Heavy-Vehicle Scheduling with Maintenance considerations for optimizing Project completion times while also considering Crew Allocation and Dynamic Disruption Scenarios

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Introduction

A large number of heavy vehicle applications are necessary in the construction and mining industry for various tasks. Majority of the vehicles employed for diverse vehicle type-specific tasks are generally a part of the schedule planned for the effective completion of specific projects (like in the mining or construction industry). However, optimal allocation of vehicles for one project could essentially cause sub-optimal allocation-scheduling across other project sites. We therefore consider the problem of optimizing the allocation of heavy vehicles for an aggregator such that the completion times of all projects are respected to the maximum, thereby reducing time-extensions above the critical completion times across all projects. The critical completion time for projects can be estimated using the well-known Critical Path Method (CPM).

While considering this problem of Heavy-**Vehicle Scheduling**, the associated problem of **Maintenance Scheduling** for each vehicle is also considered by us. Additionally, through a separate predictive model, estimation of vehicle health based on sensor data is also developed; this helps us understand if dynamic disruptions in the schedule needs to be considered for some emergency maintenance activity. Since **Crew Allocation** is an important aspect of such scheduling problems, we develop a holistic mathematical formulation (Mixed Integer Linear Program) to tackle this problem as well, while considering the **sleep-rest and leave considerations for crews**.

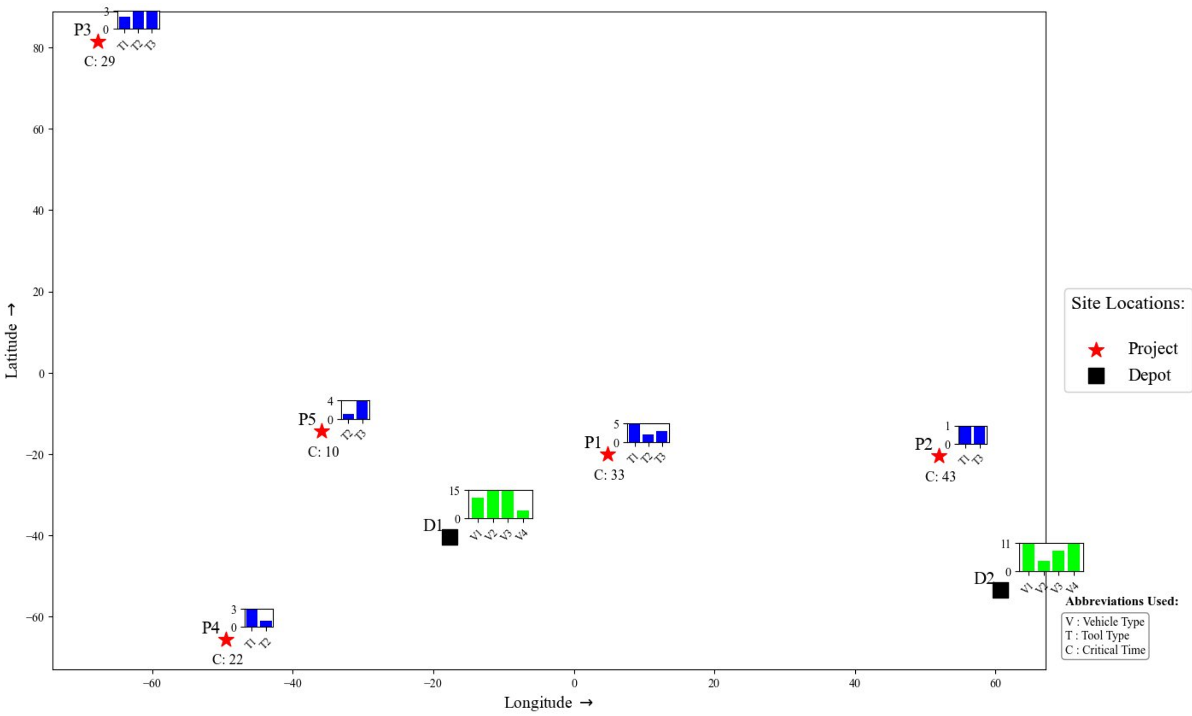

Figure 1: A sample problem instance is shown, with each Project Site containing tools and Depot locations containing vehicles of different types.

Problem Description

We consider multiple locations of Project Sites and Heavy Vehicle Depots distributed across a wide geography. Each Project Site is associated with multiple Activities, such that some Activities can have start dependencies over the necessary completion of other Activities under that same project (as pre-requisites). Each Activity can span over a number of pre-determined days with each day requiring a specific number/combination of heterogeneous vehicle fleet. Each Vehicle Depot has a known Heterogeneous Vehicle Fleet provided at DAY 0 which is routed across the Project Sites. The objective function for the Vehicle Aggregator would be to develop the best Vehicle Scheduling such that the Projects can be completed in minimal time. In case there are sufficient number of vehicles, then each project can be completed within their respective critical times; the actual optimization challenge arises when the vehicles are limited and the number of projects are considerably higher. The Figure 1 depicts a typical problem instance with some inputs shown in the image.

Solution Approach

We develop a Mixed Integer Linear Program (MILP) and solve the same using Gurobi. We will also compare a smaller non-linear formulation with Seeker and Gurobi Non-Linear. We may consider the development of a Heuristic depending on the performance of the solvers, and client requirements. In this regard, suitable real-world problem instances to perform a case study would prove beneficial; we will consider publishing the case-study results in a paper provided only when client clearance is given. We can have multiple different minimization objectives to choose from, some of them being the minimization of:

- the sum of the excess time taken above the critical time, across all projects
- project-wise cascaded makespan minimization

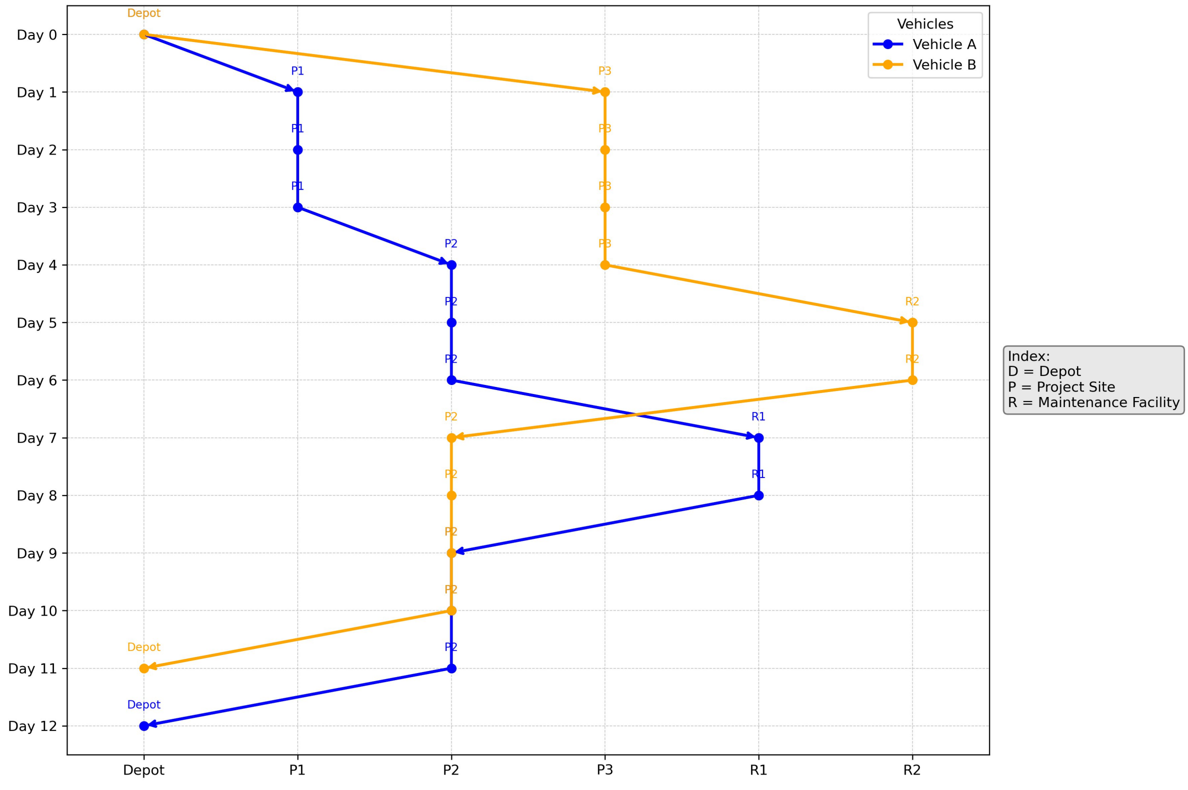

Figure 2: This sample solution depicts routing of two different types of vehicle while also considering maintenance

A sample routing solution is shown in Figure 2; the scheduling/allocation of the vehicles is a separate part of this solution such that vehicles may be used only in some days while it is at a project site. Another sample solution is depicted in Figure 3, which also includes crew allocations.

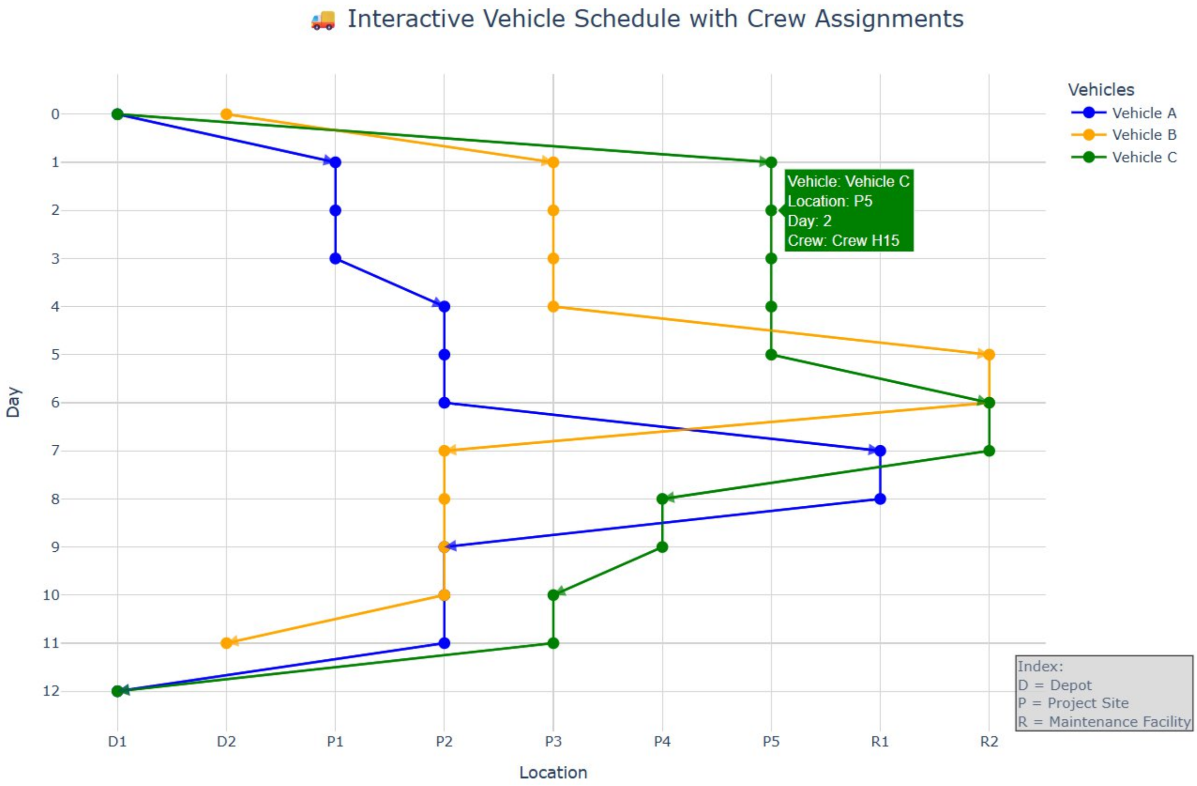

Figure 3: Vehicle Assignment across Project Sites considering Maintenance, as well as Crew Allocations

Conclusion

The intended research is focused on the effective routing-scheduling of heavy vehicles which are required for mining or construction processes. This optimization will prove beneficial in cases when individual projects can be modelled as Activities (like in the cases of PERT/CPM, and should also be similarly applicable in case TAKT planning method is used) where each Activity can have dependencies only on other Activities within the same Project. We can also add constraints on the maximum time (days) within which an activity must start after its previous dependencies are completed; currently we relax this to allow the starting of Activities any time after all their previous dependant Activities are concluded. This will allow vehicle aggregators to plan for detailed schedules only with a basic Activity-breakdown structure for each Project.