A Review on Bus Driver Scheduling and Optimization

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Abstract— Efficiency of any transportation system pivot on many parameters such as accessibility, reliability, comfort, frequency, safety etc. Vehicle scheduling and bus driver scheduling are also significant parameters which affects the quality of public transport system. For any public transport system to be successful optimization of all this parameters are required to gain maximum benefits to the operators as well as commuters at minimum cost. Following work focuses specifically on bus driver scheduling keeping in mind the labour agreement rules and the research on the optimization of bus driver scheduling using genetic algorithm, tabu search algorithm along with other heuristics has been reviewed.

Key words: Optimization, Vehicle scheduling, Bus driver scheduling, Public transport system

I. Introduction

Public transport is an integrated group of transportation facilities which enables people or freight to be transported from one place to another. Public transport systems or mass transit system are significant part of transportation system as its overall objective takes care of people rather than vehicles.

There are ample research works carried out for improving the efficiency of public transport system by working on the parameters such as frequency, accessibility, reliability, safety, comfort etc. Bus driver scheduling optimization is one of the means by which the efficiency of mass transport system can be improved.

A. Driver Scheduling

In designing an effective and efficient public transportation system, virtually every transit authority in the world must optimize their available resources such that costs are minimized and numerous other criteria are met. Primary tasks in planning for transit systems include route design, vehicle scheduling, and driver scheduling. Aside from minimization of costs, the criteria involved in conducting these tasks may include operational time, the number of vehicles and/or drivers required, and a variety of driver-satisfaction aspects, including union rules. As such, the tasks become multi-objective processes.

The scheduling problem of bus driver usually have objective related to the minimizing the total number of bus driver. These problems have multiple conflicting objectives and constrain. It is difficult to determine optimal solution for such problems with the help of conventional approaches. It is found that genetic algorithm performs well for such multi objective problems. (SRC: Jingpeng Li & Raymond S.K. Kwan 2003).

Driver Scheduling: It is a solution that contains a set of shifts that cover all the required driver work.

Relief opportunity: It is time and place where a driver can leave the current vehicle for reasons such as taking a meal-break or transferring to another vehicle.

Piece of work: The work between two consecutive relief opportunities on the same vehicle is called piece of work.

Shift: The work a single driver carried out in a day is called a shift. This is composed of several spall of work. A spell contains a number of consecutive pieces of work on the same vehicle. The driver scheduling problem can be formulated as a set covering integer linear programming.

Integer programming: It is an extension of linear programming with only integer values for the decision variables of the problem.

B. LABOUR AGREEMENT RULES

The Rules governing the construction of duties are mostly determined by past practices and local conditions and are agreed between the bus company and the union as internal regulations while other regulations are provided by the government. some of the rules are given as guidelines which are relaxed i.e. SOFT rules and some are adhered to HARD rules. Most rules are relevant to all bus companies even though their parameters differ, while some are the additional rules made by the company itself which needs to be considered for driver requirements. The tightness of the rule plays an important part in the scheduling process.

Typically the global rules are:

- The paid allowance for signing on and off the garage.
- The maximum time a driver can work without a meal break. This may usually four to five hours.
- The minimum length of meal break. This may be usually 30 minus plus the time required to travel to the canteen.
- The total working time.
- The total Spread over (duration between the beginning and the end of the trip).

II. Literature Review

The bus driver scheduling has received much attention since last few years. The scheduling problem of bus driver consists in finding a set of trips which covers the bus schedule so as to utilize the resources effectively and satisfy a set of constraints laid down by the company labour regulations. The minimum cost set of feasible daily duties that cover all trips or vehicle blocks should be found. A vehicle block is the itinerary of a vehicle between its departure from the garage and its returns to the garage. These problems have multiple conflicting objectives and constrain. Several formulations and algorithms has been proposed for the crew-scheduling problem.

Mingming Chena and Huimin Niua(2012), “Research on the Scheduling Problem of Urban Bus Crew Based on Impartiality” studied on the scheduling problem of urban bus crew based on impartiality. They considered impartiality constraint which is on the basis of assurance to meet the time shift of trips and work intensity for the crew, and establishes a crew scheduling model with the objective of minimizing the total idle time. They are assuming (1) The type of urban bus line is a ring one, which means that the starting station and terminal are the same bus station. (2) The departure and arrival time of all trips are determined, and trips have been numbered in sending departure time order (3) The number of crew is large enough to meet the demand for bus trips, and a crew should be restricted to work in the same vehicle during the bus operating time. (4) The type of duty is a single mode. Based on this assumption they give the optimization formulation.

A. Objective function

It can be expressed by minimizing the total idle time of crew.

$y_{ij}^{k}(d_j - a_i)$ it is used for the calculating idle time of crew between two adjacent trips i and j

$$\min \sum_{k=1}^{m} \sum_{i=1}^{n} \sum_{j=2}^{n} y_{ij}^{k} (d_j - a_i) \qquad \ldots(1)$$

B. Constrain

Each trip will be carried out by exactly one crew. Therefore, we have

$$\sum_{k=1}^{m} x_i^k = 1, \forall i \qquad \ldots(2)$$

The relationship between variable y_{ij}^{k} and decision variable x_i^k can be formulated by the following equation.

$$\mathbf{y_{ij}^{k}} = x_i^k x_j^k \qquad \ldots..(3)$$

The adjacent two trips carried by the same crew should meet time shift constraint, which means the difference between departure ($x_j^k d_j$) time of latter trip and arrival time ($x_i^k a_i$) of former trip should not be less than the minimum layover time T_0.

The crew should satisfy work intensity constrain, which means the total work time of each crew does not excced the maximum number of work hours T_1.

$$\sum_{k=1}^{m} x_i^k (a_i - d_i) \leq T_1, \forall k \qquad \ldots.(4)$$

In order to express impartiality constraint, the difference between the maximal work time and minimal work time should not exceed the specified value T_2 . We can introduce a parameter.

$$G_k = \sum_{k=1}^{m} x_i^k (a_i - d_i) \leq T2 \qquad \ldots(5)$$

This constraints minimize the total idle time of the crew and manage the trips effectively.

Maikol M. Rodrigues , Cid C. de Souza & Arnaldo V. Moura (2006), “Vehicle and crew scheduling for urban bus lines” described a computational tool developed for solve the urban transportation problem in the large metropolitan area of Sao Paulo, Brazil. They have used hybrid strategy mathematical programming models and heuristics were combined with it for solving the optimization problems related to scheduling.

Jingpeng Li & Raymond S.K. Kwan (2003), “A fuzzy genetic algorithm for driver scheduling” studied on a hybrid genetic algorithm based on the fuzzy set theory for the public transport bus driver scheduling problem. The basic objectives are to minimize the total number of shift & total shift cost. They presented the greedy algorithm framework in GAFE. The mathematical model of fuzzy comprehensive evaluation is then discussed. They gave some definitions like relief opportunity (RO), piece of work, shift and driver schedule A greedy heuristic(GA) is used, which constructs a schedule by sequentially selecting shifts, from a very large set of pre-generated legal potential shifts, to cover the remaining work. Individual shifts and the schedule as a whole have to be evaluated in the process. Fuzzy set theory is applied on such evaluations. Comparative results using real-life problems, some of which are very large instances, are presented.

Christors Valouxis and Efthymios Housos (2000), “Combined bus and driver scheduling” studied on the combined bus and driver scheduling. In this paper optimized model for the solution of the combined bus and driver scheduling problem is presented for Greece public transport. The planning is presently done manually or follows a fixed inflexible and often inefficient historical set of shift patterns. This paper presents a quick heuristic scheduling procedure for the solution of the problem. In addition, a column generation procedure named CGQS that uses an LP-solver and the QS process as its integer solution finder is presented. CGQS starts from the solution point of a single QS run and then performs several iterations in which LP problems are solved and new promising shifts are created using the LP dual solution.

Optimization formula:

$$\min \sum_{j=1}^{n} c_j x_j$$

$$\text{subjected to} \sum_{j=1}^{n} a_{ij} x_j \leq 1, i \in B$$

$$\sum_{j=1}^{n} b_{kj} x_j = 1, k \in T$$

Definition use in this model:-

n= Number of generated shift, i= index of busses.

J= index of shift, k= index of crew.

B= set of busses, T= set of segment.

a_{ij}= 1 if bus i is covered by shift j, otherwise value is 0.

b_{kj}= 1 if trip segment k is covered by shift j, otherwise value is 0.

x_i^k= It is the decision variable which indicates whether trip I is carried out by crew k. it takes two values: 1 if trip i is carried out by crew k. or 0 if trip is not carried out crew by k.

y_{ij}^{k}=it is a binary zero-one variable which is used to represent the status of trip i and trip j carried out by crew k.

Thus they focused on the minimization of cost which increases the efficiency.

Helena Ramalhinho Lourenço, Jose Pinto Paixao & Rita Portugal, “Metaheuristics for The Bus-Driver Scheduling Problem” presented metaheuristics for solving real crew scheduling problems in a public transportation bus company. However, the metaheuristics presented in this research can also be applied to other crew-scheduling problems in different sectors, as for example, train and airlines companies.

In this paper four metaheuristics are used for solving a problem.

– Linear programming base method.

- The greedy randomized adaptive search procedure (GRASP).
- Tabu search algorithm.
- Genetic algorithm.

There are three primary programs currently in use for driver and vehicle scheduling: TRAPEZE, HASTUS, and TRACS.

TRAPEZE (Fulton, 2006) is optimization software capable of optimizing vehicle and bus driver scheduling together or individually as per the need of the user. Before solving for an optimal solution, the user is allowed to specify both hard and soft constraints. Hard constraints detail the labor union rules of operation, management controls, and vehicle and operator limitations, while soft constraints control quality control aspects. In terms of drivers, they can set the maximum or minimum number of drivers they wish to have on staff and can choose if they want their solution to decrease shifts, decrease pay, decrease work time, or decrease overtime pay. In this step, they can implement labor union agreements and define part-time vs. full-time employees. Additionally, in terms of vehicles, the transit agency can determine the maximum or minimum number of buses available to perform the services and the maximum or minimum buses stored at a particular depot.

To solve the driver and vehicle scheduling problem, there are three stages that are implemented. The first stage involves subdividing the large problems into homogeneous sets, modeling the constraints using linear programming, and using successive decomposition to determine the most appropriate relief points. The second stage involves combining the sub problems, using linear programming to extract shifts, and when the problem is small enough, use of integer programming to complete the solution. The final stage is to map out the solution to determine the number of consecutive pieces of work that can be performed by the same bus, and use of assignment algorithms to shift the segments to improve the solution.

HASTUS scheduling software is used by over 250 bus and rail companies in the world (HASTUS, 2006). The initial software was developed 25 years ago as a collection of optimization algorithms. This optimization tool has evolved to adapt to the needs of individual transit companies and is now capable of solving vehicle and crew scheduling problems either separately or combined (Fleurent, 2006). It begins by cutting the blocks into pieces of work, then matches pieces of work to form drivers' schedules, then assigns actual operators, and finally improves the solution heuristically (Wren and Rousseau, 1995). The first three steps are performed by three subsystems, HASTUS-Bus, HASTUS-Macro, and HASTUS-Micro, respectively (Rousseau and Blais, 1985). Although the subsystems are fully integrated, HASTUS-Macro can run alone without involving other parts of the system. It is considered an “intelligent-interactive” system since it allows interplay between mathematical optimization tools and human guidance input.

TRACS (Fores and Proll, 1998) scheduling system is currently used by many bus operators in the United Kingdom. The system prefers to first build vehicle schedules to cover sets of predetermined journeys, which gives the user flexibility of making changes to the vehicle schedules. Driver shifts are then assigned to the blocks of work created. There are three stages to determining the optimal driver scheduling solution. First, a set of shifts which are valid according to labor agreement rules is generated. A subset of shifts is chosen heuristically due to the many million potential shifts. If necessary, the size of the generated shift set is reduced using integer linear programming. Once the set of shifts is determined, a subset is selected which covers all the vehicle work at a minimal cost.

III. Research Extracts

When a transit agency has reached a sufficiently large fleet and employment size, it becomes obvious that shifting from a manual to an automated system is necessary to perform driver and vehicle scheduling in way that will provide the most efficient and cost effective service to the passengers. There are three primary programs currently in use for driver and vehicle scheduling: TRAPEZE, HASTUS, and TRACS. All of these are optimization programs with similar objective functions. Each program's objective is to minimize cost, allowing users to enter any constraints particular to their agency or labor union agreements. All of these methodologies have allowed for significant cost savings for public transit agencies in terms of the amount of money spent on drivers, vehicles, and manpower to perform the scheduling task itself. Although there are many benefits to the automated system, there is still room for improvement in these methodologies.

Prior information required for optimization: Information such as total number of buses, number of crew members, number of trips, arrival time and departure time of each trip, layover time, frequency of buses, break time etc.

IV. Conclusions

Bus Driver Scheduling if done manually may not be able to satisfy all the constraints. Genetic algorithm proves to be very efficient for Bus Driver Scheduling along with mathematical model. Hybrid Genetic algorithm, Tabu search algorithm, metahuristics etc results in efficient optimization with minimum cost.

Further if the need of extra drivers is considered in case of contingencies such as driver not reporting due to illness or any other reason or extra buses required in cases of some maintenance then more optimal solution could be obtained.

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