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Truck and trailer scheduling in a real world, dynamic and heterogeneous context

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ABSTRACT

We present a new variant of the Vehicle Routing Problem based on a real industrial scenario. This VRP is dynamic and heavily constrained and uses time-windows, a heterogeneous vehicle fleet and multiple types of job. A constructive solver is developed and tested using dynamic simulation of real-world data from a leading Scottish haulier. Our experiments establish the efficiency and reliability of the method for this problem. Additionally, a methodology for evaluating policy changes through simulation is presented, showing that our technique supports operations and management. We establish that fleet size can be reduced or more jobs handled by the company.

1. Introduction

Over the last few decades, an increasing number of studies focusing on optimization problems has arisen from the field of logistics, particularly with respect to vehicle routing and scheduling as recently reviewed in Berbeglia et al. (2007, 2010), Laporte (2009) and Schorpp (2011). This increasing interest is driven by the difficulties experienced on a daily basis by logistic companies such as the high numbers of tasks to be performed and dynamically-varying job information.

In this paper, we present a dynamic vehicle scheduling problem derived from the operations of ARR Craib Ltd. (ARRC), a UK haulage company based around Aberdeen harbour, the largest hub for oil and gas in Europe. The problem consists of assigning trucks and trailers to a set of jobs subject to a variety of constraints. Jobs can be received at any time during the day, so the problem must be repeatedly solved dynamically and in real time. The problem includes jobs with time windows, multiple customers, many types of job, and the use of rigid trucks, non-rigid units and trailers that may be dissociated. Use of subcontracted resources is permitted but costly to the company.

Instances of the Vehicle Routing Problem (VRP) (Golden et al., 2008) studied in the literature consider subsets of these problem features, however none of them deals with all features simultaneously. Therefore, the problem presented in this paper differs from previous research. Moreover, since this problem is common to haulage operations around industrial harbors across the globe, we argue that its study is of broad practical significance.

Hence, this paper contributes to the field of operational optimization by (a) describing a new variant of VRP; (b) explaining its relationship to existing VRPs; (c) presenting a lightweight constructive solver capable of real-time dynamic optimization;

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(d) assessing the operational impact of the optimized schedules for a large haulage company; and (e) presenting a methodology for company policy-making through simulation.

The paper is organized as follows. In Section 2, the problem is described in detail and a mathematical formulation is established. In Section 3, background on vehicle routing problems is provided with reference to related work in the literature. Section 4 describes our proposed constructive solver. Experiments and results are presented and discussed in Section 5. Finally, conclusions and directions for further research are presented in Section 6.

2. Problem description

2.1. General description

ARRC is a leading truck haulage company based in Aberdeen, operating the largest haulage fleet in Scotland and generating an annual turnover of around £35 m. Its activities are organized into two main areas: local and long-haul jobs, each managed from a separate office. Long-haul jobs involve transportation of goods across the UK whilst local jobs are all carried out within a fixed perimeter around Aberdeen. Local jobs present a significant scheduling and routing challenge compared with long-haul. Local jobs turn over quickly with trucks performing several jobs within a single day. Customer calls arrive throughout the day, and job length can be significantly affected by various delays, so the scheduling and routing problem varies dynamically throughout the day. This paper focusses exclusively on the problem of handling local jobs on a daily basis.

ARRC local customers are from a variety of industries. However, being located in Aberdeen, the vast bulk of the goods being transported are for the oil and gas industry. The local office of ARRC has an operations team of four members in charge of allocating trucks and trailers to the different jobs. The general policy of ARRC is to accept all jobs from their customers and to meet all deadlines. In order to make this possible, ARRC is able to subcontract resources from alternative haulage companies when needed. Naturally, this comes at a cost and so a general objective of operators at ARRC is to keep the number of subcontracted trucks, trailers and drivers as low as possible.

A key challenge is that jobs can be received or updated at any time. The level of dynamism is highly variable because the activity varies significantly between days. Some jobs require immediate action on notification while others are known, and can be planned, days in advance. For a more precise analysis, we refer the reader to Section 5, where metrics from the literature are applied to several real datasets obtained from ARRC.

A number of different job types exist. First, *ad-hoc* jobs are standard pick-up-and-drop jobs that do not require a change of trailer. Ad-hoc jobs may run between any pair of locations as required by the customer. Any type of truck and trailer may be used for ad-hoc jobs subject to customer requirements and internal policies.

Outbound shipping jobs are those transporting goods to the dock to be loaded onto vessels prior to their departure from the harbour to offshore oil installations. Outbound shipping jobs can only be performed by flatbed trailers, may be collected from any location and are always delivered to a quayside. Loads arriving at quaysides must wait to be loaded onto vessels by independent quayside workers. Hence, loaded trailers arriving at a quayside are detached and left there. Thus a truck that completes an outbound shipping job will detach its trailer.

Finally, *inbound shipping* jobs transport goods from the quayside to their final onshore destination. Inbound shipping jobs are always collected at a quayside location and can be delivered to any other location. Similarly to outbound shipping jobs, cargos are managed by independent quayside workers who load them onto empty trailers that can then be picked up by trucks. Thus, only a specific trailer type can be considered. A truck assigned to an inbound shipping job will attach a loaded trailer on collection. This may require detachment of an existing attached trailer. Inbound shipping jobs may be communicated by the quayside workforce at any time during the day.

The different types of job are allocated together and it is important that any compatible resource can be used for any job. There are approximately 100 vehicles and 150 trailers in the fleet, although numbers vary on a daily basis due to maintenance or unavailability of drivers. Trailers have different capacities and some vehicles are rigid and cannot be detached from their trailers (e.g. vans). Since the fleet is heterogeneous, some loads can only be handled by trailers of specific capacity. It may be acceptable to use trailers that are oversized for some jobs in order to meet customer deadlines. For example, a job defined for a van but performed by a 15-ton truck is preferable to hiring a subcontracted van. At the same time, operators normally wish to avoid using extremely large trailers for small loads. Using a flatbed trailer to perform the job of a van is a sign of misused resources. Table 1 shows a limited number of acceptable substitutions to perform a job for a specified type of trailer. In addition, Table 1 lists all types of trailers ranked by increasing capacity. Those trailer types that are not dissociable are indicated by an asterisk.

Due to the hazardous nature of the goods being transported, some jobs require specialized handling. Job allocations must comply with the European Agreement on international carriage of Dangerous goods by Road (ADR).[1] The ADR scheme defines nine types of special goods, including for instance explosives, gases or radioactive materials. Thus, a job can only be allocated to

[1] More details on ADR can be found on the Health and Safety Executive (HSE) website at http://www.hse.gov.uk/cdg/manual/classification.htm (accessed September 2013).