CRT-AI Constraint Week 2025 - Programming Challenge

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Abstract

This document describes the Challenge Problem for the CRT-AI Constraint Week 2025, the annual training course for Irish PhD students in AI held at UCC in Cork. The challenge will be presented in steps, the initial problem will be presented on Monday, with possible extensions being presented on Tuesday, Wednesday, and Thursday. The problem looks at the current work on extending the local railway services in Cork, and considers the allocation of train crew for these services.

1 Introduction

Rail transport is an important part of public transport for any urban area, and can play a major role in decreasing the number of car journeys that are undertaken in a city. In this project we want to understand the problem of train crew allocation for a train network, and see how future service changes will affect the resource requirements. Understanding these staffing requirements is an important part of planning any future network extension.

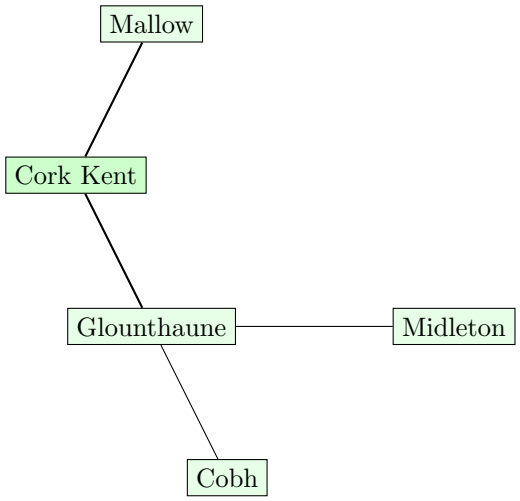

Figure 1: Cork Area Train Network

We start with the current network, we want to know how many trains and drivers are required to perform the current services, so that we have a baseline to compare any future scenario.

Figure 1 shows the current commuter rail network in the Cork area. The main station is Cork Kent, in Cork city, which is connected to the north with Mallow, and to the south-east to Midleton and Cobh. The lines to Cobh and Midleton share a double-tracked section from Cork to Glaunthaune, while the section from Glaunthaune to Midleton currently is single-tracked. On the double-tracked parts, trains in opposite directions can pass each other, on a single-tracked line only one train in one direction can run at any one time.

Work is underway to double-track the line to Midleton, Figure 2 shows an aerial shot from a video by youtube videographer DroneHawk documenting the current work.

Figure 2: Double Tracking the Cork-Midleton Line (Youtube video by DroneHawk `https://www.youtube.com/watch?v=t2owkfWuaS8`)

In order to understand the scheduling of the line, we want to perform the train crew allocation for a typical working day (Monday to Friday) for the network. Each train is operated by a single driver, who takes the train from Cork Kent to one of the endpoints, and back again. The driver may then continue with the same train, or switch to another train. Their shift starts with the departure of the first train they operate, and ends with the arrival back in Cork Kent of the last train they operate.

The working time for train drivers is limited to nine hours per day, the daily driving time is limited to seven hours. The start and end times for each driver will be different, and are not linked to any generic start or end times for shifts, in order to cover the required work from early in morning to late in the evening.

We assume that all drivers are qualified to operate all trains over all lines.

In this simplified study we only consider a single day of operation, there is a secondary rostering task which deals with the allocation of drivers to work

shift on consecutive days, respecting rest times between two working days, and total working time limits over different period lengths. We do not consider this rostering problem in this study.

In a more complex network, we may also have to consider that drivers can change trains not only in a central hub, but at other locations in the network as well. The Cork network is sufficiently simple so that we do not have to consider this.

2 Data

Figure 3 shows the start of the current time table for the Cork train operations, the full timetable is found at `https://www.irishrail.ie/en-ie/train-timetables/timetables-by-route`.

Figure 3: Current Service Timetable (Source: Iarnród Éireann)

		Luan go hAoine Monday to Friday										Dé Luain amháin Mon Only	Máirt - Aoi. Tues. - Fri.	Luan go hAoine Monday to Friday						
													Ó Thrá Lí From Tralee					Ó Heuston From Heuston		
MALA	Ime																			
MALLOW	Dep	..	..	..	..	..	..	..	06:50	..	..	07:29	07:29	..	..	07:50	..	08:05	..	08:30
STÁISIÚN CHEANNT, CORCAIGH	Ist																			
KENT STATION, CORK	Arr	..	..	..	..	..	..	..	07:15	..	..	07:54	07:54	..	..	08:15	..	08:32	..	08:52
STÁISIÚN CHEANNT, CORCAIGH	Ime																			
KENT STATION, CORK	Dep	05:30	05:45	06:15	06:30	06:45	07:00	07:15	..	07:30	07:45	..	..	08:00	08:15	..	08:30	..	08:45	..
An tOileán Beag	Ime																			
Littleisland	Dep	05:38	05:53	06:23	06:38	06:53	07:08	07:23	..	07:38	07:53	..	..	08:08	08:23	..	08:38	..	08:53	..
An Gleanntán	Ime																			
Glountaune	Dep	05:41	05:56	06:26	06:41	06:56	07:11	07:26	..	07:41	07:56	..	..	08:11	08:26	..	08:41	..	08:56	..
Carraig Thuathail	Ime																			
Carrigtwohill	Dep	..	06:01	06:31	..	07:01	..	07:31	..	..	08:01	..	..	..	08:31	..	..	..	09:01	..
MAINISTIR NA CORANN	Ist																			
MIDLETON	Arr	..	06:08	06:38	..	07:08	..	07:38	..	..	08:08	..	..	..	08:38	..	..	..	09:08	..
Fóta	Ime																			
Fota	Dep	05:45	..	..	06:45	..	07:15	..	..	07:45	..	..	..	08:15	..	..	08:45	..	..	..
Carraig an Lua	Ime																			
Carrigaloe	Dep	05:49	..	..	06:49	..	07:19	..	..	07:49	..	..	..	08:19	..	..	08:49	..	..	..
Rinn an Chabhlaigh	Ime																			
Rushbrooke	Dep	05:52	..	..	06:52	..	07:22	..	..	07:52	..	..	..	08:22	..	..	08:52	..	..	..
AN CÓBH	Ist																			
CÓBH	Arr	05:56	..	..	06:56	..	07:26	..	..	07:56	..	..	..	08:26	..	..	08:56	..	..	..

We provide the required data in form of a JSON structure, which describes each round-trip from Cork Kent station to one of the three endpoints. A trip starts at the departure time from Cork, and ends when the train returns to Kent station. Departure and arrival times are given in minutes from midnight, the duration is the duration of the trip in minutes, while the driving time records the required driving time in minutes. The driving time excludes the turn-around at the end of the line.

```
include "globals.mzn";

int:nrTrips;
int:workingTimeLimit;
int:drivingTimeLimit;

type Trip = record(string:destination,
                   int:nr,
                   int:departure,
                   int:arrival,
                   int:duration,
                   int:drivingTime);
array[1..nrTrips] of Trip:trips;
```

The data file has the name `monday.mzn`.

2.1 Questions

In order to cover a normal Monday-Friday working day, how many drivers must be available on each day?

How many trains will be required to operate the services?

Is there a simple way to estimate how many drivers will be required in the best case, without solving a complete optimisation problem?

2.2 Bonus Question

(Only work on this if you have already found an answer to the main questions.)

Minimising the number of train drivers is the main objective of this optimisation problem, but there are many other criteria that can be used to say that one schedule is better than another. What would be your second objective to select the "best" amongst all possible schedules?

3 Tuesday

When we showed our results to the train company, their first reaction was dismay:

> You have forgotten about the breaks for the drivers! They must have a one hour break between the third and sixth hour of their shift, and the break must be in Kent station. Each driver also must have a 15 minute clock-on and clock-off period at the start (resp. the end) of their shift, when they visit the office, get updates on the service to operate, discuss problems with equipment, etc. These times count as working time, but not as driving time.

3.1 Question

If you add these additional tasks to the schedule, how many drivers will be required to cover all services?

3.2 Bonus Question

The European working time directives for train crew (see `https://europa.eu/youreurope/business/human-resources/transport-sector-workers/rail-staff/index_en.htm` for a description) only requires a 45 minute break if the working time is 8 hours or more, and a 30 minute break if the working time is less than that. If we were to implement these rules, how many train crew are required?

4 Wednesday

The double tracking of the line will allow an increase of the services run. Figure 4 shows the planned improvements in the service levels. This is part of a more comprehensive extension of the train services in Cork described in `https://www.irishrail.ie/en-ie/about-us/iarnrod-eireann-projects-and-investments/cork-area-commuter-rail`. A video describing the plans in much more detail can be found on youtube `https://www.youtube.com/watch?v=DDJrmCVJ36o`.

Figure 4: Planned Service Extension (Source: Iarnród Éireann)

A possible timetable for the Cork area based on the service levels given above is given as data file `wednesday.mzn`.

4.1 Question

How many trains/drivers are needed to implement this service?