IMPACS - A BUS CREW SCHEDULING SYSTEM USING INTEGER PROGRAMMING

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Introduction

The IMPACS system described here makes use of integer programming, combined with a variety of heuristic methods, to compile bus crew schedules, that is, the lists of duties to be worked by the drivers (and conductors, if any) in the course of a bus company’s regular daily operations. In most places in this country, crew scheduling is done after a bus schedule has been constructed, that is, a vehicle has been allocated to every planned bus journey.

The bus schedule consists of a set of running boards which indicate the journeys to be operated by each bus from the time it leaves the garage until it returns. For crew scheduling purposes, we need to know on each running board the times at which there is an opportunity to change the crew, so that one crew can leave the bus, to take a break or finish their duty, and another crew can take over the operation of the bus, having just started their duty or having already worked on another bus. Relief opportunities occur at relief times, when the bus is at one of the places where crews can change over; such places are called relief points. Hence, each potential relief opportunity has an associated relief time and relief point. Figure 1 shows a

![Fig. 1. A set of running boards.](image-url)
bus schedule, with each running board represented by a horizontal line indicating the period of the day for which the bus is in operation. The relief opportunities are shown by the vertical lines. (In order to construct a crew schedule, we should need to know the exact time and the relief point for each relief opportunity, but for clarity these details have been omitted).

Crew scheduling involves covering a set of running boards by a set of crew duties, in such a way that:

(a) every part of every running board is assigned to a duty;
(b) the duties conform to a set of agreed rules governing their legality and acceptability;
(c) the cost of the schedule, in terms of the number of duties required and their cost in wages, is minimised;
(d) subject to (c), the number of duties with undesirable features is kept to a minimum.

The interval between two consecutive relief times on a running board must be worked by a single crew, since by definition there is no opportunity to change crews except at relief times. Hence, this interval is, from the crew scheduling point of view, an indivisible piece of work. A crew duty consists of one or more spells, each of which consists of one or more consecutive pieces of work on one bus. In the U.K., duties normally work on at least two buses, with an intervening mealbreak taken away from the bus. Figure 2 is a graphical representation of a crew schedule showing how the set of duties cover the bus schedule of Figure 1. Only those relief opportunities which are used to change crews are marked. In this example, all the

Fig. 2. A graphical representation of a crew schedule.