COMP5920M Scheduling

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Q1:

(a): (i):

As for long term planning for UK rail transport, it usually generates regular operations timetables that can last for a very long period, like several months or half a year. Thus, the optimisation is vital.
Also, for the train planning process like regard the unit diagrams as the primary input. It requires the train unit diagrams are finalised so that it can move on to the crew scheduling. If the train unit diagram is not good enough, it will affect the crew scheduling. So for long term planning, people need to optimise the schedule as good as possible. For example, minimise the crew cost for crew scheduling, and minimise operating cost for train unit scheduling.
The algorithm or approach that long term planning usually used is GaS, ILP, etc. These require much more time and effort to generate, calculate and select a good schedule.
As for very short term planning, it's usually used for re-generate a schedule or solution for unplanned disruptions. For example, if a train crew is calling a sick or a train unit has broken down, it requires some real-time information for substitution and re-scheduling. Thus, it also needs a very short term planning to generate a solution or timetable.
People tend to use heuristic for very short time planning. It's may not good or optimisation enough. But it works, the process is swift, and the job can be done in a short period.

(ii):

Planning horizons are aiming to give a suitable solution or timetable to a specific problem. The real-world problem like a franchise or council tender bids for many years may prefer an approach like ballpark estimates, which require no detailed operational schedules.
Some of the real-world problems like regular operations for half-yearly timetables is predictable and can be used for a long time once the timetable generated. The approach is to focus more on the degree of optimisation and reduce cost. It tends to find global optimisation rather than the local one. So approach like generate and select approach can be useful in this problem.
Some of the problems like holiday or maintenance timetable are predictable service changes and need re-scheduling in advance. The best way to do is to minimise the original timetable changes and improve the schedule robustness against unexpected, such as delays.
Other problem like unplanned disruptions. It allows the solution may not good enough or only reach local optimisation, but generate fast. An approach like heuristic is a perfect match it's required. And people would use such a strategy to deal with short term problems.

(b):

- Bus fleet size estimation. Find the target number of buses in service, which means the number of simultaneous trips.
- Construct an initial solution. Assign several buses to the earliest departures. Then link each assigned trip to it's earliest unassigned and feasible successor repeatedly. Then assign any trips remaining to the first bus.
- Iterative improvements. Minimise the infeasibility, dead running time and idle time. Pairing up solution components and restructuring them in a simple two-way swap. Design acceptance criteria. Compare the cost and penalty of the old and new solution. The solution can be link-based or block-based.
- Then modelling a swap operation. First, define contents to be swapped, like one trip and links before and after on the same bus. Then determine how the swap contents updated, like trips at the end of the links are swapped.
- Also, infrequently used LLH might gradually be given added priority to be selected.

(c):

It requires knowledge from many fields, like computer vision, scheduling, distributed system, cloud computing, edge computing, psychology and so forth.

- In the aspect of computer vision, someone with the knowledge of CV will be able to use the suitable technologies to do the image segmentation like pedestrian recognition and motion detection like tracking. The technological compromise would be more precise.
- About the distributed system and edge/cloud computing. These techniques can be useful in this case. Each camera can be regarded as a network unit, which can upload data or video stream to the cloud, and process the video, analyse in the cloud or local to get the result that people may want. A leader should test if this would work and feasible for this system.
- Psychology is also essential. A leader should come up with ideas to tell the difference between ordinary and strange behaviour. For example, theft always looks around and act sneakily. They can use technology to distinguish unnormal behaviour according to these characteristic.
- Scheduling is the most important. It's like the central role of integrating different field of knowledge into a solution method.

Also, there are other necessary pieces of knowledge like multi-objective optimisation, camera technology, surveillance and security mathematics, AI and so on.
The guys with these pieces of knowledge in different fields have much more benefit of leading the project. He/ she would be able to consider in the context of other discipline and can have a good understanding of the best expertise in all the disciplines involved.

Q2：

(a): (i):

A timetable should be given to form a set of train nodes. Each node represents a trip along with its time, seat demand, arr/dep station and so on.
Then add source and sink nodes to the graph.
Assess and insert potential arcs and rule out many possible arcs due to time infeasible, etc.
Other possible arcs, like several kinds of time allowances, may be needed. Empty running train nodes may be inserted.
Finally, arcs from/to source/link inserted.

(ii):

This model does not consider station infrastructure. So in the optimal solution that the model generated may exist unit blockage.
This model does not include shunting operation. So the solution may lack platforms, siding and depots assignment as well as the paths of shunting movements.
Finally, this model also not include the unit position in a coupled formation. Like the unit, the position is in the front or middle or rear of the train. It's also lead the solution interrelated with blockage and shunting.

(iii):

Train units can be coupling or decoupling according to the different seat demand. As for its fleet size, which is used in vampires algorithm, it would be dynamic changed and more complex. It's not like the bus problem, which the fleet size can be estimated quickly and improve.
Train unit scheduling can have more constrain than bus schedules. For example, the train has to run on the railway, and then shunting movements may be needed. And for vampires algorithm, it's not considering that.
The train also may have potential blockages, and it won't be included in vampire algorithm. Besides, in swap operation, it may cause unnecessary blockages.
Train units sometimes won't fit in some platform, due to its length. And this algorithm also cannot add this condition as constrains.
Train unit would take more time to turn around. And some platforms are through the platform; some are dead-end platform. This can be infeasible and not being considered in the vampire algorithm.

(b):

Generate and select approach (GaS) can be useful in crew scheduling. Similar to SLIM, they both use integer linear programming (ILP) as a powerful solver. ILP is used in the select phase, and it's the most successful based on the set covering model at present. ILP aims to select a few shifts from the enormous pot of candidates, and it focuses more on optimising if an optimal solution exists.

And branch & bound (B & B) also can be useful for the solution of the integer. Both SLIM and GaS would use B&B technique. Specialised branching strategies and divides the search space more efficiently. Progressively adds extra constraints can be considered at B&B. B&B is beneficial to solve large problems.
As for the initial instance or solution can be low quality in both SLIM and GaS. Heuristics are both used in SLIM and generate phase. It's suitable and fast.
Finally, iterative convergence to a high-quality solution can be generated for both SLIM and GaS.

Q3:

(a) (i):

First, in the generate phase, we can create a vast number of staff shifts without considering optimisation or if a change would fit well with others. But all of the shifts should be legal and operable. Use heuristic reduction to make the number of shifts smaller, like reduce relief opportunities. Focus on several characteristics like work to be covered by staff, some hard rules, soft rules and some preferences.
Then in the select phase. Use the enormous pot of candidates shifts from generate phase as input. And use ILP to optimise the solution, select the minimum cost solution. Set covering model, set ground elements like work piece in flight diagram, and staff diagram as a subset. Set covering crew scheduling ILP, clarify the objective function to minimise the cost and number of cabin staff. Some side constraint may be needed. And set lower/upper bound. Then use the revised simplex method to solve the relaxed LP. Column generation also useful for solving the LP. Then use the branch and bound technique to derive an all integer solution. With the help of heuristics can speed up the computation.

(ii):

Their constraints determine the difficulty of two problems using the same approach. The airline would be easier. As for airline crew, they don't need relief opportunity during the workday. They can finish their lunch or break during the flight. Especially for long-distance non-stop flight. The cabin staff can work and relief in the work time. And their shifts begin and end in the same city. The flight crew may not need extra travel, which reduces the problems complexity.

(iii):

We can use this rule to reduce the pot of candidate shifts before it as input to the ILP.
Repeat

If (l_j > α_d):

Remove j from J_d

During the ILP, the cost c_j is a positive correlation with the length for each shift.

(b):

The idea is excellent, it would get closer to global optimality in train operations planning, only if it's implemented successfully. The algorithm has to deal with the constraints of crew scheduling as well as the unit scheduling. And the parameter for crew and train unit also has to be considered at the same time. Massive data for train unit and crew will increase the calculated amount and the complexity.

(c):

In bus vehicle scheduling, the shortest paths can improve the matrix for the bus route. It can find a short path between locations and save time and cost. Some times the dead runs are quicker, it's also one way to save time. So in this way, we try every cell as potential via location, and test which matrix cell could benefit using it. After each cell value is updated, previous searches have to be repeated. So in my opinion, the shortest path in bus scheduling is kind of like exhaustive searching, it will try every possible combination. Such a huge number of iterations can increase the time complexity of the computation. But the timetable after Floyd's algorithm is much more efficient and minimise cost compare with the previous schedules.

For train crew scheduling, we cannot search every possibility shifts to find the optimal solution. This is because there are huge candidate shifts in the pot. We need some approach, like heuristic or B & B, to reduce the size of the pot, then find the best solution. Crew scheduling is not independent scheduling; people prefer taking the unit diagrams as the main input. This also means that the crew cannot begin scheduling until the train unit diagrams are finalised. So the shortest path for crew scheduling can be effect by the train unit scheduling as well, and that makes the problem even harder.