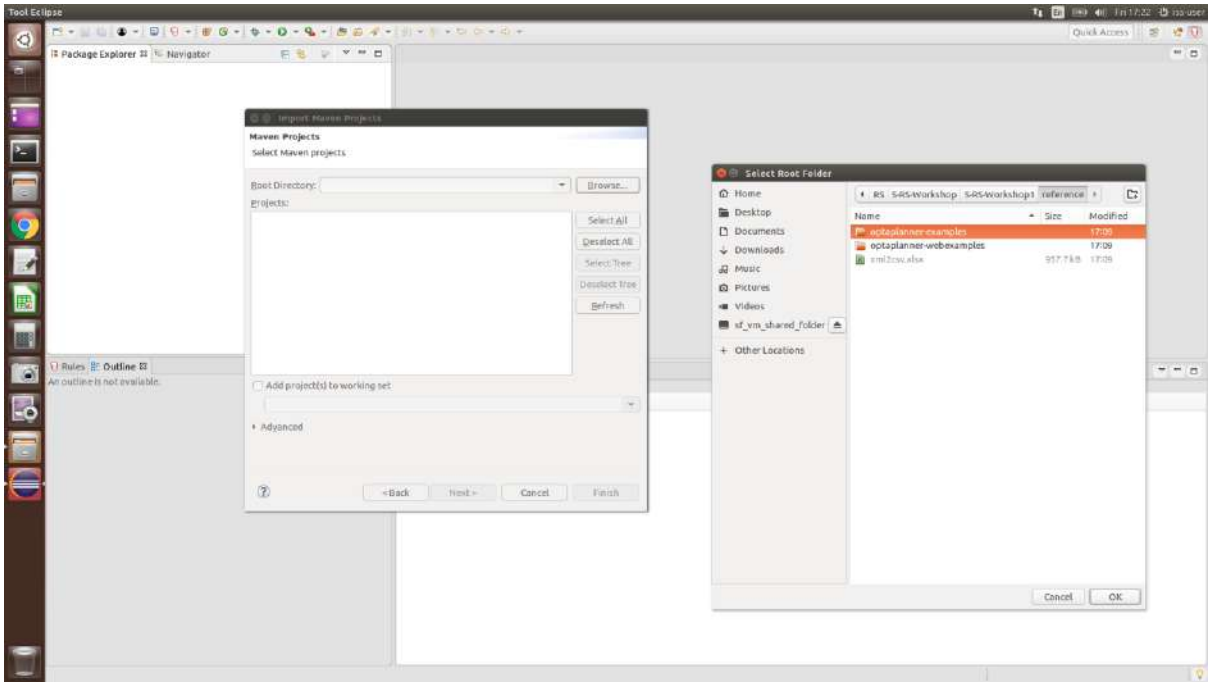
4) Select **Existing Maven Projects**; Click **Next**



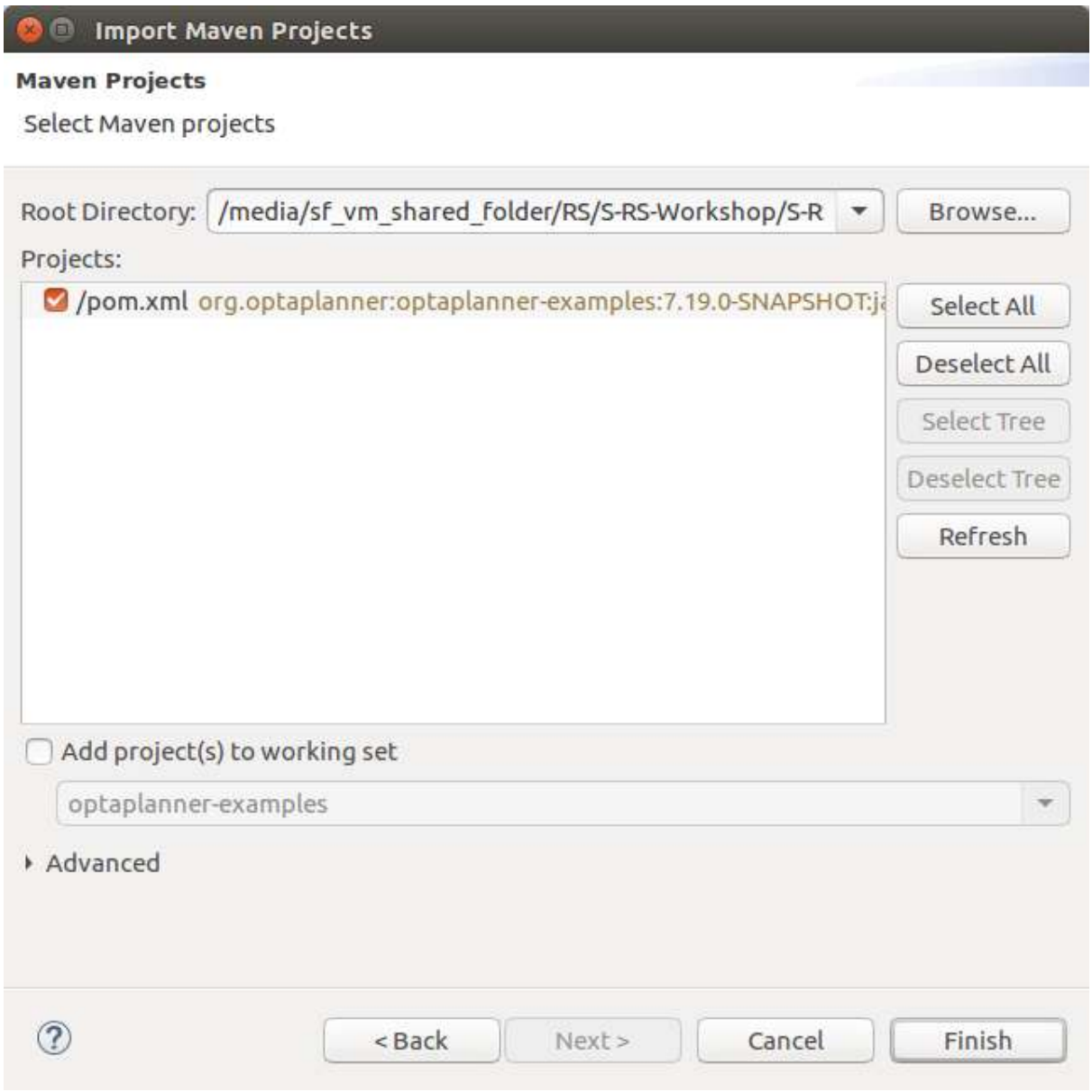
5) Click **Browse…**



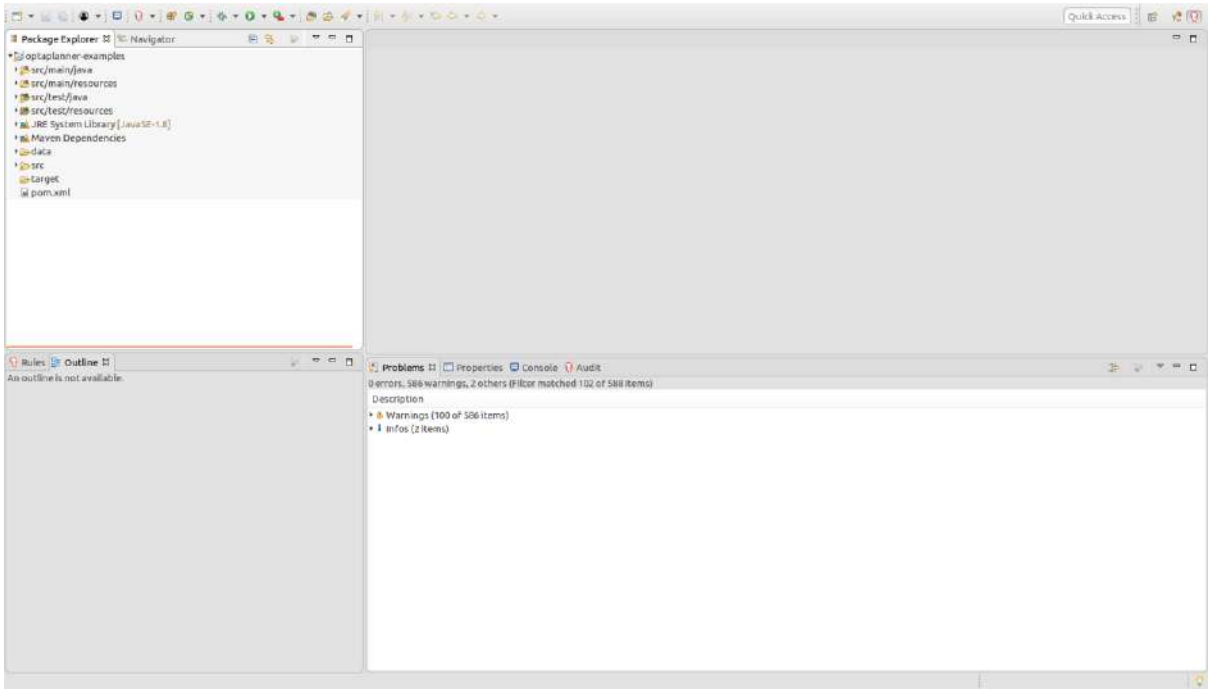
6) Browse to locate the **optaplanner-examples** sub-folder from downloaded workshop materials in local computer; Click **OK**
…/S-RS-Workshop/S-RS-Workshop1/reference/optaplanner-examples



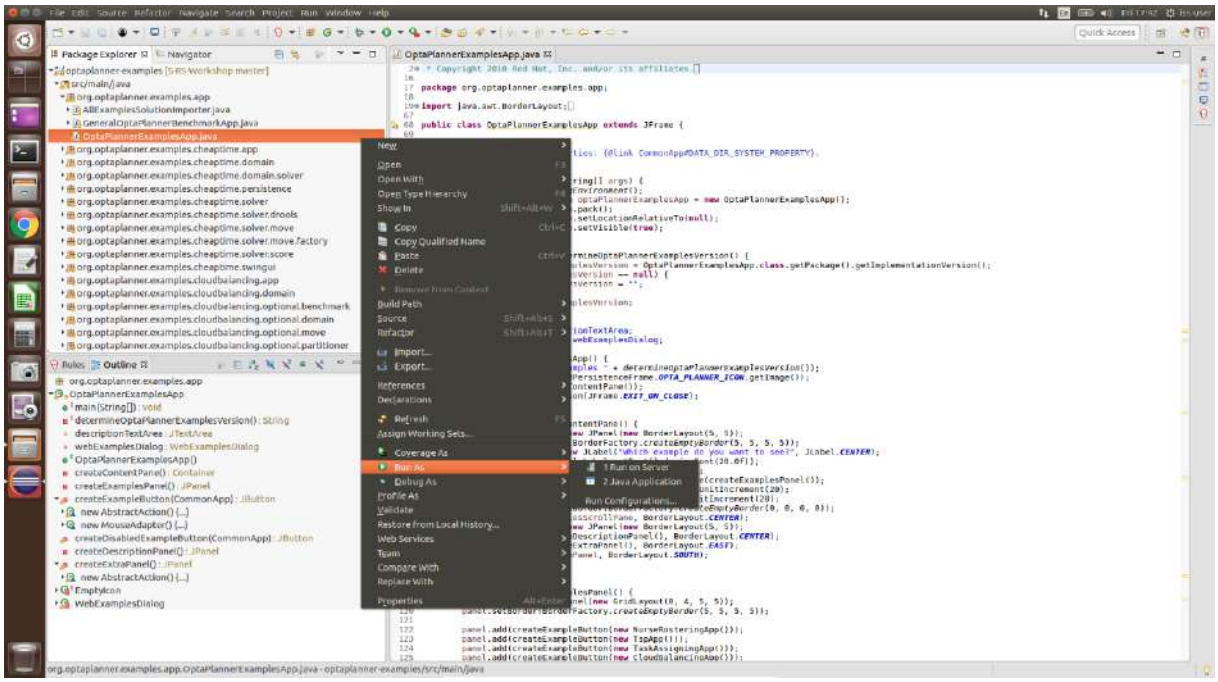
7) Click **Finish**.

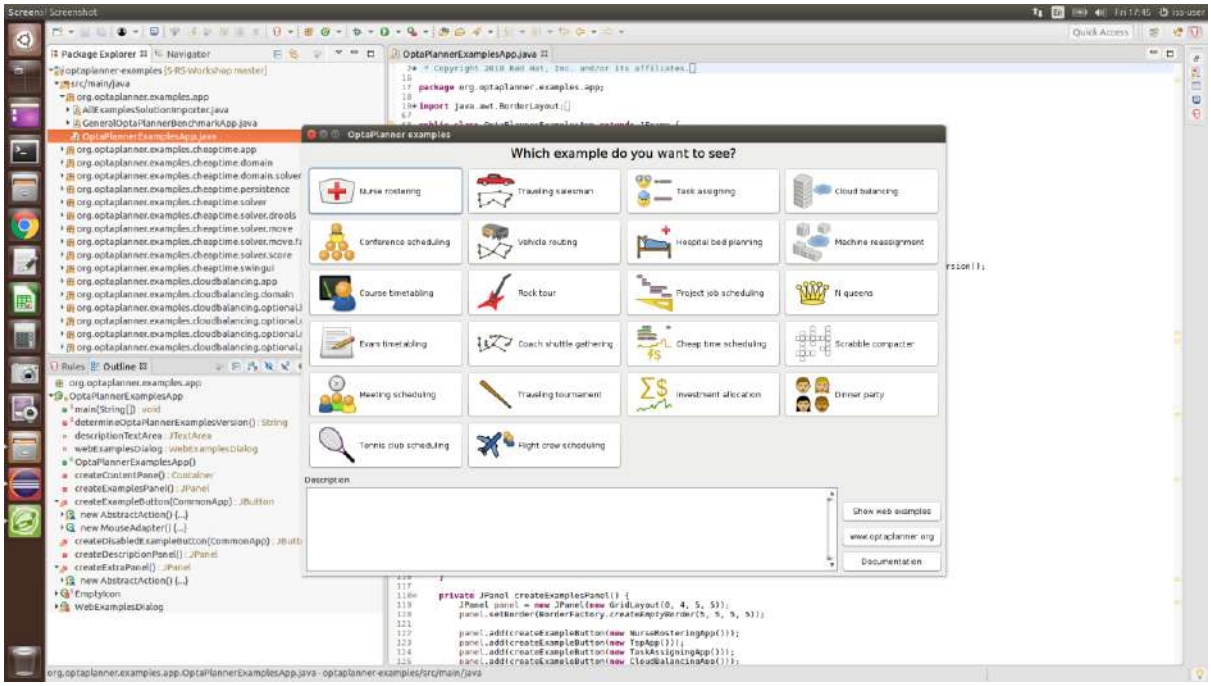


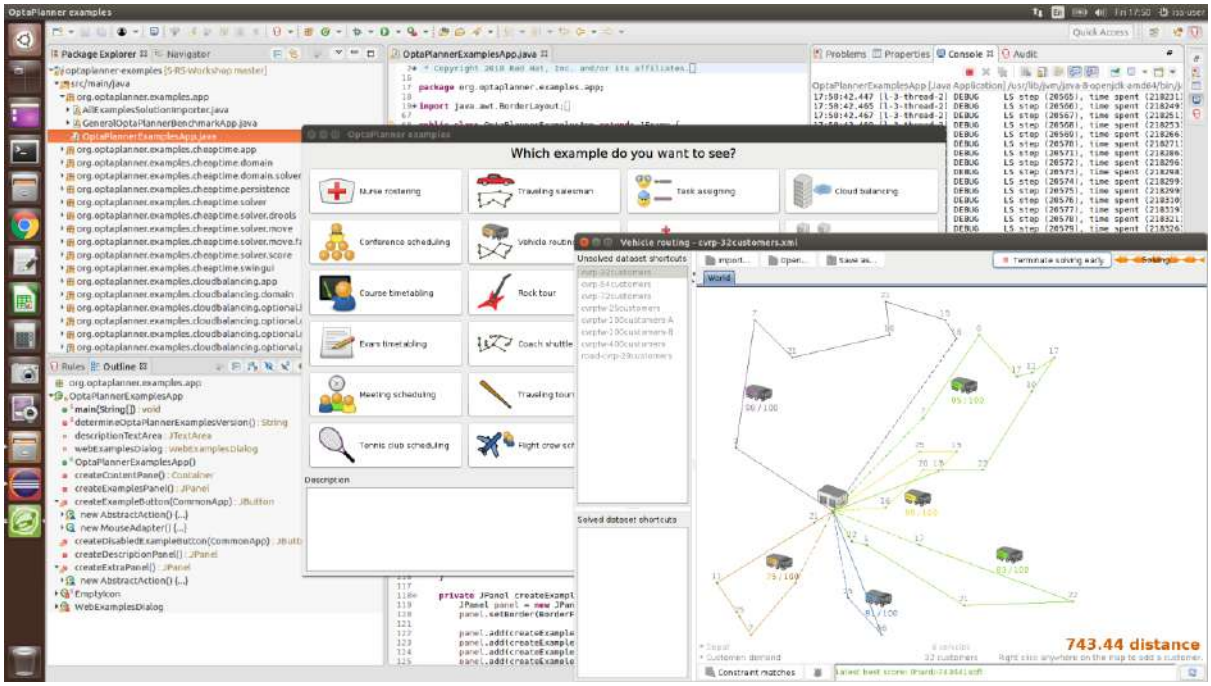
8) Wait for the completion of import;



9) Expand project to ***OptaPlannerExampleApp.java***; right click mouse to call menu; Select **Run As** : **2 Java Application**;







Now both **GUI binary version** and **Java source code version** have been running successfully! Thus further enhancements can be made in source code to build customized solutions for business resource optimization.

☺ Congratulations!

You have completed today's challenging workshop!

2. ANNEX

2.1. ANNEX 1 – Workshop Project Candidate

2.1.1. Workshop Project Candidate One

Hybrid Airport Gate Assignment System (HAGAS)

The Airport Gate Assignment Problem: Scheduling Algorithms and Simulation Approach

Ahmed Thanyan AL-Sultan

The rapid development of airlines has made airports busier and more complicated. The assignment of schedule to available gates is a major issue for daily airline operations. We consider the over-constrained airport gate assignment problem (AGAP) where the number of flights exceeds the number of available gates, and where the objectives are to minimize the number of ungated flights and the total walking distance or connection times. The procedures used in this project are to create a mathematical model formulation to identify decision variables to identify, constraints and objective functions. In addition, we will consider in the AGAP the size of each gate in the terminal and also the towing process for the aircraft. We will use a greedy algorithm and a Tabu search meta-heuristic to solve the problem and compare it with other scheduling methods. Actual and forecasted data will be simulated in the experiment. The greedy algorithm minimizes ungated flights while providing initial feasible solutions that allow flexibility in seeking good solutions, especially in case when flight schedules are dense in time. Experiments conducts give good results. The distance a passenger has to walk in any airport to reach various key areas, including departure gates, baggage belts and connecting flights provide for an important performance measure for the quality of any airport. While certain walking distances are fixed, others are dynamic. In particular, the distances traversed by passengers from check-in counters to gates and from gate to gate, in the case of transfer or connecting passengers, change according to how scheduled flights are assigned to gates. This allows for the ground handling agents and airlines, together with airport authorities, to dynamically assign airport gates to scheduled flights so as to minimize walking distances while, consequently, minimizing connection times. Which flight to gate assignment policy to be used so as to achieve such minimum times can be derived at the start of such planning day based on published flights schedules and booked passenger loads. The airport gate assignment problem (AGAP) seeks to find

feasible flight to gate assignments so that total passenger connection times and walking distances is minimized. Distances that are taken into account are those from check-in to gates in the case of embarking or originating passengers, from gates to baggage claim areas (check-out) in the case of disembarking or destination passengers and from gate to gate in the case of transfer or connecting passengers. In the over-constrained case, where the number of aircraft exceeds the number of available gates, we include the distance from the apron or tarmac area to the terminal for aircraft assigned to these areas.

...

Reference

The Airport Gate Assignment Problem: Scheduling Algorithms and Simulation Approach, Ahmed Thanyan AL-Sultan, Graduate School of environmental science, March 2012

http://ousar.lib.okayama-u.ac.jp/files/public/4/48534/20160528091554614463/K0004584_honbun.pdf

2.1.2. Workshop Project Candidate Two

OptaPlanner Application Implementation in KIE Workbench & Server

Objective:

Construct a useful business reasoning system using KIE product suite, incorporating an OptaPlanner solver as an embedded optimization engine/task for automated machine reasoning.

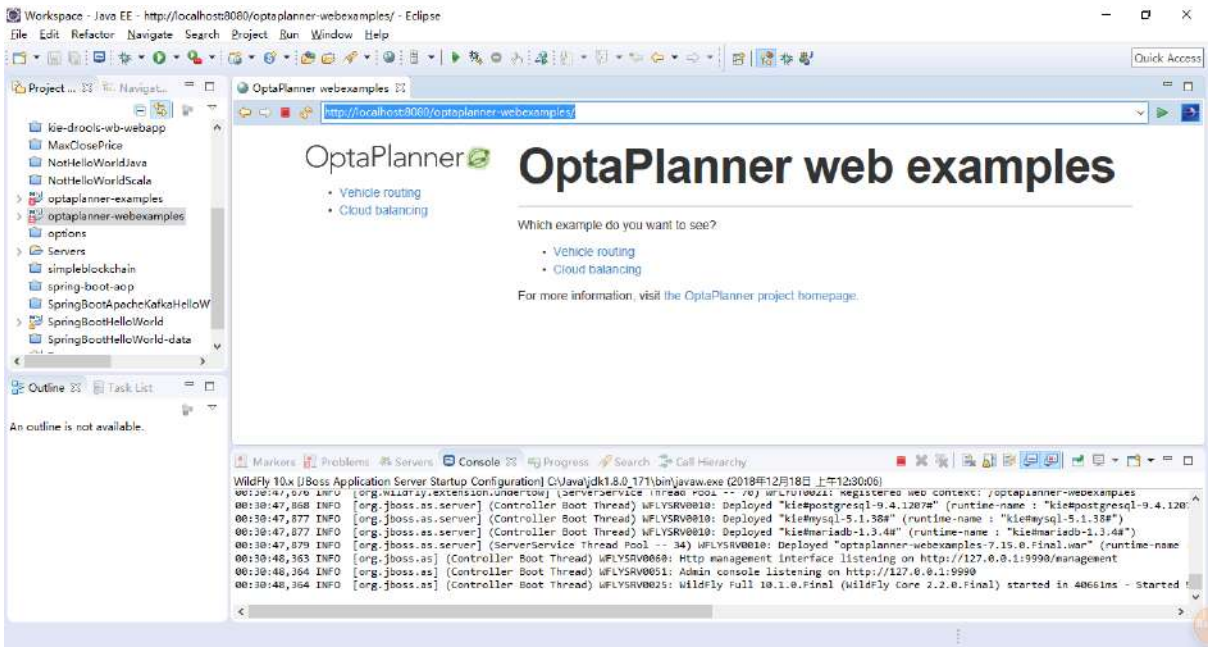
Source new problem **or** choose one OptaPlanner example application from below:

- Cloud balancing
- Course timetabling
- Vehicle routing with time windows
- Project job scheduling
- Exam timetabling
- Nurse rostering
- Cheap time scheduling
- Flight crew scheduling

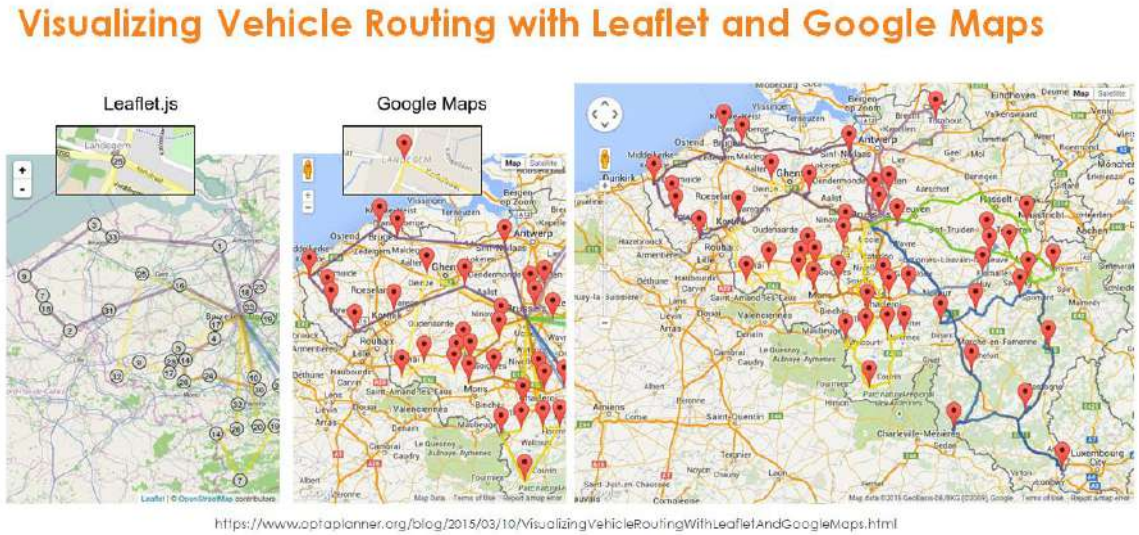
System Requirements:

- Make use of KIE BRMS (Drools) & BPMS (jBPM) capability;
- Define at least one practical business enhancement/requirement based on OptaPlanner example;
- Convert/migrate original Maven/Eclipse OptaPlanner project with enhancements into KIE (jBPM) Workbench project;
- Develop an extensive (web-based) User Interface; Enable configuration of business parameters, e.g. number of cloud computers, number of CPUs per computer, etc.
- Use Restful API between User Interface and KIE Server;
- Deploy the developed system onto KIE Server for use;

OptaPlanner web examples



Above: example web applications



index.jsp | leaflet.jsp | VehicleRoutingSolver... | DefaultVehicleRouting... | VehicleRoutingRestSe...

```
/**
 * @see DefaultVehicleRoutingRestService
 */
@Path("/vehiclerouting")
public interface VehicleRoutingRestService {

    @GET
    @Path("/solution")
    @Produces("application/json")
    JsonVehicleRoutingSolution getSolution();

    @POST
    @Path("/solution/solve")
    @Produces("application/json")
    JsonMessage solve();

    @POST
    @Path("/solution/terminateEarly")
    @Produces("application/json")
    JsonMessage terminateEarly();
```

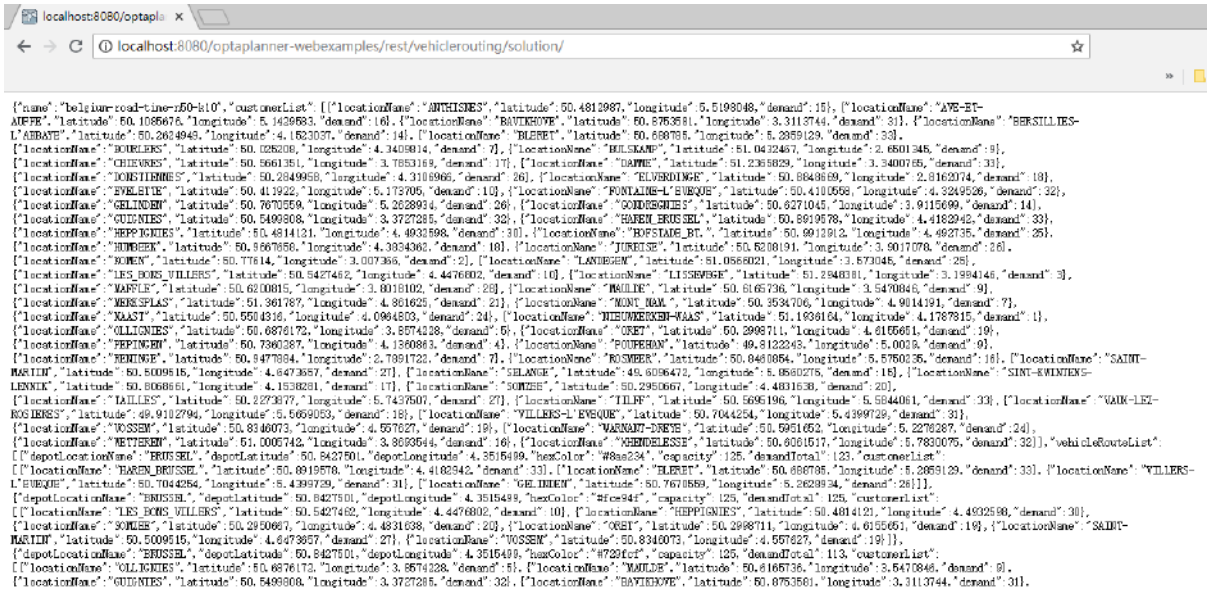
Above: example KIE server interaction via RESTful API

index.jsp | leaflet.jsp | VehicleRoutingSolver... | DefaultVehicleRouting... | VehicleRoutingRestSe... | CloudB

```
};

loadSolution = function() {
  $.ajax({
    url: "<%=application.getContextPath()%>/rest/vehiclerouting/solution",
    type: "GET",
    dataType : "json",
    success: function(solution) {
      var markers = [];
      $.each(solution.customerList, function(index, customer) {
        var customerIcon = L.divIcon({
          iconSize: new L.Point(20, 20),
          className: "vehicleRoutingCustomerMarker",
          html: "<span>" + customer.demand + "</span>"
        });
        var marker = L.marker([customer.latitude, customer.longitude], {icon: customerIcon});
        marker.addTo(map).bindPopup(customer.locationName + "</br>Deliver " + customer.demand + " items.");
        markers.push(marker);
      });
      map.fitBounds(L.featureGroup(markers).getBounds());
    }, error : function(jqXHR, textStatus, errorThrown) {ajaxError(jqXHR, textStatus, errorThrown)}
  });
};
```

Above: example server end point



{"name":"belgium-road-time-n50-k10","customerList":[{"locationName":"ANTHISNES","latitude":50.4812987,"longitude":5.5198048,"demand":15},{"locationName":"AYE-ET-AUFFE","latitude":50.1085676,"longitude":5.1429583,"demand":16},{"locationName":"BAVIKHOVE","latitude":50.8763581,"longitude":3.3113744,"demand":8},{"locationName":"BERSILLIES-L'ABBAYE","latitude":50.2624949,"longitude":4.1523037,"demand":14},{"locationName":"BLERET","latitude":50.686785,"longitude":5.2859129,"demand":33},
{"locationName":"BOURLERS","latitude":50.025208,"longitude":4.3409814,"demand":7},{"locationName":"BULSKAMP","latitude":51.0432467,"longitude":2.6501345,"demand":9},
{"locationName":"CHIEVRES","latitude":50.5661351,"longitude":3.7853169,"demand":17},{"locationName":"DAVRE","latitude":51.2365829,"longitude":3.3400765,"demand":33},
{"locationName":"DONSTIENNES","latitude":50.2849958,"longitude":4.3108966,"demand":26},{"locationName":"ELVERDINGE","latitude":50.8648669,"longitude":2.8162074,"demand":18},
{"locationName":"EVELETTE","latitude":50.411922,"longitude":5.173705,"demand":10},{"locationName":"FONTAINE-L'EVEQUE","latitude":50.4100568,"longitude":4.3249526,"demand":32},
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Above: example solution enquiry via RESTful API

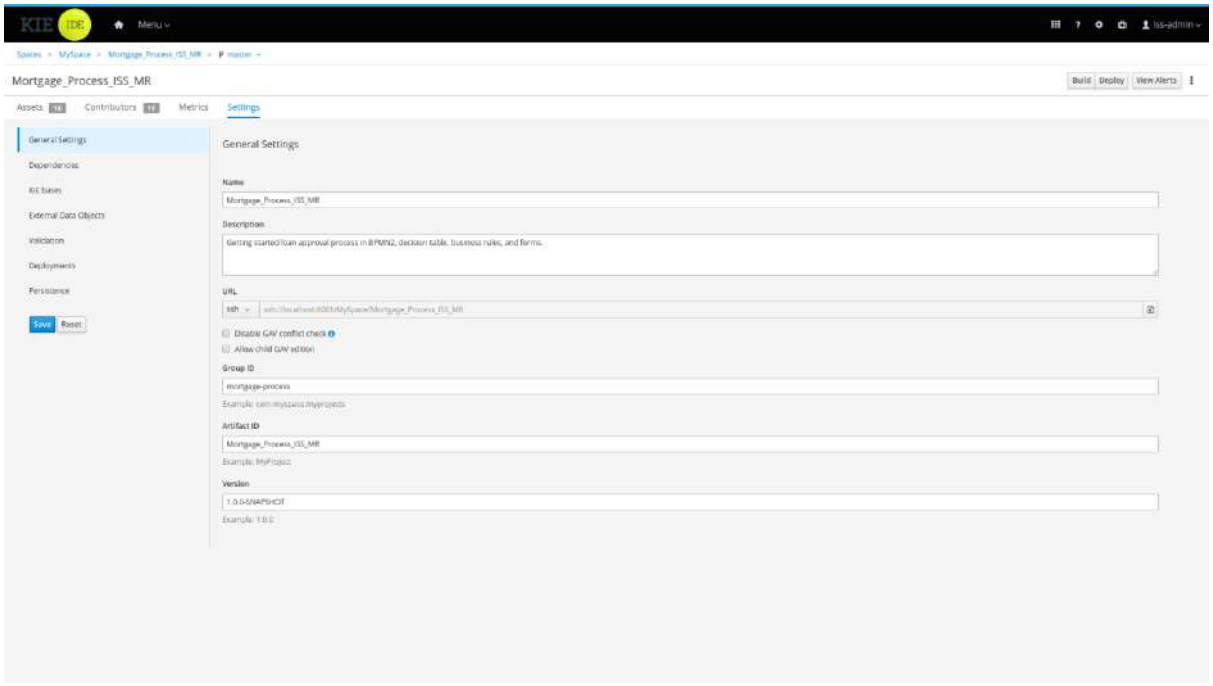
Reference

- https://github.com/kiegroup/optaplanner/tree/master/optaplanner-webexamples
- https://docs.optaplanner.org/latest/optaplanner-docs/html_single/index.html#quickStart

2.2. ANNEX 2 – Project Code Export & Import Using KIE Workbench

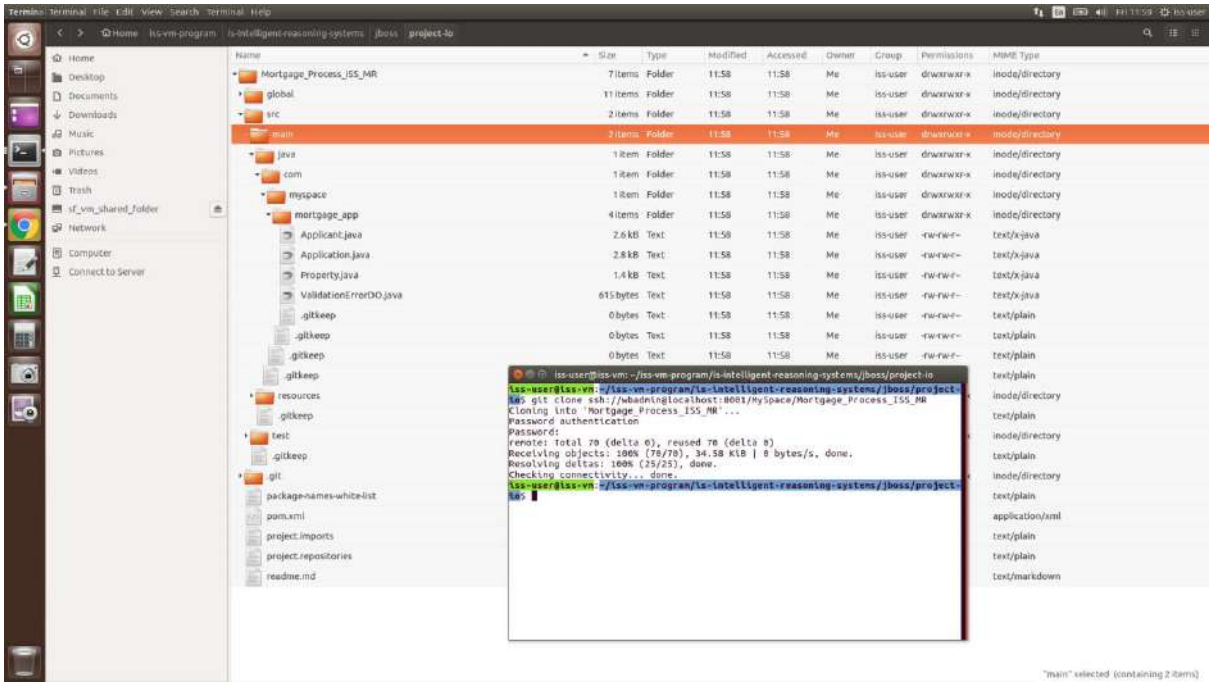
Example: export KIE project ***Mortgage_Process_ISS_MR*** from work space ***MySpace***

Review project settings to obtain project URL link



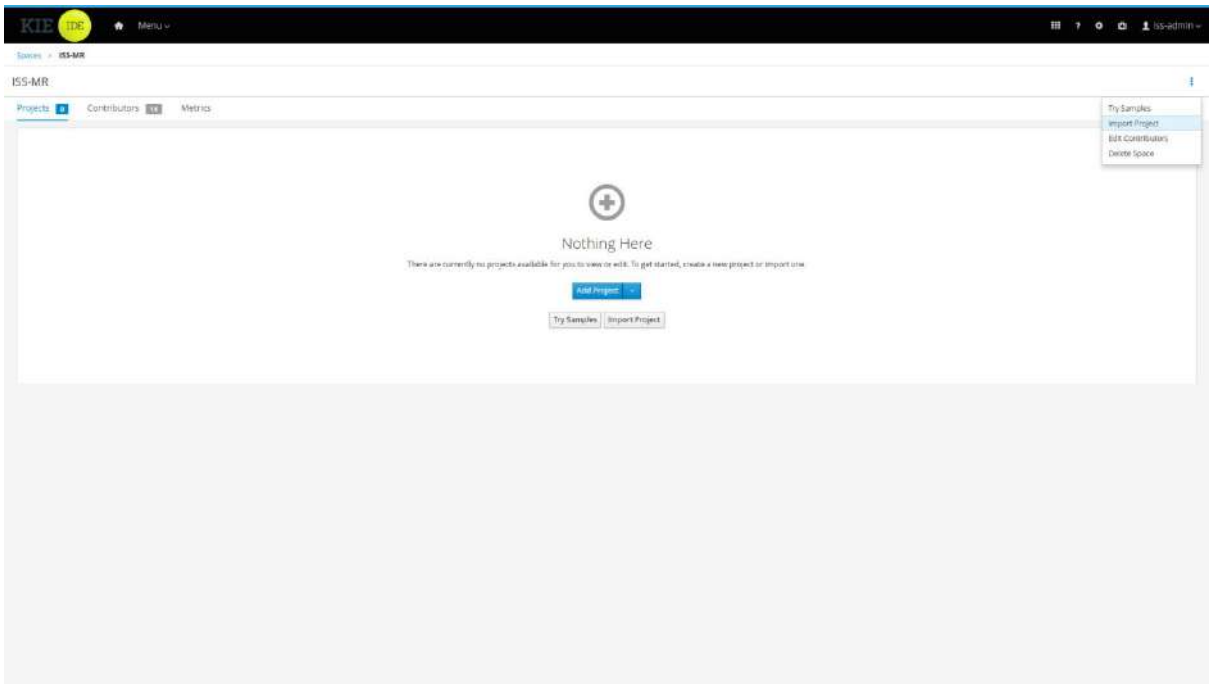
2.2.1. Export project from KIE Workbench

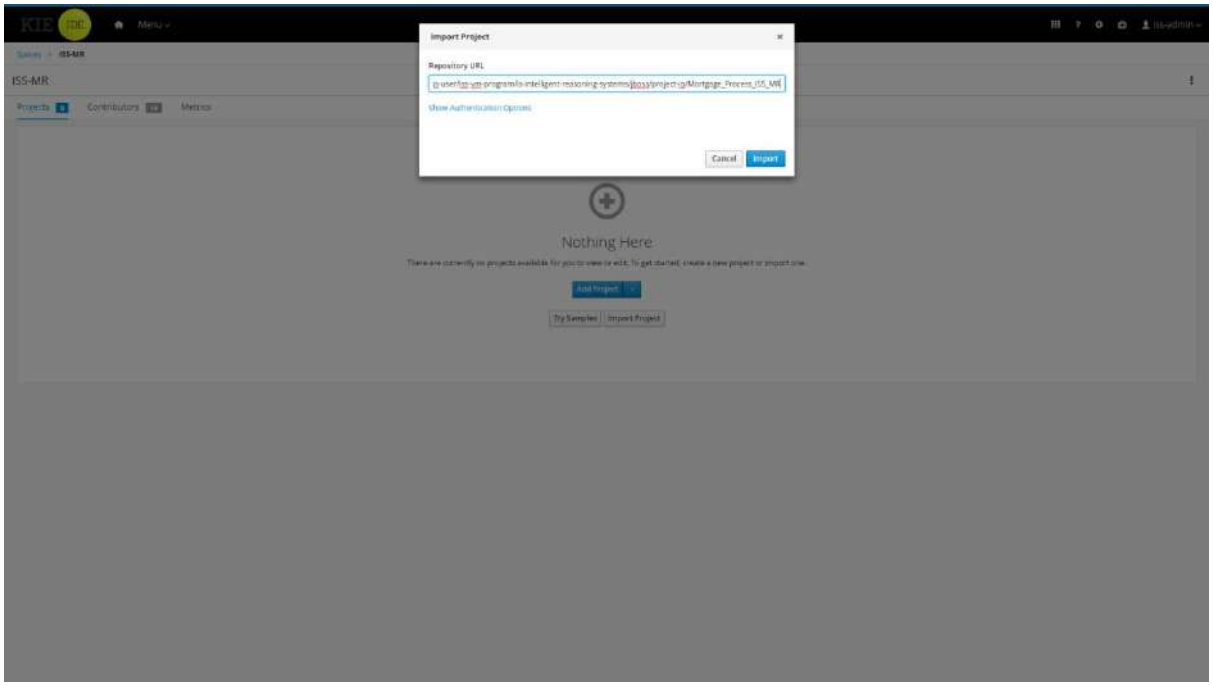
1) Select a folder for exporting, example here uses ***/home/iss-user/iss-vm-program/is-intelligent-reasoning-systems/jboss/project-io***
2) Start a Terminal there, key in command ***git clone ssh://wbadmin@localhost:8001/MySpace/Mortgage_Process_ISS_MR***
3) Key in password '***wbadmin***' for user wbadmin

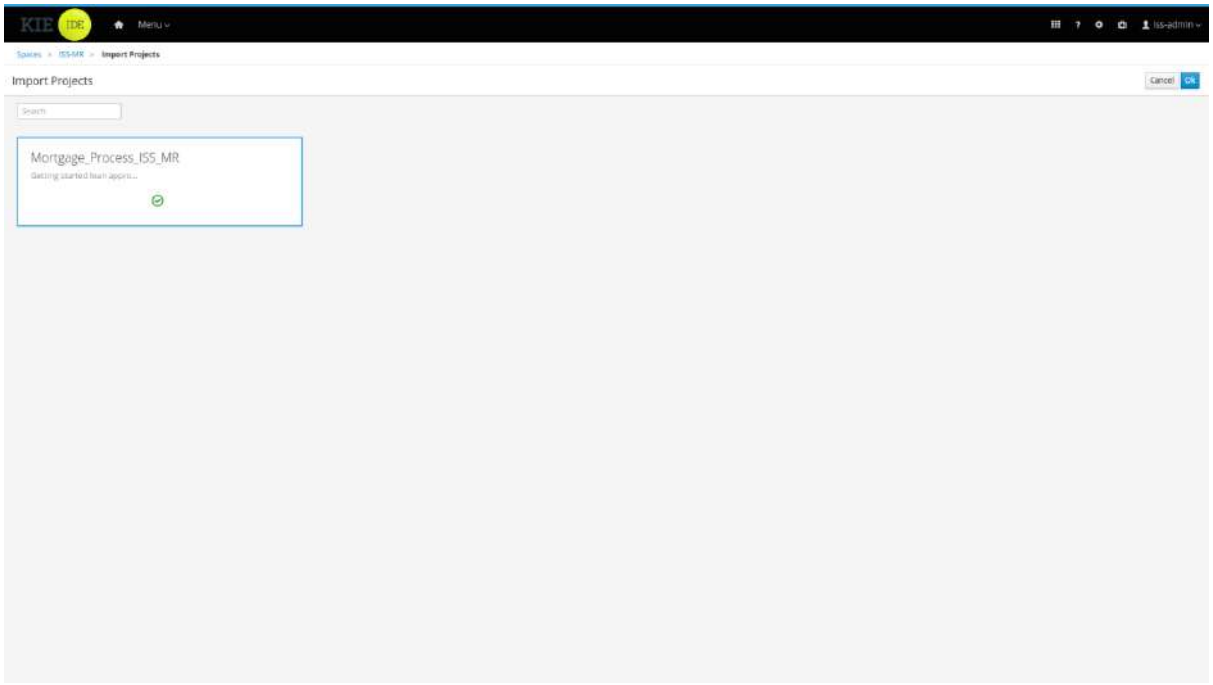


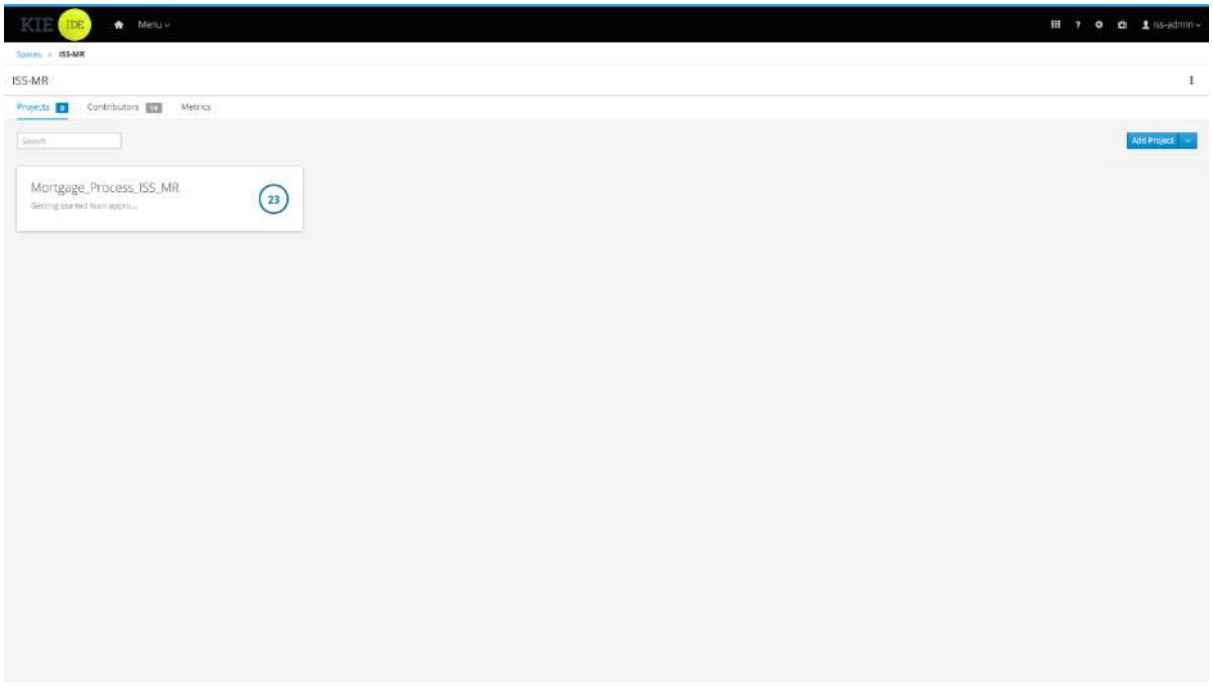
2.2.2. Import project into KIE Workbench

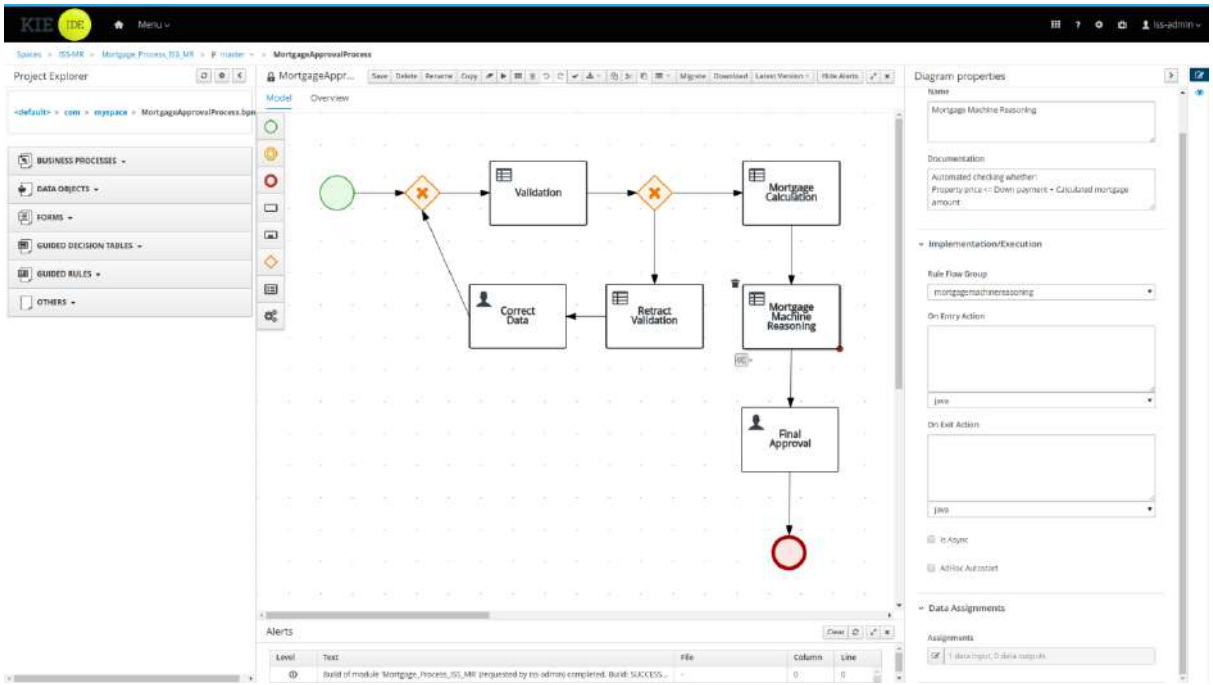
1) In KIE workbench, select/create a project Space, example here uses ***ISS-MR***
2) Click menu function '***Import Project***'
3) For Repository URL, key in **file:///*/home/iss-user/iss-vm-program/is-intelligent-reasoning-systems/jboss/project-io/Mortgage_Process_ISS_MR***




Import Project
Repository URL
Cancel
Import
Nothing Here


Import Projects
Cancel
Ok
Mortgage_Process_ISS_MR





Reference

https://developer.jboss.org/thread/269991

https://developer.jboss.org/thread/237411

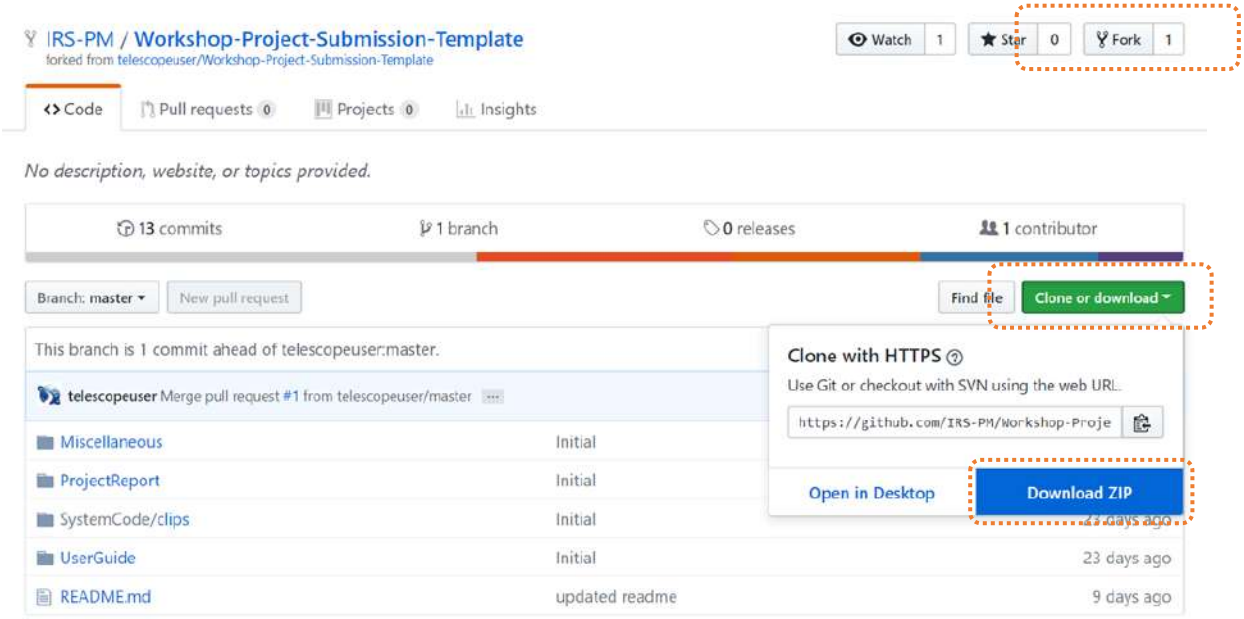
https://developer.jboss.org/thread/252588

2.3. ANNEX 3 – Workshop Project Submission

1) Create Github repository for project submission;
2) Download Github repository as a ZIP file, then upload to NUS LumiNUS;

Reference

https://github.com/IRS-PM/Workshop-Project-Submission-Template

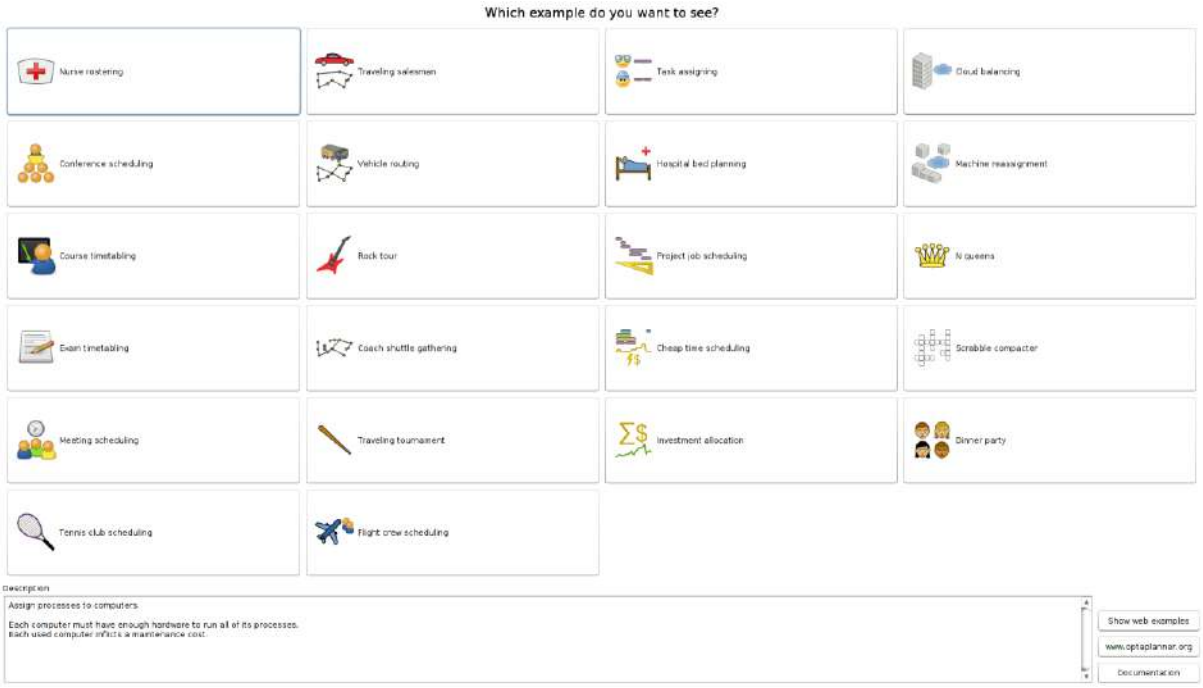


{ Tips } Workshop Project Submission Template: Github Repository & Zip File

[Naming Convention] CourseCode-StartDate-BatchCode-Group_or_Individual-TeamName_or_PersonName-ProjectName.zip

- [MTech Group Project Naming Example] IRS-MR-2019-01-19-IS1PT-GRP-AwsomeSG-HDB_BTO_Recommender.zip
- [MTech Individual Project Naming Example] IRS-MR-2019-07-01-IS1FT-IND-SamGuZhan-HDB_BTO_Process.zip
- [EEP Group Project Naming Example] IRS-MR-2019-03-13-EEP-GRP-AwsomeSG-HDB_BTO_Recommender.zip
- [EEP Individual Project Naming Example] IRS-MR-2019-08-22-EEP-IND-SamGuZhan-HDB_BTO_Process.zip

2.4. ANNEX 4 – KIE OptaPlanner Examples



Reference

https://docs.optaplanner.org/latest/optaplanner-docs/html_single/index.html#useCasesAndExamples

ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Dinner Party

- **Business Scenario / Problem Description**
- **Miss Manners is throwing another dinner party.**
  - This time she invited 144 guests and prepared 12 round tables with 12 seats each.
  - Every guest should sit next to someone (left and right) of the opposite gender.
  - And that neighbour should have at least one hobby in common with the guest.
  - At every table, there should be two politicians, two doctors, two socialites, two coaches, two teachers and two programmers.
  - And the two politicians, two doctors, two coaches and two programmers should not be the same kind at a table.

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ANNEX 4 : KIE OPTAPLANNER EXAMPLES

Exercise: Draw Class Diagram

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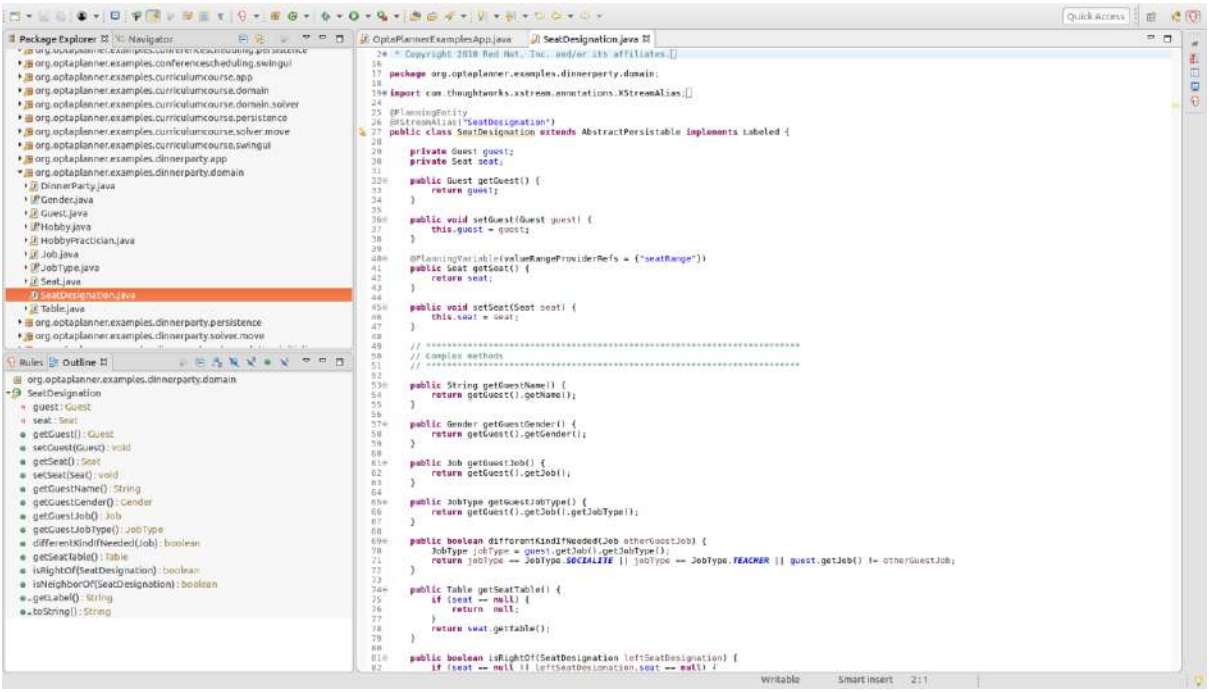

ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Tennis Club Scheduling

- **Business Scenario / Problem Description**
- **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.

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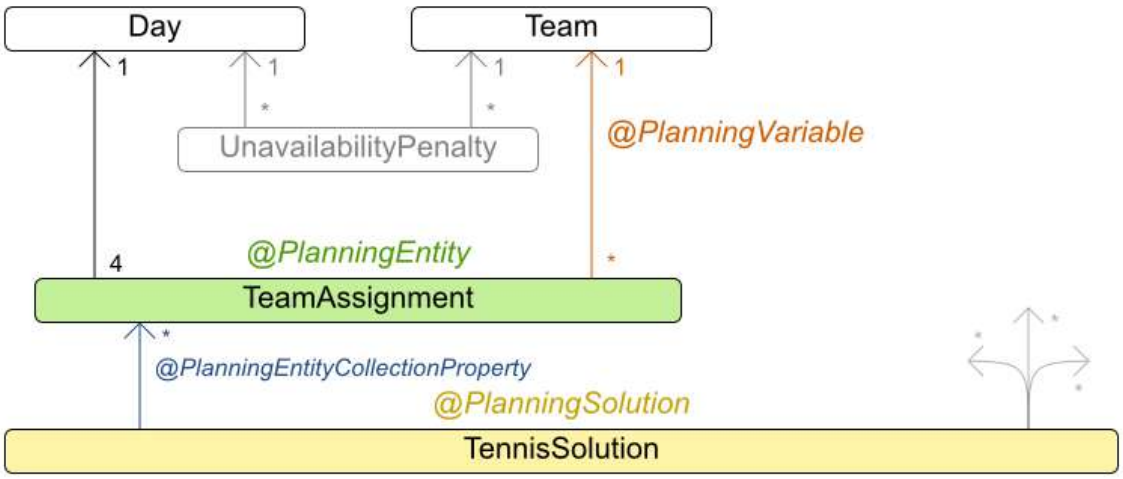
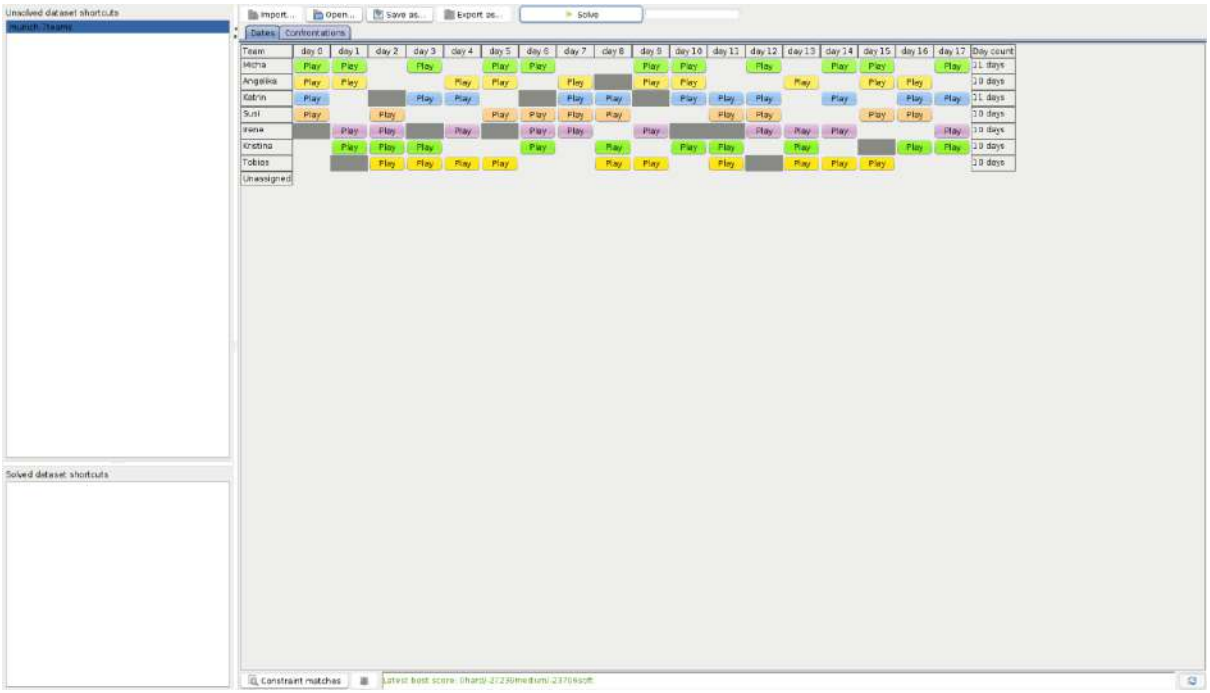
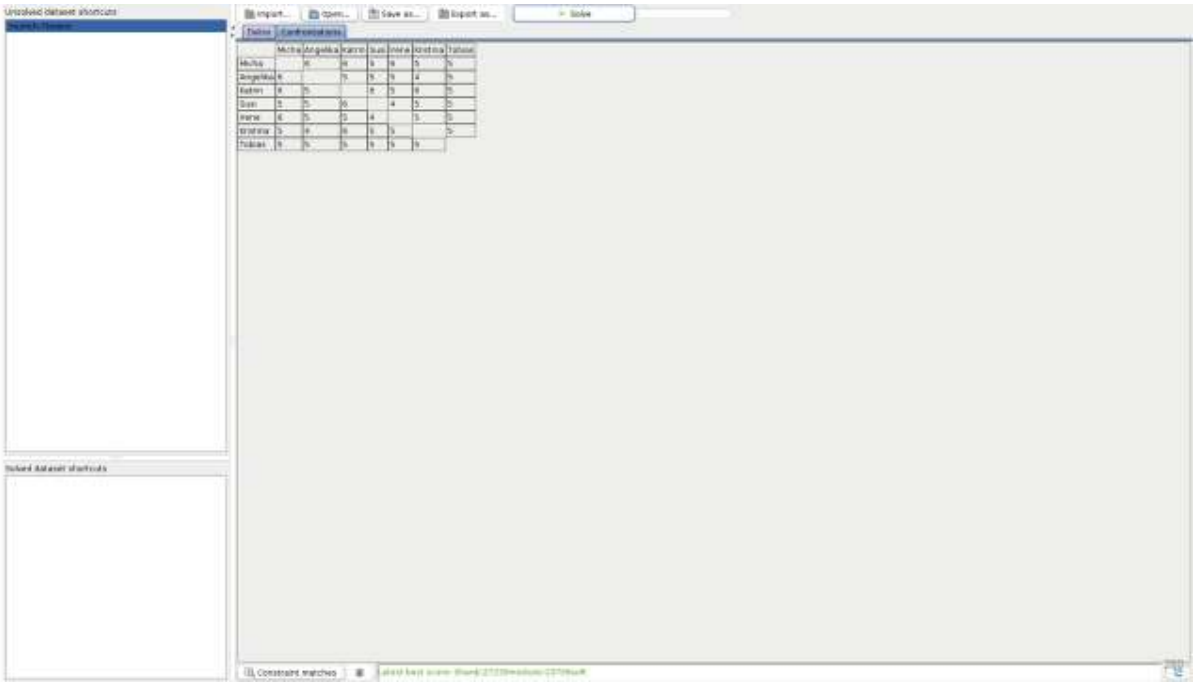
Tennis class diagram







ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Meeting Scheduling

- **Business Scenario / Problem Description**
- **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.

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ANNEX 4 : KIE OPTAPLANNER EXAMPLES

Exercise: Draw Class Diagram

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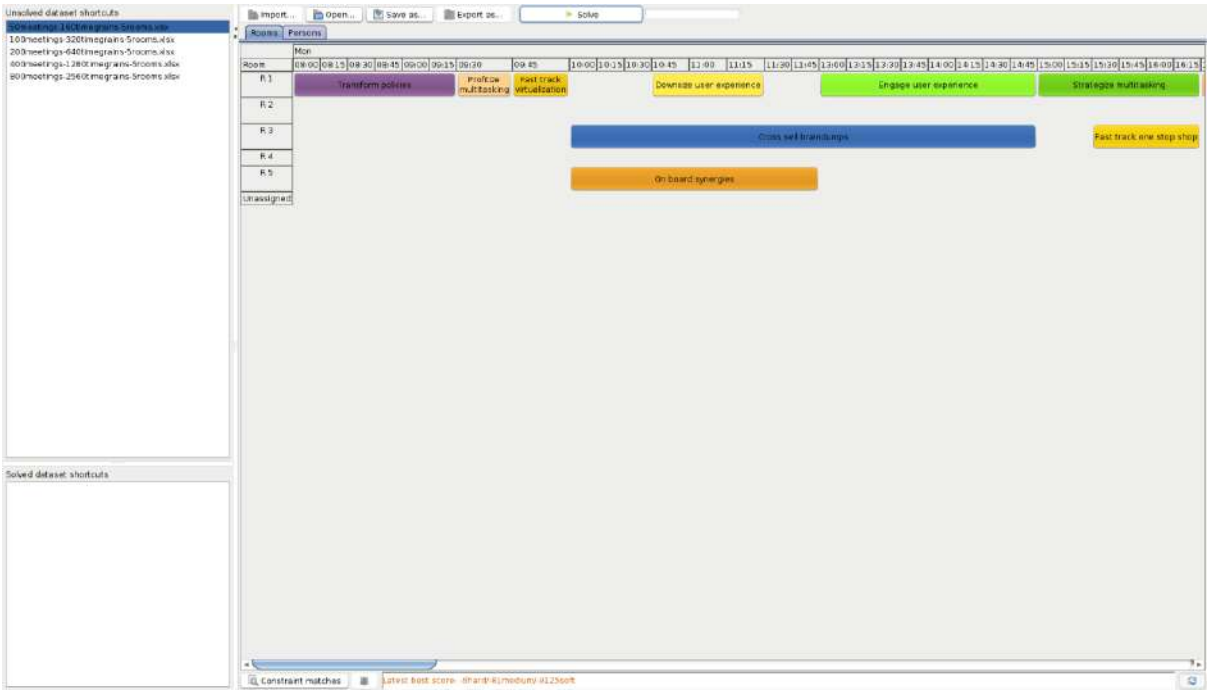

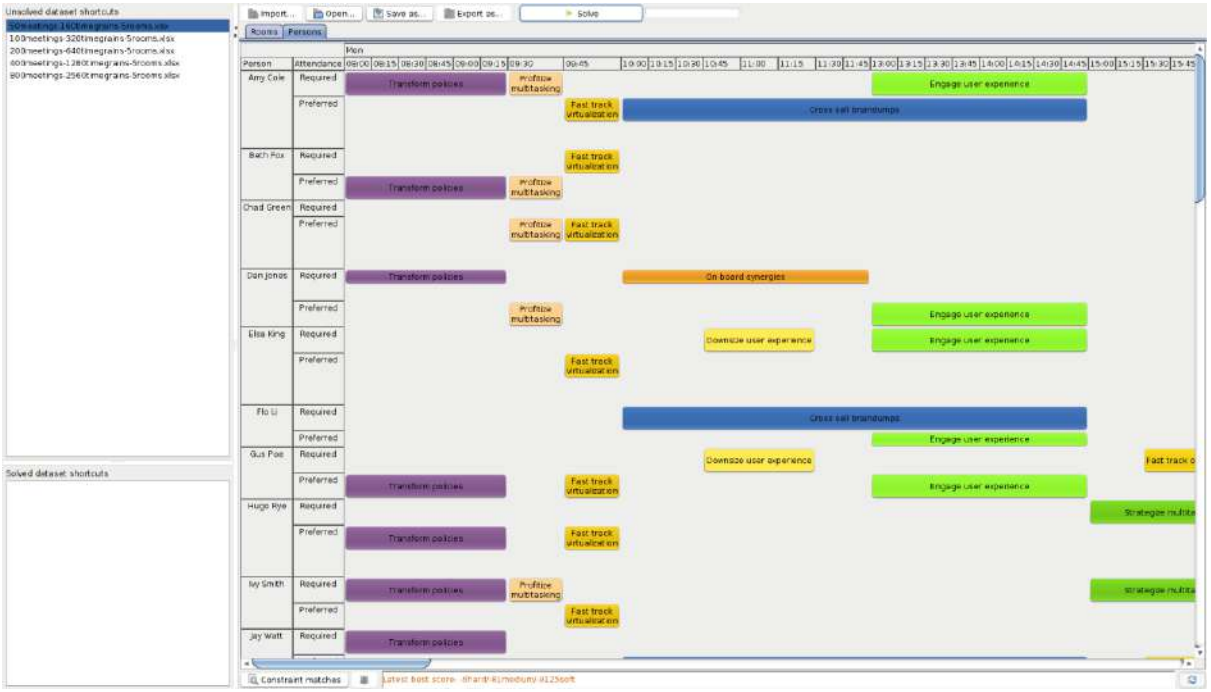

ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Curriculum Course Scheduling

- **Business Scenario / Problem Description**
- **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.**
  http://www.cs.qub.ac.uk/itc2007/curriculmcourse/course_curriculm_index.htm

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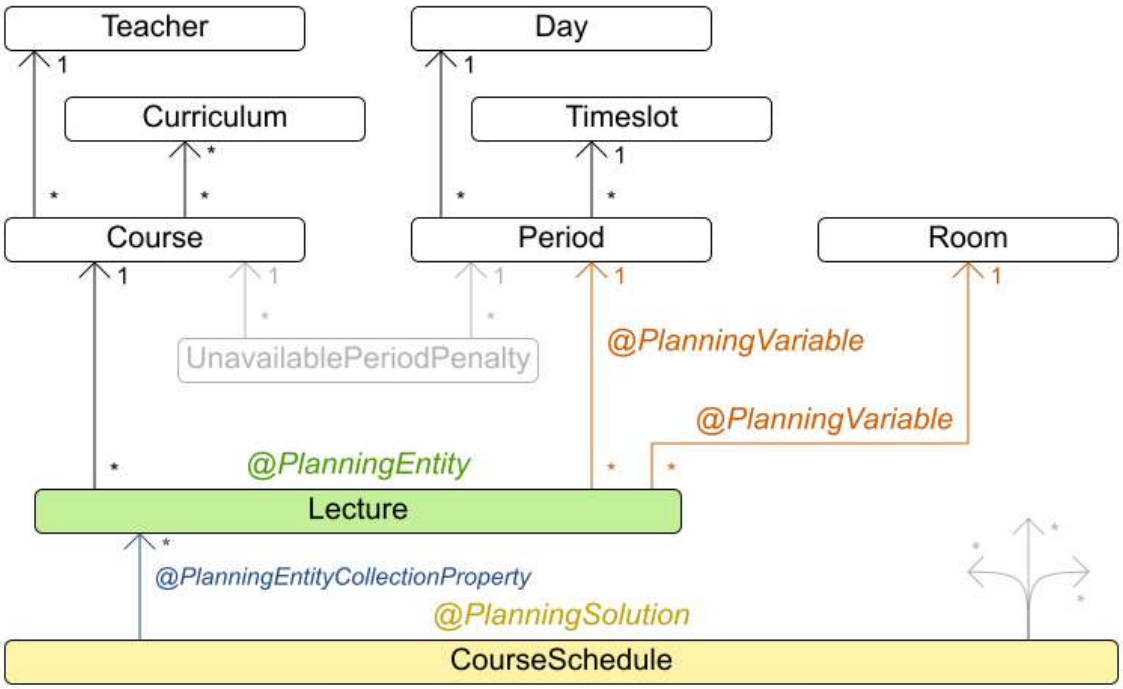
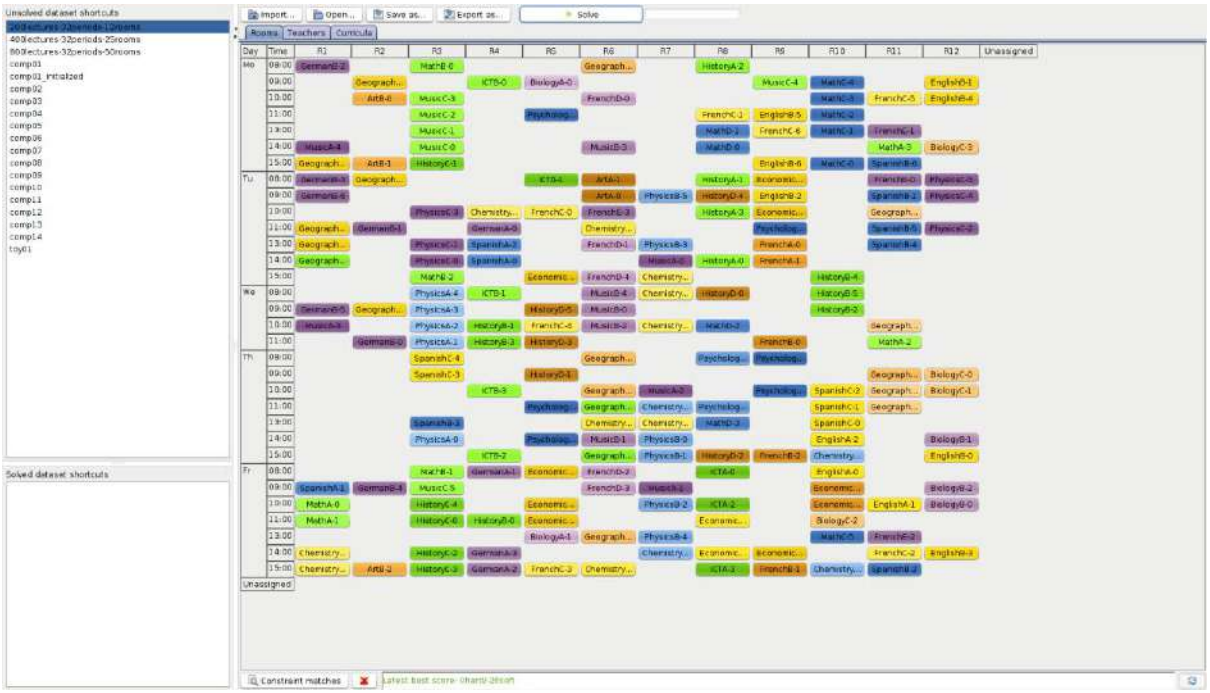
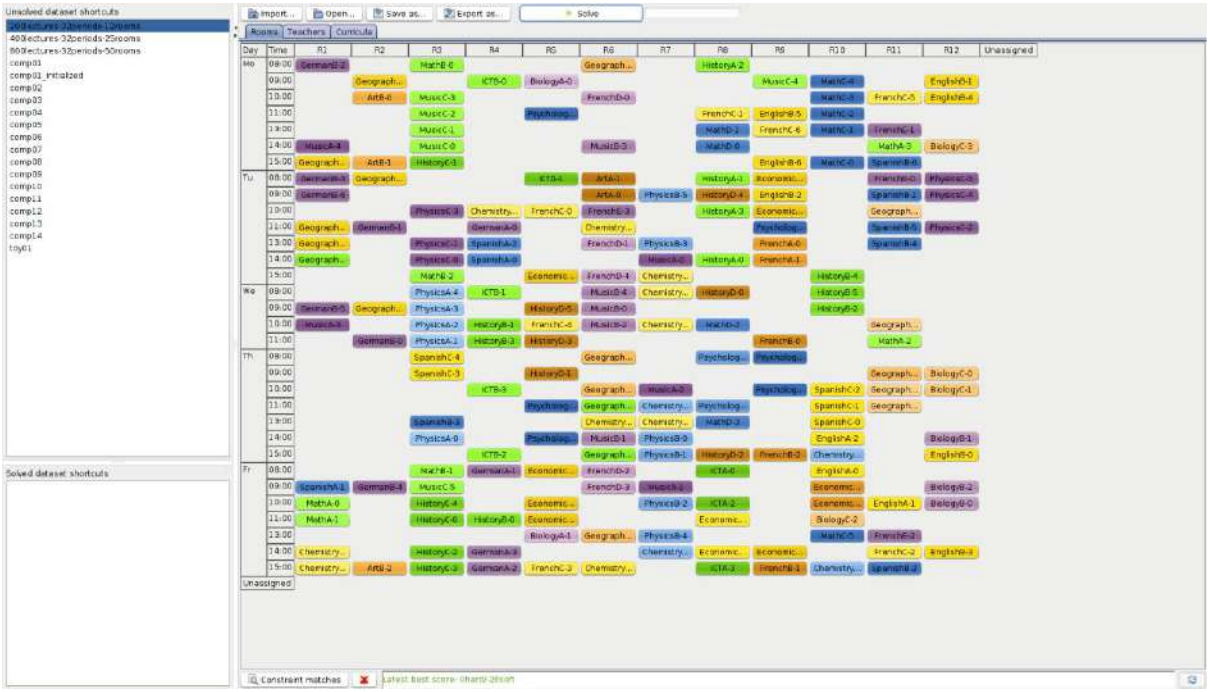
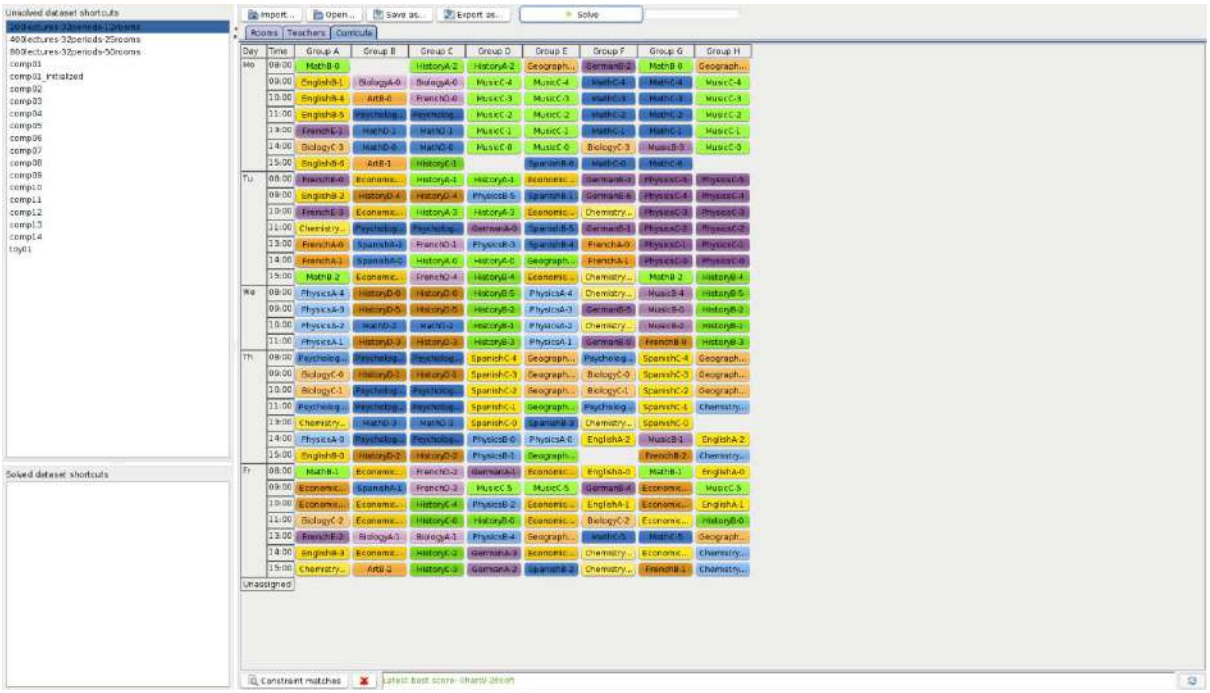
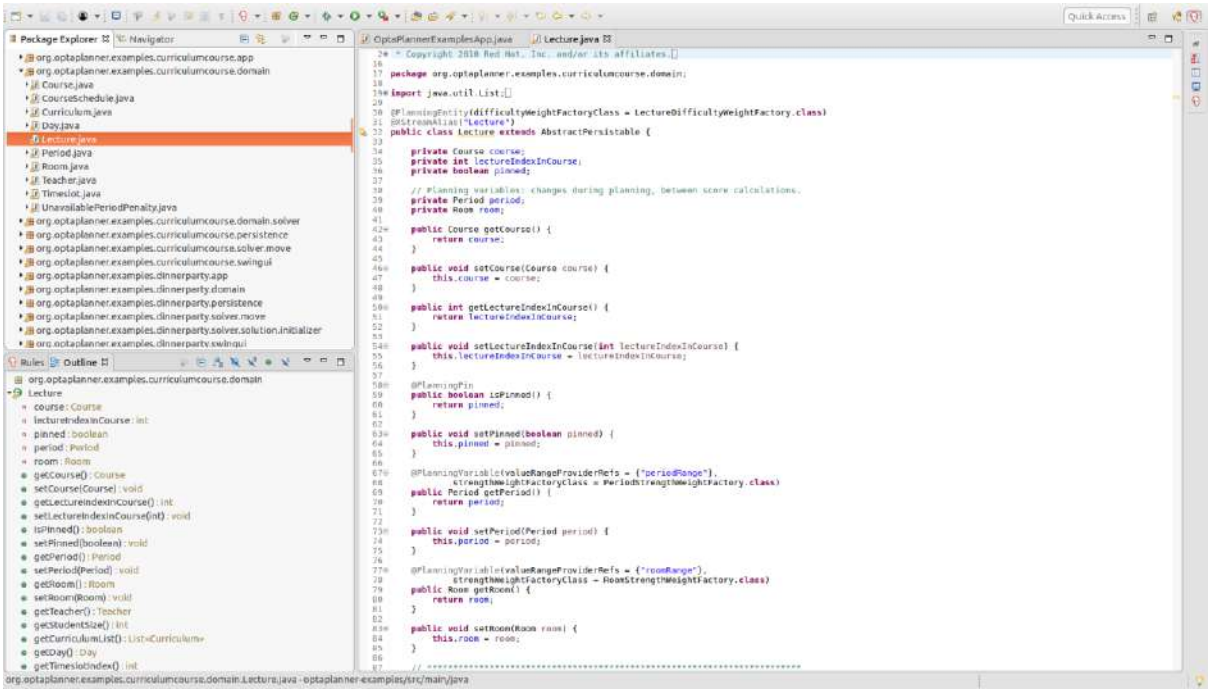
Curriculum course class diagram











ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Machine Reassignment

- **Business Scenario / Problem Description**
- 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, 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.**

http://challenge.roadef.org/2012/en/

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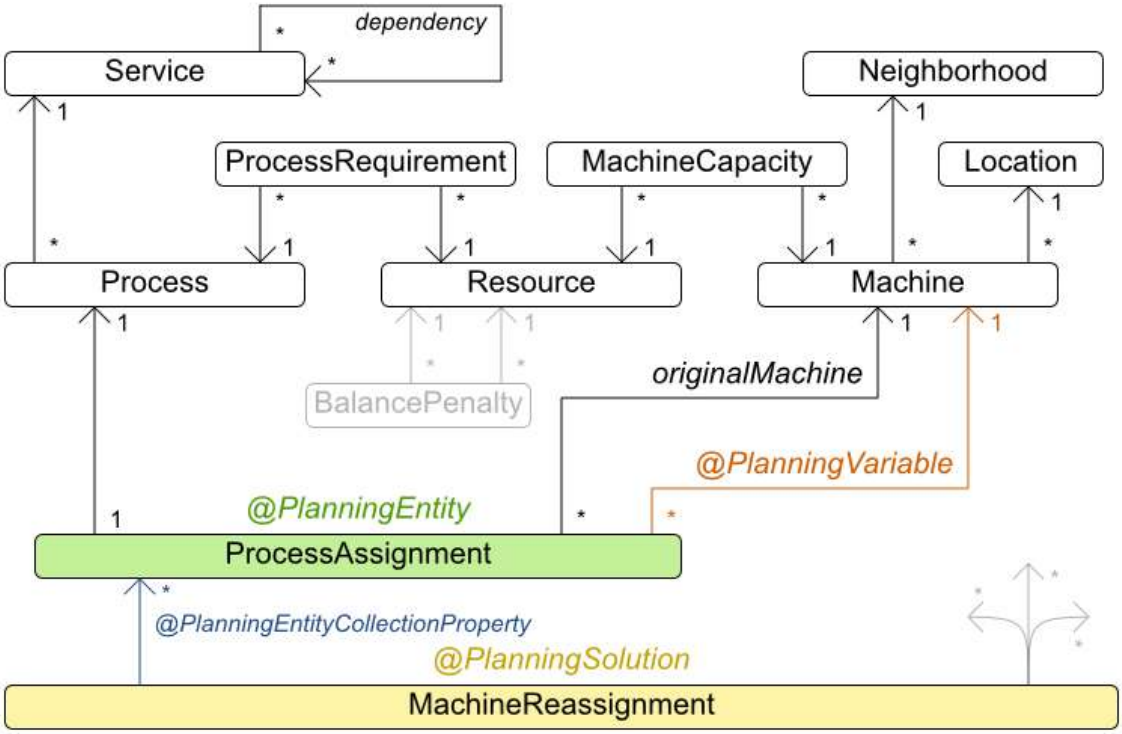
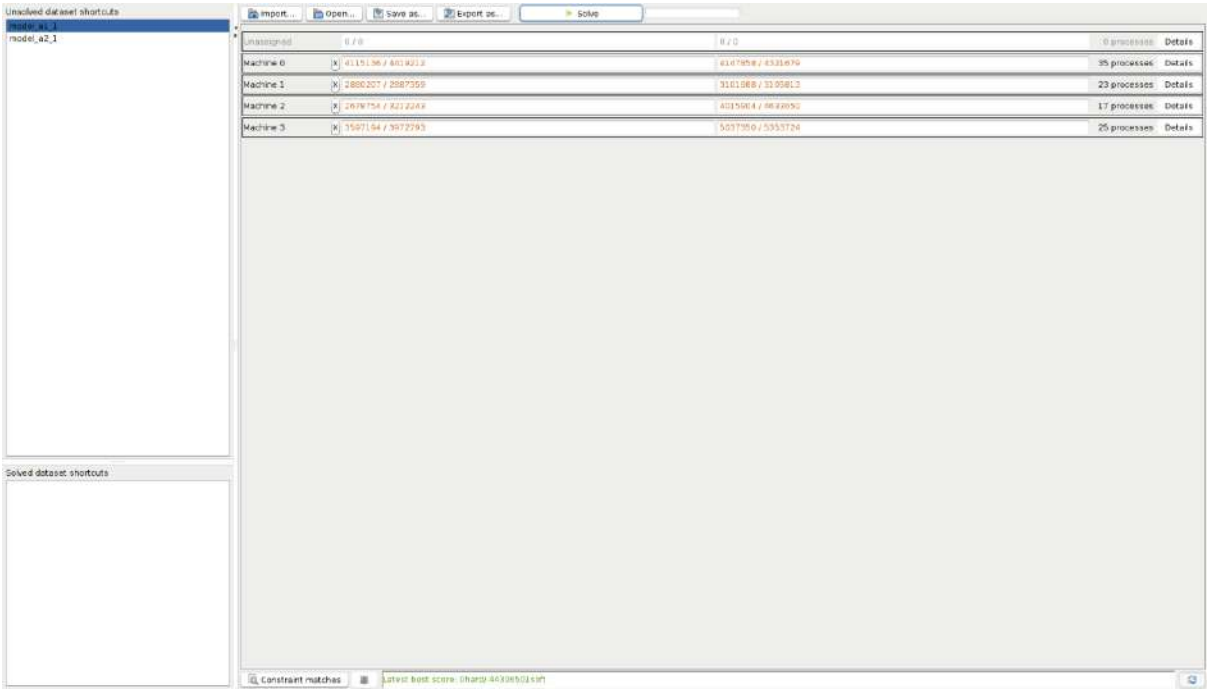
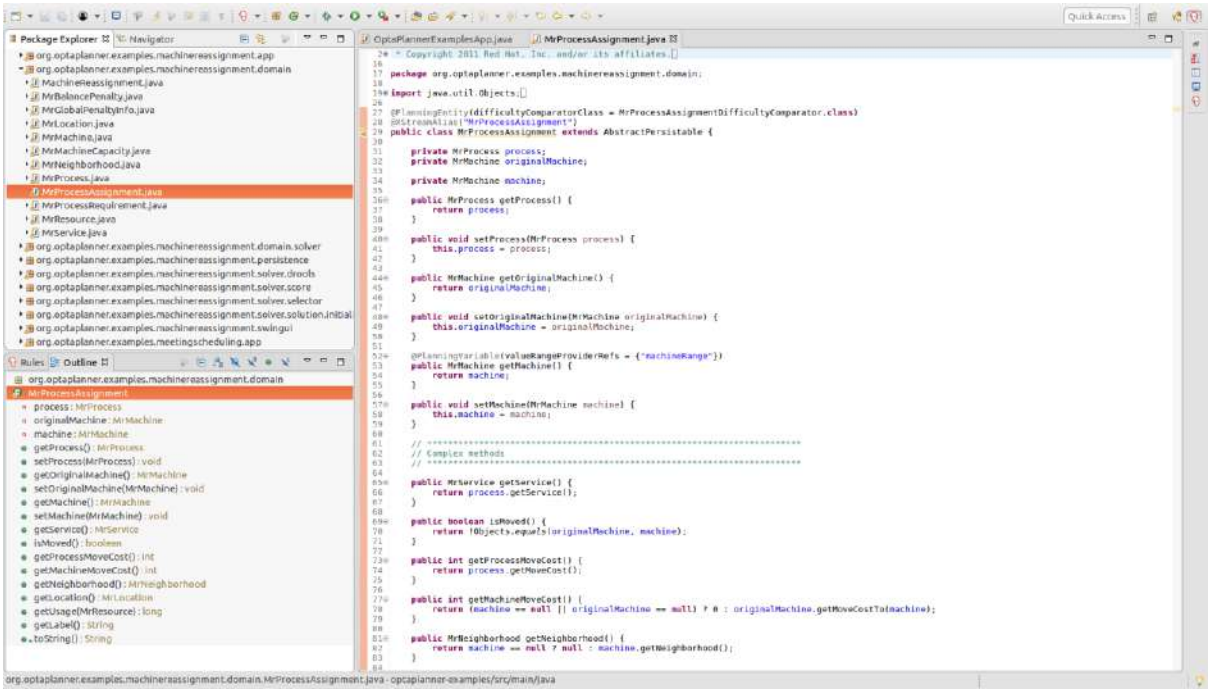
Machine reassignment class diagram




Unsolved dataset shortcuts
model_a1_1
model_a2_1
Solved dataset shortcuts
Import...
Open...
Save as...
Export as...
Solve
Unassigned
Machine 0
Machine 1
Machine 2
Machine 3
Details
Constraint matches


Package Explorer
Navigator
OptaPlannerExamplesApp.java
MrProcessAssignment.java
Rules
Outline
org.optaplanner.examples.machinereassignment.domain.MrProcessAssignment.java - optaplanner-examples/src/main/java

ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Vehicle Routing

- **Business Scenario / Problem Description**
- **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.** http://neo.lcc.uma.es/vrp/

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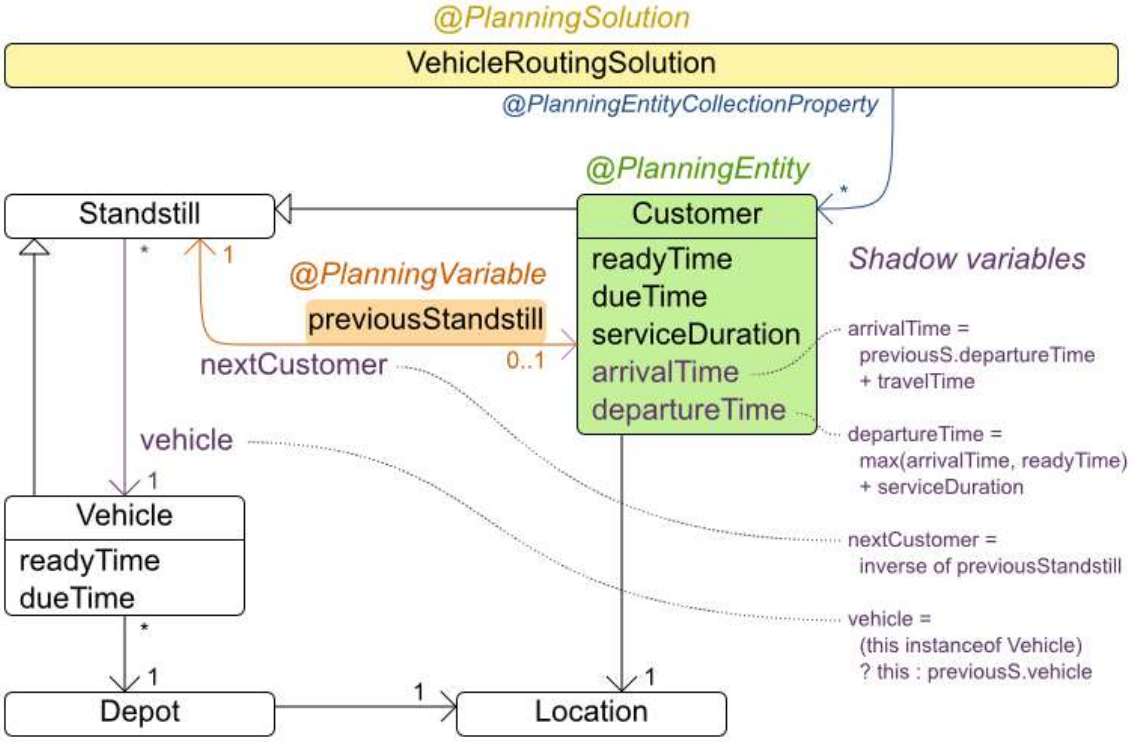
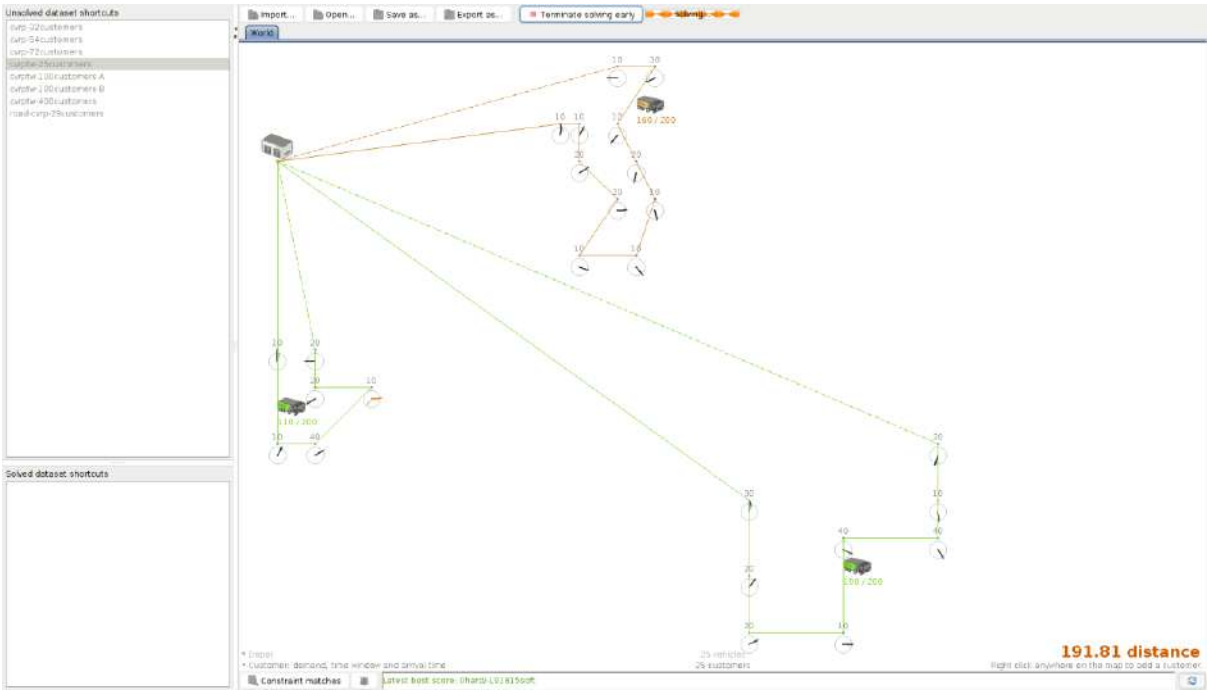
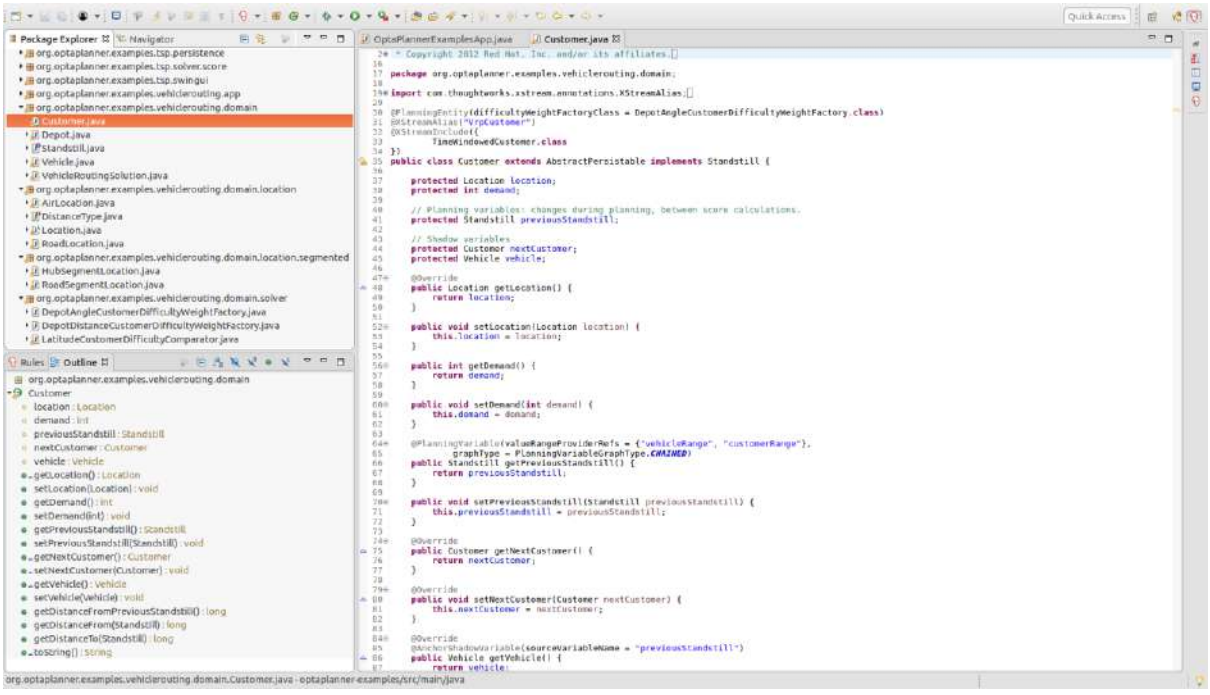
Vehicle routing class diagram




Unsolved dataset shortcuts
Solved dataset shortcuts
Import...
Open...
Save as...
Export as...
Terminate solving early
World
191.81 distance


Package Explorer
Navigator
Rules
Outline
OptaPlannerExamplesApp.java
Customer.java

ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Project Job Scheduling

- **Business Scenario / Problem Description**
- **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)
  - Resource 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.
- **The problem is defined by the MISTA 2013 challenge**. http://gent.cs.kuleuven.be/mista2013challenge/

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ANNEX 4 : KIE OPTAPLANNER EXAMPLES

Exercise: Draw Class Diagram

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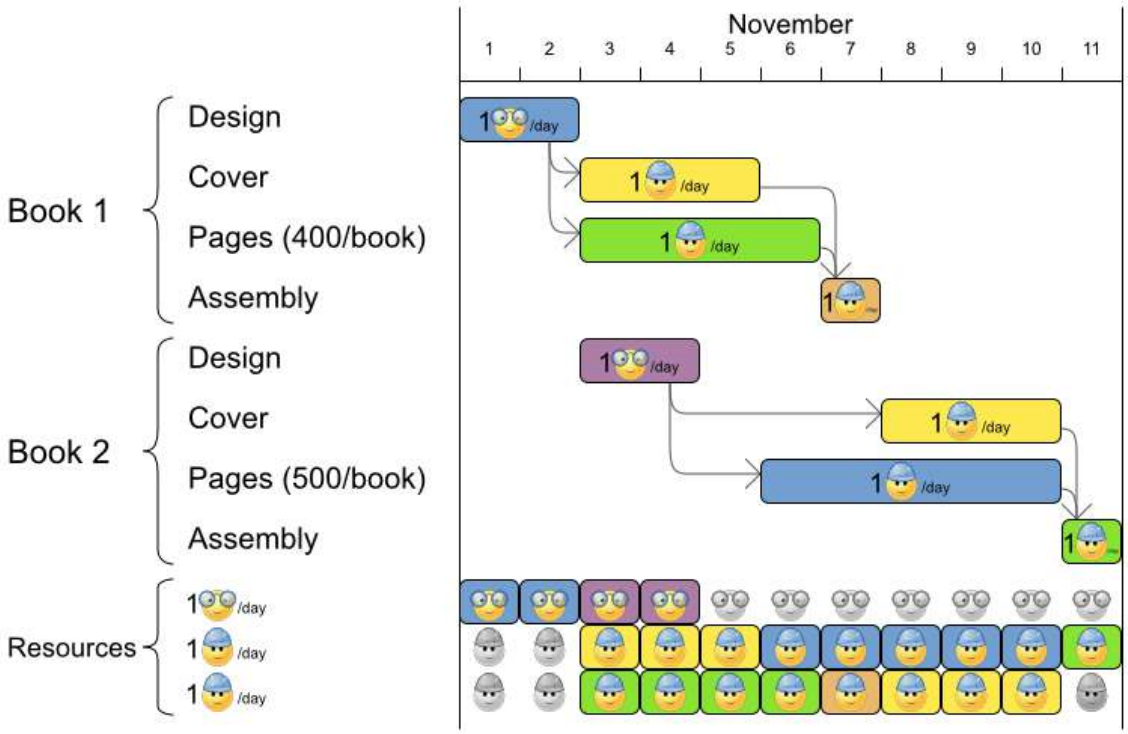
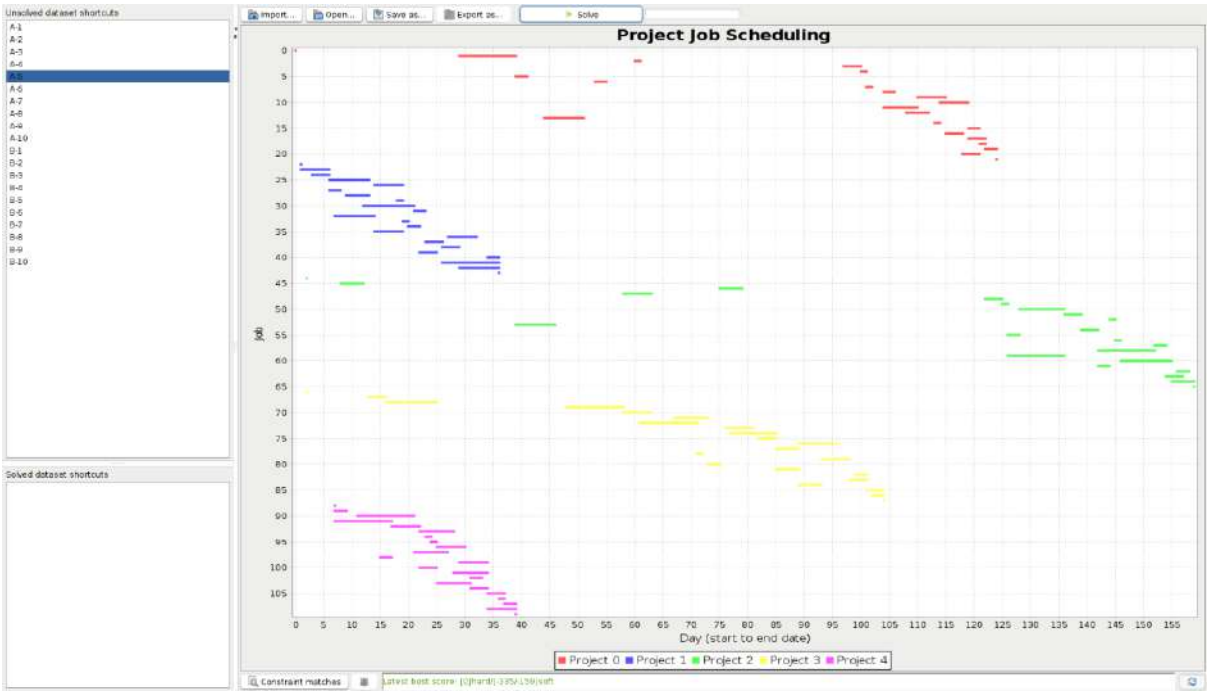

Project job scheduling
For each job, choose an execution mode and a start time.
November
1 2 3 4 5 6 7 8 9 10 11
Book 1
Design
Cover
Pages (400/book)
Assembly
Book 2
Design
Cover
Pages (500/book)
Assembly
Resources
1 /day
1 /day
1 /day


Project Job Scheduling
Day (start to end date)
Project 0
Project 1
Project 2
Project 3
Project 4

ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Hospital Bed Planning (PAS)

- **Business Scenario / Problem Description**
- Assign each patient (that will come to the hospital) into a bed for each night that the patient will stay in the hospital. Each bed belongs to a room and each room belongs to a department. The arrival and departure dates of the patients is fixed: only a bed needs to be assigned for each night. This problem features overconstrained datasets.
- **Hard constraints:**
  - Two patients must not be assigned to the same bed in the same night. Weight: -1000hard * conflictNightCount.
  - A room can have a gender limitation: only females, only males, the same gender in the same night or no gender limitation at all. Weight: -50hard * nightCount.
  - A department can have a minimum or maximum age. Weight: -100hard * nightCount.
  - A patient can require a room with specific equipment(s). Weight: -50hard * nightCount.
- **Medium constraints:**
  - Assign every patient to a bed, unless the dataset is over-constrained. Weight: -1medium * nightCount.
- **Soft constraints:**
  - A patient can prefer a maximum room size, for example if he/she wants a single room. Weight: -8soft * nightCount.
  - A patient is best assigned to a department that specializes in his/her problem. Weight: -10soft * nightCount.
  - A patient is best assigned to a room that specializes in his/her problem. Weight: -20soft * nightCount.
  - That room specialty should be priority 1. Weight: -10soft * (priority - 1) * nightCount.
  - A patient can prefer a room with specific equipment(s). Weight: -20soft * nightCount.
- The problem is a variant on **Kaho's Patient Scheduling**. https://people.cs.kuleuven.be/~wim.vancroonenburg/pas/

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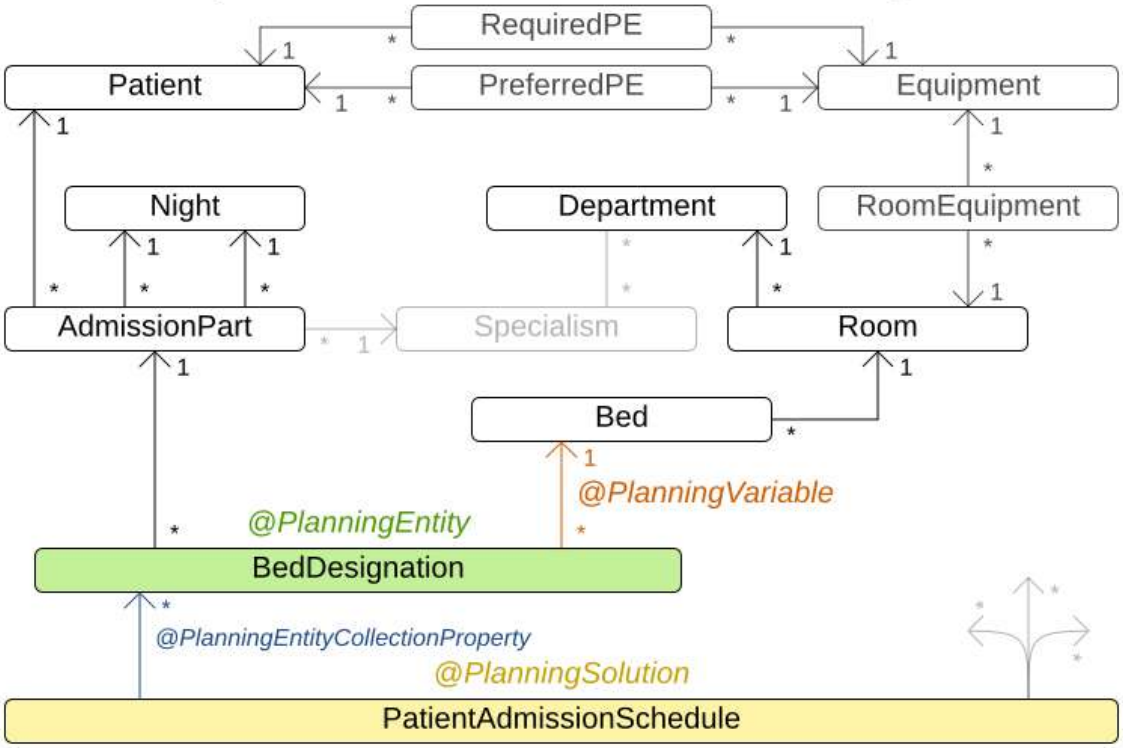
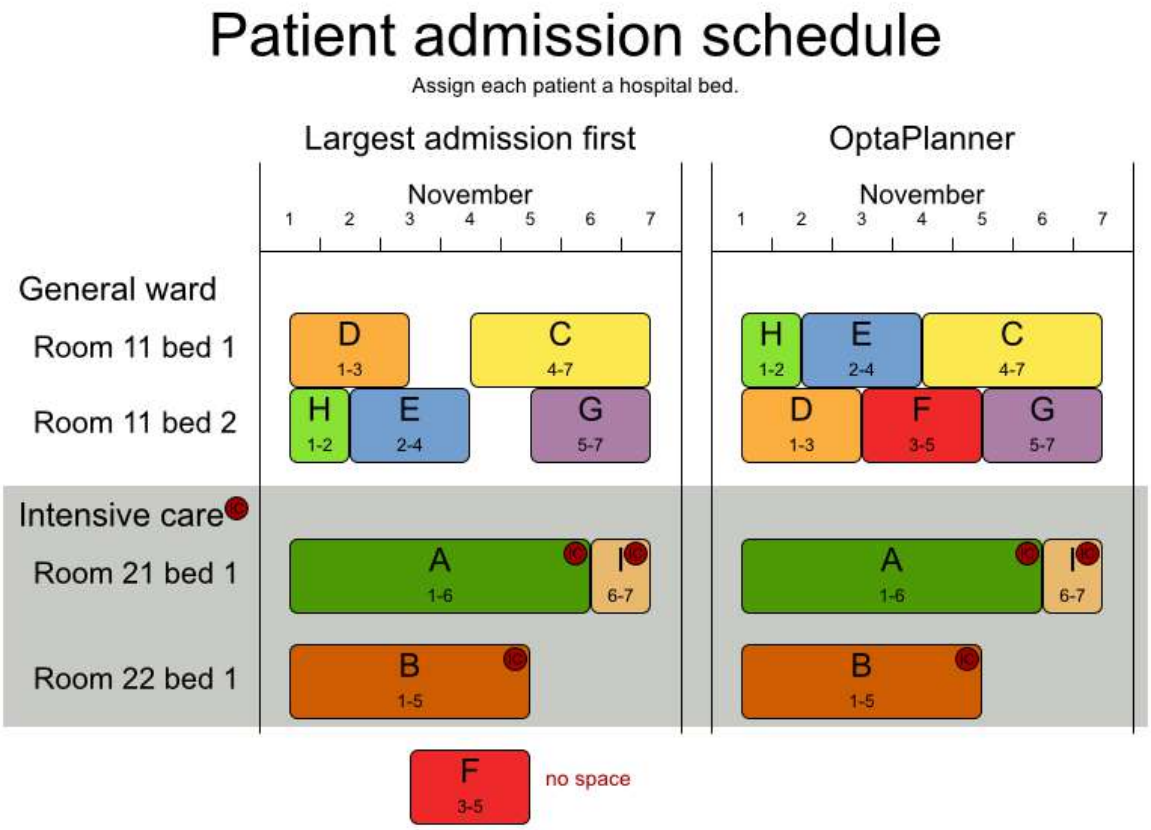
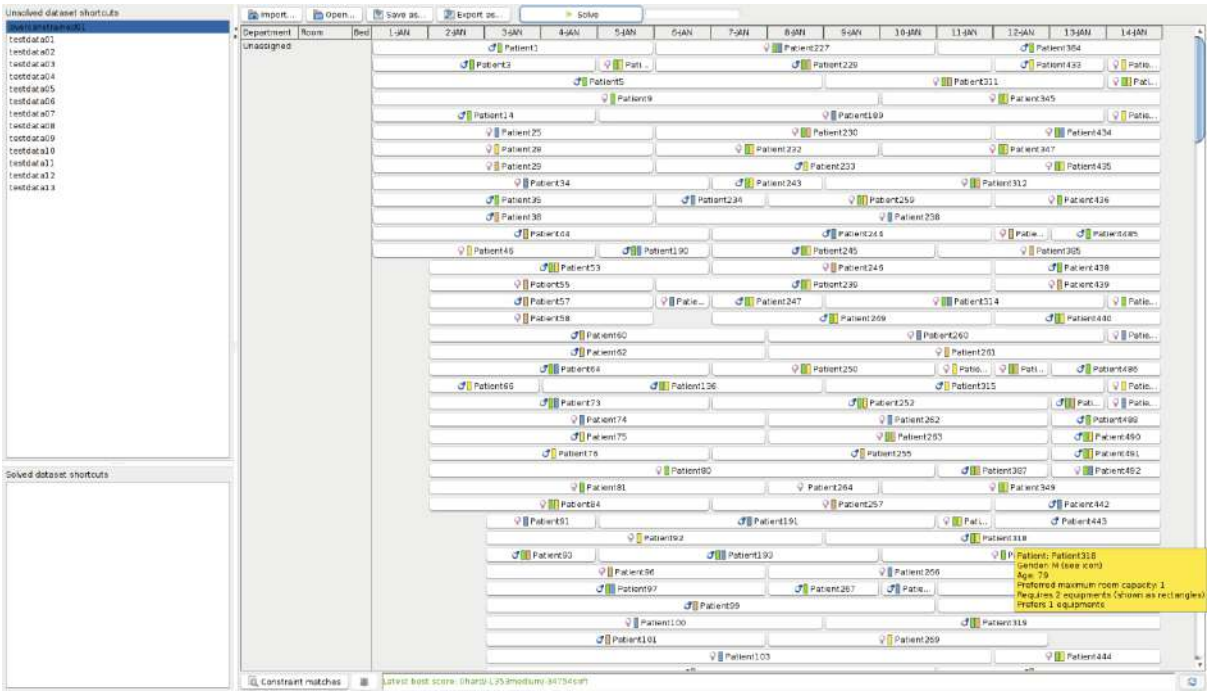
Hospital bed allocation class diagram




Patient admission schedule
Assign each patient a hospital bed.
Largest admission first
OptaPlanner
November
1 2 3 4 5 6 7
General ward
Room 11 bed 1
Room 11 bed 2
Intensive care
Room 21 bed 1
Room 22 bed 1
D 1-3
C 4-7
H 1-2
E 2-4
G 5-7
A 1-6
I 6-7
B 1-5
F 3-5
no space



ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Task assigning

- **Business Scenario / Problem Description**
- **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 posses 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 creates 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.

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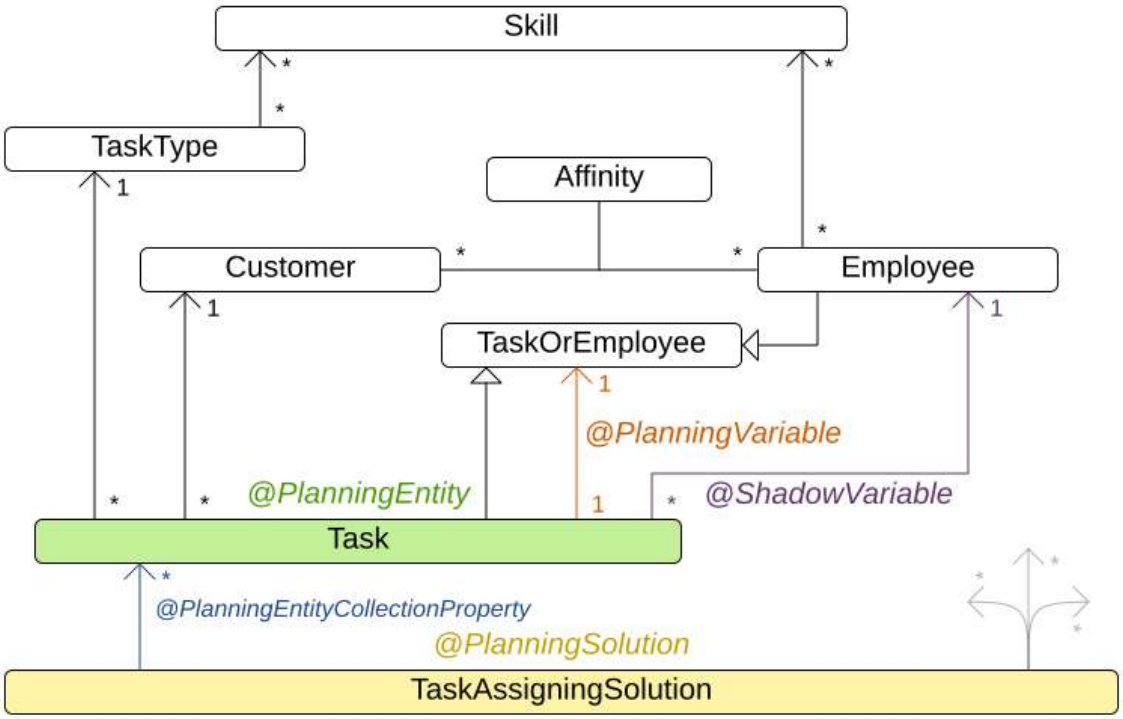
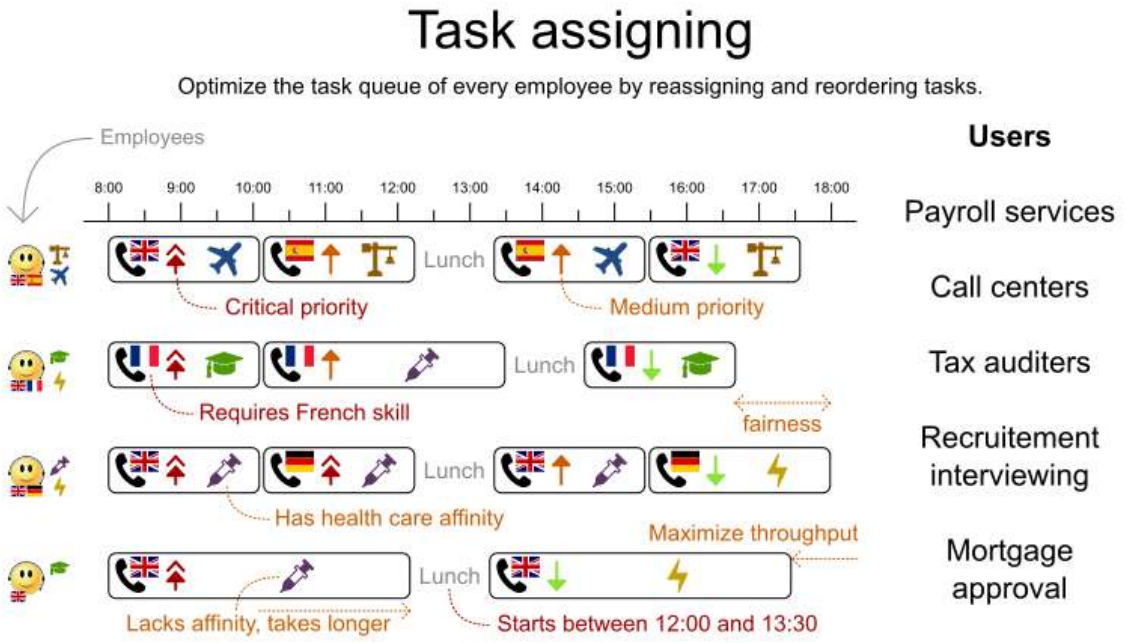
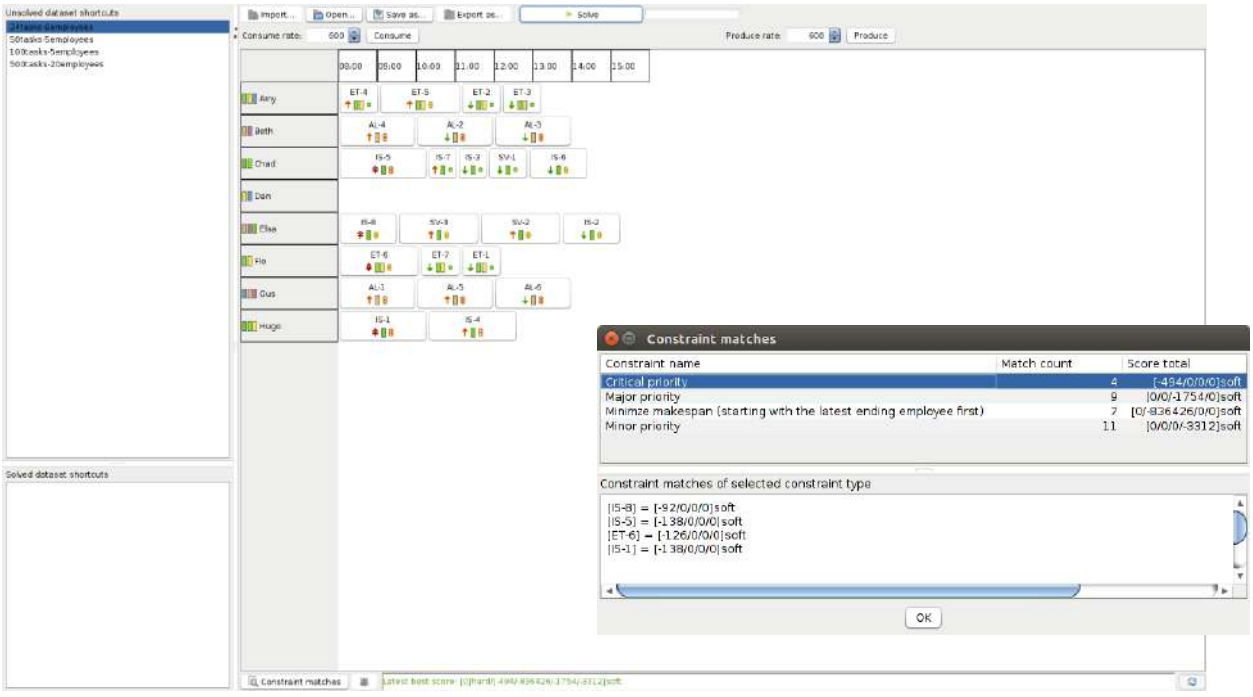
Task assigning class diagram



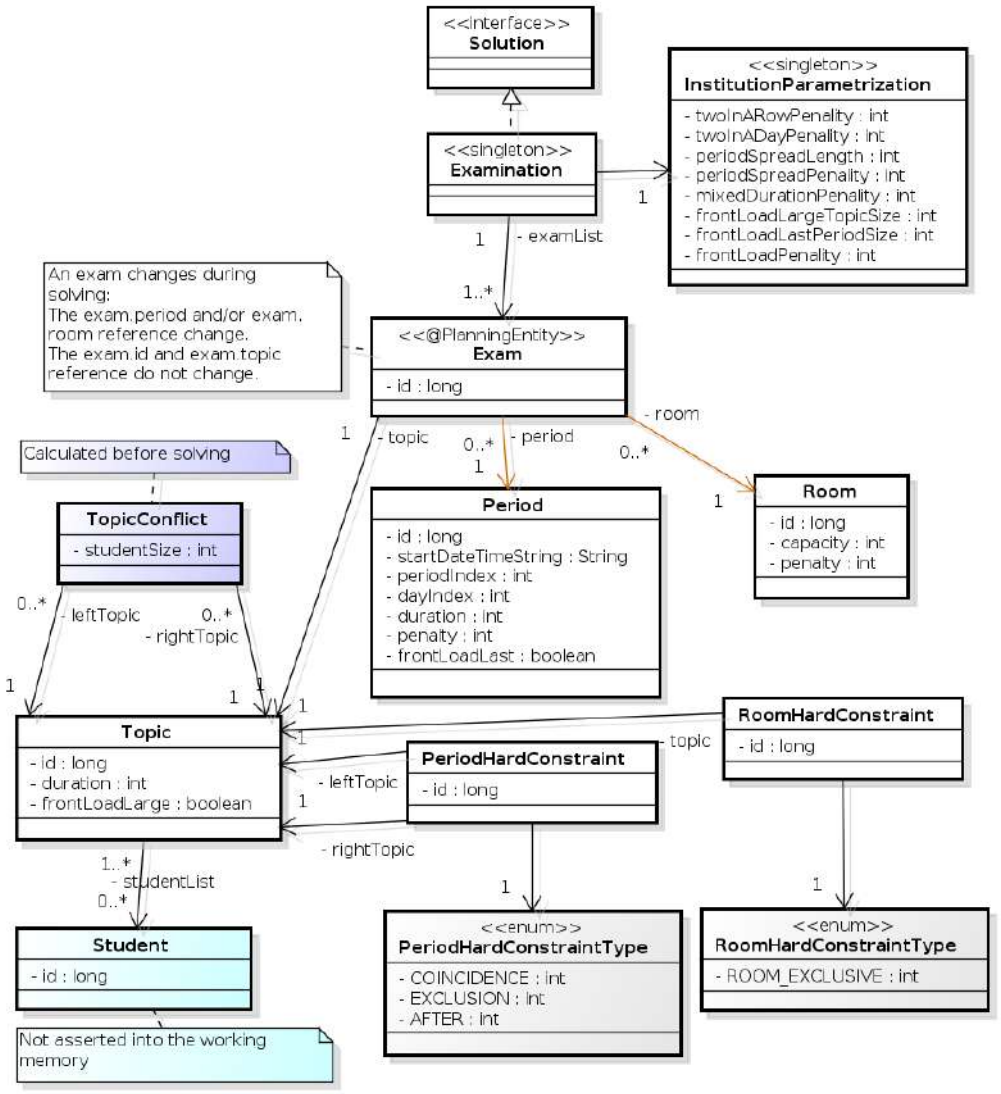

Task assigning
Optimize the task queue of every employee by reassigning and reordering tasks.
Employees
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
Lunch
Critical priority
Medium priority
Requires French skill
fairness
Has health care affinity
Maximize throughput
Lacks affinity, takes longer
Starts between 12:00 and 13:30
Users
Payroll services
Call centers
Tax auditers
Recruitement interviewing
Mortgage approval

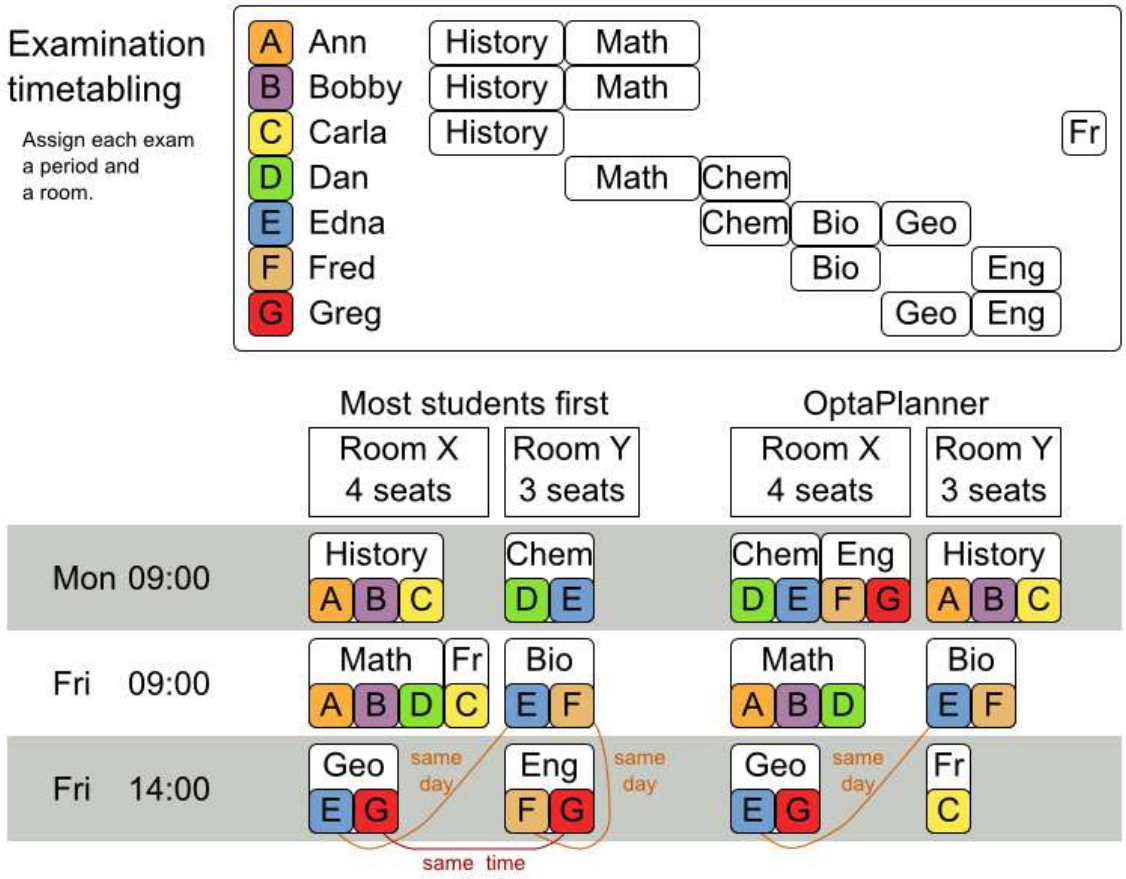

Constraint matches
Constraint name
Match count
Score total
Critical priority
Major priority
Minimize makespan (starting with the latest ending employee first)
Minor priority
Constraint matches of selected constraint type
OK

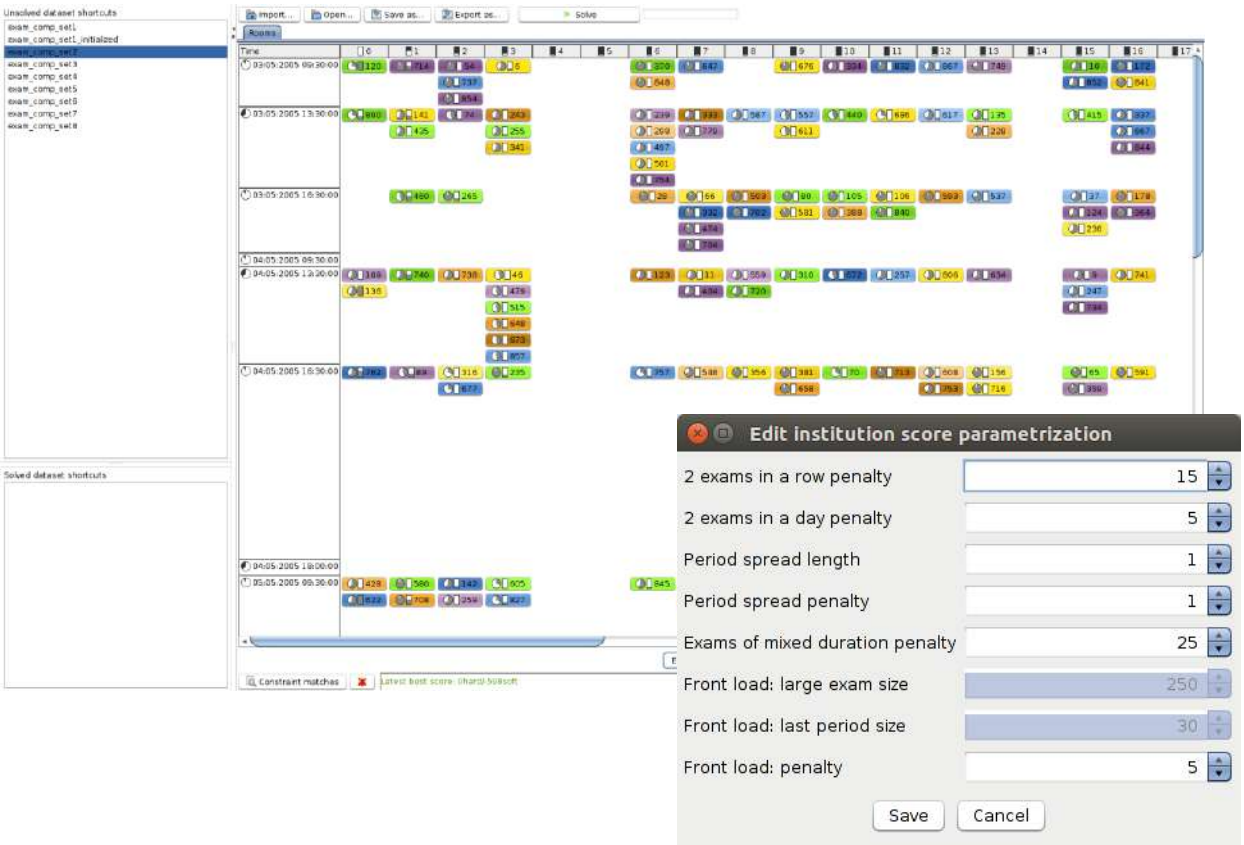
ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Exam Timetabling

- **Business Scenario / Problem Description**
- **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.**
  http://www.cs.qub.ac.uk/itc2007/examtrack/exam_track_index.htm




Examination timetabling
Assign each exam a period and a room.
A Ann History Math
B Bobby History Math
C Carla History Fr
D Dan Math Chem
E Edna Chem Bio Geo
F Fred Bio Eng
G Greg Geo Eng
Most students first
OptaPlanner
Room X 4 seats
Room Y 3 seats
Mon 09:00
Fri 09:00
Fri 14:00
same day
same day
same time


Edit institution score parametrization
2 exams in a row penalty 15
2 exams in a day penalty 5
Period spread length 1
Period spread penalty 1
Exams of mixed duration penalty 25
Front load: large exam size 250
Front load: last period size 30
Front load: penalty 5
Save
Cancel

ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Employee Rostering

- Business Scenario / Problem Description
- 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, http://www.kuleuven-kortrijk.be/nrpcompetition

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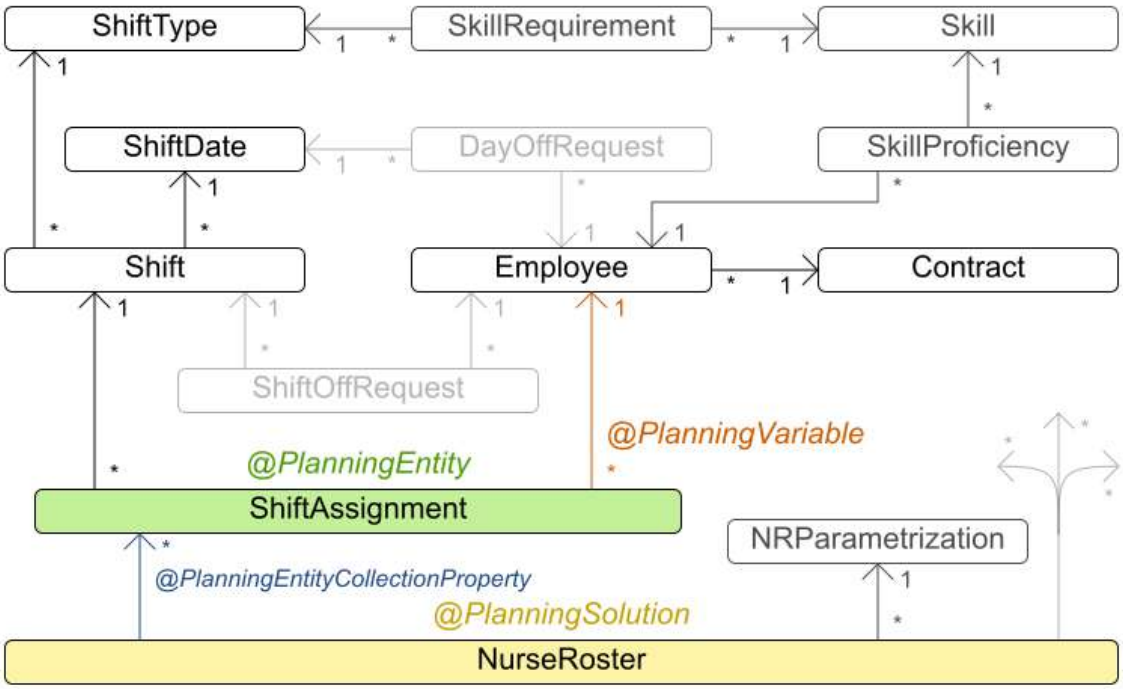
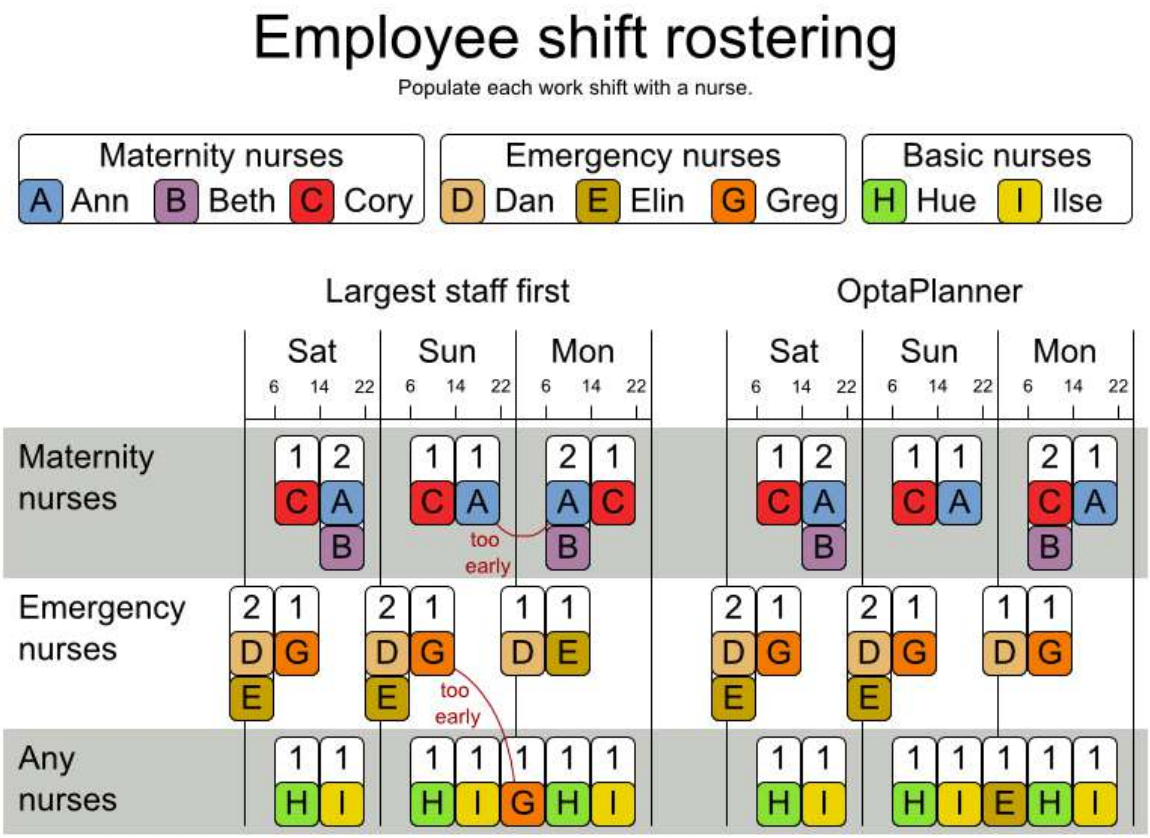
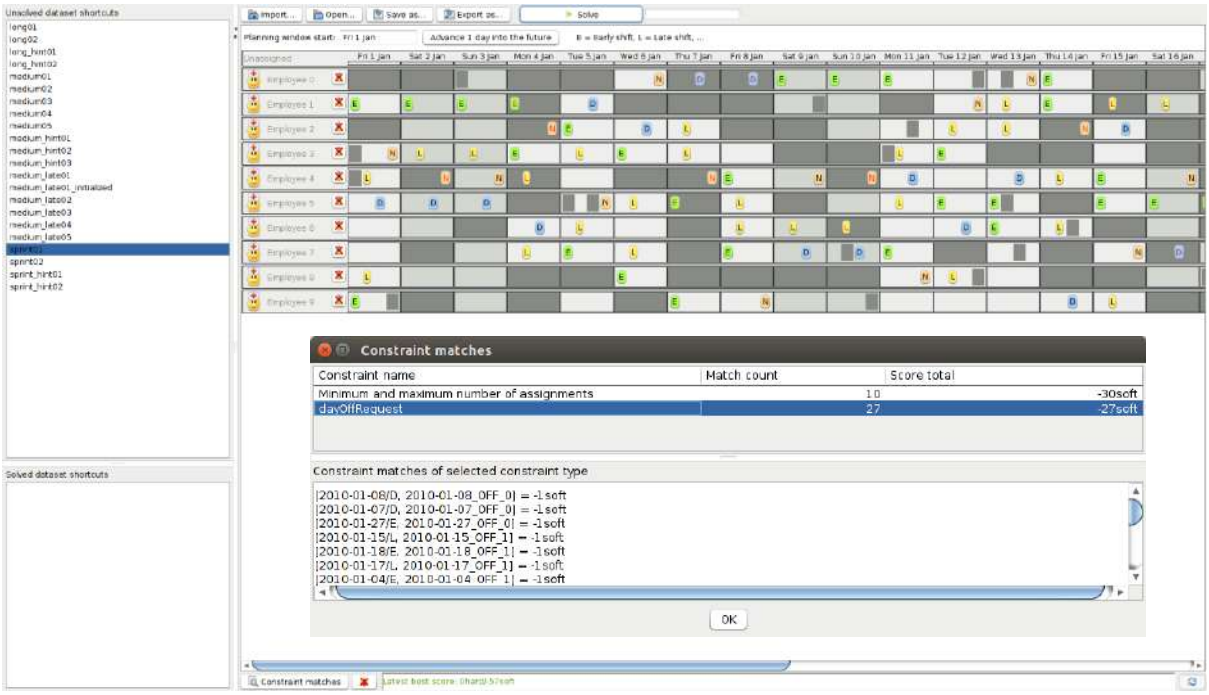
Nurse rostering class diagram




Employee shift rostering
Populate each work shift with a nurse.
Maternity nurses
A Ann
B Beth
C Cory
Emergency nurses
D Dan
E Elin
G Greg
Basic nurses
H Hue
I Ilse
Largest staff first
OptaPlanner
Sat
Sun
Mon
6
14
22
Maternity nurses
Emergency nurses
Any nurses
too early
too early


Constraint matches
Constraint name
Match count
Score total
Minimum and maximum number of assignments
10
-30soft
dayOffRequest
27
-27soft
Constraint matches of selected constraint type
OK

ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Traveling Tournament Problem (TTP)

- **Business Scenario / Problem Description**
- **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.**
  http://mat.tepper.cmu.edu/TOURN/

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ANNEX 4 : KIE OPTAPLANNER EXAMPLES

Exercise: Draw Class Diagram

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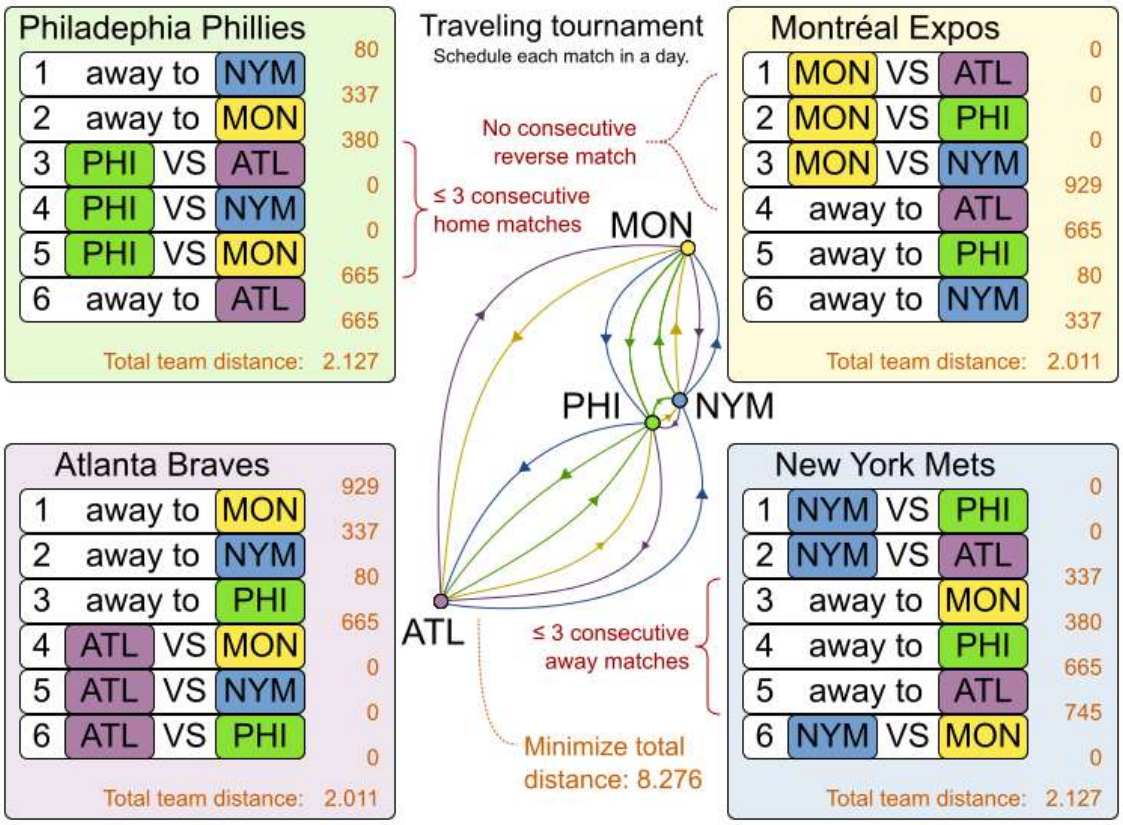
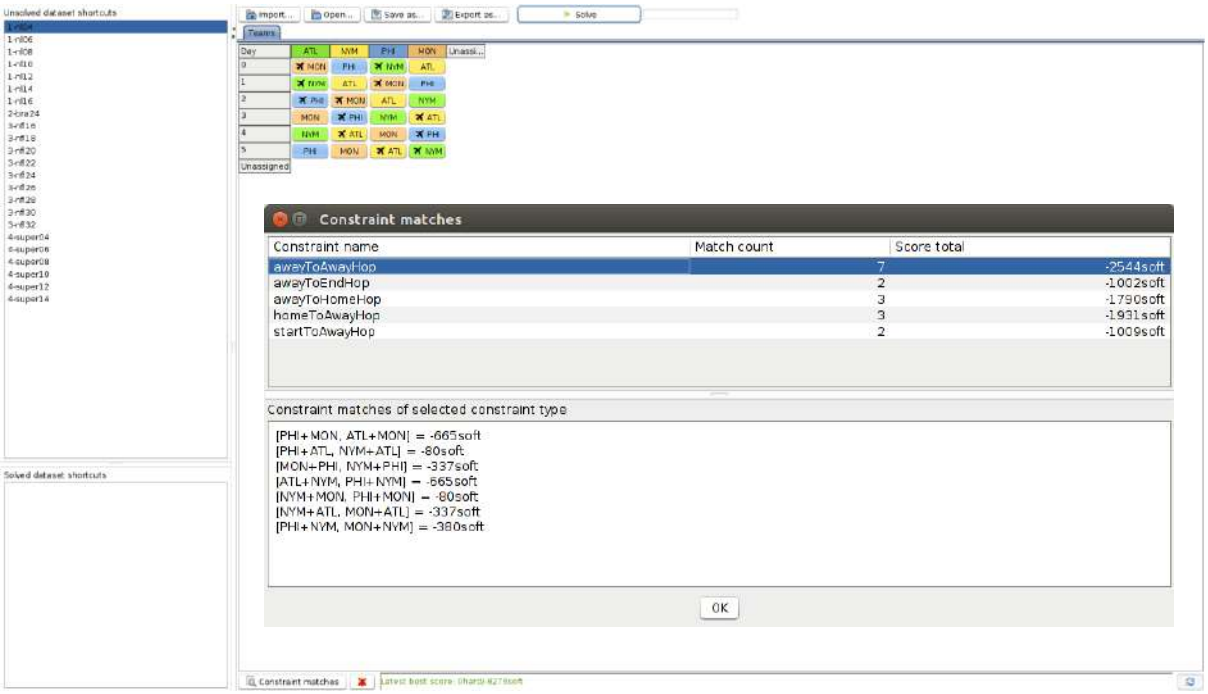

Philadephia Phillies
1 away to NYM 80
2 away to MON 337
3 PHI VS ATL 380
4 PHI VS NYM 0
5 PHI VS MON 0
6 away to ATL 665
Total team distance: 665 2.127
Traveling tournament
Schedule each match in a day.
No consecutive reverse match
≤ 3 consecutive home matches
≤ 3 consecutive away matches
Minimize total distance: 8.276
MON
PHI
NYM
ATL
Montréal Expos
1 MON VS ATL 0
2 MON VS PHI 0
3 MON VS NYM 0
4 away to ATL 929
5 away to PHI 665
6 away to NYM 80
Total team distance: 337 2.011
Atlanta Braves
1 away to MON 929
2 away to NYM 337
3 away to PHI 80
4 ATL VS MON 665
5 ATL VS NYM 0
6 ATL VS PHI 0
Total team distance: 0 2.011
New York Mets
1 NYM VS PHI 0
2 NYM VS ATL 0
3 away to MON 337
4 away to PHI 380
5 away to ATL 665
6 NYM VS MON 745
Total team distance: 0 2.127


Constraint matches
Constraint name | Match count | Score total
awayToAwayHop | 7 | -2544soft
awayToEndHop | 2 | -1002soft
awayToHomeHop | 3 | -1790soft
homeToAwayHop | 3 | -1931soft
startToAwayHop | 2 | -1009soft
Constraint matches of selected constraint type
[PHI+MON, ATL+MON] = -665soft
[PHI+ATL, NYM+ATL] = -80soft
[MON+PHI, NYM+PHI] = -337soft
[ATL+NYM, PHI+NYM] = -665soft
[NYM+MON, PHI+MON] = -80soft
[NYM+ATL, MON+ATL] = -337soft
[PHI+NYM, MON+NYM] = -380soft
OK

ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Cheap Time Scheduling

- **Business Scenario / Problem Description**
- **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.

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ANNEX 4 : KIE OPTAPLANNER EXAMPLES

Exercise: Draw Class Diagram

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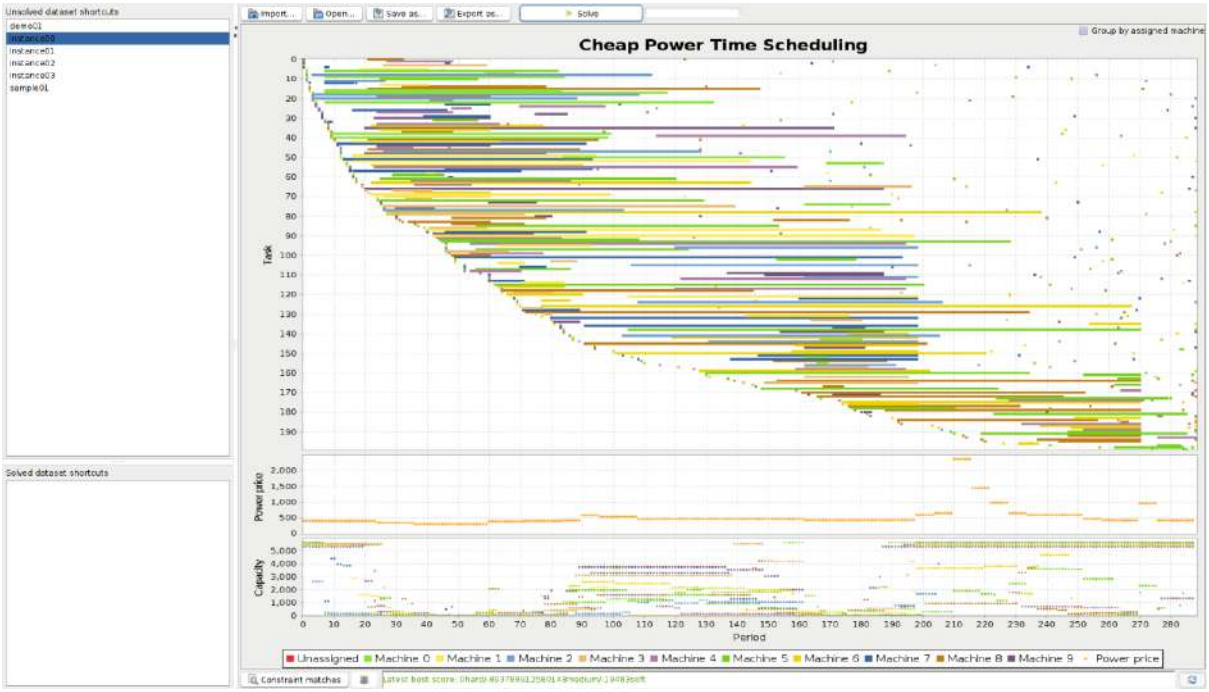
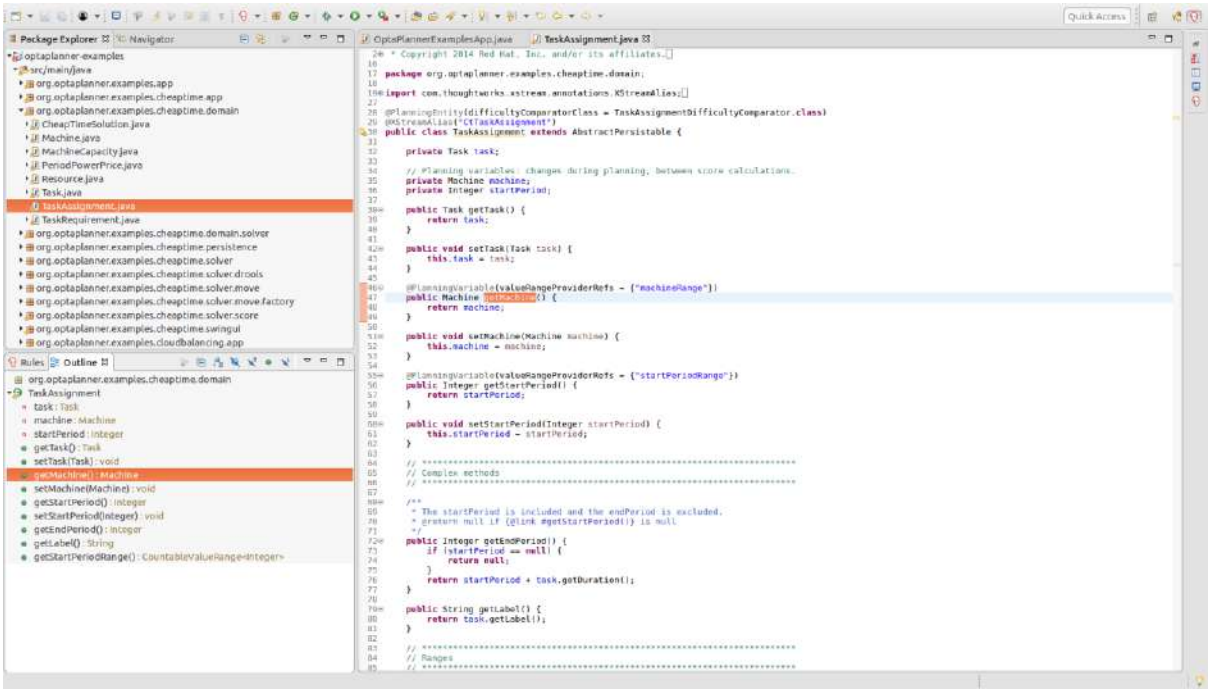

Cheap Power Time Scheduling
Task
Power price
Capacity
Period
Unassigned
Machine 0
Machine 1
Machine 2
Machine 3
Machine 4
Machine 5
Machine 6
Machine 7
Machine 8
Machine 9
Power price



ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Investment Asset Class Allocation

- **Business Scenario / Problem Description**
- **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.

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ANNEX 4 : KIE OPTAPLANNER EXAMPLES

Exercise: Draw Class Diagram

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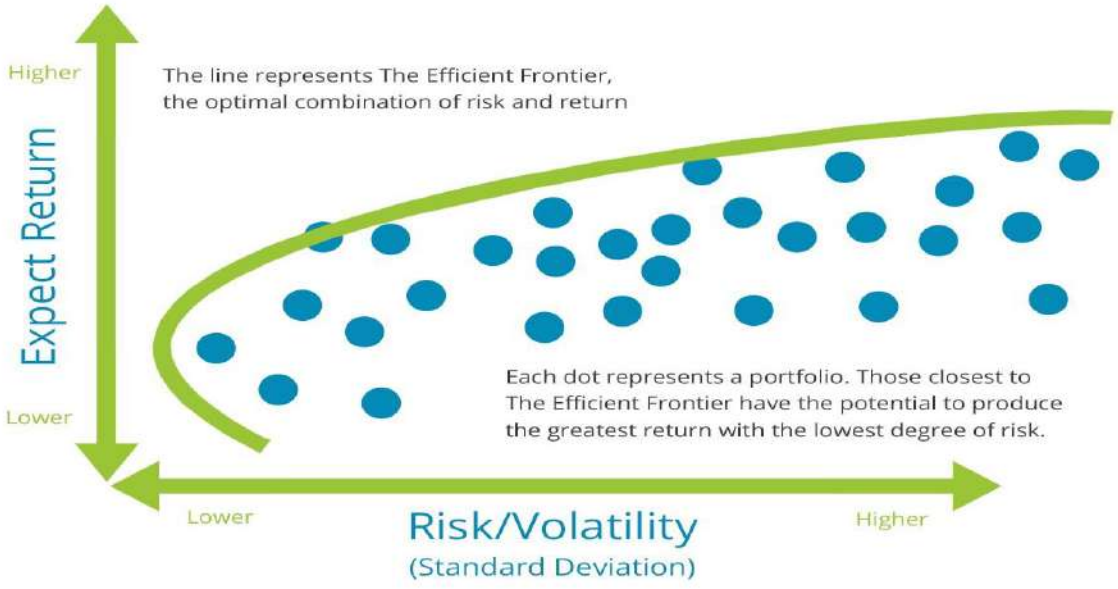
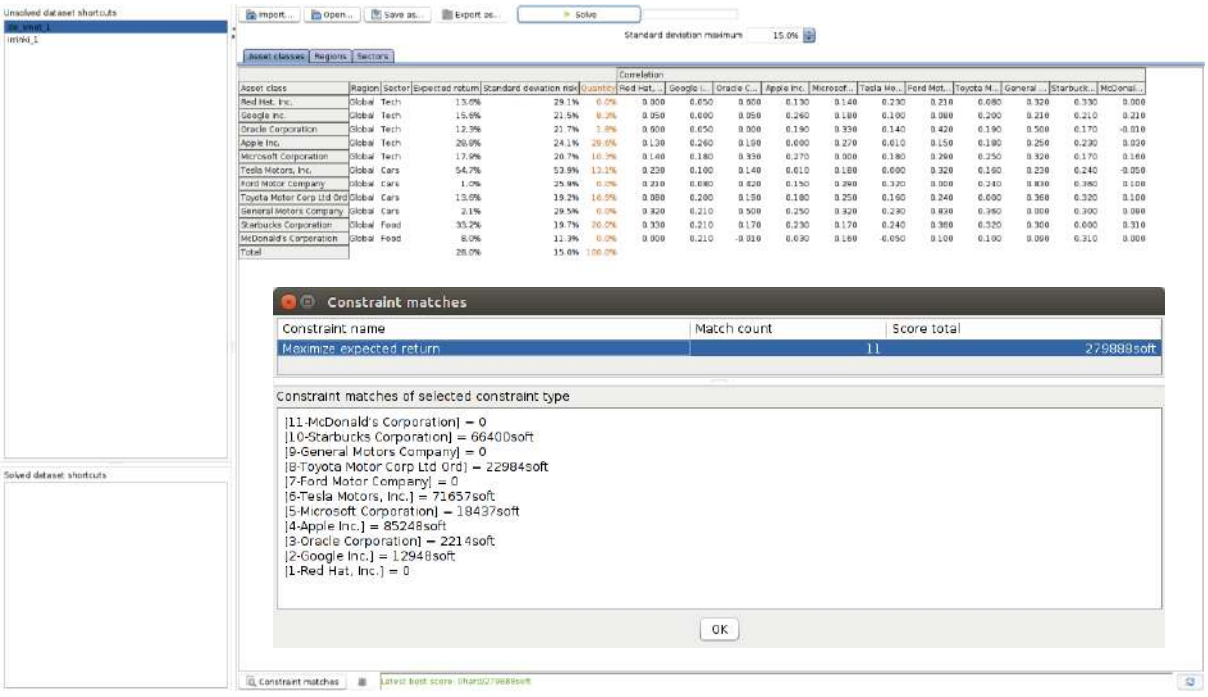


Link https://www.guidedchoice.com/video/dr-harry-markowitz-father-of-modern-portfolio-theory/



ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Conference Scheduling

- **Business Scenario / Problem Description**
- **Assign each conference talk to a timeslot and a room, after the talks have been accepted.**
- **Hard constraints (unless configured otherwise):**
  - 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 tags: 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 tags: 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 tags: If a talk has a required timeslot tag, then it must be assigned to a timeslot with that tag.
    - Talk prohibited timeslot tags: If a talk has a prohibited timeslot tag, then it cannot be assigned to a timeslot with that tag.
    - Speaker required room tags: If a speaker has a required room tag, then all his/her talks must be assigned to a room with that tag.
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    - Talk required room tags: If a talk has a required room tag, then it must be assigned to a room with that tag.
    - Talk prohibited room tags: If a talk has a prohibited room tag, then it cannot be assigned to a room with that tag.
  - Talk prerequisite talks: A talk must be scheduled after all its prerequisite talks.
  - Consecutive talks pause: A speaker who has more than one talk must have a break between them.
  - Talk mutually-exclusive-talks tags: Talks that share such tags must not be scheduled in overlapping timeslots.
- **Medium constraints (unless configured otherwise):**
  - Published timeslot: A published talk must not be scheduled at a different timeslot than currently published. If a hard constraint's input data changes after publishing (such as speaker unavailability), then this medium constraint will be minimally broken to attain a new feasible solution.

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ANNEX 4 : KIE OPTAPLANNER EXAMPLES

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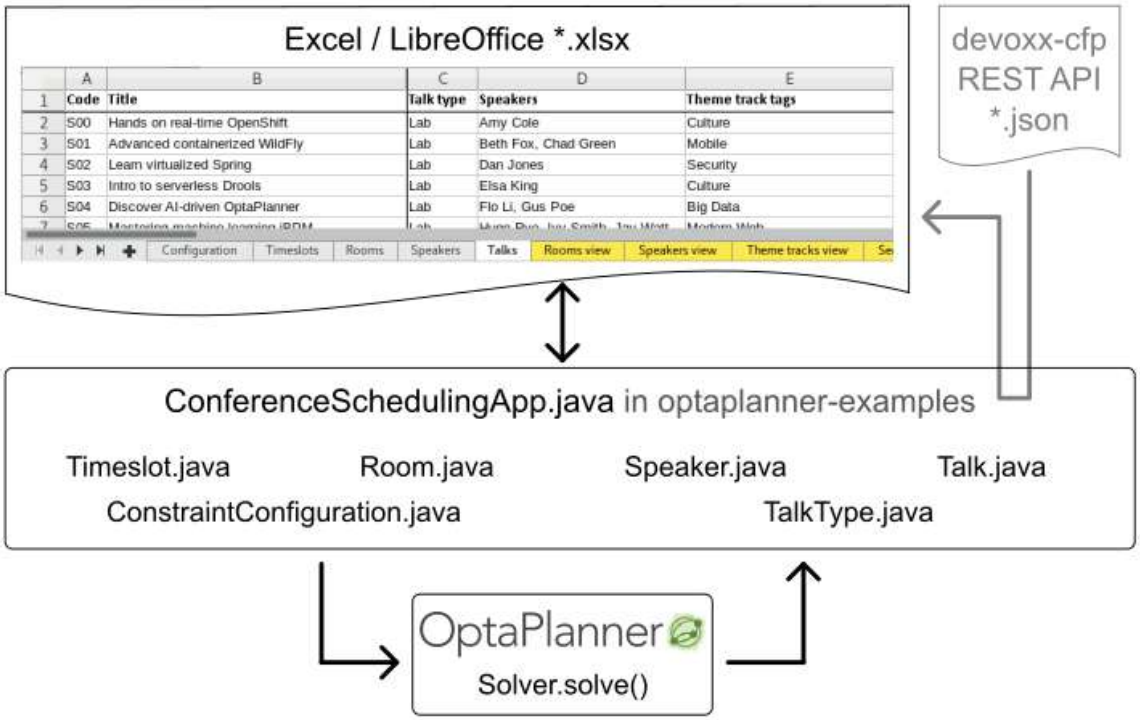
Conference scheduling architecture

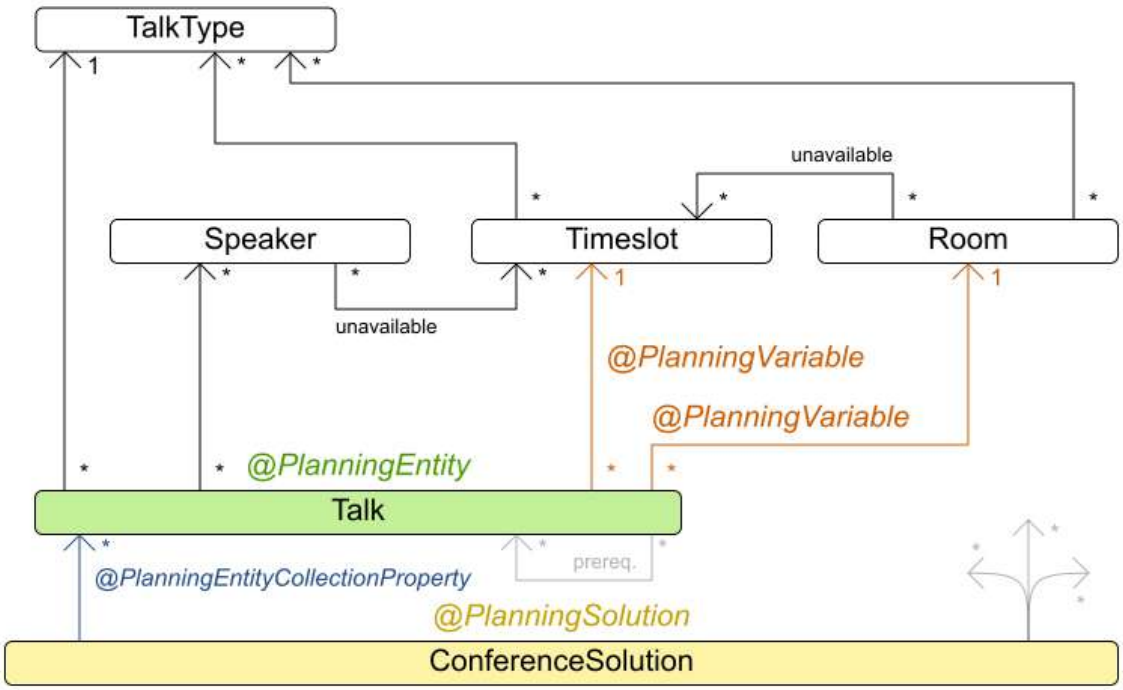
Planner works with plain Java objects that are read/written to *.xlsx

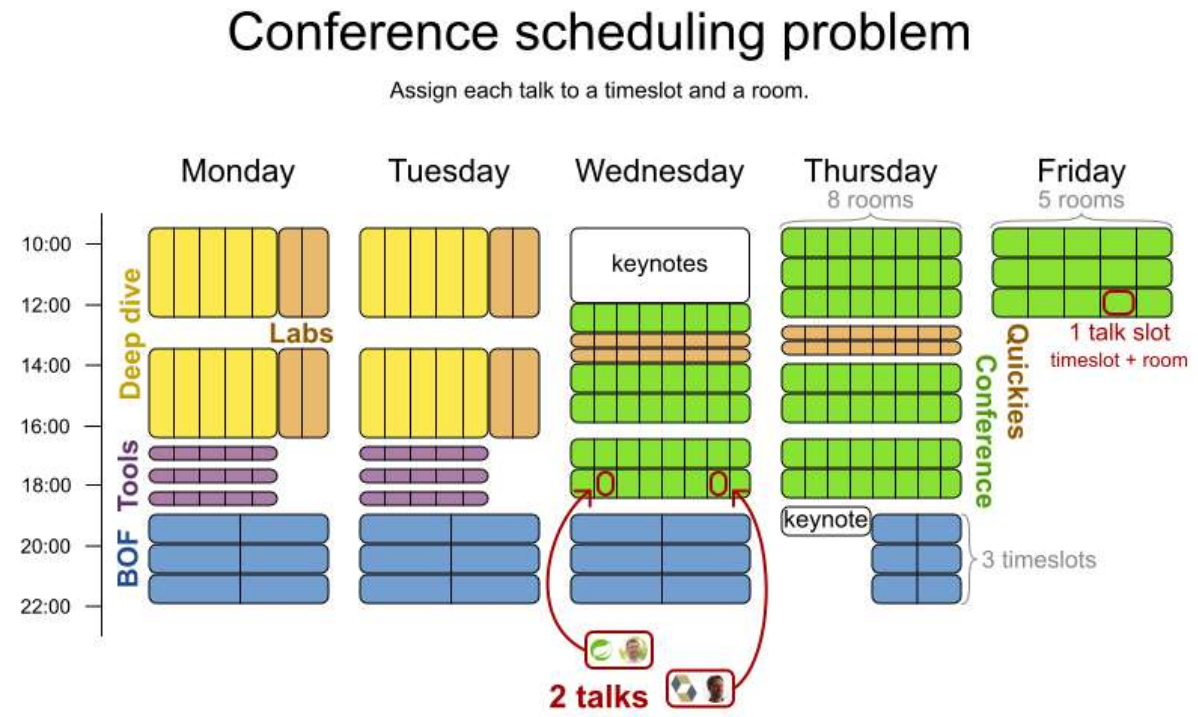


	A	B	C	D	E
1	Code	Title	Talk type	Speakers	Theme track tags
2	S00	Hands on real-time OpenShift	Lab	Amy Cole	Culture
3	S01	Advanced containerized WildFly	Lab	Beth Fox, Chad Green	Mobile
4	S02	Learn virtualized Spring	Lab	Dan Jones	Security
5	S03	Intro to serverless Drools	Lab	Elsa King	Culture
6	S04	Discover AI-driven OptaPlanner	Lab	Flo Li, Gus Poe	Big Data

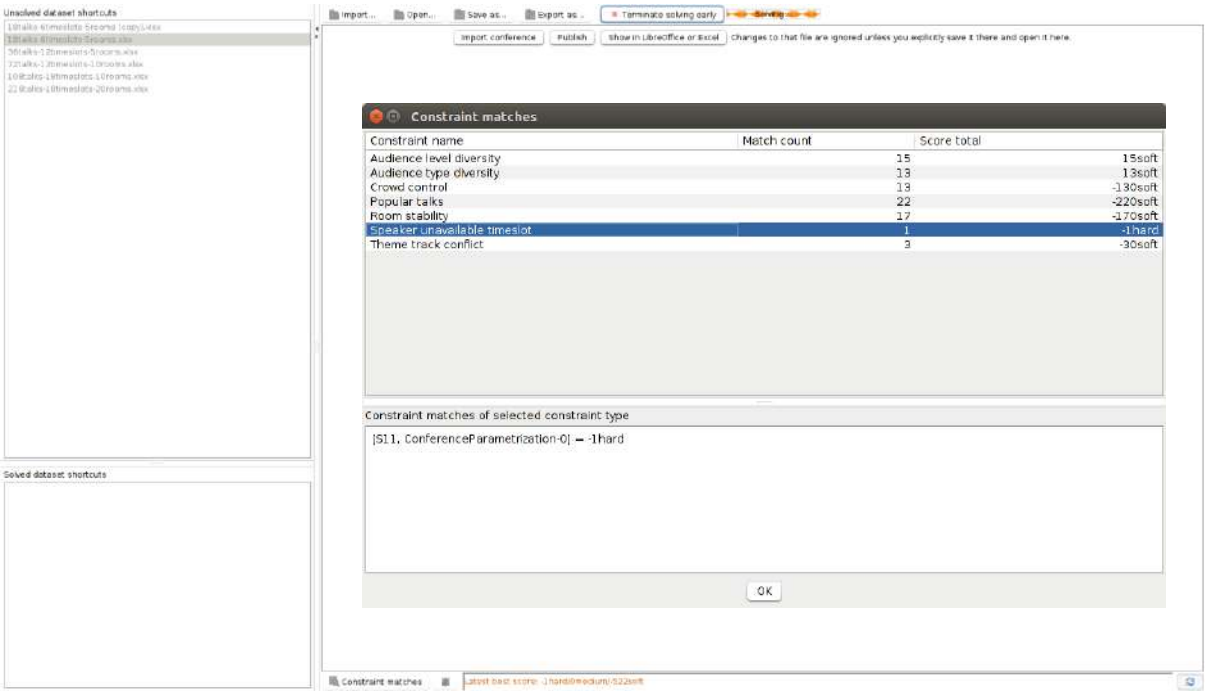
Configuration | Timeslots | Rooms | Speakers | Talks | Rooms view | Speakers view | Theme tracks view

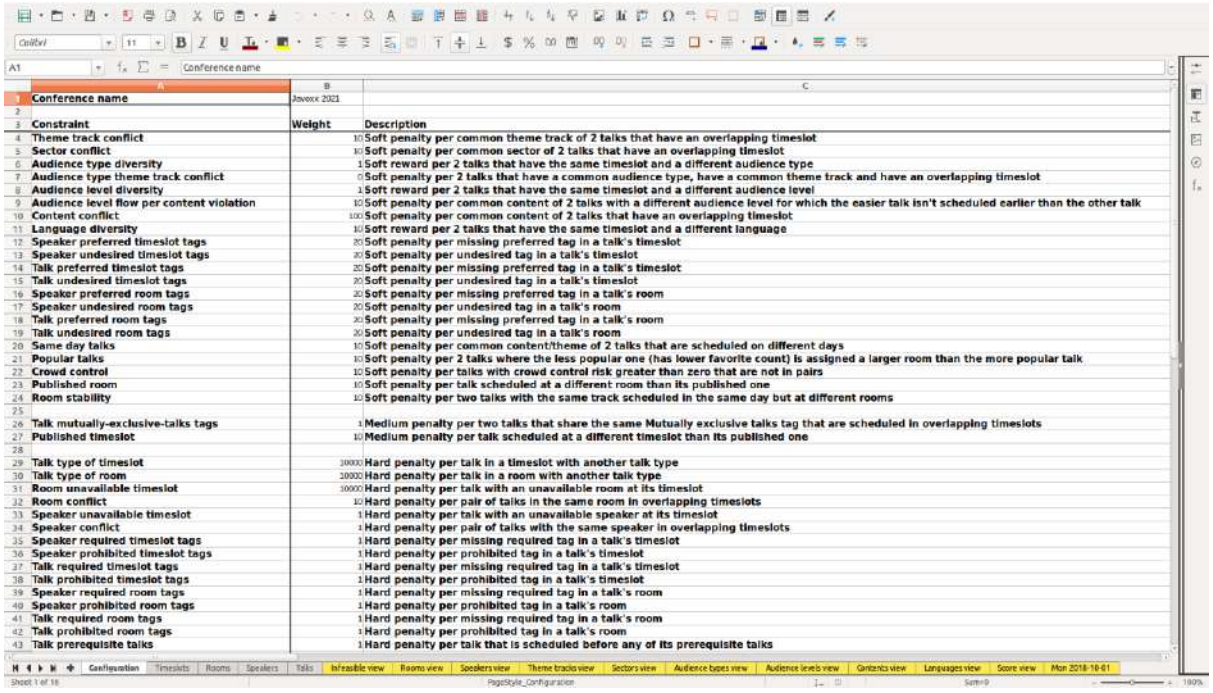
Conference scheduling class diagram



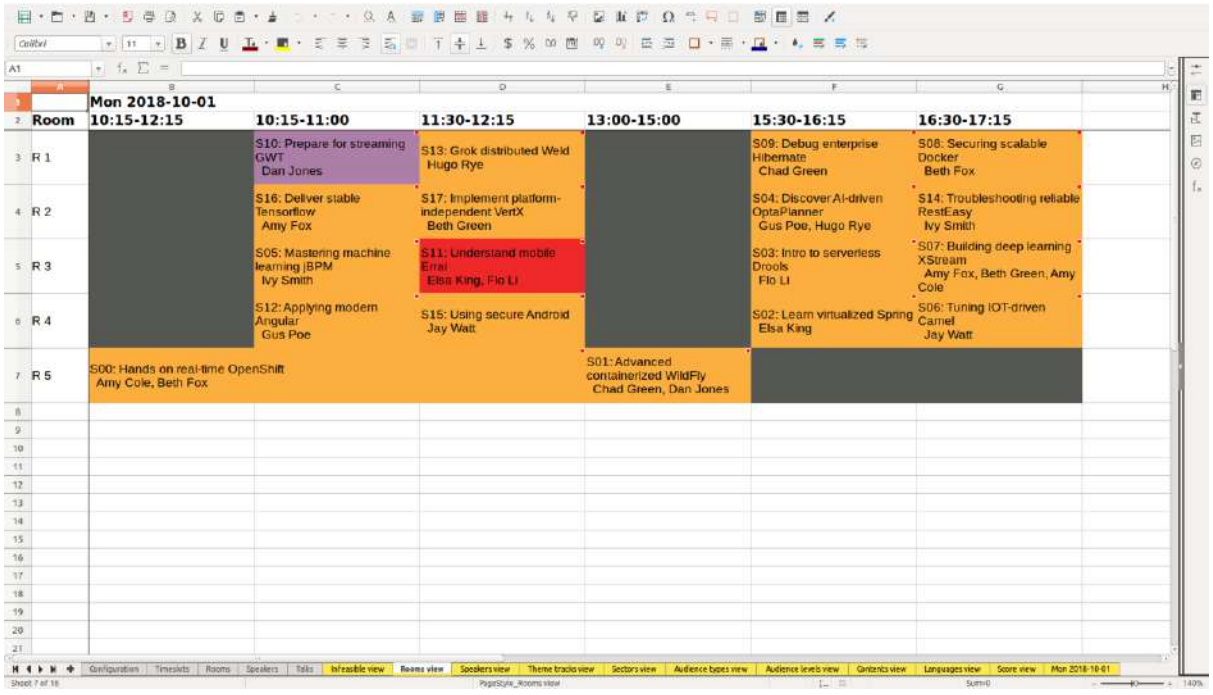


Devoxx Belgium assigns 214 talks to 40 timeslots and 10 rooms for 3500 attendees.





Conference name	Javaxx 2021	
Constraint	**Weight**	**Description**
Theme track conflict	10	Soft penalty per common theme track of 2 talks that have an overlapping timeslot
Sector conflict	10	Soft penalty per common sector of 2 talks that have an overlapping timeslot
Audience type diversity	1	Soft reward per 2 talks that have the same timeslot and a different audience type
Audience type theme track conflict	0	Soft penalty per 2 talks that have a common audience type, have a common theme track and have an overlapping timeslot
Audience level diversity	1	Soft reward per 2 talks that have the same timeslot and a different audience level
Audience level flow per content violation	10	Soft penalty per common content of 2 talks with a different audience level for which the easier talk isn't scheduled earlier than the other talk
Content conflict	100	Soft penalty per common content of 2 talks that have an overlapping timeslot
Language diversity	10	Soft reward per 2 talks that have the same timeslot and a different language
Speaker preferred timeslot tags	20	Soft penalty per missing preferred tag in a talk's timeslot
Speaker undesired timeslot tags	20	Soft penalty per undesired tag in a talk's timeslot
Talk preferred timeslot tags	20	Soft penalty per missing preferred tag in a talk's timeslot
Talk undesired timeslot tags	20	Soft penalty per undesired tag in a talk's timeslot
Speaker preferred room tags	20	Soft penalty per missing preferred tag in a talk's room
Speaker undesired room tags	20	Soft penalty per undesired tag in a talk's room
Talk preferred room tags	20	Soft penalty per missing preferred tag in a talk's room
Talk undesired room tags	20	Soft penalty per undesired tag in a talk's room
Same day talks	10	Soft penalty per common content/theme of 2 talks that are scheduled on different days
Popular talks	10	Soft penalty per 2 talks where the less popular one (has lower favorite count) is assigned a larger room than the more popular talk
Crowd control	10	Soft penalty per talks with crowd control risk greater than zero that are not in pairs
Published room	10	Soft penalty per talk scheduled at a different room than its published one
Room stability	10	Soft penalty per two talks with the same track scheduled in the same day but at different rooms
Talk mutually-exclusive-talks tags	1	Medium penalty per two talks that share the same Mutually exclusive talks tag that are scheduled in overlapping timeslots
Published timeslot	10	Medium penalty per talk scheduled at a different timeslot than its published one
Talk type of timeslot	10000	Hard penalty per talk in a timeslot with another talk type
Talk type of room	10000	Hard penalty per talk in a room with another talk type
Room unavailable timeslot	10000	Hard penalty per talk with an unavailable room at its timeslot
Room conflict	10	Hard penalty per pair of talks in the same room in overlapping timeslots
Speaker unavailable timeslot	1	Hard penalty per talk with an unavailable speaker at its timeslot
Speaker conflict	1	Hard penalty per pair of talks with the same speaker in overlapping timeslots
Speaker required timeslot tags	1	Hard penalty per missing required tag in a talk's timeslot
Speaker prohibited timeslot tags	1	Hard penalty per prohibited tag in a talk's timeslot
Talk required timeslot tags	1	Hard penalty per missing required tag in a talk's timeslot
Talk prohibited timeslot tags	1	Hard penalty per prohibited tag in a talk's timeslot
Speaker required room tags	1	Hard penalty per missing required tag in a talk's room
Speaker prohibited room tags	1	Hard penalty per prohibited tag in a talk's room
Talk required room tags	1	Hard penalty per missing required tag in a talk's room
Talk prohibited room tags	1	Hard penalty per prohibited tag in a talk's room
Talk prerequisite talks	1	Hard penalty per talk that is scheduled before any of its prerequisite talks



	Mon 2018-10-01					
Room	10:15-12:15	10:15-11:00	11:30-12:15	13:00-15:00	15:30-16:15	16:30-17:15
R 1		S10: Prepare for streaming GWT Dan Jones	S13: Grok distributed Weld Hugo Rye		S09: Debug enterprise Hibernate Chad Green	S08: Securing scalable Docker Beth Fox
R 2		S16: Deliver stable Tensorflow Amy Fox	S17: Implement platform-independent VertX Beth Green		S04: Discover AI-driven OptaPlanner Gus Poe, Hugo Rye	S14: Troubleshooting reliable RestEasy Ivy Smith
R 3		S05: Mastering machine learning jBPM Ivy Smith	S11: Understand mobile Errai Elsa King, Flo Li		S03: Intro to serverless Drools Flo Li	S07: Building deep learning XStream Amy Fox, Beth Green, Amy Cole
R 4		S12: Applying modern Angular Gus Poe	S15: Using secure Android Jay Watt		S02: Learn virtualized Spring Elsa King	S06: Tuning IOT-driven Camel Jay Watt
R 5	S00: Hands on real-time OpenShift Amy Cole, Beth Fox			S01: Advanced containerized WildFly Chad Green, Dan Jones		

ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Rock Tour

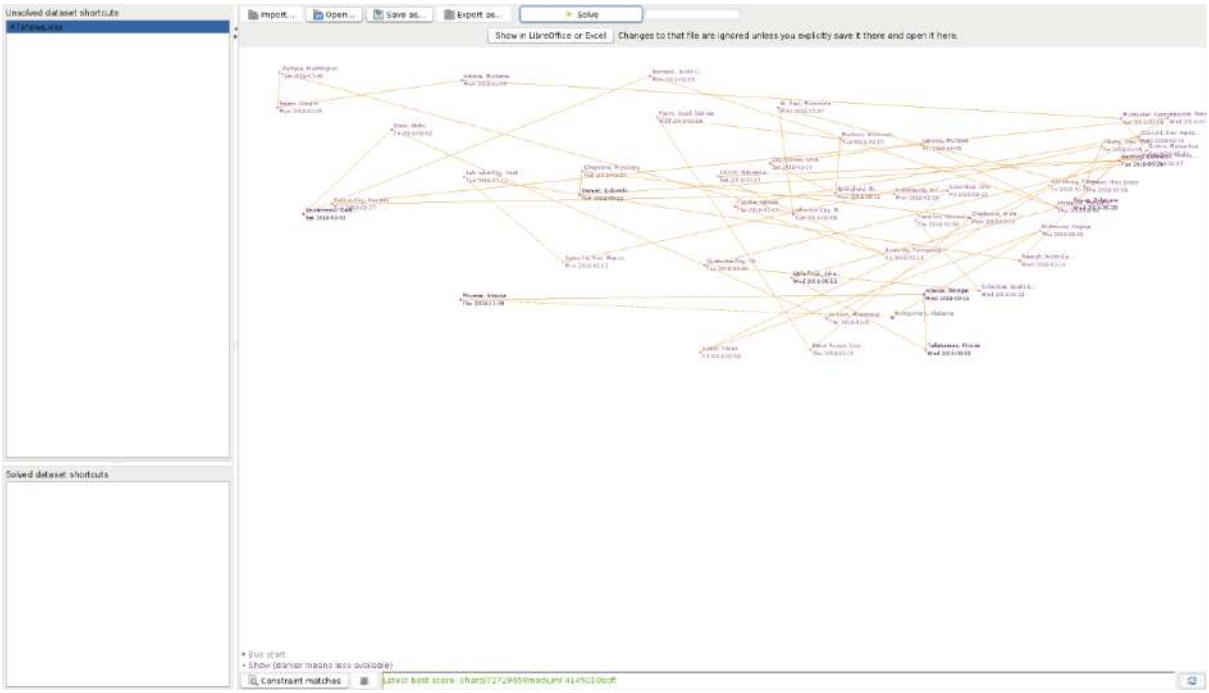
- **Business Scenario / Problem Description**
- **Drive the rock bus from rock-show to rock-show, but schedule rock-shows only on available days.**
- **Hard constraints:**
  - Schedule every required show.
  - Schedule as many shows as possible.
- **Medium constraints:**
  - Maximize revenue opportunity.
  - Minimize driving time.
  - Visit sooner than later.
- **Soft constraints:**
  - Avoid long driving times.

409

ANNEX 4 : KIE OPTAPLANNER EXAMPLES

Exercise: Draw Class Diagram

410



Date	Venue name	City name	Driving time	Driving time per week	Latitude	Longitude	Duration (in days)	Revenue opportunity	Required	Available dates size
Thu 2018-02-01	Richmond, Virginia	Richmond, Virginia	0 hours 6 minutes		37.538857	-77.43364	0.5	2400000	0	224
Fri 2018-02-02	Austin, Texas	Austin, Texas	0 hours 2 minutes		30.27467	-97.740349	0.5	200000	0	256
	Harrisburg, Pennsylvania	Harrisburg, Pennsylvania	0 hours 0 minutes		40.264378	-76.883598	0.5	100000	0	252
Sat 2018-02-03	Boston, Massachusetts	Boston, Massachusetts	0 hours 1 minutes		42.358162	-71.063698	0.5	600000	0	225
	Montpelier, Vermont	Montpelier, Vermont	0 hours 0 minutes		44.262436	-72.580536	0.5	100000	0	209
Sun 2018-02-04				0 hours 12 minutes						
Mon 2018-02-05	Helena, Montana	Helena, Montana	0 hours 1 minutes		46.585709	-112.018417	0.5	1300000	0	215
	Salem, Oregon	Salem, Oregon	0 hours 0 minutes		44.938461	-123.030403	0.5	1200000	0	231
Tue 2018-02-06	Olympia, Washington	Olympia, Washington	0 hours 0 minutes		47.035805	-122.905014	0.5	1800000	0	222
	Jefferson City, Missouri	Jefferson City, Missouri	0 hours 3 minutes		38.579201	-92.172935	0.5	1800000	0	235
Wed 2018-02-07	St. Paul, Minnesota	St. Paul, Minnesota	0 hours 1 minutes		44.955097	-93.102211	1	600000	0	248
Thu 2018-02-08	Trenton, New Jersey	Trenton, New Jersey	0 hours 3 minutes		40.220596	-74.769913	0.5	1100000	0	227
Fri 2018-	Albany, New	Albany, New	0 hours 0							

ANNEX 4 : KIE OPTAPLANNER EXAMPLES

KIE OptaPlanner Deep Dive – Flight Crew Scheduling

- **Business Scenario / Problem Description**
- **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

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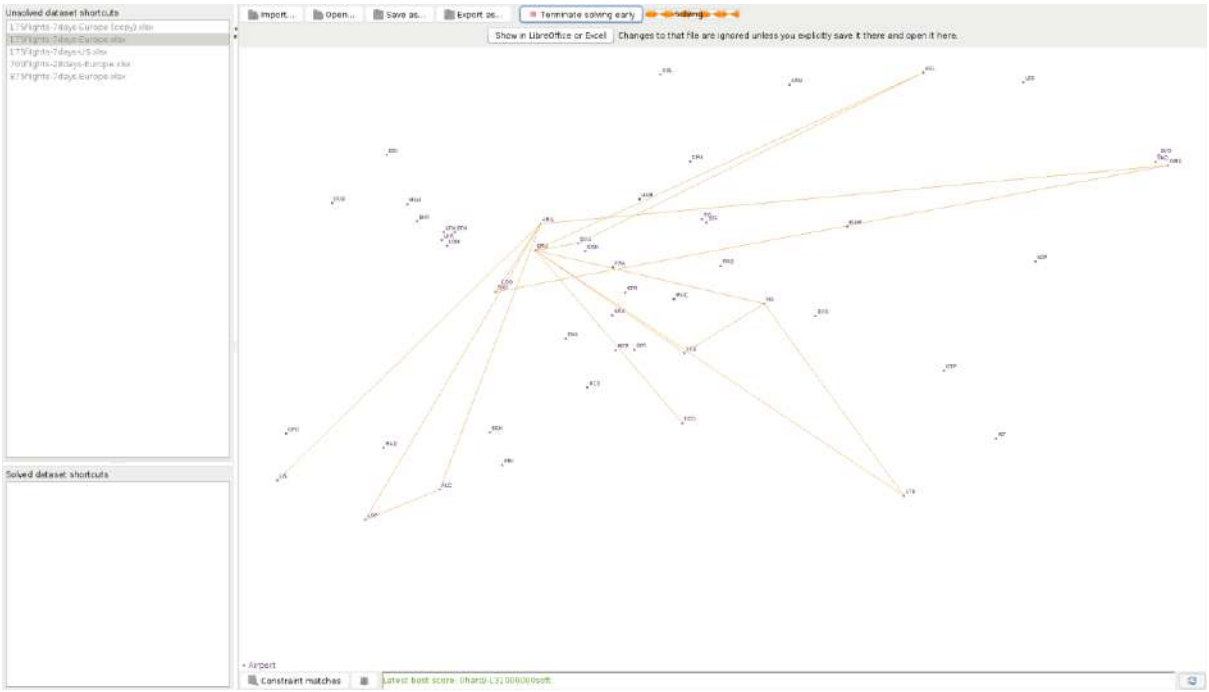
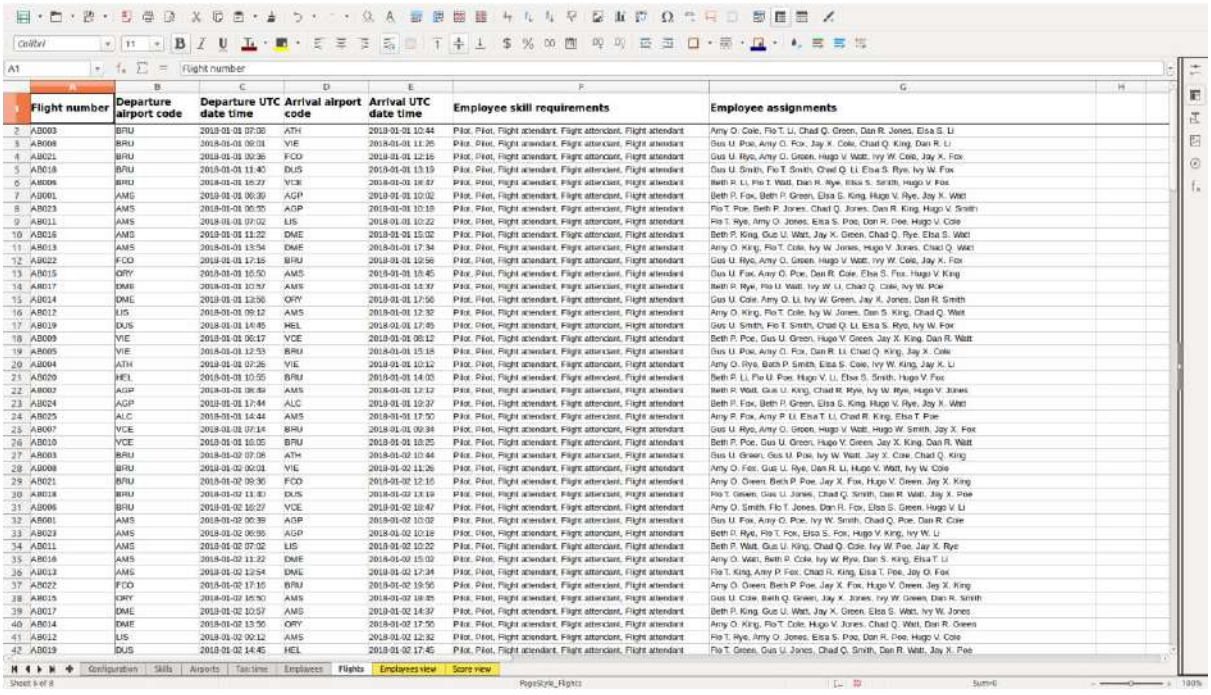
ANNEX 4 : KIE OPTAPLANNER EXAMPLES

Exercise: Draw Class Diagram

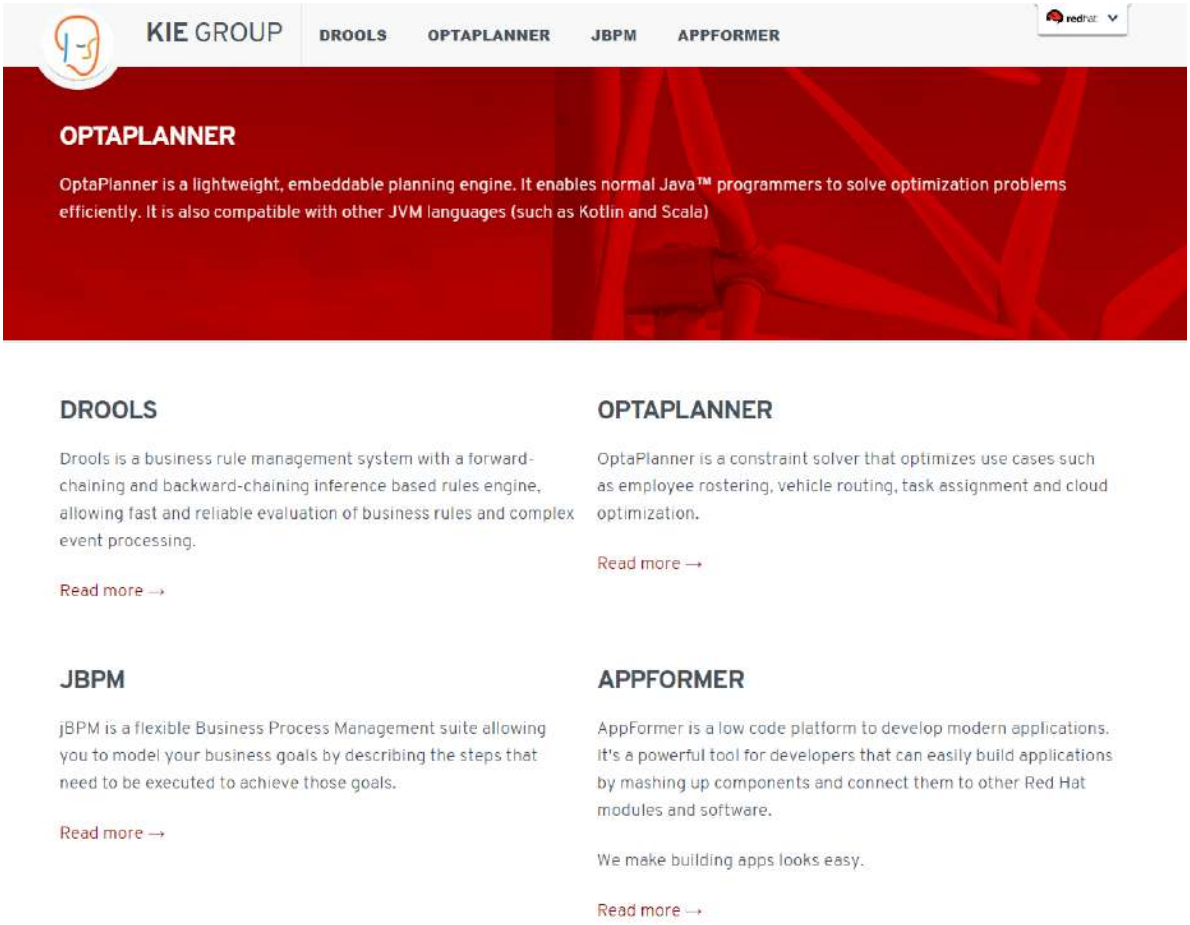
421





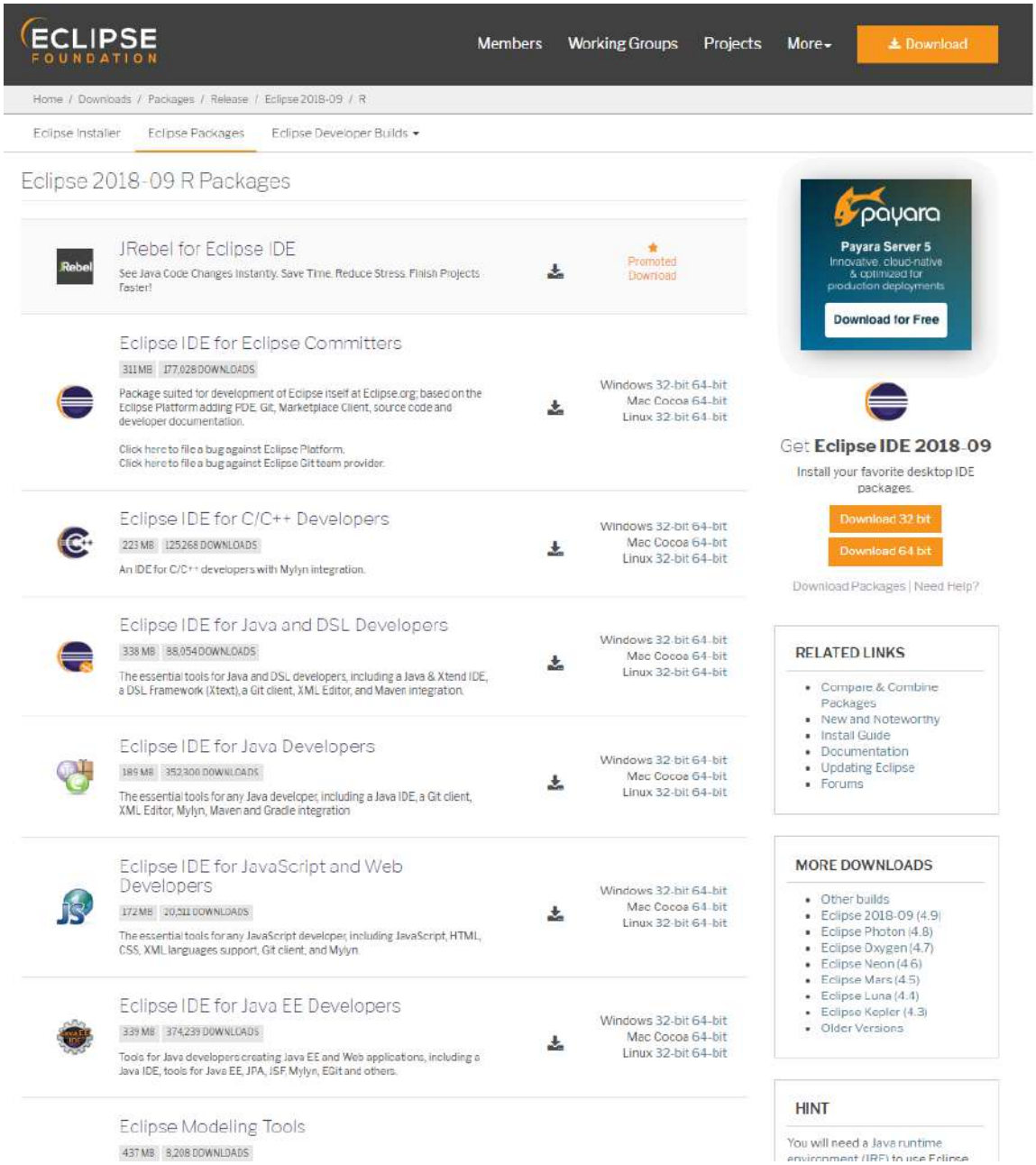
Flight number	Departure airport code	Departure UTC date time	Arrival airport code	Arrival UTC date time	Employee skill requirements	Employee assignments
AB003	BRU	2018-01-01 07:00	ATH	2018-01-01 10:44	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Amy O. Cole, Flo T. Li, Chad Q. Green, Dan R. Jones, Elsa S. Li
AB008	BRU	2018-01-01 09:01	VIE	2018-01-01 11:26	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Gus U. Poe, Amy O. Fox, Jay X. Cole, Chad Q. King, Dan R. Li
AB021	BRU	2018-01-01 09:36	FCO	2018-01-01 12:16	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Gus U. Rye, Amy O. Green, Hugo V. Watt, Ivy W. Cole, Jay X. Fox
AB018	BRU	2018-01-01 11:40	DUS	2018-01-01 13:19	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Gus U. Smith, Flo T. Smith, Chad Q. Li, Elsa S. Rye, Ivy W. Fox
AB006	BRU	2018-01-01 16:27	VCE	2018-01-01 18:47	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Beth P. Li, Flo T. Watt, Dan R. Rye, Elsa S. Smith, Hugo V. Fox
AB001	AMS	2018-01-01 06:30	AGP	2018-01-01 10:02	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Beth P. Fox, Beth P. Green, Elsa S. King, Hugo V. Rye, Jay X. Watt
AB023	AMS	2018-01-01 06:55	AGP	2018-01-01 10:10	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Flo T. Poe, Beth P. Jones, Chad Q. Jones, Dan R. King, Hugo V. Smith
AB011	AMS	2018-01-01 07:02	LIS	2018-01-01 10:22	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Flo T. Rye, Amy O. Jones, Elsa S. Poe, Dan R. Poe, Hugo V. Cole
AB016	AMS	2018-01-01 11:22	DME	2018-01-01 15:02	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Beth P. King, Gus U. Watt, Jay X. Green, Chad Q. Rye, Elsa S. Watt
AB013	AMS	2018-01-01 13:54	DME	2018-01-01 17:34	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Amy O. King, Flo T. Cole, Ivy W. Jones, Hugo V. Jones, Chad Q. Watt
AB022	FCO	2018-01-01 17:15	BRU	2018-01-01 19:56	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Gus U. Rye, Amy O. Green, Hugo V. Watt, Ivy W. Cole, Jay X. Fox
AB015	ORY	2018-01-01 16:50	AMS	2018-01-01 18:45	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Gus U. Fox, Amy O. Poe, Dan R. Cole, Elsa S. Fox, Hugo V. King
AB017	DME	2018-01-01 10:57	AMS	2018-01-01 14:37	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Beth P. Rye, Flo U. Watt, Ivy W. Li, Chad Q. Cole, Ivy W. Poe
AB014	DME	2018-01-01 12:56	ORY	2018-01-01 17:56	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Gus U. Cole, Amy O. Li, Ivy W. Green, Jay X. Jones, Dan R. Smith
AB012	LIS	2018-01-01 09:12	AMS	2018-01-01 12:32	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Amy O. King, Flo T. Cole, Ivy W. Jones, Dan S. King, Chad Q. Watt
AB019	DUS	2018-01-01 14:45	HEL	2018-01-01 17:45	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Gus U. Smith, Flo T. Smith, Chad Q. Li, Elsa S. Rye, Ivy W. Fox
AB009	VIE	2018-01-01 06:17	VCE	2018-01-01 08:12	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Beth P. Poe, Gus U. Green, Hugo V. Green, Jay X. King, Dan R. Watt
AB005	VIE	2018-01-01 12:53	BRU	2018-01-01 15:18	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Gus U. Poe, Amy O. Fox, Dan R. Li, Chad Q. King, Jay X. Cole
AB004	ATH	2018-01-01 07:26	VIE	2018-01-01 10:12	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Amy O. Rye, Beth P. Smith, Elsa S. Cole, Ivy W. King, Jay X. Li
AB020	HEL	2018-01-01 10:55	BRU	2018-01-01 14:05	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Beth P. Li, Flo U. Poe, Hugo V. Li, Elsa S. Smith, Hugo V. Fox
AB002	AGP	2018-01-01 06:59	AMS	2018-01-01 12:17	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Beth P. Watt, Gus U. King, Chad R. Rye, Ivy W. Rye, Hugo V. Jones
AB024	AGP	2018-01-01 17:44	ALC	2018-01-01 19:37	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Beth P. Fox, Beth P. Green, Elsa S. King, Hugo V. Rye, Jay X. Watt
AB025	ALC	2018-01-01 14:44	AMS	2018-01-01 17:50	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Amy P. Fox, Amy P. Li, Elsa T. Li, Chad R. King, Elsa T. Poe
AB007	VCE	2018-01-01 07:14	BRU	2018-01-01 09:34	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Gus U. Rye, Amy O. Green, Hugo V. Watt, Hugo W. Smith, Jay X. Fox
AB010	VCE	2018-01-01 16:05	BRU	2018-01-01 18:25	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Beth P. Poe, Gus U. Green, Hugo V. Green, Jay X. King, Dan R. Watt
AB003	BRU	2018-01-02 07:06	ATH	2018-01-02 10:44	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Gus U. Green, Gus U. Poe, Ivy W. Watt, Jay X. Cole, Chad Q. King
AB008	BRU	2018-01-02 09:01	VIE	2018-01-02 11:26	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Amy O. Fox, Gus U. Rye, Dan R. Li, Hugo V. Watt, Ivy W. Cole
AB021	BRU	2018-01-02 09:36	FCO	2018-01-02 12:16	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Amy O. Green, Beth P. Poe, Jay X. Fox, Hugo V. Green, Jay X. King
AB018	BRU	2018-01-02 11:40	DUS	2018-01-02 13:19	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Flo T. Green, Gus U. Jones, Chad Q. Smith, Dan R. Watt, Jay X. Poe
AB006	BRU	2018-01-02 16:27	VCE	2018-01-02 18:47	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Amy O. Smith, Flo T. Jones, Dan R. Fox, Elsa S. Green, Hugo V. Li
AB001	AMS	2018-01-02 06:39	AGP	2018-01-02 10:02	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Gus U. Fox, Amy O. Poe, Ivy W. Smith, Chad Q. Poe, Dan R. Cole
AB023	AMS	2018-01-02 06:55	AGP	2018-01-02 10:10	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Beth P. Rye, Flo T. Fox, Elsa S. Fox, Hugo V. King, Ivy W. Li
AB011	AMS	2018-01-02 07:02	LIS	2018-01-02 10:22	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Beth P. Watt, Gus U. King, Chad Q. Cole, Ivy W. Poe, Jay X. Rye
AB016	AMS	2018-01-02 11:22	DME	2018-01-02 15:02	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Amy O. Watt, Beth P. Cole, Ivy W. Rye, Dan S. King, Elsa T. Li
AB013	AMS	2018-01-02 12:54	DME	2018-01-02 17:34	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Flo T. King, Amy P. Fox, Chad R. King, Elsa T. Poe, Joy O. Fox
AB022	FCO	2018-01-02 17:15	BRU	2018-01-02 19:56	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Amy O. Green, Beth P. Poe, Jay X. Fox, Hugo V. Green, Jay X. King
AB015	ORY	2018-01-02 16:50	AMS	2018-01-02 18:45	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Gus U. Cole, Beth Q. Green, Jay X. Jones, Ivy W. Green, Dan R. Smith
AB017	DME	2018-01-02 10:57	AMS	2018-01-02 14:37	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Beth P. King, Gus U. Watt, Jay X. Green, Elsa S. Watt, Ivy W. Jones
AB014	DME	2018-01-02 13:56	ORY	2018-01-02 17:56	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Amy O. King, Flo T. Cole, Hugo V. Jones, Chad Q. Watt, Dan R. Green
AB012	LIS	2018-01-02 09:12	AMS	2018-01-02 12:32	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Flo T. Rye, Amy O. Jones, Elsa S. Poe, Dan R. Poe, Hugo V. Cole
AB019	DUS	2018-01-02 14:45	HEL	2018-01-02 17:45	Pilot, Pilot, Flight attendant, Flight attendant, Flight attendant	Flo T. Green, Gus U. Jones, Chad Q. Smith, Dan R. Watt, Jay X. Poe

2.5. ANNEX 5 – KIE OptaPlanner Installation



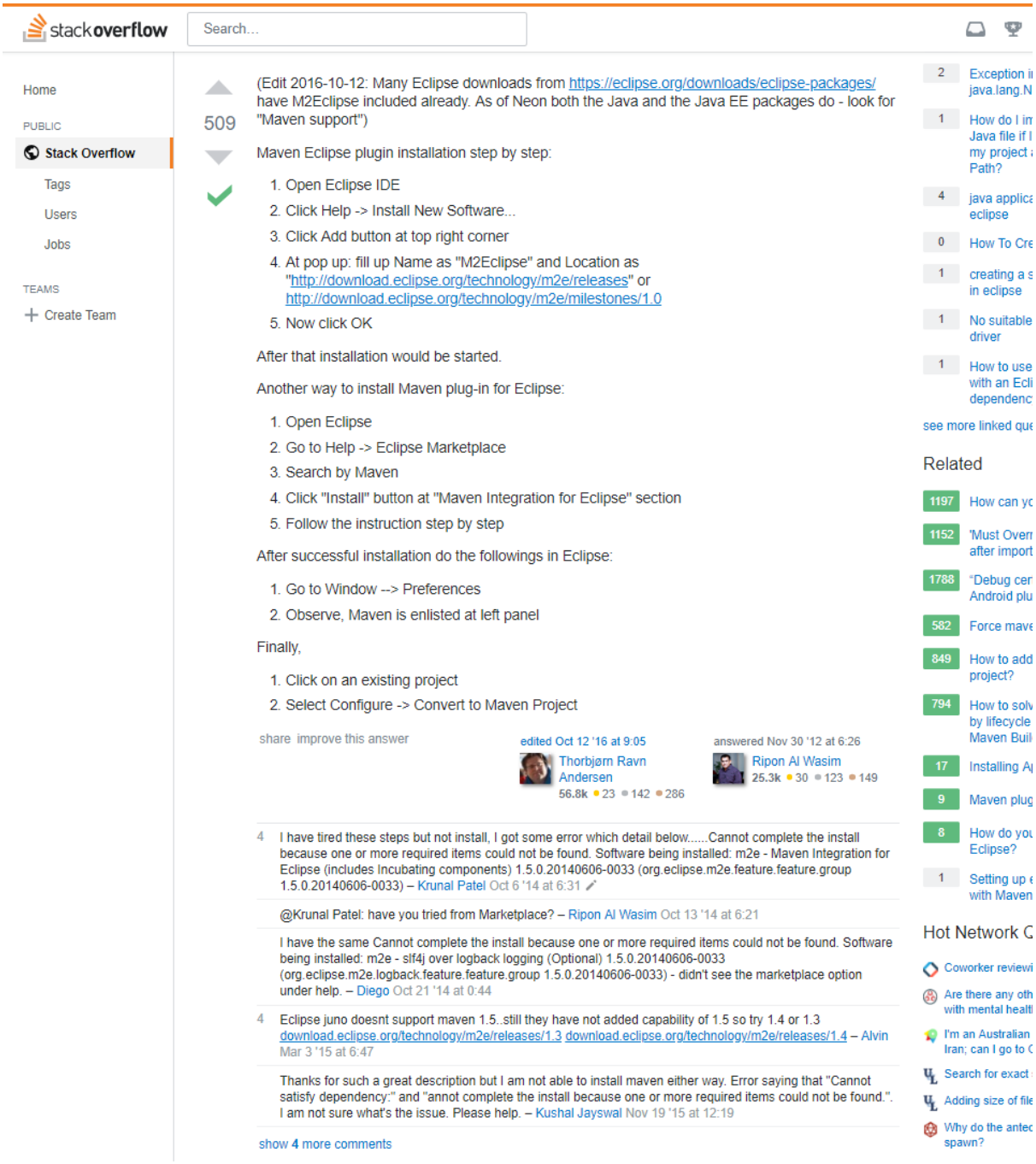
Above: OptaPlanner Installation

https://www.optaplanner.org/



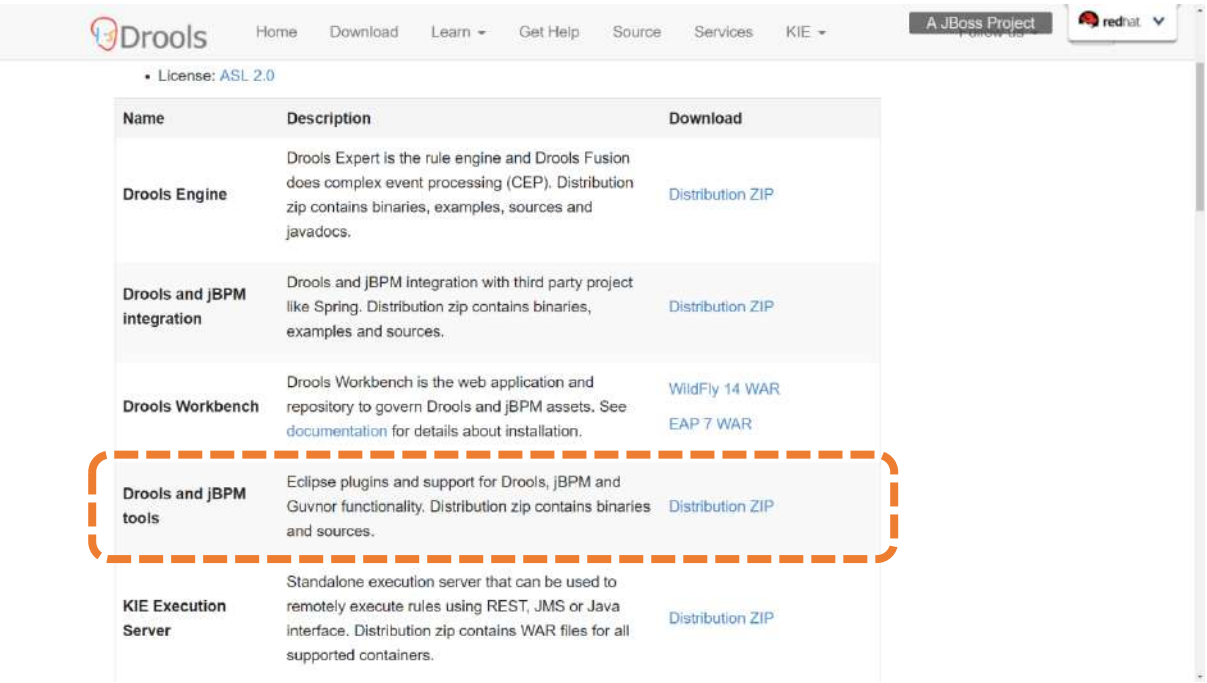
Above: Install Eclipse IDE

https://www.eclipse.org/downloads/packages/



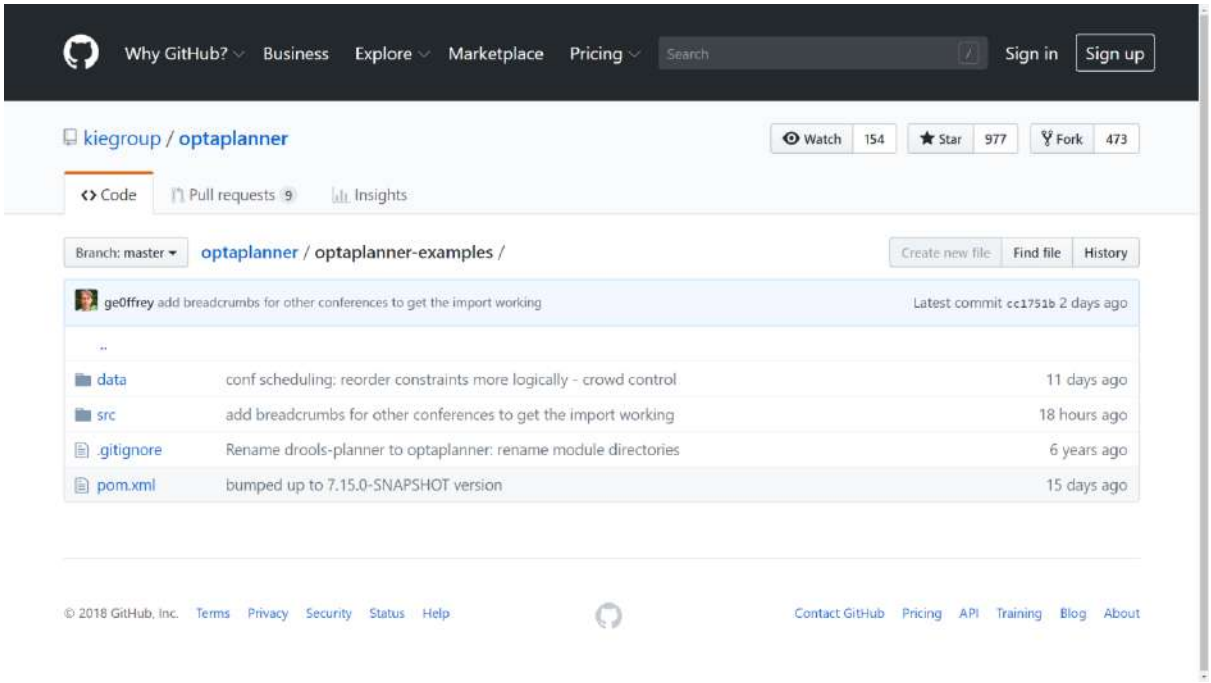
Above: Install Maven in Eclipse

https://stackoverflow.com/questions/8620127/maven-in-eclipse-step-by-step-installation



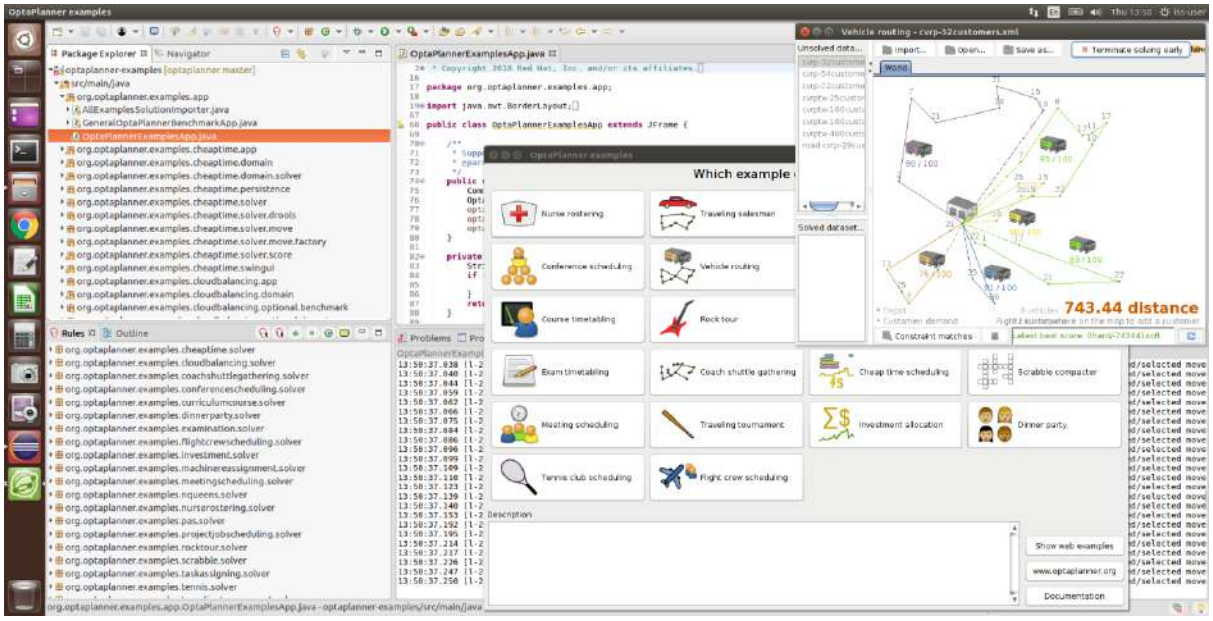
Above: Install KIE plug-in for Eclipse

https://www.drools.org/download/download.html

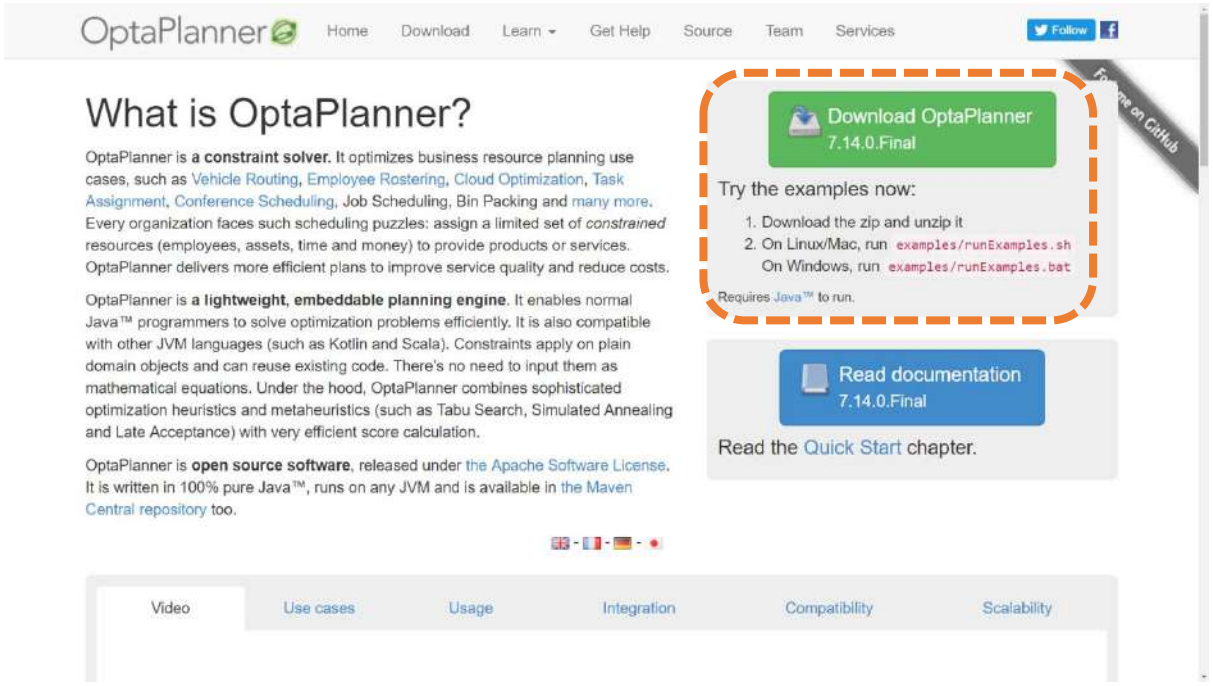


Above: Download OptaPlanner source code and example cases

https://github.com/kiegroup/optaplanner



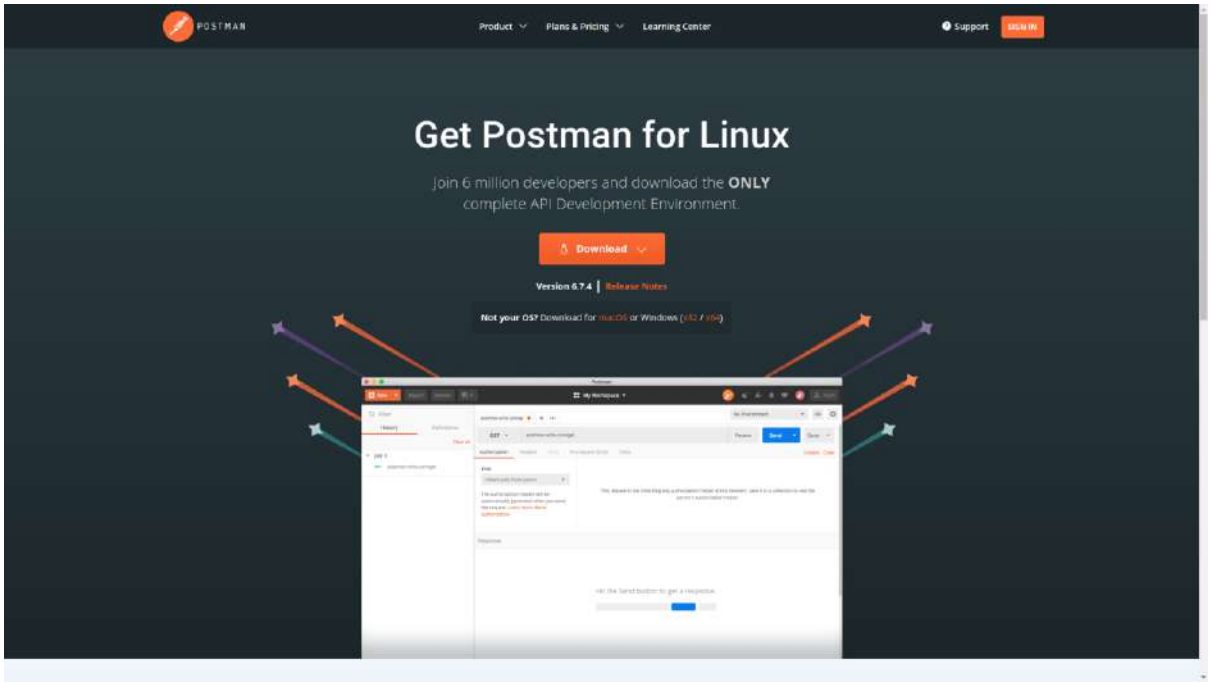
Above: Import OptaPlanner example cases as Maven project in Eclipse



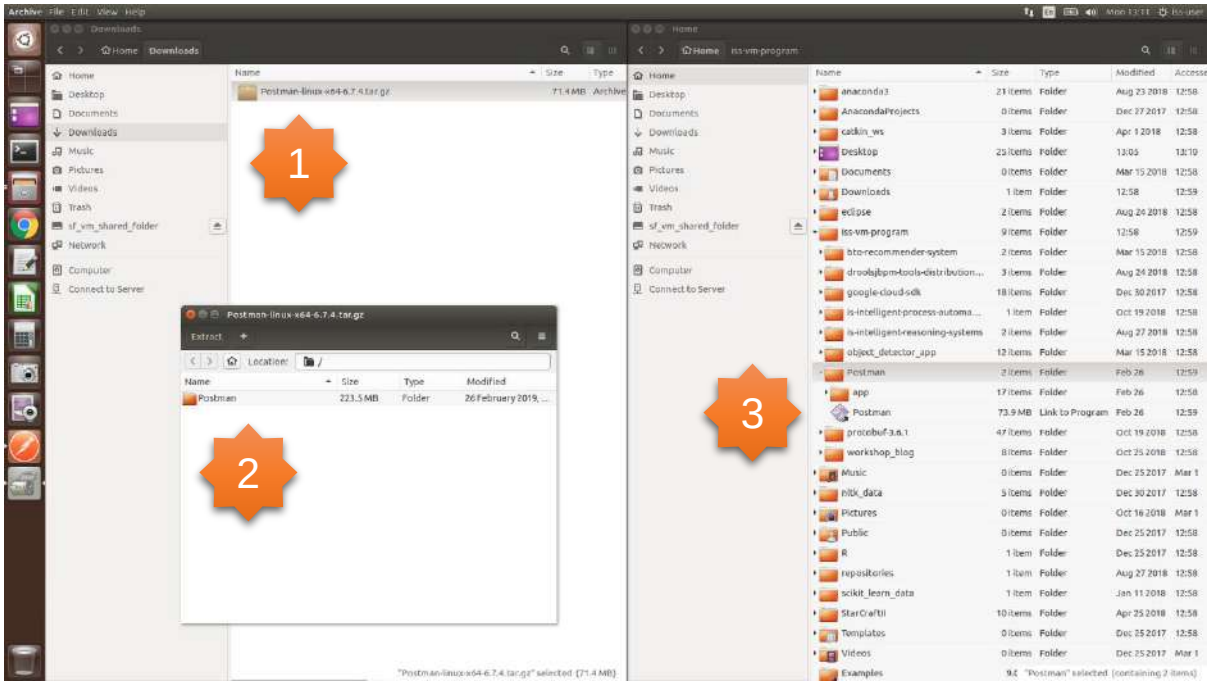
Above: Standalone OptaPlanner

https://www.optaplanner.org/

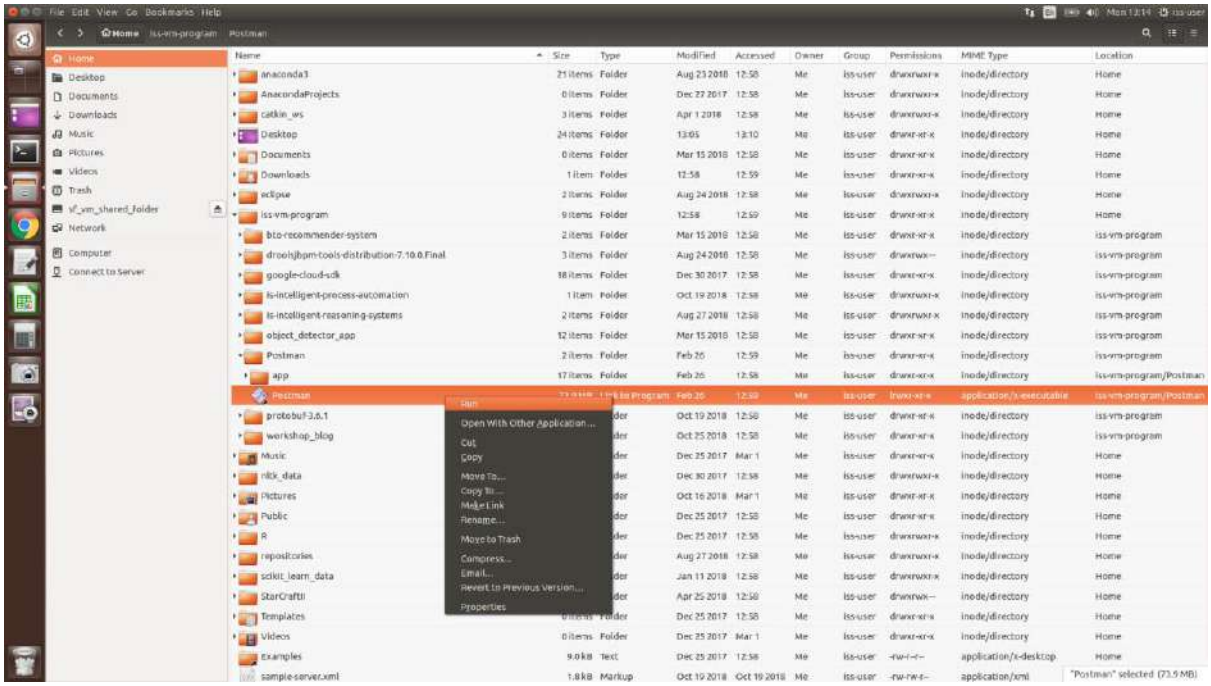
2.6. ANNEX 6 – Postman Installation



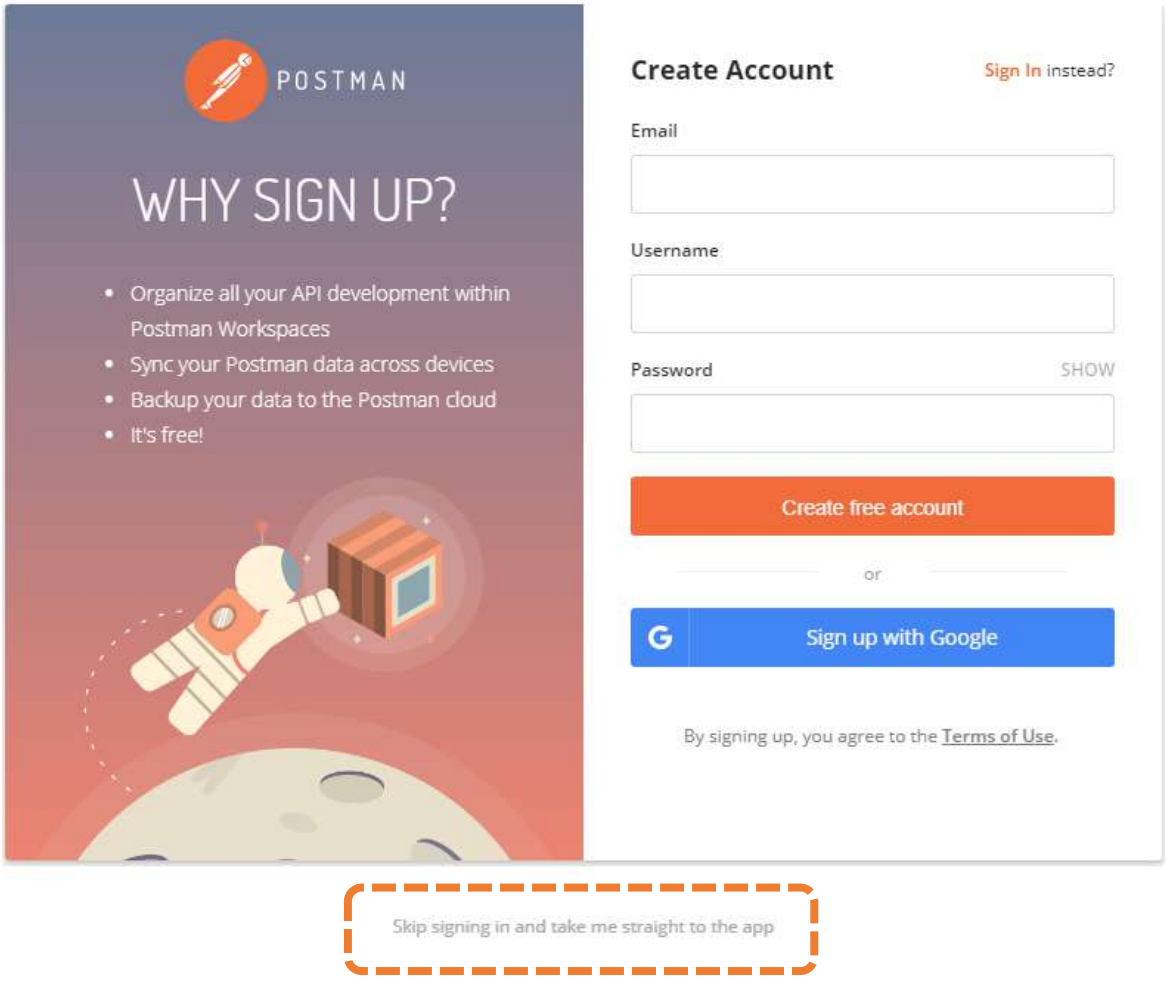
https://www.getpostman.com/downloads/

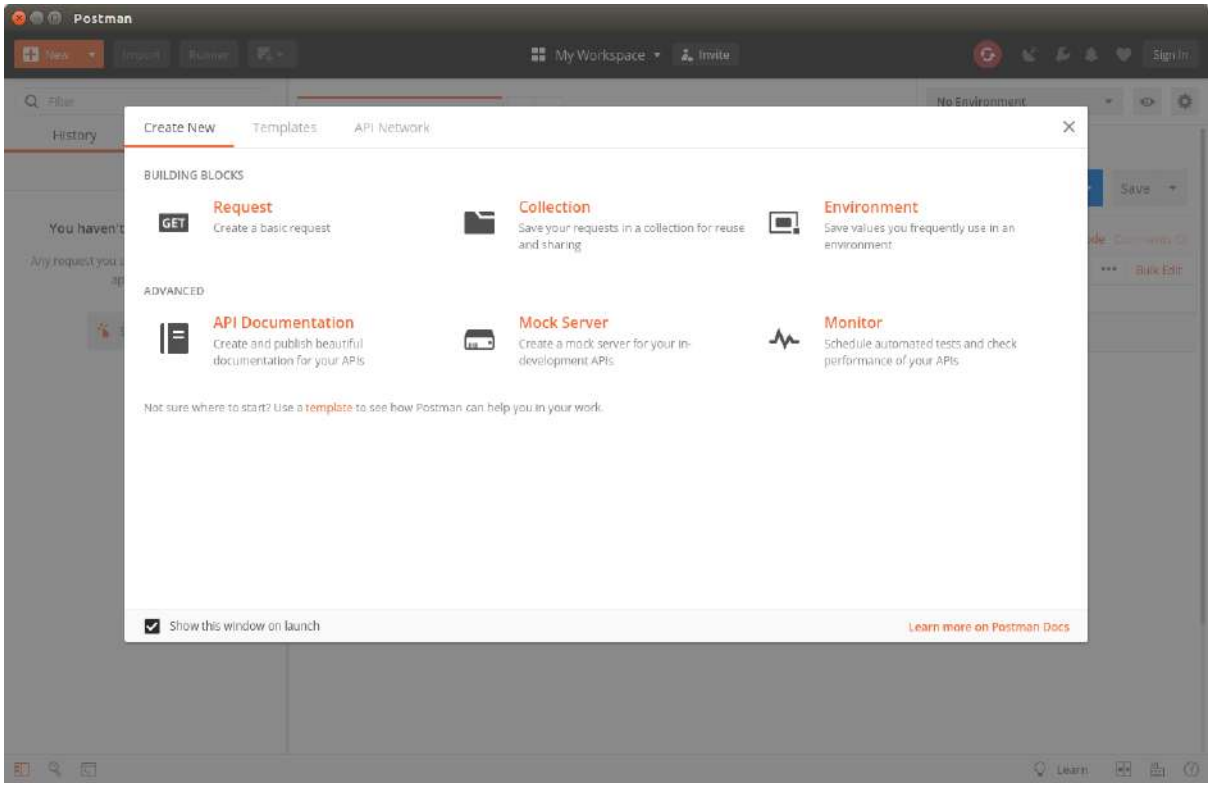


Open/Up-compress downloaded file xxx.tar.gz; Copy folder ***Postman*** to ***/home/iss-user/iss-vm-program/***

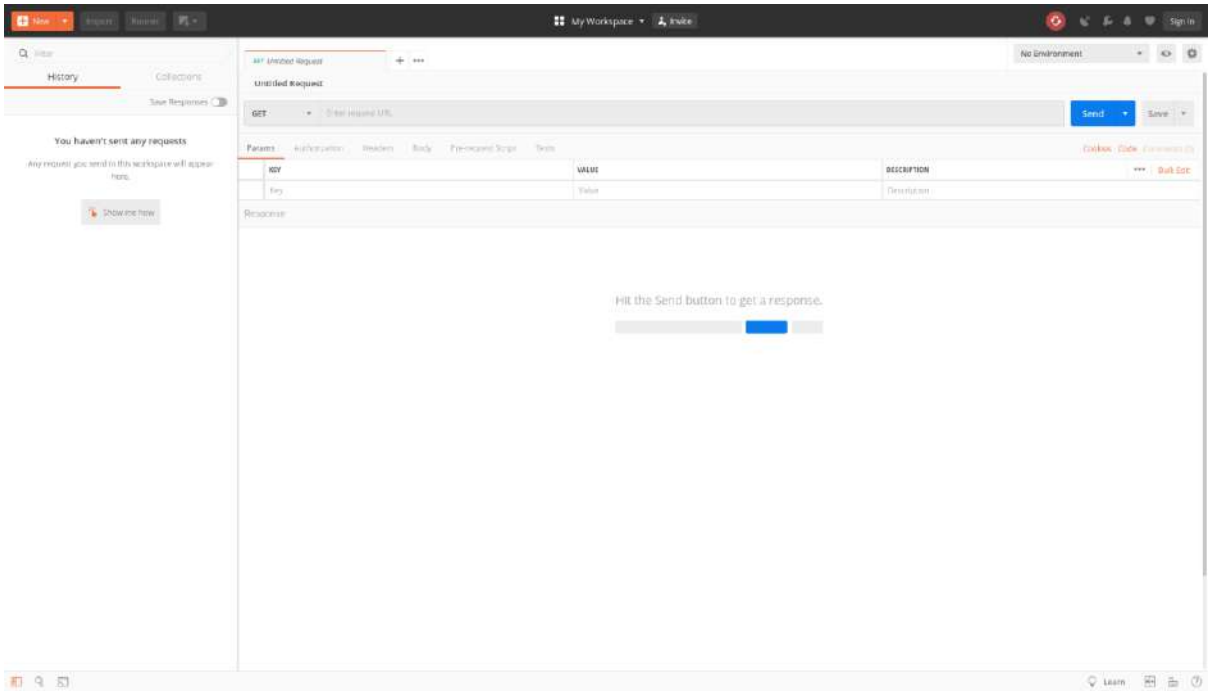


Test: Start Postman; Click skip signing in at the bottom





Test: Close the welcome window



The End of Workshop Project Guide