CAPTURING THE REQUIREMENTS FOR A BUS DRIVER SCHEDULING SYSTEM

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Abstract. *Capturing the requirements is an important activity in system development life cycle. It defines what are the user's need and help developers to design the right software for the user. Bus driver scheduling system is generally a complex system due to the large number of resources, complex driving hour rules and unpredictability of bus operation. This research focuses on the disruption by the unpredictable events to crew schedules and searches for ways to manage them. This paper presents the findings from interviews with three bus companies in London, and then analyse them. Based on the findings this paper proposes a set of functional requirements for a driver scheduling system that is able to perform driver reassignment in real time given the occurrence of unpredictable events such as lateness for duty, sick on-duty, or driver absenteeism without prior notice. The proposed system aims to dynamically maintain optimality throughout day-to-day operations.*

1.0 Introduction

Capturing system requirements is critical in the analysis stage of the system development life cycle. It defines what are the users' needs and helps developer to design a suitable software for the user. Without such understanding, users and developers will face a big difficulty. In this case, users do not know why build the system and developer does not really understand what are being developed. Therefore, allocating ample time to the requirements understanding and capture process early is necessary to avoid reworking and retrofitting post-launch.

One of the major operational problems faced by the bus operators is driver scheduling. Driver scheduling problem is hard to manage due to its complexity, especially when it involves a huge number of drivers to drive the scheduled buses. Bus operators have to work in accordance with driving rules and existing agreements with Trade Unions (TU); and, in the meantime have to minimise the total shift and operational costs.

There are two main reasons why drivers' schedule is immensely important. First, payment to the driver forms a large portion of the bus operational costs. According to Meilton (2000), the cost of driver is at least 45% of the total operational costs. This proportion is likely to rise as the shortage of bus drivers, a common phenomenon in London and the whole of the United Kingdom (UK), is considered to be increasing and not decreasing (Kwan et al. 2004). Second, the system will determine the level of efficiency of services that are offered by the bus operator in fulfilling the requirements of a city council or the authority that authorised its operations.

The aim of this research is to find ways of managing the disruption to crew schedule by the unpredictable events. One part of the research that is discussed in this paper is to understand unpredictable problems in depth and to analyse how bus companies currently manage their schedules. The information is elicited from the literature and interviews with a three bus companies in London. Then, this paper proposes a set of functional requirements for a driver scheduling system that is able to perform driver reassignment in a real time given the occurrence of unpredictable events such as lateness for duty, sick on-duty, or driver absenteeism without prior notice. The proposed system aims to dynamically maintain optimality throughout day-to-day operations.

This paper has been organised as follows. Section 2 discusses the driver scheduling problem in details. Section 3 presents interviews with the three bus companies in London concerning unpredictable events, and how they manage them. Section 4 proposes a set of functional requirements for a bus driver scheduling system. Section 5 concludes the discussion and suggests further research in the matter.

2.0 Driver scheduling problem

Generally, the main purpose of developing any bus driver schedule is to achieve optimum and dynamic schedules. Optimum schedules mean that the resultant schedules should minimise the operation cost, whilst dynamic schedules mean that the schedule is able to maintain optimality throughout the scheduled duration. However, the main obstacle for keeping such optimality throughout day-to-day operation is unpredictable events such as, late driver, sick while on duty, or absenteeism without prior notice. Bus service usually operates in an unpredictability environment, especially in the high-frequency route in a busy city. Whenever an unpredictable event occurs, it affects the bus operations.

In the UK, causes of unpredictable events are categorised into four categories that are traffic, staff, mechanical and others (Copley et al. 2003). In London, London Bus Services Limited produces a performance report on a quarterly basis and the latest report of the Year 2005 (www.tfl.gov.uk/buses) stated that 2.3% scheduled-kilometres were lost due to the mechanical faults (0.5%), staff problems (0.2%), traffic occurrences (1.3%) and others (0.3%). The reasons for this phenomenon are the cancellation of the bus service due to inadequate driver, no suitable vehicle is available, mechanical breakdown and traffic congestion. Other reasons are such as, demonstrations and road closures associated with the visit of foreign leaders, roadwork and increased loadings.

Usually bus operators are not penalised if the scheduled-kilometres are lost due to traffic instances but they will be penalised if it is related to mechanical or staff problems (London Transport Users Committee, 2001). Smooth running of vehicles and staff is the responsibility of the bus operators. This shows that bus operators should/need to manage their vehicles and staff properly so that no service disruption will occur, otherwise they will be penalised.

The existing system such as, TRACS (Kwan et al., 2004; Fores et al., 2002), HASTUS (Rousseau and Blais, 1985), and IMPACS (Wren et al., 1985) are good in producing optimal or near optimal original schedules. However, to maintain such optimality throughout day-to-day operations (dynamic reassignment), driver scheduling systems should be able to perform driver reassignment. Driver reassignment mean that if any of the drivers fails to turn up, the driver schedule will remain the same but their duty will be assigned to other available drivers without violating rules. This extended capability does not necessarily work as a stand-alone scheduling system because it could be added to an existing system. Note that the issue here is not to develop a new scheduler for producing optimal driver schedules but merely to assist supervisor in managing driver reassignment in daily operation whilst maintaining the original schedule.

3.0 Capturing the requirements

There are many evidences of the aforementioned unpredictability problem in the literature. However, there is no literature that discusses how a typical bus company manages the resource (driver) whenever unpredictable events occur, in a particular driver schedule. Therefore, the aim of the undertaken interview is to gain understanding on the practical experiences of bus companies in managing the unpredictable events. The objectives of the interview in details are as follows: (1) to know what are the types of unpredictable events that are likely to occur and what are their effects on daily operation; (2) to understand how a typical bus company manages the unpredictable events that are related to daily schedules; (3) to gain awareness of the tools or software that assist bus company in managing and controlling the unpredictable events; and (4) to examine the possibility of using technology in managing the unpredictable events that is related to the driver schedule. Before we discuss about the outcome of the interviews, the following subsection provides a brief background of the companies.

3.1 Background of the companies

Three bus companies were chosen based on their main operation in London. Due to confidentiality reason, the bus companies are coined as Company A, Company B and Company C. These companies operate in a regulated environment under a contract with Transport for London (TFL), whereby the contracts being awarded for 5 or 7 years via a rolling tendering programme.

Company A has two subsidiaries companies in London. They operate over 1300 buses, employ over 3900 staff, and operate from nine garages. Company A provide nearly 15% of the London bus routes, and account for approximately 260 million bus journeys annually on about 100 day and night routes. One of the subsidiaries runs 600 buses in the southeast and central London from four garages. Another operates a fleet of 700 vehicles in the southwest and central London from fives garages.

Company B operates a fleet of over 650 buses on 60 routes within Central and South West London and neighbouring Surrey. The company employs more than 2,000 people whereby 1,600 of them are drivers. The company operates from six garages.

Company C employs around 4200 staff and operate around 1300 buses. It operates bus services on behalf of London Buses from ten bus garages. Company C also operate the London City Airport shuttle bus services and have one coach subsidiary namely East London Coaches. This subsidiary operate a series of day trips within the UK and the continent as well as providing vehicles for private hire.

3.2 Describing the interviews

In relation to the first objective that is the types of unpredictable events that are likely to occur and what effect it has on daily operation, the respondents highlighted that the problems are caused by the driver, traffic and vehicle. Traffic is the most critical problem because it is unpredictable and uncontrollable in nature. According to Company C, the most unpredictable day is Friday since it is the last working day of the week and; therefore, people want to go out for fun or organise a gathering or marching. In addition, sometimes the road might be closed due to security alert, demonstration, or accident. Finally, the behaviour of the motorists that use a bus lane and park near to the bus stop also increase the traffic problem.

Some of the unpredictable problems that are related to the driver are such as, drivers do not come to the workplace without prior notice, fall sick while on duty and come late to the workplace. Vehicle is the least critical problem. Vehicle breakdown, either on the road or in the garage, causes delay in the bus service.

Relating to the second objective of the interview that is how a typical bus company manages the unpredictable events that are related to daily schedules, the respondents highlighted that the problems are managed by the supervisors in the garages. Supervisor is a person who is responsible for making sure that the bus service operates smoothly. If something wrong happen, the supervisor will make some adjustments or changes to the schedules. There is no standardised procedure in doing this and is solely based on the supervisor's experiences.

Everyone can agree that there is no absolute solution for the traffic problems. When they occur, bus will be late and not follow the schedule. That is why the times schedule takes into account the recovery time in its traffics timing. Traffic problems will be solved case by case. For example, if one route is closed due to accident, security alert or others, the driver has to re-route the bus journey and; therefore, a few stops are omitted from the original route.

The problem concerning the drivers is that they always come late to the workplace. If this happen, his/her duty will be given to other drivers that are available at that particular time. When he/she arrives at the workplace, a new duty will be assigned to him/her. If a driver does not come, then his/her duty will be assigned to a spare driver that is available in the garage at that particular time. Company A has a policy that the numbers of a spare drivers is at least 20% from the whole staff. However, the other two companies did not mention any figure. If a driver fall sick during duty, which is quite often (according to company A), then he/she has to change at the depot or relief point or nearest stop, whatever possible. The spare driver will take over the remaining duty.

If a bus got problem then it will be substituted with other bus that is available at that particular time. If the bus is breakdown at the middle of the journey, it has to stop at the nearest stop and contact the supervisor. A replacement bus will be sent from the nearest depot. Company A has a policy that is the number of the spare busses must at least 20% from the whole buses. The other two companies, however, did not mention any figure.

On the other hand, the third objective of the interview is regarding the tools or software that can assist bus operators in managing and controlling the unpredictable events. The respondents stated that the tools that are used are such as, radio, AVL (Automatic Vehicle Locator) and GPS (Global Positioning System). These tools are used to locate busses and communicate with drivers. However, there is no software or tool that enable the supervisor to adjust the affected schedule. Normally, all the adjustments or reassignments are undertaken manually. The current scheduling packages do not offer this kind of feature. The systems are only able to undertake a complete rescheduling.

Finally, the fourth interview objective is concerning the possibility of using technology in managing the unpredictable events that is related to the driver schedule. The responses from the respondents are positive. In this case, all the respondents agree that it is a good idea to have a dynamic schedule that is able to re-schedule the disruption day or week.

3.3 Interview analysis

A number of lessons could be learned from the undertaken interviews. All the companies have more or less similar codes of operation. The driver schedules produced by schedulers are mostly based on scheduling packages such as Trapeze (Company B), IMPACS (Company A) and CAP GEMINI (Company C). The

objective of the scheduling package is solely to achieve an optimal schedule. Once a schedule is produced then it is up to the supervisors at the garage to manage the schedule manually.

The supervisor has various responsibilities. The main responsibility is to make sure that all the buses run on time, that is based on the predetermined schedule. The bus company has to comply with the schedule that has been agreed upon with the TFL. If the company does not perform well, the contract will be suspended. In addition, the supervisor has to manage the schedules (times, driver and ROTA), supervise the drivers, and organise the busses daily. These responsibilities are immensely hard especially when dealing with the unpredictable events.

All the companies agree that the unpredictable or unforeseen event can be occurred everyday and every time. As mentioned in the previous section, the event can be derived from the traffics, driver or bus. As stated by Company C, there is no such a day that is similar as yesterday, and Friday is probably the most favourite day that such unforeseen events, like marching, accident or bad traffic congestion, can happen. In short, there is no an absolute solution. They have to manage the problem case-by-case.

The role of a supervisor in dealing with the unpredictable events is illustrated in Figure 1.The supervisor has times, driver, and ROTA schedules. The times schedules show the movement of every bus,(times against location) while driver schedule show the activity for every duty that is from sign-in to sign-off. ROTA schedules show the duties that are assigned to one person in a week. The supervisor also involves in managing resources that are drivers and busses. When a certain unpredictable event occurs, the supervisor must perform appropriate adjustments to the schedule or change the resource allocation. The times and driver schedule will remain the same and only the re-allocation or reassignment is undertaken to cover the schedule. For instance, if a bus is broken down then a spare bus will be allocated to cover the remaining schedule. Similarly, if a driver does not turn up, then his duty will be assigned to a spare driver. Supervisors in the garage will manually reallocate or reassign the resources to cope with the unpredictable events. This practice is similar in all the researched companies.

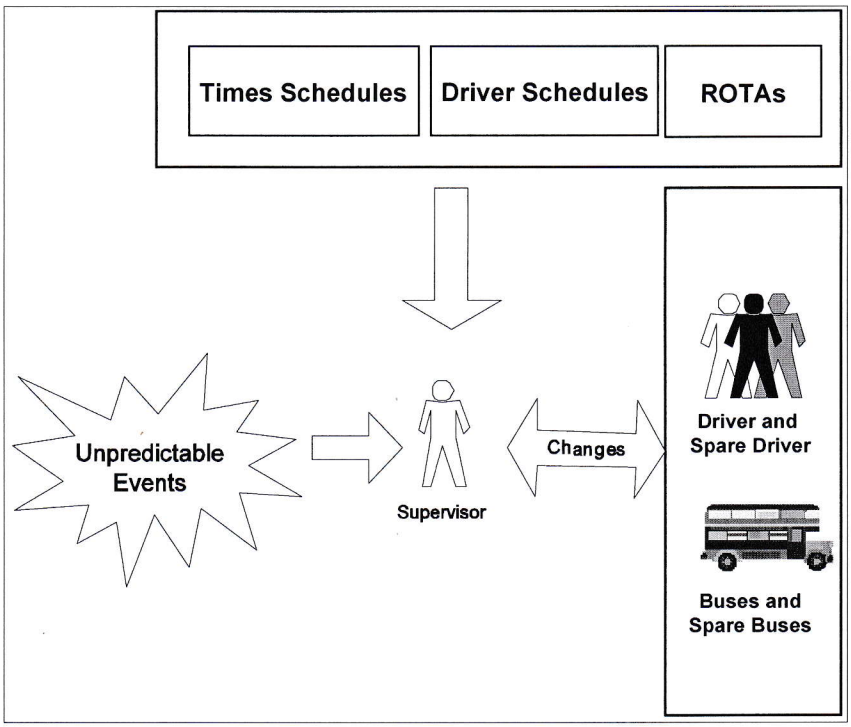

Figure 1 Supervisor manage the unpredictable events in everyday operation

Although there is a management tool, for example Automatic Vehicle Location (AVL), the supervisor still has to manage the busses and drivers properly to ensure that all the busses run on a predetermined schedule. AVL is an automatic tool that is able to pinpoint the location of an operating vehicle. According to Company C, AVL can give you the location but not the reason. For example, if Bus A is late 15 minutes from the AVL screen, its location appears on the AVL's screen but the supervisor does not know the reason that delay its service. He has to contact the driver through radio to know the reason.

From the above discussion it can be seen that the existing driver scheduling systems do not support the process of reassignment. All the reassignment is done manually. The existing system is only trying to find an optimal solution. It is fine to have optimal schedules but when the unpredictable problem occurred, the schedule is not optimal anymore. Thus, a driver scheduling system that supports the process of reassignment is needed to help a supervisor in dealing with daily drivers' operational problems.

Two issues have been discussed in this section that are the unpredictable events and the role of a supervisor in managing such events. From the first issue it can be seen that the driver is one of the sources of the unpredictable events and has a significant impact on the driver schedule and in turn daily operation. From the second issue, on the other hand, we realise that the supervisor play an important role in managing the unpredictable events and driver reassignment is a way of dealing with such events, which currently is done manually.

4.0 The proposed functional requirements for a bus driver scheduling system

The objective of the intended system is system is to assist the supervisor to reassign driver for daily operations in order to cope with the unpredictable events such as, late driver, sickness, or absenteeism without prior notice. The proposed system aims to achieve an optimal driver schedule throughout the process. Optimal in the sense of minimizing the use of spare driver and dynamic in providing quick solutions to the supervisors when dealing with such events. To achieve this objective, the system should have functional requirements as follows:

Function 1: Interface with the existing system.

Objective: This function is needed to acquire driver schedules and duty assignment that are generated by the existing driver scheduling system.

User: Supervisor

Description: The system should be able to connect with the existing driver scheduling system. User can view duty assignment and predetermined driver schedules, which includes duty number, route number, garage name, number of spell, sign-in times, start driving times, finish driving time, start break time, finish break time, sign-off time, total driving time, and total duty time.

Function 2: Storing real time information.

Objective: The objective of this function is to make sure that the system knows about the status of drivers and driver schedules because when the system want to do reassignment the current status of every drivers and driver schedules need to be known.

User: Supervisor

Description: The system should be able to store real-time information concerning driver and duty schedules. The driver real time information includes sign-in times, start driving times, finish driving time, start break time, finish break time, current status of driver, sign-off time, total driving time, and driving time left. The driver schedules real time information includes total covering time, covering time left, total covering point, and covering point left.

Function 3: Reassignment whenever needed.

Objective: To reassign drivers when unavailable drivers happen.

User: Supervisor

Description: The system should be able to do reassign drivers in a real time whenever needed without violating the EC Driving Hour Rules. The most important thing is that the rules concerning the break and daily driving hours are upheld. The continuous driving hours should not exceed four and a half, and total daily driving time should not exceed ten hours. The break should be at least forty-five minutes. The reassignment is based on the manual reassignment that is currently practised by the companies that are participated in this research. Reassignment should cover four events:

(1) Driver comes late for duty: The system should be able to assign duty to the available driver at the garage. The available driver could be driver that have signed-in but has not started driving, driver that is on a break, or driver which have completed their duty but not signed-off yet. The system should choose a driver who has the lowest driving hours and the duty time needed should not exceed daily driving limit. The chosen driver's original duty may be given to the late driver.

(2) Absent-without-prior notice: Normally, a duty consists of two spells. The system should be able to divide the duty into a predetermined spell. Then the system should assign each spell to the available driver at the garage. The available driver could be driver that have completed their duty but not signed-off yet. The system should choose a driver who has the lowest driving hours and the duty time needed should not exceed daily driving limit. If there is no match in this, a spare driver will be used to cover the duty.

(3) Sick-on-duty: The system should be able to assign their remaining duty to the available driver at the garage. The available driver could be driver that is on break, or driver that have completed their duty but not signed-off yet. The system should choose a driver that has the lowest driving hours and the duty time needed

should not exceed daily driving limit, and not clash with the driver duty. If there is no match in this, a spare driver will be used to cover the duty.

(4) Unavailable part of the duty: Sometimes the driver might not be available on part of the duty because of some unforeseen reasons such as, need to go for a hospital appointment. The system should be able to assign his unavailable duty to the available driver at the garage. The decision mechanism should be same as in (a), (b) and (c).

5.0 Conclusions

This paper has described the unpredictable events problem in the daily bus operation based on the practical experiences of three London bus companies. It is evident that the unpredictable or unforeseen events are likely to occur everyday and every time. The current driver schedule system architecture is not capable of handling this problem due to the objective of the current system is to solely achieve an optimal schedule. Once a driver schedule is produced then it is manually manage by the supervisors at the garage.

The task of a supervisor is proved to be very difficult. He has to manage resources that are drivers and busses. When a certain unpredictable event occurred the supervisor must perform appropriate adjustments to the schedule or change the resource allocation. A dynamic driver scheduling system that supports the process of reassignment is needed to help a supervisor in dealing with daily operational problems.

This paper has proposed a set of functional requirements for a bus driver scheduling system that is able to do reassignment in daily operation when dealing with unpredictable events. The propose system aims to keep driver schedule optimal and dynamic throughout daily operation. Optimal in the sense of minimize use of spare driver and dynamic means provide quick solution to the supervisor when dealing with such events in a real time.

The ongoing research is implementing the propose system using multi agents system (MAS) concept. MAS are particularly good at handling changes that inevitably occur during the bus operation. The driver reassignment is done through negotiations among agents that represent resources and demands in a so-called virtual market. Agents negotiate the best matches, that is, the minimum-cost allocations of drivers to duties, which satisfy, as far as possible, specific requirements of each duty and every driver member. This approach although very novel and not yet tested in the area of bus driver scheduling, has been tested and evaluated on other scheduling problems such as manufacturing, logistic management and meeting scheduling.

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