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Abstract

This research paper explores the relative importance of strategic and tactical objectives during the crew scheduling and rostering process between smaller and larger bus companies via a survey of bus companies in Victoria, Australia. Results indicate that larger bus companies emphasise reduced labour cost through maximising their operational efficiency. They acknowledge the importance of keeping their customers satisfied and to a lesser extent their drivers, however, doing so is not as important as it is to smaller organisations. Whilst reducing labour cost plays an important role to small bus companies their main focus is maximising customer service levels. To a lesser extent keeping their drivers satisfied is also important, however, in both cases smaller companies are willing to sacrifice labour cost and operational efficiencies to ensure these two objectives are met.

A modelling exercise was undertaken to determine the impacts of applying large company priorities to small bus operators. The key strategic objective applied during this process was reducing labour cost whilst at an operational level maximising the use of on-road meal break locations and reducing meal breaks during peak periods were the focus. As anticipated in both cases the labour costs were reduced (by between 1.5% and 13.3%). Dead running distances increased in both cases, however, these would have a minor impact on overall operating costs savings.

The results of both this survey and subsequent modelling have implications for both research and practice. Research in the area of crew scheduling and rostering for smaller companies has been quite limited. Most literature has focussed primarily on the objectives of larger companies. Implications for future research and practice are identified.

1. Introduction

Scheduling and rostering of drivers and vehicles is a necessary task of all transit agencies worldwide (TCRP 2009). This often involves difficult tradeoffs between scheduling objectives associated with reducing resources and costs whilst maintaining user service levels and mandatory requirements to meet driver hour working rules for safety reasons (Ceder 2007 & Friedrich et al. 1999)

Anecdotal experience suggests that smaller bus companies have fewer resources to allocate to personnel management and recruitment than larger companies and hence are more concerned with maintaining driver acceptance as a critical tactical objective in new schedules compared to larger companies. How important these factors are to operators of different size is not well researched. The research literature has tended to focus on meeting strategic cost and service level concerns and the development of methods to optimise schedules within the context of these strategic objectives. What is unclear is how important more tactical objectives are to operators of various sizes and how these might impact outcomes in schedule/roster optimisation.

This research paper aims to explore the importance of strategic and tactical objectives in schedule and roster design between smaller and larger bus companies using a survey of bus companies in Victoria, Australia. A central focus of the research is the relative priority given to maintaining workforce hours and conditions when developing schedules/rosters to retain drivers. The research also aims to assess changes in resource outcomes when alternative priorities for schedule design are adopted using a schedule/roster optimisation model.

The paper commences with a summary of relevant research literature. The survey methodology and approach are then described. This is followed by an outline of the major survey results. Modelling the impacts of adopting alternative schedule/roster priorities is then explained and the results summarised. The paper concludes with a summary of key findings and a discussion of their implications for planning and practice. Future areas for research are then described to promote further consideration.

2. Research context

Transport planning which encompasses the key components of crew scheduling and rostering (Ceder & Wilson 1986) can be defined as a multi-objective problem, where the users' and the operator's interests conflict (Guihaire & Hao 2008). This point is supported by Van Nes and Bovy (2002) who state that the main dilemma in transit network design is the controversy between these two viewpoints. From the users' perspective the system should provide a cost efficient and direct service (Guihaire & Hao 2008). Alternatively, the operator's objective is to maximise the return on investment (Guihaire & Hao 2008). They are predominantly concerned with the revenues and the associated operational costs which are surmised by their desire to maximise cost-effectiveness (Van Nes and Bovy 2002). The objectives of users and operators highlight the fundamental conflict in transport planning. To solve this conflict the transport planner needs to determine an acceptable balance by equally considering two incompatible planning objectives; the maximisation of service quality and the minimisation of operational costs (Friedrich et al. 1999).

Assigning drivers to a scheduled sequence of operations is commonly referred to as crew scheduling (Vuchic 2005). In this activity vehicle blocks, which represent the allocation of all required trips to an operation's fleet, are split and renumbered into legal driver shifts. Ultimately the crew assignment process must comply with some constraints, which are usually dependent on a labour contract. The purpose of this assignment process is to determine a feasible set of driver duties in an optimal manner. Usually, the objective is to minimise the cost of the duties (Ceder 2007). White (2002) supports this notion by stating that it should be the operator's aim to adequately manage the crew's paid time. Assuming that drivers do no other duties, White maintains that driving time per shift is to be maximised. The key criteria for crew scheduling is based on an efficient use of manpower resources whilst maintaining the integrity of any work-rule agreements (Ceder 2007).

Crew rostering differs from crew scheduling as it deals with the assignment of duties to a particular set of drivers. Alternatively crew scheduling creates a set of duties that covers the bus schedules for a given period (Moz et al. 2009). There is a wide range of literature on crew scheduling, however, as supported by Ernst et al. (2004) only a few studies have been published on transport crew rostering. This can most likely be attributed to the fact that crew scheduling is generally a standardised process as opposed to crew rostering which is more specialised in nature (Moz et al. 2009).

The general rostering problem is how to assign working days and rest days to employees so that the predicted workload is met. In doing so, the constraints of the type of work and the preferences of the workers have to be taken into account. The ultimate objective in this scenario is to establish an egalitarian annual allocation of work to drivers (Lezaun et al. 2006). Transport operators require careful management of human resources due to the requirement to provide a high quality service that is cost efficient. An effective roster should not only comply with the employer, but also with the workers' themselves. This is to ensure worker satisfaction is heightened, thus reducing the likelihood of accidents, absenteeism and professional illness associated with working hours and conditions. Consequently, rostering in accordance with the other stages of the public transport planning process requires a multi-objective model to balance conflicting interests (Moz et al. 2009). Ultimately the aim in rostering is to determine a feasible roster that covers all relevant duties and satisfies objectives such as minimising crew required and balancing the equity of workload and days off (Ceder 2007).

3. Methodology

3.1. Survey Aim

The survey seeks to determine the relative priority allocated to key objectives when bus companies create new sets of schedules and rosters for their driving workforce. It contrasts relative priorities between 'small' and 'large' bus companies.

Satisfying National Driving Regulations, industry awards and company workplace agreements are mandatory objectives in the crew scheduling and rostering process and hence, not considered in the survey.

3.2. Survey Approach – Questionnaire/Interview

A total of eight bus companies were approached of which all agreed to participate in the survey. Three were defined as 'large' given that they operate in excess of 100 peak vehicles in their scheduled operations. The remaining five companies are defined as 'small' given that they operate less than 25 peak vehicles in their scheduled operations. At each of the companies the desired respondent is the person primarily responsible for the crew scheduling and rostering process. In the smaller companies this is often the company owner whilst in the large companies the respondent often occupied the role of scheduling manager.

The survey approach consists of a structured interview where predetermined questions are posed to the respondent. The interviewer is present at this time to ensure that any clarification or potential ambiguity could be resolved prior to the questionnaire's completion.

3.3. Outline of Questionnaire

The questionnaire consists of four questions.

Question one concerns strategic objectives in creating new sets of shifts and rosters and their relative priority. The question asks respondents to rank five objectives from 1 to 5 with 5 being the most important. A sixth objective titled 'Other' is allowed so that respondent defined objectives can also be assessed and ranked.

Question two is a multiple choice question. When creating additional shifts and rosters, decisions often have to be made regarding the number of drivers required and their associated earnings. In such a process there are often trade-offs between having more, less or the same number of drivers earning more, less or the same monetary amounts. Respondents are asked to choose between four common alternatives in respect to their company's preference. These alternatives are:

   I.   maintain driver numbers, each earning more money;
  II.   reduce driver numbers, each earning more money;
 III.   employ more drivers each earning less money; and
  IV.   employ more drivers each earning the same money.

In questions three and four the focus shifted to the criteria that need to be satisfied at an operational level during the crew scheduling process (question 3) and the crew rostering process (question 4). Although these processes are commonly integrated in research, this questionnaire explores how the priorities allocated to objectives vary between these two processes. In both questions respondents are presented with ten commonly applied criteria which they are asked to rank from 1 to 10 with 10 being the most important.

4. Survey Results

4.1. Question One – Strategic Objectives in Scheduling

Figure 1 – Priority Ranking of Strategic Objectives (average rank, 1-5, 5= most important)

Figure 1 shows the results for question 1 concerning the relative priority given to strategic objectives in the scheduling process. The most important strategic objective for large bus companies is minimising peak vehicle requirements; whilst reducing labour cost was of similar importance. In contrast, smaller bus companies ranked maximising customer service levels highly, whilst ranking reducing labour cost was equal second in conjunction with keeping the labour force satisfied. The high ranking of maximising service to customers and keeping the labour force satisfied indicates that small companies are willing to sacrifice operational efficiencies to ensure that these objectives are satisfied. Obviously the size of their operation makes this easier to achieve. It is worth noting that maximising service to customers primarily refers to maintaining a high level of train/bus and bus/bus connections within the allocated route service levels and frequencies and other company nuances such as retaining the same drivers on the same routes/trips. The overall high ranking of reducing the labour cost clearly indicates its importance and is to be expected given that labour cost is the most significant recurring operational cost to bus companies.

Large bus companies place greater emphasis on minimising peak vehicle requirements and additionally in minimising dead distance and time than their smaller counterparts. This may be because small companies inherently account for this in timetable design and therefore do not value its importance when creating shifts and rosters. Such a design element is not always possible at larger companies due to their size. Additionally, the impact on sacrificing such objectives at a larger company would be more significant to their ongoing operating costs. As a number of smaller companies operate in close proximity to their depots this may reduce the need to consider such objectives as highly; particularly dead distance and time.

4.2. Question Two – Staffing Level and Remuneration Preferences in Creating Additional Shifts/Rosters

Figure 2 – Staffing Level & Remuneration Preferences (% small/large companies preferring one selection)
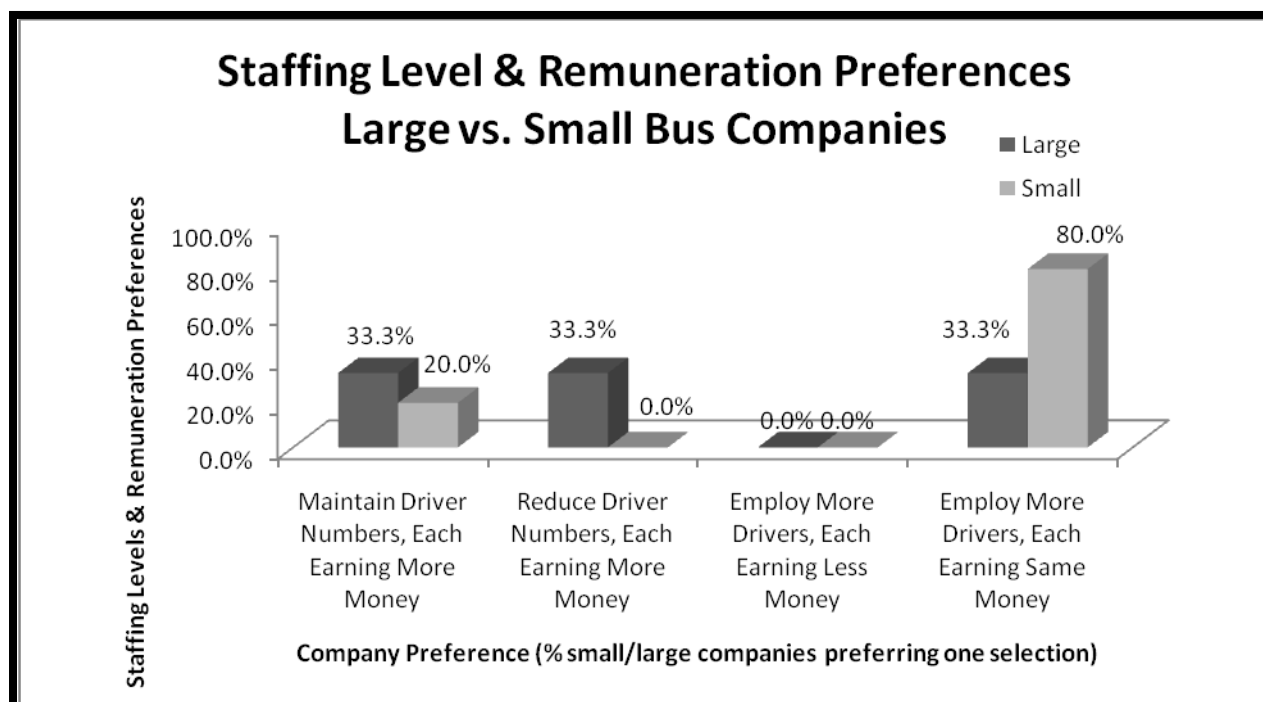

Figure 2 shows the results from question 2 which identified each company's preferred trade off between staffing and remuneration when increasing service. Amongst smaller bus companies the clear preference was to employ more drivers, each earning the same money. Discussion with operators during the survey established that the main reason for this preference is to ensure there is still staff willing to look for overtime and to ensure that staff do not become overworked as this will inevitably impact on annual leave, sick leave, workers compensation claims and accidents. The preference of maintaining driver numbers, each earning more money received limited acknowledgement from both large and small bus companies. Company preference regarding this and the aforementioned alternative are impacted by the current context of network/timetable improvements which are occurring in Victoria. These are dictating the creation of new shifts and rosters. Companies are often willing to concede slight increases in existing drivers' earnings whilst maintaining driver numbers if the network/timetable improvements are minor and can be easily and legally accommodated by the existing driving force. However, growth in services is causing operators to want to expand their workforce to maintain flexibility for future service expansion proposals.

Amongst the larger companies the preferences were more diverse with each company indicating a different level of preference, however, for both large and small companies, the option of employing more drivers, with each earning less money was not selected. Realistically it is not an option to have drivers lose pay which would explain this option's lack of support. Only one large company indicated a preference to reduce driver numbers, each earning more money which is an indication that this alternative is not feasible unless there are reductions in staffing levels prior to the creation of a new set of shifts and rosters. This is more likely at a larger company where staff turnover is higher.

4.3.   Question Three – Operational Criteria in Crew Scheduling

Figure 3 – Ranking of Operational Criteria in Crew Scheduling (average rank 1-10, 10= most important)
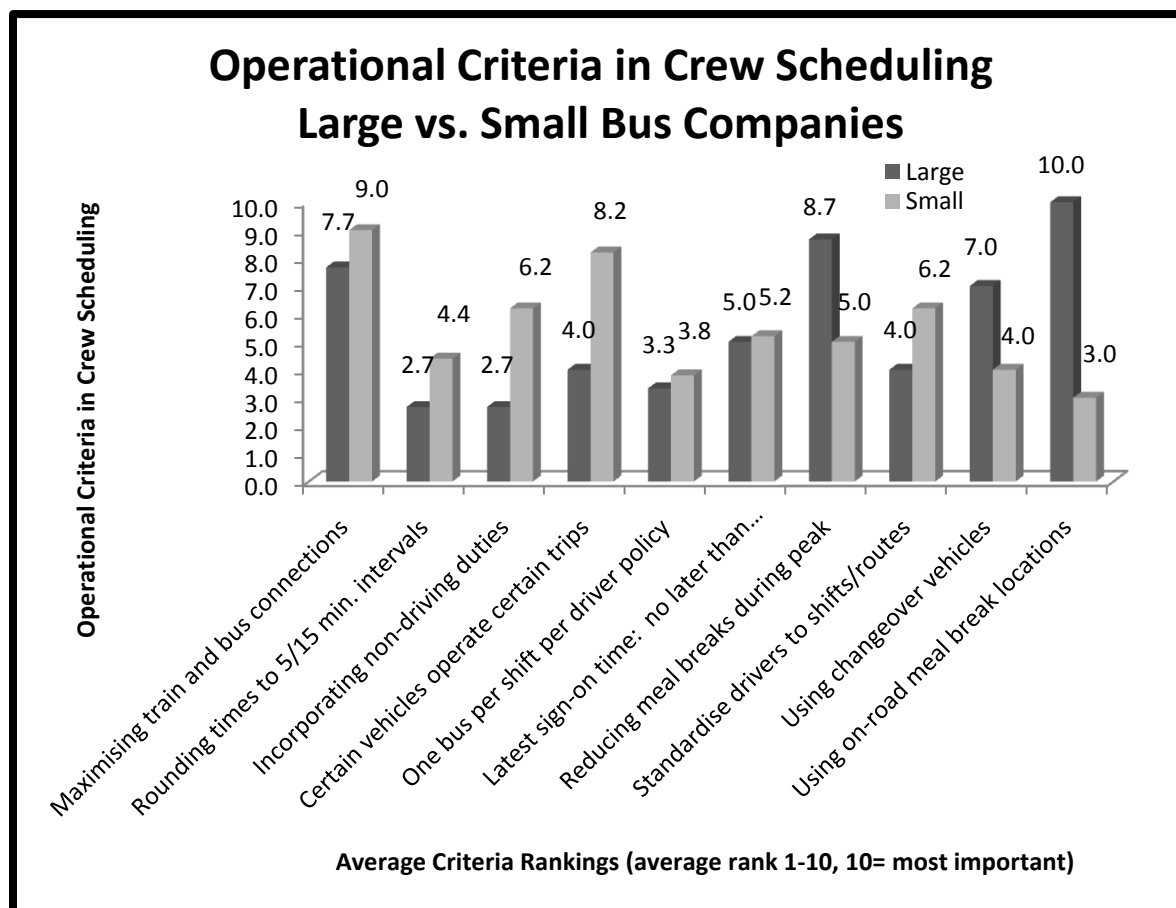

Figure 3 shows the results for question 3 which involved ranking a series of operational criteria for crew scheduling. Maximising train and bus connections was the most important priority amongst all bus companies. For smaller bus companies, customer satisfaction measures are rated higher and this is reflected by the high ranking of this criterion. The criterion regarding the appropriate allocation of vehicle types to trips was then subsequently favoured, which once again highlights their desire to maximise customer service. Most companies did, however, note that this criterion is becoming more important as they now have to indicate the trips operated by wheelchair accessible vehicles on public timetables.

The small companies also ranked highly the incorporation of non-driving duties into shifts and standardising drivers to shifts and routes. Small companies can achieve efficiencies by making use of drivers in off-peak periods to clean and refuel buses as such non-driving positions do not often require full-time employees. Alternatively, large companies due to their size, usually hire full-time employees to fulfil these roles. The desire to standardise drivers to shifts and routes is consistent with small companies' attempts to please both customers and the labour force. Customers prefer to have the same drivers operating their routes/trips whilst drivers similarly prefer this regularity. Whilst this criterion is not difficult to achieve at smaller companies, even though some efficiencies are compromised, it is too impractical to consider at a larger company.

In reference to the larger companies, maximising train and bus connections was placed third overall after the importance of using on-road meal break locations and the reduction of driver breaks during peak periods. This once again indicates the importance that larger companies place on minimising dead distance and time (using on-road meal break locations) and minimising peak vehicle requirements (minimising driver breaks in peak periods). The use of on-road meal break locations is not a valued criterion amongst smaller companies. Drivers generally prefer to have their meal breaks at their depots, however, in doing so, companies must sacrifice certain operating efficiencies. The smaller companies surveyed possess a greater desire to please their labour force and this is one example of how this is achieved. The use of changeover vehicles was also ranked highly amongst larger companies which is another indication of their desire to minimise dead distance and time. Not only is this method a cost-efficient way of relieving drivers whilst maximising vehicle on-road time but in the case of the Victorian SmartBus a requirement of the service.

4.4.　　Question Four – Operational Criteria in Crew Rostering

Figure 4 – Ranking of Operational Criteria in Crew Rostering (average rank 1-10, 10= most important)
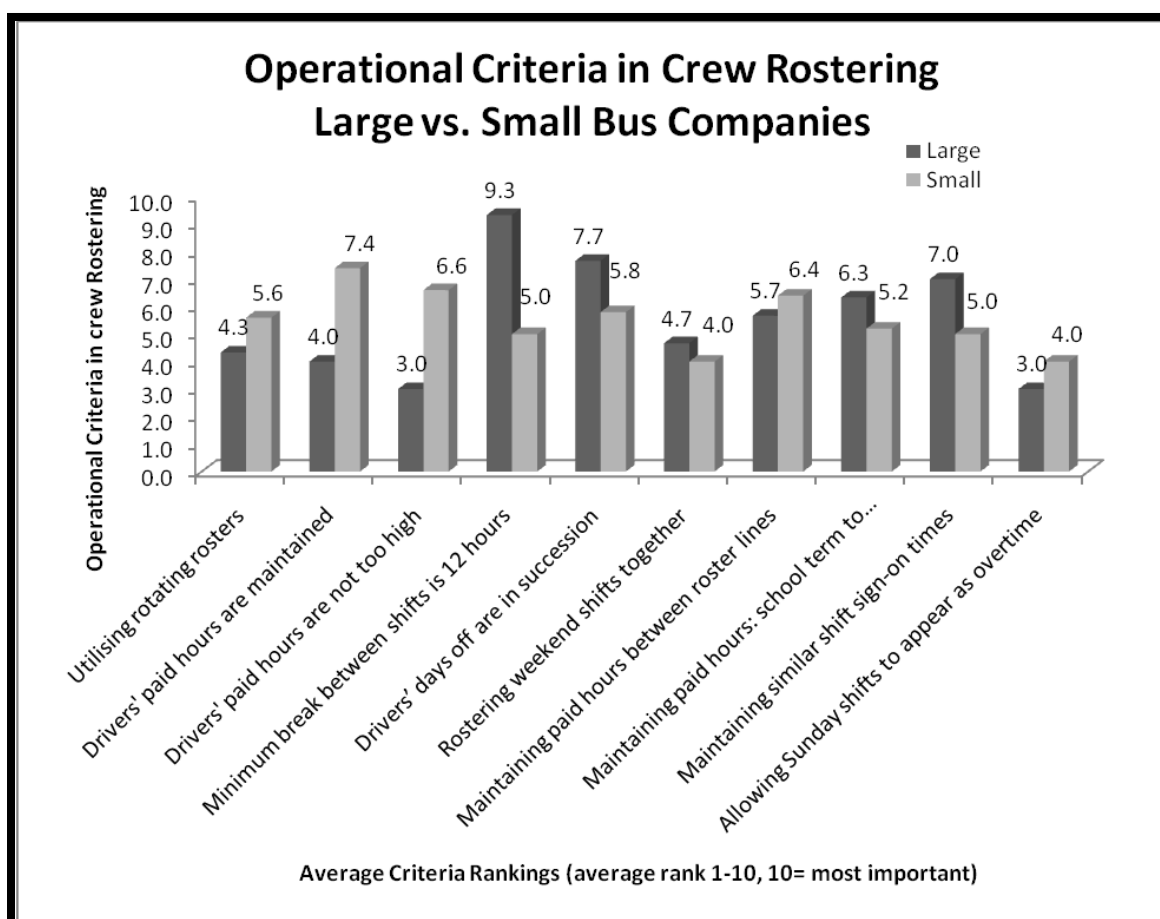
Figure 4 shows the results for question 4 which concerns the ranking of operational criteria for crew rostering. Ensuring minimum breaks between shifts are at least twelve hours was the most highly regarded criterion amongst larger companies. This illustrates the desire of these companies to be more mindful of driver fatigue. Although current regulations allow for a minimum 10-hour break between shifts, due to greater shift choice and flexibility when rostering, larger companies are now trying to ensure a minimum 12-hour break. Of secondary importance to large companies was ensuring that drivers' days off are in succession. Given the recent bus service level improvements in Victoria, the traditional Saturday and Sunday leave are becoming increasingly scarce. Consequently, there is a strong desire for drivers to ensure that if days off are to be on weekdays they need to be coupled. Given their size, the larger companies have been the prime beneficiaries of service upgrades and this is reflected in their need to be conscious of driver leave planning and driver preference.

Smaller companies value maintaining drivers' paid hours from a current to a proposed roster. These companies appear to give priority to driver satisfaction and therefore ensuring staff retention. Maintaining similar average paid hours is one way of achieving this. Secondly, smaller companies want their drivers' paid hours to be limited. These companies place great emphasis on ensuring they have drivers willing to perform overtime which is a reflection of the smaller pool of drivers they have to choose from. The smaller companies were also keen to ensure drivers' paid hours were balanced between roster lines. Again this is an initiative of drivers to aid budgeting requirements by avoiding the occurrence of high and low paying roster lines in succession.

Although the results indicate average rankings for the utilisation of rotating rosters, selected individual responses reflect varying patterns. Rotating rosters allow drivers to do a variety of shifts within a roster line before rotating onto the next line. Alternative roster options are ones where drivers do the same shift or a couple of shifts for a week. Rotating rosters allow companies greater flexibility when allocating work which ultimately reduces their labour cost. In regards to the use of rotating rosters a company either uses them or they make use of an alternative rostering mechanism. Consequently this is reflected by seven of the eight companies ranking this criterion either lowly (i.e. a ranking of one or two) or highly (i.e. a ranking of ten).

In summary it is evident that when fulfilling their scheduling requirements the focus of smaller bus companies is maximising the level of service to their customers whilst additionally maintaining a high level of driver satisfaction. Although minimising labour cost is important it is not the sole focus. Alternatively larger companies have a much stronger focus on reducing costs. Whilst they acknowledge the importance of fulfilling their customers' requirements their primary goal is to reduce their labour costs through maximising operational efficiencies. In crew rostering there was a much greater spread of preferences allocated to criteria. This demonstrates the unique nature of rostering and highlights the need to separately consider these issues. Disparities exist in relative priorities for crew rostering between different companies even if of similar sizes. For the majority of companies surveyed the resultant labour cost is based on the shifts themselves and not on how they are rostered. Therefore the cost to companies through attempts to satisfy drivers' desires is negligible. Larger companies do, however, have a greater advantage when rostering due to a larger pool of staff.

The important question that arises from the survey is 'to what extent are smaller companies sacrificing labour costs in their attempts to satisfy their customers and their labour force'. In the case of two of the smaller companies surveyed this is explored in a modelling exercise in the next section.

5. Schedule Modelling

The aims of the modeling exercise were to examine how small bus companies sacrifice labour costs to maintain high levels of customer and driver satisfaction. Modeling was performed using the Austrics software package which had already been implemented at the two bus companies who agreed to participate in this modeling exercise.

As part of this modeling exercise new sets of shifts were created for two of the small companies surveyed. In this process the companies' traditional scheduling objectives (with an emphasis on driver satisfaction) were replaced with an emphasis on cost reduction. From a strategic perspective the sole focus in this modeling exercise was to reduce labour cost. In respect to crew scheduling the key criterion that were to be satisfied were maximising the use of on-road meal break locations and reducing the use of meal breaks during peak periods. Alternatively, those crew scheduling criterion which were deemed not important to large bus companies (i.e. driver satisfaction criteria) were not used in the analysis. These were 'rounding schedule times to 5/15 minute intervals' and 'incorporating non-driving duties into shifts'.

In assessing the impacts of altering these objectives, the percentage change to key performance indicators was determined. These are reported in summary form rather than absolute values of resources so that the operator's confidentiality was maintained. It should be noted that the schedule modelling was undertaken with the agreement of both companies concerned. In making accurate comparisons the timetables belonging to both companies remained unchanged. Hence the 'base case' represented the existing schedule using current or pre-existing schedule and roster design criteria. In designing the new roster, every attempt was made to ensure staff numbers remained consistent, however, there were occasions where this could not be avoided. The results are indicated in Tables 1 and 2.

Table 1: Impact of Reduced Driver Satisfaction Criteria on Small Bus Company Schedules – Company A Modelling Results

Company A	Weekdays (per day)	Saturday (per day)	Sunday (per day)
% Change in Paid Hours	-13.3	0.0	0.0
% Change in Dead kms	14.8	0.0	0.0
% Change in Peak Buses	0.0	0.0	0.0
% Change in Relief Vehicles	0.0	0.0	0.0
% Change in Staff Numbers	12.5	0.0	0.0

Table 2: Impact of Reduced Driver Satisfaction Criteria on Small Bus Company Schedules – Company B Modelling Results

Company B	Weekdays (per day)	Saturday (per day)	Sunday (per day)
% Change in Paid Hours	-1.5	-2.5	-2.9
% Change in Dead kms	5.0	145.4	146.4
% Change in Peak Buses	0.0	50.0	28.6
% Change in Relief Vehicles	-66.7	-66.7	-100.0
% Change in Staff Numbers	-4.2	0.0	7.7

The results in Tables 1 and 2 indicate that both companies are currently incurring additional labour cost expenses in their attempts to satisfy their customers and drivers. For company A the additional cost of doing so is quite significant (13% of labour hours), however, in both cases the labour cost savings come at the expense of additional dead running distance. It is often cheaper from a labour cost perspective to operate buses to and from the depot, whilst subsequently incurring additional dead running distance. The alternative to this is utilsing relief vehicles to change over drivers, whilst keeping the bus on the road. In the case of Company B this is evident given that both labour cost and the use of relief vehicles has been reduced whilst the dead distance has increased (on all day types). Additionally, on weekends the number of peak vehicles required has also increased. Although this is not ideal it is expected given that there are now more buses travelling to and from the depot.

For both companies their weekday peak bus requirements have remained the same and this substantiates the fact that inherently timetable design at such companies includes the successful allocation of all buses. There were some variations to staff numbers and although the percentage change figures illustrated are significant, in practice this is minimal given the small companies sizes examined. An increase in driver numbers results in a decrease in labour cost. This is because each driver is now earning less on average, given that the amount of work allocated still remains the same. This is also contrary to the objectives shown for both large and small bus companies.

Overall the modelling results demonstrate that higher labour hours are incurred (representing between 1.5% and 13.3% of total hours) when driver satisfaction measures are given priority in small bus companies. There is some saving in dead running kilometers resulting from this, however, this will not offset the more expensive labour costs being incurred.

6. Discussion and Conclusions

This research paper aims to explore the relative importance of strategic and tactical objectives during the crew scheduling and rostering process between smaller and larger bus companies. This was done using a survey of bus companies in Victoria, Australia. Results indicate that larger bus companies emphasise reduced labour cost through maximising their operational efficiency. These companies acknowledge the importance of keeping their customers satisfied and to a lesser extent their drivers, however, doing so is not as important as it is to smaller organisations. Whilst reducing labour cost plays an important role to small bus companies their main focus is maximising their customer service levels. To a lesser extent keeping their drivers satisfied is also important, however, in both cases smaller companies are willing to sacrifice labour cost and operational efficiencies to ensure these two objectives are met. The size of these smaller organisations and the proximity of their depots to their scheduled services often make compliance easier to achieve. Additionally the financial sacrifice is not as significant as it would be to their larger counterparts.

A modelling exercise was undertaken to determine the impacts of applying large company priorities to small bus operators. This was done to assess the labour cost and operational efficiencies being sacrificed by smaller companies to address customer and driver satisfaction objectives. As part of this exercise new shifts were constructed for two of the small bus companies surveyed. The key strategic objective applied during this process was reducing labour cost whilst at an operational level maximising the use of on-road meal break locations and reducing meal breaks during peak periods were key criteria. As anticipated, in both cases the labour costs were reduced (by between 1.5% and 13.3%). Dead running distances increased in both cases, however, these would have a minor impact on overall operating costs savings. It is worth noting that the use of other scheduling software packages or of course traditional manual methods may slightly alter the results achieved.

The results of both this survey and subsequent modelling have implications for both research and practice. Research in the area of crew scheduling and rostering for smaller companies has been quite limited. Most literature has focussed primarily on the objectives of larger companies. As a consequence, literature identifies key scheduling objectives as being to reduce labour cost, minimise peak vehicle requirements and minimise dead running distance and time. Little mention is made of the desire to keep the workforce satisfied or the driver's role as a key stakeholder in the overall scheduling process.

A larger sampling of bus companies is needed to provide a more definitive result and as a result conclusions drawn in this paper should be regarded as tentative. Sampling of interstate Australian and international companies would explore impacts of cultural and climate based differences. A wider range of objectives and criteria may be identified and these could subsequently be tested for significance. Overall this would allow further research to be conducted in an area that has predominantly focused on larger transport suppliers. Furthermore the possible incorporation of interstate Australian and international companies into an expanded sample size would allow an examination of public transport systems where there is a stronger commitment to network-based service planning. Unfortunately in Melbourne, historical legacy heavily influences current timetable and route structures which ultimately impacts on companies' ability to schedule and roster their staff and vehicles. Thus in the context of this paper such legacies are constraints on scheduling and rostering flexibility for the companies surveyed. Further work in this area could also involve an evidence based approach whereby survey results for operators could be compared with their actual timetables, shifts and rosters to verify that certain objectives were in fact higher priorities in comparison to other operators who did not similarly value their importance.

Lastly, the need to treat the stages of crew scheduling and crew rostering independently has been justified by these results. Although this study identified ten key operational criteria in the crew rostering process there are likely to be more. This is an area that could be explored in future research. From a practical perspective these results can be useful in gaining insight into how smaller bus companies schedule and allocate their resources. This can be beneficial for scheduling software providers whose major focus has been larger companies. Similarly for Governments and transport consultants, scheduling practices can be a useful input when designing transport networks and timetables as ultimately the design of these impacts on the crew scheduling and rostering process.

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