Interactive Software Tool for Scheduling of Individual Bus Operators on a Fixed Route


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1.0 INTRODUCTION

Bus scheduling has been an entirely manual process in Sri Lanka and only practiced in the State Owned Sri Lanka Central Transport Board (SLCTB). Presently both private sector buses and public sector buses operate without a proper scheduling system. Experienced schedulers/timetable compilers(persons who are carrying out scheduling process) who worked in the SLCTB have retired without passing their experience and knowledge to the new generation. Therefore, there is a need to attract and train schedulers to the industry. To this end there is a need to develop a computer aided tool to carry out scheduling more efficiently and speedily.

The present bus operating system in Sri Lanka has several unique features. In the first instance, the majority of buses are owned by individual operators instead of companies, as in other countries. As a result of this both vehicle and crew assignment has to be integrated. That is to say that each operator has a single vehicle and that vehicle has a unique crew. This disables crew assignment between vehicles of the same operator as well as bus running assignment between vehicles belonging to the same operator(The term “running” is used to describe a schedule of a bus for a day). In addition, each vehicle is also assigned to a given route. This disables assigning the same vehicle to different routes. The removal of these degrees of freedom makes it extremely difficult to automate this process and hence there are no proper algorithms to be found in literature or in practice (Sitarski, 1997). This paper investigates the development of interactive software where both the automated process and the schedulers experience can be combined.
Previous work on the bus scheduling considered dispatching buses on a route from either single or multiple depots (Huisman-Dennis, 2004 and Freling et al, 1999). In all the above papers, all buses operating on a route were assumed to belong to individual owners in the form of either a company or a person. Therefore the earlier work attempts to minimize the overall operational and the capital cost of the single operators who serviced the route. The models and the algorithms presented in these earlier papers are inappropriate for adaptation to a country like Sri Lanka, where almost all the operators are individuals and each bus is only permitted to operate only on a pre-specified route.

Therefore when scheduling is carried out, the question of equitable distribution of revenue between each bus becomes a major consideration. This adds a further constraint to the scheduling criterion which also needs to include minimizing the overall total cost to passengers, crew working conditions and rules of the regulating body. Each of these concerns that are advantageous to maximize for one party may reduce the expectations of another party. Hence in scheduling buses, an objective function which includes all these constraints has to be developed as a first step. The objective function developed by Kumarage and Piyadasa(2002) was used here. This objective function considers economic cost of passenger, cost of operation and revenue of operator. The cost of waiting, cost of traveling standing were considered in economic cost of passengers and overheads, variable cost, overtime costs, marginal cost saving by non operation of bus, etc… are considered in cost of operations. The buses were dispatched with average headway $h_e$ for a day for a route, where $h_e$ is the headway that minimize the total economic cost of bus operation as a country.

2.0 INTERACTIVE FRAMEWORK FOR PLANNING AND SCHEDULING

According to Kwan et al (1993), the main objective of scheduling and planning of routes is to provide the best quality service using the minimum number of buses. In Sri Lanka, the planner or scheduler has to accept the currently available number of buses in each route and thereafter provide the best quality service using these buses as a given constant. This becomes a sub optimal function when there are more buses than already available on such a route. Thus the solution also becomes sub optimal where the route has to financially support the existence of more buses than required. Hence, the quality of service that can be provided to the passenger diminishes.

The planning process will determine the dispatching times of buses, which focus mainly on the service quality i.e. the availability of a bus at the right time at the right place. The scheduling process checks whether such bus trips can be linked efficiently. This process becomes more complex when there are only a few services, which share
a common stretch of a route where the scheduler has to time several departures in order to prevent several buses from departing at the same time.

The development of a scheduling algorithm that can automatically find “the best” solution which provide the required breaks for the crew, layover times for buses to meet peaking function in passenger demand, the reintroduction of buses after breaks and layovers, compliance to maximum working hours and other regulatory requirements has been considered as an extremely difficult and complex task (Kwan et al, 1993).

Figure 1: Action Diagram of the Interactive Framework of Scheduling

This complexity requires some degree of active participation of the scheduler in scheduling and planning. Therefore, the algorithm has been developed as an interactive program where the scheduler can make certain decisions with respect to the scheduling process. This combination provides a solution that encompasses both speed as well as practicality of scheduling.

Figure 1 depicts an extension to the interactive framework for scheduling and planning as proposed by Kwan et al (1993) to suite the requirements in Sri Lanka.
In this framework a single route is considered at one time and the planning of headways is based on demand and supply. This is followed by the planning process where the scheduler uses the interactive algorithm to determine the best solution. The next stage seeks to dispatch buses based on the demand based headways and to link individual bus trips efficiently. This requires the interactive ability to interchange bus trips between two runnings, change of individual departures, provision of breaks, removal of buses and bus trips from services and the entry and termination of runnings, etc.

The report generation process is fully automated. The final step requires the reports to be reviewed by the scheduler and changes effected where necessary.

3.0 UNI-Scheduler – AN INTERACTIVE SOFTWARE TOOL FOR BUS SCHEDULING

The UNI-Scheduler, an interactive software tool for the bus scheduling described earlier, has been developed using an object oriented approach. It has a collection of different object classes. These object classes describe the service requirement in terms of demand, headways between vehicles, linkages between vehicle assignments, requirement for the interchange of trips, matching of runnings, fleet information etc.

UNI-Scheduler features Windows based graphical user interfaces. A relational database is used for storing data. Borland Delphi (Version 7) was used to develop UNI-Scheduler, MS SQL Server 2000 to implement database and report generation using Crystal Reports (Version 9). The Uni-Scheduler provides the following utilities and tools for the scheduler to speed up the scheduling process.

♦ Terminal Information Manager
♦ Route Information Manager
♦ Headway Designer
♦ Timetable Designer
♦ Report Generator

The features and methods of using these utilities and tools are described below.

3.1 TERMINAL INFORMATION MANAGER

This utility is used to maintain a database of all available terminals in the country (or area for which the routes ply) and is part of “Terminal/Route Information” step of the framework. This database is referred to whenever UNI-Scheduler or scheduler needs a terminal name. The UNI-Scheduler will not allow using any terminal name without
posting it to the database. This is done in order to maintain integrity of names. Each terminal is also assigned a three letter code known as “Terminal Code”. The Terminal Information Manager supports English, Sinhala and Tamil languages. The “Terminal Code” and terminal name in English are mandatory fields. The Sinhala and Tamil names are only used in reporting.

3.2 ROUTE INFORMATION MANAGER

This is a tool to gather information about each route and is part of “Terminal/Route Information” step of the framework. The basic information required here include the route number, its origin, via and destination. The information about the buses available for that route is also recorded here. The existing parameters such as start and end time of traffic day, travel time and route lengths are entered under the “Parameters” expansion button. The design parameters such as traffic day, number of private and state bus runnings from each terminal are decided by the scheduler and entered here.

3.3 HEADWAY DESIGNER

This tool is based on the passenger demand survey or information from respective transport authorities. This comes into the interactive headway designing step of framework. The scheduler decides the dispatching times of buses based on the demand pattern of the passengers seeking service on the route. The Headway Designer tool automatically calculates the start time of each time period with the associated headway based on passenger demand. It also calculates the cumulative number of trips for the whole day. The scheduler uses the formula

\[ \text{Round Trip Time} = rt_{1} + tt_{12} + tt_{21} + rt_{2} \]

to calculate the required number of buses for a given period. A graphical expression of the components of the round trip made up of travel times \( (tt_{12}, tt_{21}) \) and recovery times \( (rt_{12}, rt_{21}) \) is given below.

The tool also calculates the average headway for the day to compare it with the optimum headway range provided by the objective function developed by Kumarage and Piyadasa(2002).
3.4 TIMETABLE DESIGNER

This is a collection of tools, which enables the scheduler to design the timetables more effectively and efficiently. Timetable designer includes following tools and it is the heart of the interactive framework (i.e. dispatching buses, Provide Breaks and Layovers… step).

- Dispatcher
- Departure Changer
- Remover
- Trip Interchanger
- Break Provider
- Service Provider
- Running Information Viewer
- Fleet Information Viewer

The first tool in this designer is the bus dispatcher. This tool will dispatch a bus at the time it is required for first dispatch and will continue in service for the whole day according to the required headways, as determined by the Headway Design. Deciding on individual or batch dispatching and choosing the number of trips per day per that each bus is allowed are facilities available for interactive intervention of the scheduler.

The next design tool is for removal of trips or runnings. Using this tool, individual bus trips of a running can be removed. The trip interchanging design tool can be used to interchange a selected block of bus trips of a particular running with another running. The break provider is a design tool that can be used to provide breaks to runnings. The running information viewer provides detailed information such as working hours, steering hours, breaks, number of round trips etc. for a running. This tool helps the
scheduler to verify the compliance of the running with respect to duration of breaks, working hours etc.

The Break Provider is used to provide break for runnings and the Service Provider is used to assign service providers for runnings (i.e. whether running is assigned to SLCTB or private bus).

The fleet information viewer is a panel that provides a complete analysis of all the runnings from a given terminal. This will provide information such as average trips per bus, average trips per month, maximum, minimum and average working hours for all runnings etc. This will enable to verify the equitable distribution of runnings for each and every bus.

3.5 REPORT GENERATOR

The Report Generator is the only fully automated tool in the UNI-Scheduler. This will generate the timetable for a route, control sheets for a route, schedule for each running, and bus roster for a month. This comes under the only fully automated step, “Report Generation”, of the interactive framework.

4.0 SCREEN SHOTS OF MAJOR TOOLS AND OUTPUTS

The Terminal Information Manager (Figure 3) is the starting point of interactive process of UNI-Scheduler. Any terminal name used in UNI-Scheduler must be entered here.
The figure 4 depicts the Route Information Manager window and entered data for route “141”.

It includes data grid to input various information required to be entered regarding a route. By clicking on the expansion buttons under Buses, Parameters, Design Parameters, and Mid Point, information about these elements of a selected route can be entered. Figure 3 shows the expansion of Buses and it is used to input bus information for route “141”.

Figure 3: Terminal Information Manager
Figure 4: Route Information Manager

The figure 4 shows a Dispatcher window of the Timetable Designer. First two grids show the dispatched buses from each terminal and it includes Running Number (a number assign to identify each running), Arrival Time, Headway and Departure Time of each trip.

The “Available Running Numbers” column shows number of buses left to dispatch from each terminal. The First Arrival Time and Start Time are information of first trip of selected running number to be dispatched. Under “Options” there are two options one for dispatch buses in batch mode and other one to restrict number of trips. When 5 buses are needed to dispatch from one terminal with 5 minutes headway, entering starting details of first bus, Time Interval(5 minutes) and Number of Trips(5 trips) and clicking on “ADD” will be the only actions required.
The Headway Designer is the main planning tool available in the UNI-Scheduler. The screen shot of this tool is depicted in figure 5.
The figure 6 depicts the Timetable Designer.

![Timetable Designer](image)

Figure 6: Timetable Designer

The timetable and schedule for runnings for the route “141” is depicted in figure 5.

![Reports Generated by UNI-Scheduler](image)

Figure 7: Reports Generated by UNI-Scheduler

The timetable and schedule for runnings for the route “141” is depicted in figure 5.
CONCLUSION

The UNI-Scheduler is the first scheduling software tool used in Sri Lanka for scheduling and it provides tailor made solutions to the scheduling problems in Sri Lanka. It has been successfully used to schedule over 2500 buses in more than 90 routes mainly in the Western Province.

The major problem faced when using the Uni-Scheduler is the oversupply of buses in many routes. As a solution for this, only the required number of runnings for a day were used when scheduling and other buses were off scheduled. In many routes, specially in town services, there were sharp demand increases in morning and afternoon peaks. This has led to another problem; that is action required for extra buses introduced in the peak during off peak. As a solution for the extra buses introduced into the service during morning peak, in some cases recovers time during off peak was increased and in some cases buses were layover. In the afternoon, extra buses needed to cater peak demand were taken from the layovered buses during the lunch. Buses were layovered during the lunch by introducing layovered buses in the morning to the service.

The optimum headway range for a route is calculated using the software developed by Kumarage and Piyadasa(2002). Once the headway plan is developed using UNI-Scheduler, it calculates the average headway for a day. This average headway is then checked against the headway range provided by above model and changes are done if average headway does not fit into the range.

Presently UNI-Scheduler is going through a major upgrade to incorporate the inter province buses. This includes the headway and timetable designer for multiple days of a week based on the demand of each day, new rostering system, and master panel timetable creator for routes which share a common stretch of a route.

The future developments to be introduced include tools such as visual scheduler, GIS mapping, interactive reporting tool for customized reports, and web publishing tools. These tools will definitely help schedulers to carry out their work more efficiently.
REFERENCES:


Kwan Raymond, Wren Anthony, Zhao Liping, Clement Ross, Rahin Mohammad, “Applications of Information Technology for Bus and Driver Scheduling”, University of Leeds, 1993