- report

Simple Screening Method for Slow Vehicle Bays

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1 Executive Summary

1.1 Purpose

This report develops a screening method for the economic assessment of Slow Vehicle Bays (SVBs), short lengths normally up to 300m of sealed shoulder widening to create opportunities for passing slow moving vehicles and generally located on uphill sections near crests and on right hand curves. The screening method is to complement but not to replace that already in the Land Transport New Zealand (LTNZ) Economic Evaluation Manual (EEM) Vol 1, Appendix A7.

The method is developed from analysis of traffic observations at one such SVB site, together with a targeted review of New Zealand literature and overseas sources on passing opportunities, operation of SVBs and passing lanes.

1.2 Data Analysis

Vehicle classification, time and speed observations analysed from traffic counters before, through and downstream of the example SVB site in both directions of travel, yielding information on vehicles speeds and bunching over two three day periods and for vehicle hourly flow rates of up to 275 veh/hour in the SVB direction. The bunch size distribution was well represented by the Borel Tanner model. The analysis enabled the effect of the SVB in reducing platooning to be estimated, and the downstream length over which bunching levels were re-established.

1.3 Summary of the Method Developed

Using the analysed site data and data from "*Assessing Passing Opportunities – Stage 3*", Transfund Research Report No. 220 by Koorey and Gu (2001) and other sources, a simple method for evaluating the benefit cost ratio for SVBs was developed.

A spreadsheet tool has been developed to implement the method. The required data inputs are terrain, trafficable road width, percent of passing sight distance before and after the SVB, AADT, traffic growth rate, percentage slow vehicles, SVB length and whether or not the road has a high seasonal holiday peak. The average traffic speed and average speed of slow vehicles can be input directly or default values supplied by an embedded table. Also there is provision to include site crash cost analysis from an external source or to use crash reduction estimates based on a similar method to that included in the EEM for passing lanes.

1.4 Qualifications and Recommendations

The SVB evaluation method has been calibrated using data from a single SVB site together with more general results from other studies in the field. Desirably more sites covering a wider range of conditions should be sought to give greater confidence in the method and before it is introduced for general use. Also, before and after comparison of the effects of installing SVBs would better allow certain parameters, such as the downstream length of effect of SVBs, to be determined.

2 Introduction

2.1 Purpose

Slow Vehicle Bays (SVBs) are short lengths of widened shoulder on two lane rural roads provided to allow slow vehicles (mainly slow heavy vehicles and recreational vehicles towing) to pull out of the traffic stream so that other traffic can overtake, thus relieving the formation of platoons with the attendant time delays, excess vehicle operating costs, driver frustration and safety risks.

The purpose of the work is to develop a simple assessment process together with a spreadsheet tool for assessing the economic benefits attributable to SVBs using the Borel-Tanner method and based on analysis of survey data collected at one or more SVB sites under a range of traffic flow conditions.

2.2 Scope and Purpose

The scope of Services included within this assignment is:

- Literature review and brief comment centring on the Borel-Tanner model and simple manual procedure described in "*Assessing Passing Opportunities – Stage 3*", Transfund Research Report No. 220 pp 64-83; also downstream length of effects for percent time following and average travel speed;
- Include consideration of Ministry of Transportation and Highways, BC 1998 reference for determining differences in expected upstream demand for rolling and mountainous road gradient;
- Development of a stand-alone spreadsheet analysis template for easy application of the method;
- Calibrate against existing SVB sites, from data to be provided, taking account of performance over a range of traffic conditions (and noting that night time performance may differ from daytime);
- Include in the screening method and spreadsheet, relationships between traffic outputs of % bunching and speed change and EEM Vol 1 benefits of travel time savings, congestion/frustration benefits and vehicle operating costs;
- Note limitations and range of use of methodology;
- Prepare a written report with brief procedures and worked examples;
- Provide for Beca internal peer review.

2.3 Literature Review and Commentary

2.3.1 TNZ Report 220 (Koorey and Gu, 2001)

Koorey G F and Gu J (2001) developed methods for technical assessment of passing opportunities at passing lanes and SVBs based upon short period (2 - 4 hour) field surveys undertaken at eight sites with a range of traffic volumes (1600 to 5200 AADT), heavy commercial vehicles (HCVs) (11% - 20%), length of SVB (90 – 250m) and gradient (-10% to +7%).

Vehicles using the SVBs were classified into trucks and recreational vehicles (e.g. campervans, vehicles towing trailers etc). The percentage of bunching was measured immediately before and some distance after the SVB together with the percentage of vehicles using the SVB and breakdown into the two sub-categories. Hourly directional flows were also counted.

At three of the sites, the percentage bunching after the SVB was recorded as greater than that before the SVB, despite 10%-20% of the vehicles using the bays. The inference from the rather small and sometimes negative improvement in bunching was that the effect of SVBs is limited in impact and duration. It was also observed that passing vehicles need not necessarily have higher desired speeds than the vehicles being followed.

For some sites, while the order of following vehicles may have changed, the location of the survey point may not have been sufficiently downstream for the change in percentage following to be markedly different. This tendency to under-record the amount of passing behaviour appears to be more prevalent at higher values of percentage following.

The Borel-Tanner distribution was found to be a suitable mathematical model for the distribution of platoon sizes for two-lane rural roads given information on the overall proportion of vehicles following and correlated well with observations at three of the sites. The Borel-Tanner distribution of probabilities of a platoon or bunch of size **b** is given by:

$$\mathbf{P(b) = [rz\ exp(-z)]^{r-1} \cdot \frac{exp(-z)}{r!}}$$

where **z** is the proportion of vehicles following. This model is clearly useful if survey data provide information on the number of vehicles following in platoons but not the platoon distribution. The model is used to evaluate the requirement for SVB length so that more than one vehicle is able to pass, taking account of directional traffic volume. In this mode, SVBs are acting more like short passing lanes, although used primarily by heavy vehicles and, to a lesser extent, by recreational vehicles towing, and on gradients that limit the speed of the heavy vehicle, where vehicles merge at the end of the SVB rather than give way to the overtaking traffic.

The paper concludes that SVBs are limited by traffic volume and speed in where they can be effectively located. At high volumes (depending on bunching) and/or high speed (over 60 km/h) the lengths required for the bays to be effective in allowing traffic to pass would exceed the limiting 300m maximum length, so their role is limited to relatively low traffic volumes, on roads with a significant proportion of slow vehicles, at locations where speeds are low and speed differentials between slow vehicles and other traffic are relatively high.

Nevertheless, traffic volumes at the SVBs surveyed frequently exceed the 2,000 AADT guideline in Land Transport/Transit's Manual of Traffic Signs and Markings (MOTSAM) and sometimes the SVBs exceed the 300m length limit.

The paper compared TRARR against the field data, considering the SVBs as either passing bays or short passing lanes. The agreement between TRARR modelling and the field data was fairly good and it was observed that as passing bays TRARR would tend to underestimate the time savings and as passing lanes would overestimate, with the actual performance somewhere between.

It was noted that the PEM (now EEM) treats SVBs as passing lanes in the simplified procedure[1] but that this was not necessarily valid because of the different give-way requirements at the remerge between the two situations. However, it appears that many drivers assume the right to remerge without giving way, treating the SVB as a short passing lane.

The authors suggest that driver frustration benefits from reduction in platooning should be recognised in economic evaluation but question whether any time saving benefits should be claimed because of the relatively small savings involved and the offsetting effect of delays to the slow vehicles in the SVB. While the method allows the reduction in platooning at the SVB to be estimated, it does not provide guidance on the downstream length of influence of the bunching reduction which is needed to estimate a benefit value, and a value of time savings should this be warranted.

2.3.2 MOTC BC Warrant for Passing Lanes

Ministry of Transportation and Highways, British Columbia (1998) Technical Bulletin DS98003 provides an empirically based method of estimating the percentage of vehicles following according to level, rolling and mountainous terrain.

The relevant formulae are:

(i) headway factor **HF** (the percentage of time when the headway in the opposing vehicle stream exceeds the time required for a vehicle to pass in the direction of flow, nominally 25 seconds):

$$\mathbf{HF = exp[-k \;.\; Q_{opp}]}$$

where $\mathbf{k}$ is a constant calibrated for level, rolling and mountainous terrain, and $\mathbf{Q_{opp}}$ is the opposing traffic flow in vehicles/hour; the bulletin notes that "planners may wish to use actual headway factors measured in the field rather than use an estimate based on the k constant".

How terrain is classified will be important. In the NZ procedures, terrain is combination of horizontal terrain (curvature – degrees/km) and vertical terrain (section averaged absolute gradient – rise and fall per km). In the British Columbia method the three terrain types and their calibration coefficients appear to have been derived from data generalised over three

[1] The reference here is to the simplified procedure previously included in the PEM between 1999 and 2005, rather than the current procedure which is an adaptation of that used for strategic planning of passing lane provision and specifically excludes SVBs. The previous simplified procedure is based on a road segment model of unsatisfied passing demand.

different highways or highway sets as flat, rolling and mountainous but without clear definition of what horizontal and vertical alignment and sight distance ranges constitute each terrain type.

(ii) proportion of time available for safe overtaking, **APO,** based on sight distance and opposing traffic:

$$\mathbf{APO = PSD \, . \, HF}$$

where **PSD** is the proportion of the road length with available passing sight distance; and

(iii) proportion of vehicles following, **z,** on a 2-lane highway without any auxiliary lanes where a_0, a_1 and a_2 are regression coefficients calibrated to level, rolling and mountainous terrain

$$\mathbf{z = a_0 + a_1 \, . \, Q - a_2 \, . \, APO}$$

where **Q** is the traffic volume in the direction of travel and $\mathbf{a_0}$, $\mathbf{a_1}$ and $\mathbf{a_2}$ are constants.

The values of the constants calibrated for Canadian conditions are:

	Level	Rolling	Mountainous
k	0.006	0.004	0.002
a0	0.53	0.58	0.67
a1	0.000365	0.000346	0.000330
a2	-0.89278	-1.09273	-1.86374

These linear relationships were obtained by regression using results from TRARR simulation. For any particular value of Q, the percent of vehicles following reduces to zero when APO reaches a certain level. The straight line graphs are an approximation of what actually happens and are inconsistent with the approach in the graphs in Section A4.4 of the EEM which do something similar although in this case using V/C ratio, the percentage time delayed and percentage of length with overtaking sight distance (PSD = PZL/L in the technical bulletin).

The percentage of vehicles following should fall to zero when APO reaches 100% for all levels of traffic. For example in the diagram for mountainous terrain, at 200 veh/h, the percentage following falls to zero at under 70% APO which is clearly not the case. The straight lines should be a family of curves that all asymptote to 100% on the abscissa. At the other end of the scale it is possible that the percent following will reach a maximum where APO is zero, but in this case the degree of bunching will depend on the length of road section, and will be progressive, dependent on the starting conditions and the vehicle dynamic performance in relation to the terrain. Given a long enough section with no passing opportunities, all traffic will eventually bunch behind the slowest vehicle, whatever the flow rate.

The potential advantage of the BC method is that it allows the proportion of vehicles following to be estimated for each class of terrain from data on the proportion of passing sight distance and the traffic volume. Vehicle speed and acceleration performance, traffic flow profile and vehicle mix (% HCVs or % slow vehicles) are not among the parameters so must be incorporated into the regression constants. Any transfer to NZ conditions should desirably calibrate the relationships to NZ or confirm that the vehicle fleets and traffic conditions are sufficiently similar – this might be done by a recalibration exercise using TRARR as was done in the original research, although we would suggest that the possibility of a non-linear calibration is included, to avoid the boundary problem noted above.

2.4 Slow Vehicle Bay Benefits

The benefits of providing slow vehicle bays arise potentially from:

- Reduction in travel delays – savings in delay to passing vehicles net of any time losses to the vehicles in the SVB and at the remerge point;
- Reduction in driver frustration – relief in the perceived disbenefit of following vehicles in a platoon due to the inability to travel at the desired speed for the conditions, over and above the travel time savings; driver frustration benefits are congestion and reliability benefits by another name but have historically been calculated as a particular benefit of rural passing lanes as a value per vehicle-kilometre of vehicle following;
- Change in vehicle operating costs – difficult to estimate outside of a detailed vehicle operating cost model as changes arise from complex interactions between gear changing, speed change cycles, elapsed running time and aerodynamic and rolling drag and may be positive or negative; the simplifying assumption made is to assume that VOC savings constitute a relatively small percentage addition to the travel time savings;
- Crash risk – there is some research that indicates an elevated crash risk where drivers are required to follow in platoons for an extended length of time and start to take risks in attempts to overtake; the crash risk is alleviated by release of this pent-up demand downstream of the passing lane and tapers out as the traffic bunching returns to the pattern that would have occurred had the passing lane not been present; it is also thought that some crash risk reduction may occur upstream of passing lanes as drivers are made aware of an upcoming passing opportunity; it is assumed that a similar crash reduction would apply in a moderated form to SVBs.

2.4.1 Operation of SVBs

Koorey (2002) and Koorey and Gu (2001) discuss the effectiveness of SVBs from empirical evidence and theoretical operation. The main issues bearing on effectiveness are:

- What proportion of platoon leaders pull over into the SVB to allow other traffic to pass;
- What proportion of slow vehicles pull over, even when not leaders in a platoon;
- To what extent slow vehicles modify their speed when in the SVB and at the lane re-entry point

The proportion of platoon leaders that use SVBs is clearly a major determinant of their effectiveness – if no-one pulls over the SVB is completely ineffective. Behaviour may be affected by the platoon size and the leading vehicle speed – a slow moving vehicle with a long following queue will probably be more motivated to use the SVB than a faster moving vehicle with only one or two following. Koorey (2002) finds that overall 45% of platoon leaders use SVBs, which is higher than overseas findings, and that more platoon leaders use SVBs where there are 2 or more vehicles queuing than only 1 vehicle queuing. However, the range of SVB use by platoon leaders over the seven field sites was very wide from 28% to 75%. Therefore, some consideration of the features that enable high use of SVBs should be taken into account when estimating SVB use.

The second point, the propensity of following slow vehicles to pull over, will have a smaller but possibly significant effect. The example of one slow vehicle trying to pass another and blocking the passing opportunities of following traffic is something that drivers encounter from time to time. So the effect in such a case may be just to replace the platoon leader but with very little increase in speed of that platoon.

The third point affects the balance between passing opportunities and time savings for following traffic offset by time losses for the slow vehicle. If the slow vehicle does not modify its speed and forces re-entry into the traffic stream, it loses no time. If the slow vehicle reduces its speed to allow the queue to pass and/or gives way on re-entry, then there is maximum benefit for the following traffic but a time loss and probably additional vehicle operating cost, for the slow vehicle.

These three behaviours will probably be affected by the design of the SVB – its length, the way it is marked, whether uphill or downhill.

2.4.2 Reduction in Travel Delays – Travel Time Benefits

The travel delay savings can be assessed from the reduction in platooning facilitated by the SVB, given data on the speed of slow vehicles using the bay and the desired speed of vehicles in platoons waiting to pass.

The delay saving is related to the number of passing opportunities provided – whether 1, 2, 3 etc following vehicles are able to pass the slow vehicle travelling in the passing bay. This in turn depends on the speed of the slow vehicle, the passing speed of the following vehicles and the length of the bay. Speeds are related to the gradient of the bay and whether uphill (vehicle mass and engine power constrained) or downhill (braking and curvature constrained).

Assuming the BT distribution calibrates satisfactorily for the test site (which it does), then this can be used to assess the distribution of platoon sizes and the theoretical numbers of following vehicles that are able to pass a slow vehicle. The time saved is then dependent on the time required for the passing vehicles to catch up to the next downstream platoon, which is determined by the speed differential between single vehicles and platoon leaders, with the majority of delay savings tapering off at this point.

Time savings are potentially offset by delay to the slow vehicle using the SVB if it is delayed in re-entering the traffic stream (as previously noted).

2.4.3 Driver Frustration Benefits

In prior versions of the PEM, driver frustration benefits for passing lanes were valued at 3.5 cents per vehicle-km in the direction of travel for vehicles released from platoons. This unit value, established in 1999, in fact needs to be updated to a 2006 cost base for compatibility with the EEM.

Where a TRARR analysis was available, the vehicle-kms over which the benefits were calculated was the product of the length of influence of the passing lane, the directional traffic volume and the difference in proportion of time spent following in platoons as a result of the passing lane. For a simpler procedure the vehicle-kms were simply the directional volume and the length of constructed passing lane.

The simplified procedures for passing lanes in the EEM now includes graphs for driver frustration benefits. These are based on embedded calculation of the vehicle-kilometres released from platoons and the unit value for frustration benefits.

2.4.4 Crash Risk and Accident Benefits

Accident benefits for passing lanes are calculated as a reduction in the mean crash rates per 100 million vehicle kilometres for open road sections of different terrain classification tapered over the downstream length of influence of the passing lane. Crash reductions are on a percentage basis for three accident types (refer Table A6.19(d) of Land Transport NZ's EEM, the source of the information being Koorey and Tate (1997)):

- Overtaking – 30%
- Head-on – 50%
- Rear-end, Hit Obstruction – 15%

The proportions of these crash types for 100 km/h rural areas from the CAS were 5%, 6% and 21% respectively in the passing lane analysis based on historic analysis of AIS crash records, with the weighted average reduction being 11% of total reported injury crashes.

There is no equivalent research for SVBs. Arguably there is a similar situation, in that the propensity for risky overtaking is reduced downstream of the SVB, although the effect will be scaled down significantly from that for passing lanes. Also, there is the possibility that traffic behaviour at the end of the SVB where slow vehicles sometimes force re-entry to the traffic lane may create some offsetting crash risk; however to our knowledge no evidence for this has been advanced.

To recognise the potential for crash savings we propose that the reduction in crash risk calculated for passing lanes be scaled down by the reduction in vehicles following as a percentage of the total vehicles following – that is a proportionate reduction assuming that passing lanes are completely effective in allowing bunched vehicles to pass, which will be an overstatement but conservative in that additional crash risks from give way uncertainty at the end of the SVB are not being included. Typically this reduces the maximum crash savings by about a half from the passing lane situation, and the shorter downstream length of effect of the SVB compared with a PL reduces the overall crash savings further.

Provision is alternately made for users to insert the results of an accident analysis for cases where a particular crash risk has been identified at the SVB site and the project is designed to remediate this as well as providing for its slow vehicle overtaking function.

3 Simple Screening Procedure

3.1 Position in the EEM

The position of this new procedure in the EEM is expected to be as a screening tool prior to Section A7.4 "Assessment of individual passing lanes". This presently specifically excludes SVBs and crawler lanes (note this SVB procedure is not intended to apply to crawler lanes).

The passing lane procedure uses a series of three sets of graphs developed for: (i) delay and VOC savings (Figure A7.7); (ii) driver frustration benefits (Figure A7.8); and (iii) accident savings (Figure A7.9). Apart from accident savings, the graphs are for all classes of terrain but distinguish passing conditions by the frequency of passing lane spacing and the passing sight distance. These two parameters together determine the accumulated passing demand. The procedure then applies correction factors for different levels of traffic growth (which could equally apply to SVBs) and for passing lane length (longer passing lanes)giving opportunity for longer platoons to clear. The procedure also gives the opportunity for accident savings to be assessed by accident-by-accident analysis – appropriate to a situation where the passing lane forms part of a wider realignment or where crashes are a significant and identifiable reason for proposing a passing lane.

3.2 Differences for SVBs Compared to Passing Lanes

The context is not the development of a general strategy for provision of SVBs over a route but as a simple screening tool for an individual site, given that the cost of establishing SVBs are relatively low compared with passing lanes and so do not warrant an elaborate and costly evaluation process.

It is still necessary to have some measure of accumulated passing demand, and the length of the SVB does influence the proportion of this demand that is released – in this respect a SVB behaves like a short passing lane, but with the observed differences discussed in Section 2.4.1 above.

In the strategic passing lane procedure, the accumulated passing demand and the proportion released by locating passing lanes at regular intervals has been determined through a process of simple traffic simulation of over a large sample of actual road alignment. This generated output in time savings per kilometre over a range of passing sight distance conditions, the simulation being run at various levels of hourly traffic volume. The simple simulation included the speed effects of gradient and curvature to simulate the overtaken and overtaking vehicle speeds. The output was graphed, the graphs smoothed and the benefits converted from an hourly traffic basis to AADT using typical flow profiles.

This technique is not applicable to the present task of evaluating SVBs because the aim is to assess particular sites, rather than the generality of placing SVBs at intervals and using specific site data.

However there is still a need to make a reasonable assessment of the accumulated passing demand or bunching, and of the opportunity and propensity for overtaking to occur, which in turn depends upon the relative speeds between the slow platoon leader, the desired speed and acceleration capability of the following queued vehicles, and the propensity for the slow vehicles to pull over into the SVB.

3.3 Common Elements between SVBs and Passing Lane Procedures

The procedure applies to roads with typical traffic flow profiles for rural state highways, with two categories of low and high rural recreational flow. The procedure uses AADT as an input and distributes the traffic volume over the assumed flow profile in hours per year. Three typical flow periods are used: peak, daytime and night.

The existing simplified procedure for passing lanes does not include directional split of traffic in the main procedure or correction factors. Within the typical range of directional split found on rural roads, the results were relatively insensitive to the directional distribution of traffic. Reasons for this are firstly that the directional pattern generally reverses through the day so evens out, and secondly the increased platooning resulting from a higher flow in the direction of the passing lane is counterbalanced by the lower opposing traffic and increased passing opportunity. Similar considerations apply for passing bays and directional split is not included as a parameter.

A traffic growth assumption of 2% is included in the passing lane procedure with a table of correction factors against the benefit components, according to AADT and the traffic growth. A similar facility is required for SVBs but could be incorporated as a direct data input to the spreadsheet tool.

3.4 Different Elements for the SVB Procedure

A main difference between the SVB procedure and that for passing lanes is the use of a simple spreadsheet tool rather than relying on a set of graphs, tables and factors that are applied manually. A spreadsheet tool allows the effect of specific site characteristics and traffic parameters to be entered into a direct calculation procedure, provided that the problem can be reduced to a series of formulae or a combination of formulae and look up tables.

The main elements of the computation are:

- estimating the percentage of vehicles following (bunched) at the start of the SVB and distribution of platoon lengths
- the proportion of slow vehicles using the SVB and any relationship with the following queue length or the speed differential between the platoon leader and overtaking vehicles, and
- the calculation of numbers of vehicles released from platoons and hence the benefit assessment

How these are treated in the simple screening procedure is described below.

3.5 Percent of Vehicles Following

Koorey and Gu (2001) offer a simple procedure for calculating the frustration benefits of SVBs. This relies on data on the percentage of vehicles following at the start of the SVB, a modelling of the distribution of bunch sizes using the BT distribution, and the assumption that for each platoon leader that uses the SVB, the immediately following vehicle will overtake and will continue at a faster speed than the remaining bunch. This procedure could clearly be extended to more than one vehicle overtaking if the speed differentials and length of the SVB allow.

The MOTH British Columbia (1998) method using regression equations would overcome the need for site observation of the proportion of vehicles following. However, an assessment of the proportion of road length with passing sight distance is still required, so that the available passing opportunities (APO) and percentage of vehicles following can be calculated. As noted, we have some reservations about using the Canadian formulae without calibration to the NZ vehicle fleet and also because of the distorting effects of using linear relationships, discussed above.

An alternative to the British Columbia method is to use the percentage of time following as a proxy for percentage of vehicles following. Koorey and Gu (2001) cite a finding by Harwood et al (1999) that the percentage of time following approximates bunching fairly well. The percentage of time following would equate with the percentage of vehicles following if the mean speed of single vehicles and platoon leaders were the same as that of following vehicles. In practice the mean speeds differ, in the sample set by 3-5%. This is close enough for the percent of vehicles following to be estimated as a minor correction to the percentage of time following.

The Highway Capacity Manual method could then be used to determine the percentage of time spent following. This can be done from formulae and look up tables from the HCM Section 20. Alternatively the Figures A4.1 (a) to (c) in the EEM provide similar information and are used in evaluation of congestion on rural two lane roads. The HCM method is applicable to flat and rolling but not mountainous terrain, which the HCM requires be analysed as specific gradients and which is applied to long lengths of sustained gradient that reduce vehicles to crawl speed.

A comparison has been made of the percentage of vehicles following between the two methods, for 12% slow vehicles and 200 vehicles/hour.

Table 1 – Comparison of HCM and MOTH British Columbia Methods for % Following

Terrain	% Passing Length	EEM Figure A4.1	% Following HCM Method	% Following MOTH BC Method
Mountainous	0%	59%		71.0%
	20%	56%		39.2%
	40%	53%		7.4%
Rolling	20%	45%	30.9%	46.3%
	40%	42%	30.7%	30.4%
	60%	37%	28.1%	14.5%
Flat	40%	34%	26.0%	35.3%
	60%	29%	23.4%	24.2%
	80%	21%	20.8%	13.2%

The MOTH method gives a much wider range of percent following than the other two methods for relatively small changes in passing sight distance as the result of using linear regression relationships, as previously observed. They seem inconsistent with the spread of results obtained by Koorey and Gu (2001) for a range of SVB sites, where the degree of bunching lies between 23% and 50% over a range of conditions.

The Highway Capacity Manual method gives % time spent following for flat and rolling terrain. In this case the range of variation seems to be rather narrow. The classification of terrain differs from that used in EEM Appendix A7, and the method does not apply to mountainous terrain which in this case is conditions that reduce heavy and recreational vehicles to crawl speed, and for which simulation modelling is recommended.

The EEM and MOTH methods are similar at the lower percentage passing sight distances for flat and rolling terrain. The EEM graphs and equations for percentage of time following have the advantage of being consistent internally with the EEM and giving a spread of values that seem reasonable when compared with the field data. Recognising that % time following will be slightly greater than % bunching, an adjustment factor may be applied.

A problem for any of the above methods is that the estimate of % following does not take account of the accumulation of passing demand over the approach to the SVB, so may not replicate the conditions at a particular SVB site. Where there is a length of road with either a passing lane or good forward visibility or major intersection upstream of the SVB, then bunching may be lower than expected; alternatively if there has been a long section with few passing opportunities then the accumulated passing demand and bunching may be particularly high. Koorey and Gu (2001) have suggested ways of modelling the accrued passing demand along a road section and further refinements have been suggested by Roozenburg and Nicholson (2004). However, these still leave questions and calibration issues and in any case require a starting point where bunching data are available.

This being the case, we have allowed for the simple method to either specify the % vehicles following at the SVB site or to substitute this with the EEM estimate of %time following, converted to % vehicles following using a simple correction factor.

3.6 Proportion of Vehicles Using the SVB

The proportion of platoon leaders using the SVB is a key parameter. Koorey and Gu (2001) found this to vary widely but overall averaged 45%. The sample count data does not allow this percentage to be exactly identified but the proportion of platoons (including single vehicles) in the SVB compared to the total platoons (excluding single vehicles) before the SVB in the sample was 66% which should be approximately the same (although including those vehicles that use the SVB without any vehicle following).

The data show a weak correlation between traffic volume and the proportion of vehicles using the SVB – a larger proportion of vehicles use the SVB as traffic volumes rise. This indirectly supports the findings in the literature that use of SVBs is influenced by the numbers of following vehicles, although again direct evidence such as video observation of the platoon leader behaviour would be needed to more clearly identify this behaviour. Also this observation may not affect the actual operation of SVBs as it may be only a reflection that slow vehicles pull over when there are vehicles following, and the likelihood of this increases with traffic volume.

The speed of the platoon leader and length of the platoon influence the propensity to use a SVB. Koorey and Gu (2001) observed that a higher proportion of platoon leaders used SVBs where there was more than one following vehicle, although the results for individual SVBs varied widely – in some cases the proportion of users doubled, in other cases increased by a lesser amount or not at all. Overall the proportion increased from 42% to 55%.

While this could be allowed for in the procedure, the difficulty would be what values to assign in view of the wide spread of observed data and no clear association with any other parameter (such as SVB gradient or speed differential between platoon leaders (slow vehicles) and single vehicles. This is discussed further in the data calibration section.

3.7 Numbers of Vehicles Released

The numbers of vehicles released when a lead vehicle uses the SVB will depend firstly on whether the lead vehicle treats the SVB as a short passing lane and merges back into the traffic stream even if the queued vehicles have not passed or the lead vehicle allows the full queue to pass even if it requires him to slow down or stop.

The length of the SVB, the speed of the lead vehicle and the acceleration capability and desired speed of the overtaking vehicles will determine how many vehicles can pass within the time taken for the lead vehicle to traverse the length of SVB.

Koorey and Gu (2001) have dealt with the overtaking calculation in a simple form by treating the overtaking speed as the mean desired traffic speed and the overtaken speed as the mean speed of the slow platoon leaders as follows:

The length to be overtaken, assuming a single vehicle in the SVB is given by:

$$L_p + L_s + 2.\ G_t.\ V_{sr} \quad \text{.......(1)}$$

Where L_p metres is the length of the passing vehicle, L_s metres is the length of the slow vehicle, G_t seconds is the clear time gap behind and ahead of the overtaken vehicle that is required to be passed, and V_{sr} metres/second is the speed of slow vehicle. At the same time that this block length is passed it is moving forward at a relative speed of $(V_p\text{-}V_{sr})$ where V_p metres/second is the speed of the passing vehicle. The road distance required for the passing manoeuvre is then:

$$V_p/(V_p - V_{sr})\ .\ [L_p + L_s + 2.\ G_t.\ V_{sr}] \quad \text{.......(2)}$$

This makes the assumption that the passing vehicle accelerates from a speed somewhat less than its desired speed and passes at a speed somewhere above its desired speed, but overall the mean traffic stream speed is a suitable approximation. This may be conservative, particularly on steeper gradients where the speed differential between slow vehicles and the desired speed and acceleration capability of overtaking vehicles are greater.

The time taken for more than one vehicle to pass, using the same methodology, is given by

$$V_p/(V_p - V_{sr})\ .\ [n.\ L_p + (n\text{-}1)\ S_t.V_p + L_s + 2.\ G_t.\ V_{sr}] \quad \text{.......(3)}$$

Where S_t is the time separation between overtaking vehicles and n is the number of overtaking vehicles.

Finally, if more than one vehicle is using the SVB, then the time for n vehicles to pass m vehicles in the bay, is given by:

$$V_p/(V_p - V_{sr}) . [n. L_p + (n-1) S_t.V_p + m.L_s + (m-1) S_t.V_{sr} + 2. G_t. V_{sr}] \ldots\ldots\ldots\ldots\ldots(4)$$

All of these equations assume that the vehicles in SVB do not slow further to give way to passing traffic.

The input data required to support this part of the calculation are therefore the desired mean traffic speed (i.e. the free flow mean speed for the road alignment), and the mean speed of platoon leaders that use the SVB, taking account of any additional slowing of these vehicles when they pull over. Both parameters will be influenced by the local road alignment – if the SVB is on a steep gradient there will be a greater difference in speed between the slow vehicle and the mean speed of the traffic stream.

A way of estimating the speed parameters is needed if the simple method is not to require site observations of speed and platooning. Our proposed way of dealing with this is to provide typical speeds for general traffic and slow vehicles against the terrain categories used in the passing lane procedures. Typical speeds can then be assigned from observations made in research projects and/or using a recognised rural road speed prediction model. Some values have been included which appear to be consistent with observation at the sample site, but data from other sites would be desirable. The spreadsheet tool allows for either observed data or the default values to be used.

3.8 Downstream Zone of Influence of the SVB

The downstream effective length or zone of influence for SVBs is a critical and sensitive parameter in the evaluation. This is the length over which the effects of the SVB on mean traffic speed and platooning taper out to the point where they are indistinguishable from the "without SVB" situation. The effects do not taper linearly but for the purposes of evaluation an equivalent linear effective length is assumed, so that benefits can be estimated at 50% x the effective length x the change in speed or percentage following at the immediate end of the SVB. The longer the effective length the greater the benefits.

While a comprehensive literature review was not part of this assignment, those sources examined provide relatively sparse information on the effective length of passing lanes and virtually none for SVBs. There is discussion on what lengths have been used in the calibration section.

The evaluation of travel time and frustration benefits is then calculated as:

- Travel time – 0.5 x unit value of time x the travel time difference for vehicles released from platoons applied over the equivalent length of effect of the SVB
- Frustration benefits - 0.5 x unit value per vehicle-km x number of vehicles released from platoons x equivalent length of effect of SVB
- Crash benefits – 0.5 unit value of crash cost x reduction in crash rate per 10^8 vehicle-kms x number of vehicles released from platoon x equivalent length of effect of SVB

The equivalent length of effect of the SVB can be thought of as the area under the curve converted to an equivalent triangle (hence the factor of 0.5).

3.9 Range of Application for SVBs

3.9.1 Guidelines and Standards

Standards and guidelines on the provision and design of SVBs are given in the following documents:

- Transit/LTNZ Manual of Traffic Signs and Markings (MOTSAM) Vol 2, Section 2.14
- Transit NZ (Draft) State Highway Geometric Design Manual (SHGDM): Section 5: Vertical Alignment; Sub-section 5.5.1
- Transit NZ Planning Policy Manual Appendix 3E: Passing & Overtaking

3.9.2 MOTSAM Guidelines

The range of application for SVBs is covered in MOTSAM Volume II:

- Winding two-lane rural roads in mountainous, coastal and scenic areas
- Usually less than 300m so as not to be confused with passing lanes which should be at least 600m in length; and not less than 60m; the guidelines for SVB lengths are by mean traffic speed on the road adjacent to the SVB
- Not closely interspersed with passing lanes to avoid confusion
- Where long platoons of vehicles are rare
- AADT is less than 2,000 veh/day
- Slow moving vehicles are at least 10% of AADT
- Slow moving vehicles are mainly recreational/tourist vehicles such as campervans, cars towing caravans and/or boats
- Passing opportunities are limited

All of the above conditions are to be met. It is expected that SVBs will be placed to end at or just beyond hill crests where towing vehicles will naturally slow, and on straights or right hand bends. SVBs are therefore unlikely to be advised in terrain classifications other than rolling or mountainous (which includes tortuous horizontal alignments on flat vertical gradients).

3.9.3 Transit SHGDM

The SHGDM gives a similar list of applications for SVBs as MOTSAM. A current AADT less than 2,500 vpd is recommended. The SHGDM emphasises the importance of visibility of the end of the SVB to following drivers, that is not obscured by blind curves or hidden below the crest of a hill.

3.9.4 Transit Planning Policy Manual

This manual provides greater latitude for the use of SVBs over a range of traffic flows. For rolling or mountainous sections, short PLs (600-800 m excluding tapers) sometimes in-series are the preferred option up to projected 4,000 vpd but this option may not be viable at low traffic flows. Therefore, as an alternative for some situations, SVBs are suggested at 25 year projected traffic volumes of up to 4,000 veh/day but with provision to be extended. This would accommodate a present day AADT of 2,000 vpd with a 4% growth rate or a present 2,500 vpd AADT at 2.4% growth rate.

3.9.5 Discussion

Despite the above advice the SVBs studied by Koorey and Gu (2001) in some cases exceed 300m in length and regularly exceed 2,000 AADT; indeed the average AADT for the sites examined was 2,500. It is also clear that, in many cases, the majority users of SVBs are slow moving heavy trucks rather than recreational vehicles.

The screening procedure should conform to recommended practice but, at the same time, also needs to recognise the realities in the field.

To recognise this, the Transit Policy Manual range limits have been recognised in the spreadsheet tool but data can be entered for SVB lengths between 50m and 400m length and up to 6,000 AADT, but with warnings generated to indicate that this use is outside the guidelines.

4 Calibration Against Site Data

4.1 Site Identification

Data for one SVB site was provided for the analysis. The site is on SH5 about 3.7 kms northeast of the SH1/SH5 intersection at Wairakei at RS 111/9.7-9.9, decreasing direction on a right hand bend, and is 325 m long with an average ascending gradient of 6.4 % so is on the borderline between rolling (3-6%) and mountainous (>6%) vertical alignment.

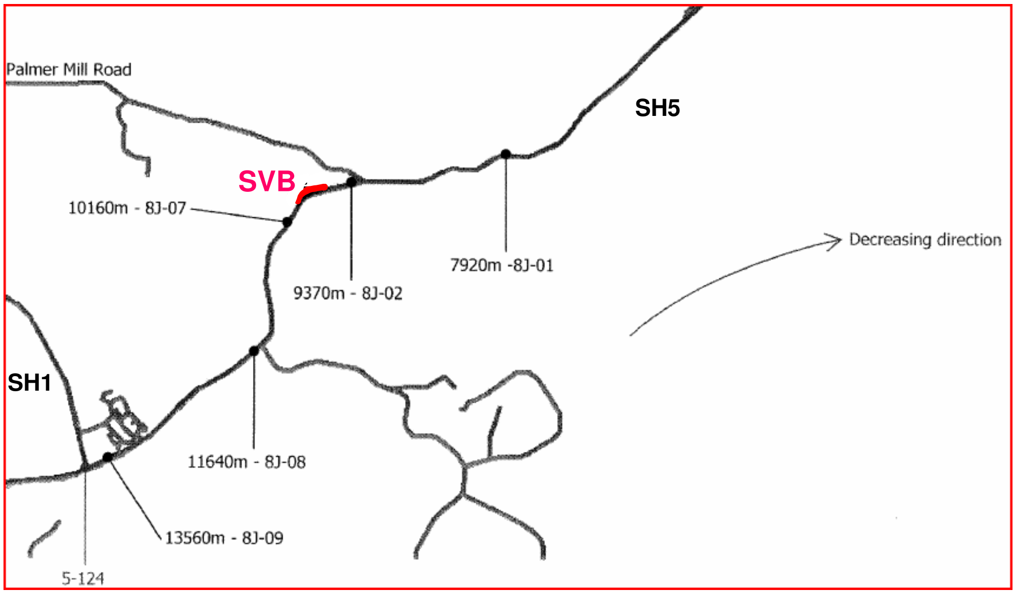


Figure 1 – Location Diagram of Sample SVB Site

Figure 2 – Aerial View of SVB

The surveys were carried out over three days, Wednesday 25 to Friday 27 July 2007 over a full 24 hour period. An earlier survey but without the same number of counters was carried out between 4 and 6 of July.

Counting sites were located in advance and downstream of the SVB as indicated above and shown in the diagram below.

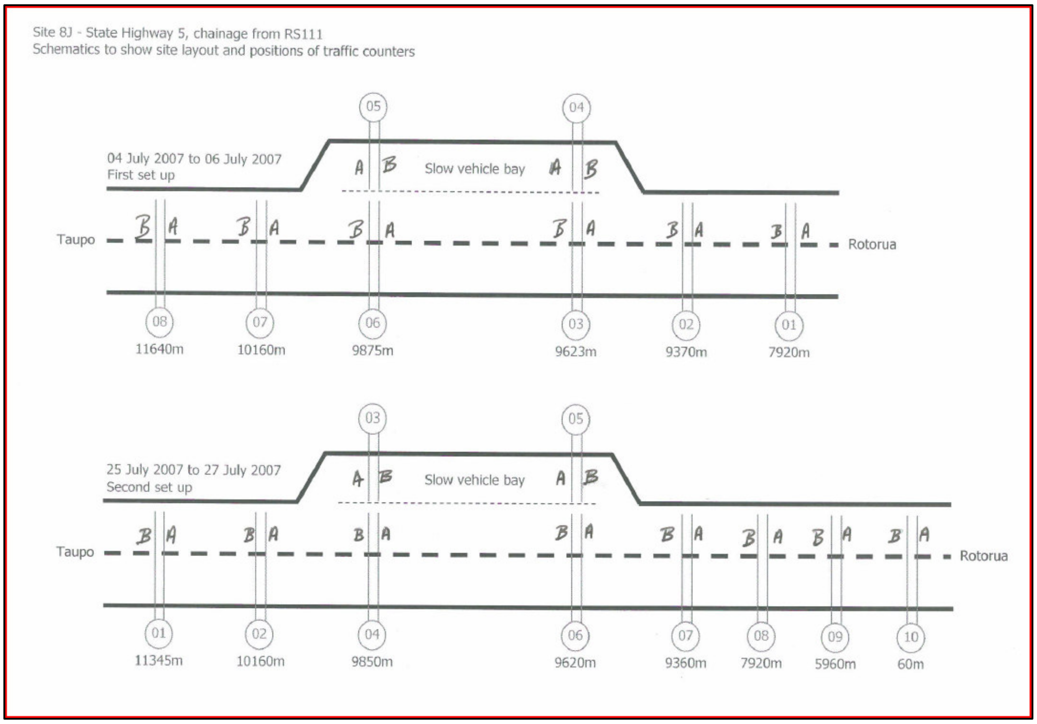


Figure 3 – Diagram Showing Location of Traffic Counters

The counter locations are numbered differently in each survey and the numbering for the second survey has been used in the analysis (e.g. data for counter 07 in the 1st survey is the equivalent of counter 02 in the second survey). In a few cases the chainages differ: counter 01 at 11345 and counter 08 at 11640; counter 03/40 at 9850m and counter 05/06 at 9875; counters 05/06 at 9620 and counters 03/04 at 9623, counter 07 at 9360 and counter 02 at 9370. The chainage differences are relatively minor and data has been pooled between the two surveys to augment the number of hours for each flow period.

4.2 Data Format

Data was provided as individual vehicle records, containing the following information:

- Date and time (hh.mm.ss)
- Direction of travel
- Instantaneous Speed, km/h
- Vehicle wheelbase, m
- Headway, s
- Gap, s (= Headway – Wheelbase)/Speed

- Axle numbers
- Transit NZ vehicle class

Data was provided at survey points ahead of, and downstream of, the SVB. This enables a comparison of speed and platooning before and after the SVB.

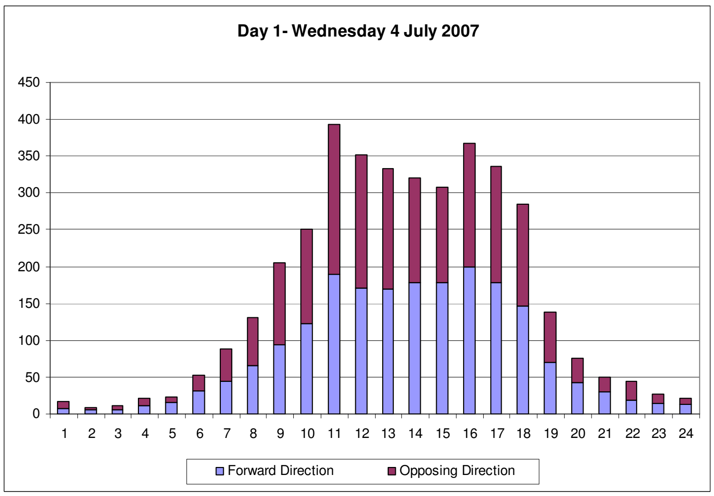
Summarised data was also provided, but our analysis was based on the vehicle-by-vehicle records.

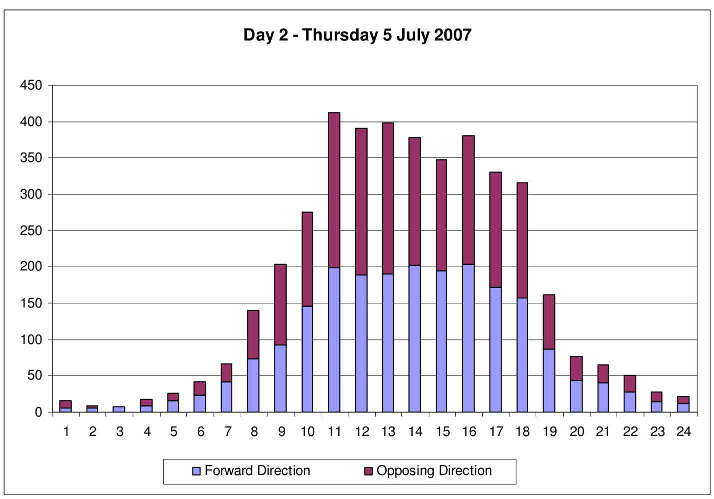
4.3 Traffic Characteristics

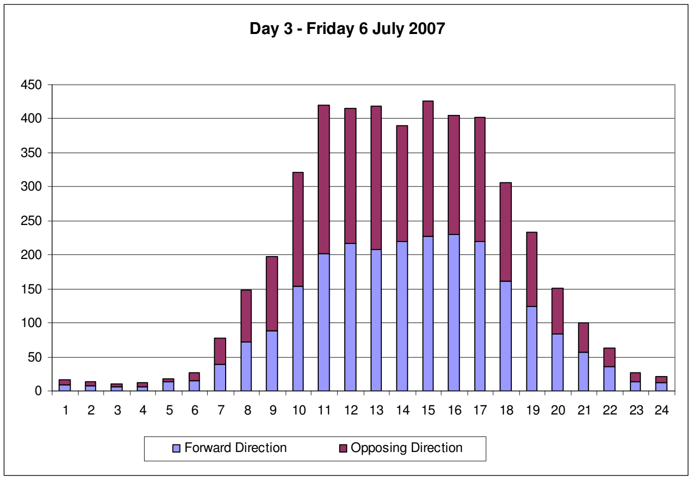
4.3.1 Hourly Flow Profile

The hourly traffic flow profile over the six days is shown in Figure 4 below.

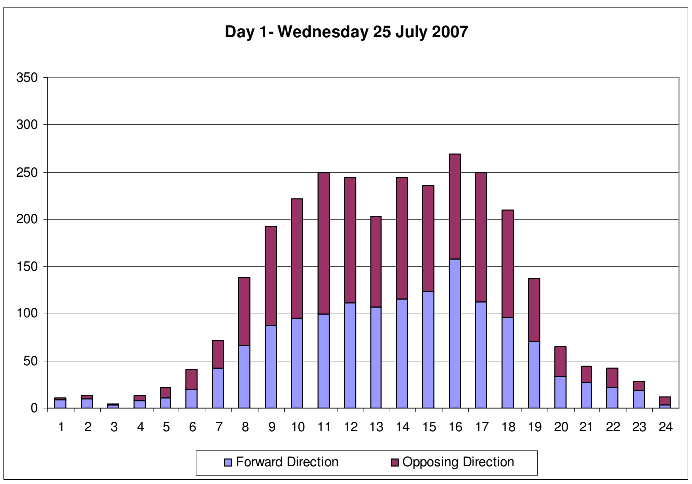
First Set of Observations:

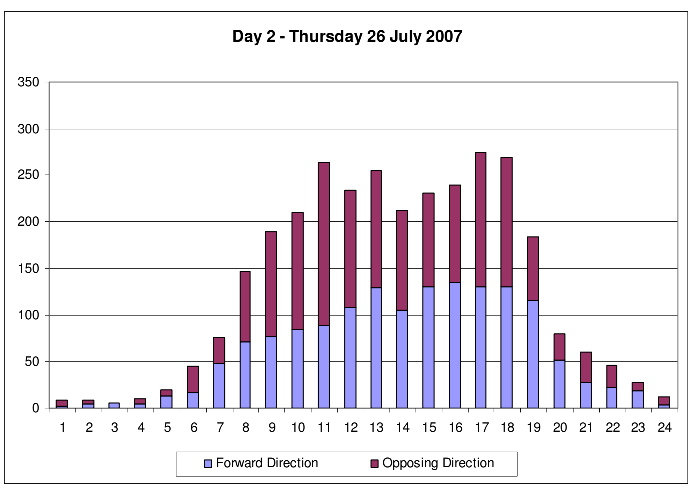






Second Set of Observations:





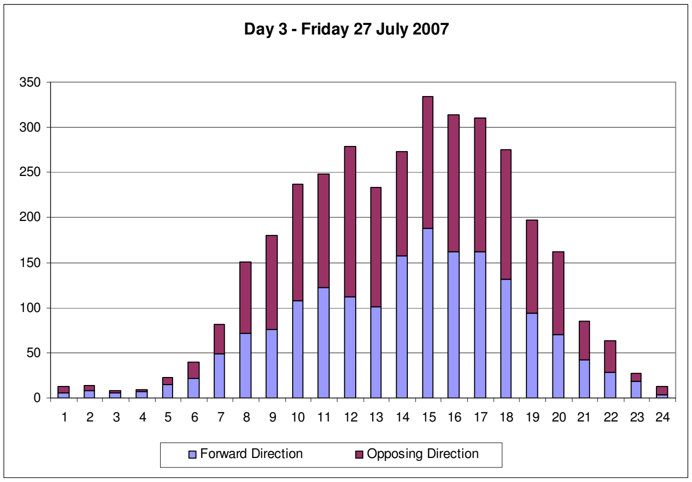


Figure 4 – Flow Profiles for each Day of Observations

The range of hourly flows for the first data set are higher, peaking at 400 to 450 vph, than the second data set, peaking at 300 to 350 vph.

The directional split averages 50/50 over the day and fluctuates between 40/60 and 60/40 through the day.

4.3.2 Percentage of Recreational and Heavy Vehicles

The classification of these vehicle types over the days of survey compares as follows:

Table 2 – Traffic Classification

	% RVs	% HCVs	% RVs+ %HCVs
1st Series			
4 July, Wed	3.1%	13.9%	17.0%
5 July, Thu	2.5%	11.5%	14.0%
6 July, Fri	2.7%	9.6%	12.3%
Total	2.7%	11.5%	14.3%
2nd Series			
24 July, Wed	2.1%	14.5%	16.7%
25 July, Thur	3.3%	17.8%	21.0%
26 July, Fri	2.8%	13.3%	16.1%
Total	2.7%	15.1%	17.9%

Friday traffic has a lower percentage of HCVs. RVs are a very similar percentage from day to day. RVs are taken to be light vehicles towing (Class 2) and heavy vehicles all classes other than Classes 1 and 2.

There is a big variation in the percentage of heavy traffic between day and night, although night time flows contribute only a small proportion of the total daily HCV flow (Figure 5).

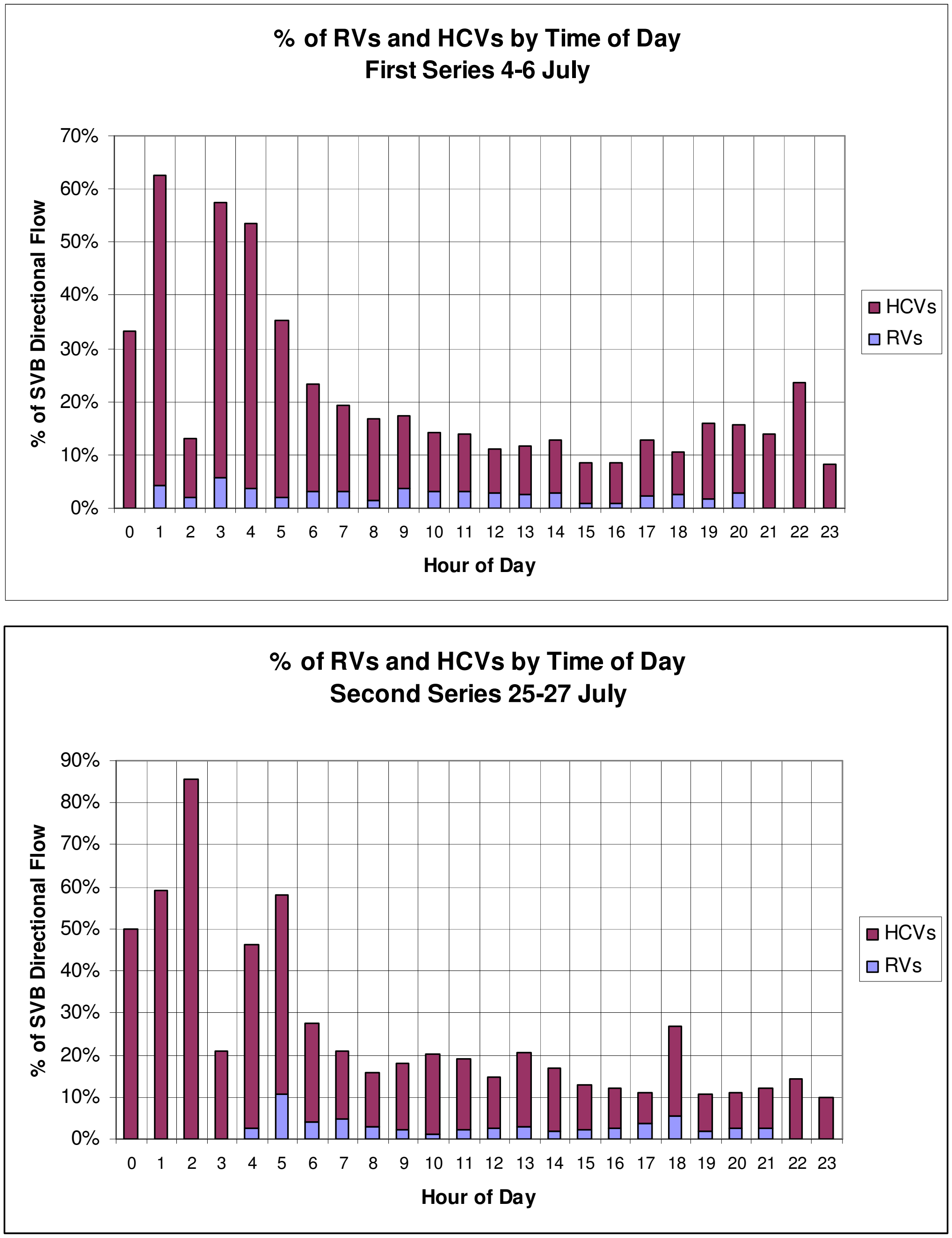
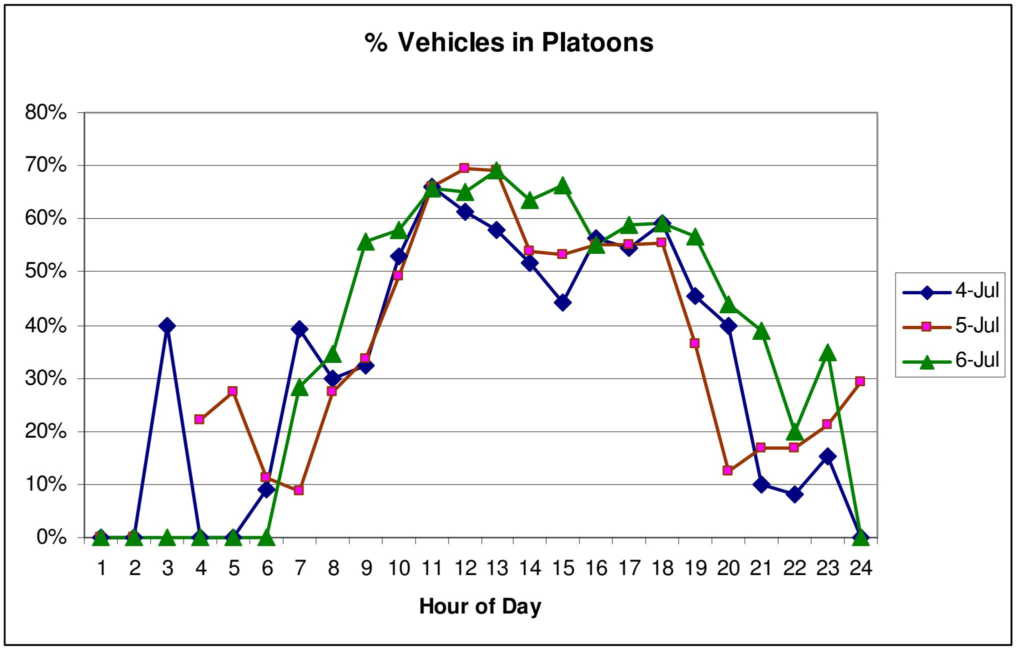


Figure 5 – Recreational and Heavy Traffic Composition by Hour of Day

4.3.3 Variation in Platooning

The percentage of vehicles in platoons (i.e. not single vehicles) at the approach to the SVB (at counter 07 in the 1st series and counter 02 in the second series) compare as follows in Figure 6.



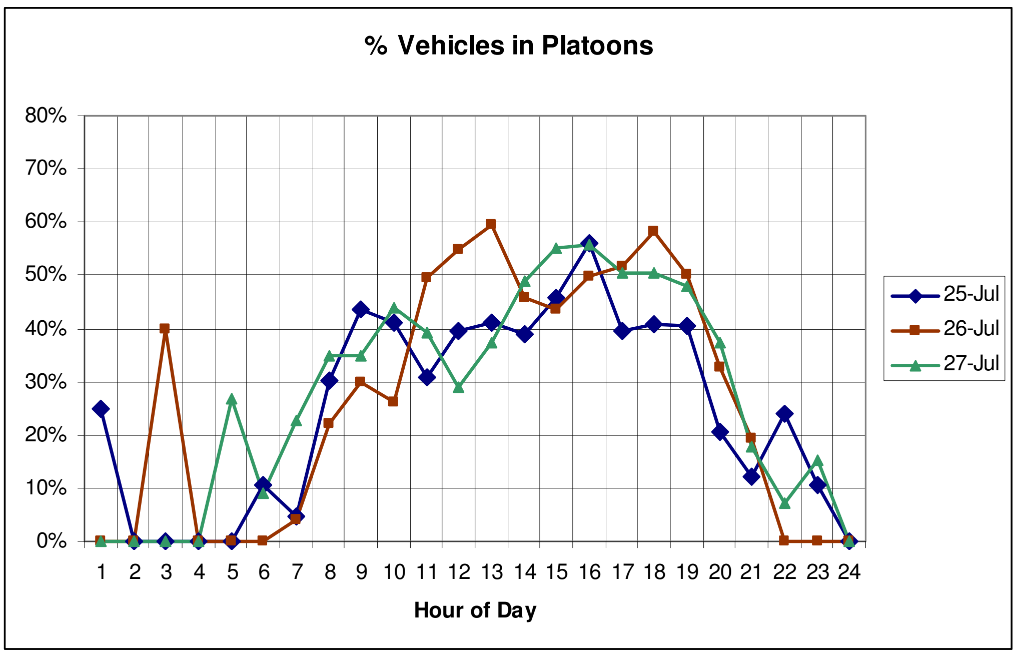


Figure 6 – Percentage of Vehicles in Platoons, by Time of Day

Platooning is higher in the first series corresponding to the higher traffic volumes. For both series, the values for low flows have a greater variation, possibly due to reduced number of vehicles.

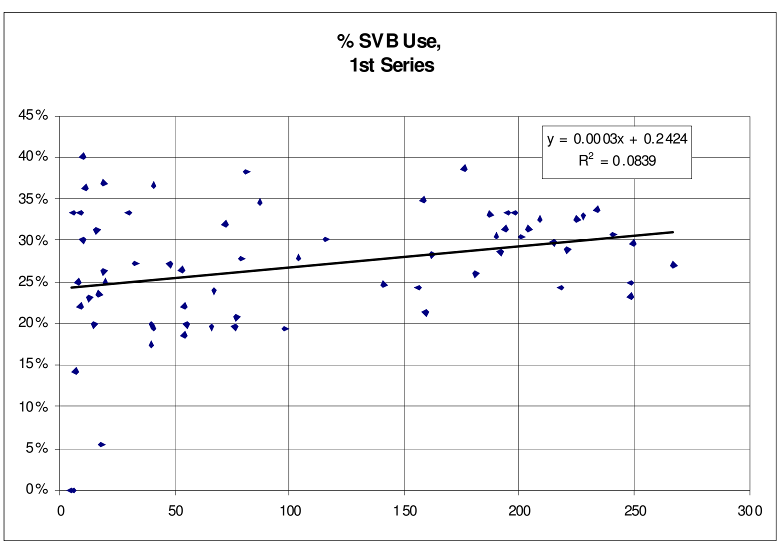
4.4 Vehicles Using the SVB – Variation Against Hourly Volume

Table 3 shows the percentage of vehicles using the SVB by traffic volume band and the percentage of platoon Scatter plots by hour of percentage use of the SVB versus traffic volume in the direction of the SVB for the two sets of observations are shown below in Figure 7. There is a very low level of correlation and only weak evidence of an increase in SVB use with increasing flow.

The percentage of vehicles using the SVB is only an indirect and approximate measure of the percentage of slow vehicle platoon leaders that use the SVB, which is the parameter that is actually wanted. It is not possible to determine this from the counter data.

Table 3 – Percent of Vehicles Using SVB by Volume Band

Flow Veh/h	% Using SVB
0-25	17.0%
26-50	16.2%
51-75	20.1%
76-100	17.7%
101-125	17.3%
126-150	19.7%
151-175	25.8%



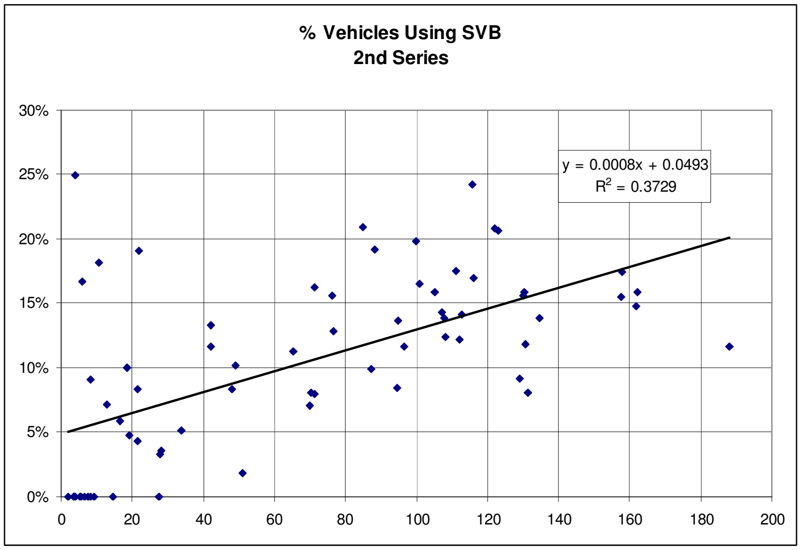


Figure 7 – Percent of Vehicles Using SVB versus Traffic Volume

4.5 Changes in Bunching Before and After the SVB

The percentage of vehicles following for the counters have been analysed in 25 veh/h bands in the direction of the SVB. The two data sets were analysed individually and also pooled.

The data are tabulated in Table 4 and graphed in Figure 8 for the first series, Figure 9 for the second series and Figure 10 for the pooled data.

Table 4 – Percentage of Vehicles Following

Counter	Location Relative to Start of the SVB, m	% Following Vehicles for Flow Volume in SVB Direction (veh/h)								
		0-25	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225
Ist Data Series	**4-6 July**									
08-BA	- 1,765	4.2%	14.6%	23.7%	21.6%	40.4%	38.2%	35.2%	39.2%	39.7%
07-BA	- 285	6.8%	13.1%	21.6%	23.6%	39.6%	39.9%	35.1%	38.3%	40.4%
05/06-AB/BA	0	7.2%	15.5%	22.7%	31.8%	41.3%	39.8%	33.0%	35.7%	37.9%
03/04-AB/BA	253	3.4%	9.0%	11.7%	19.4%	30.6%	27.4%	25.5%	26.6%	30.5%
02-BA	505	5.8%	10.6%	19.0%	23.7%	40.6%	37.0%	35.8%	38.0%	41.9%
01-BA	1,955	7.0%	16.2%	23.2%	33.9%	42.3%	41.7%	36.0%	40.2%	42.3%
2nd Data Series	**24-26 July**									
01-BA	- 1,495	4.4%	11.4%	6.9%	20.2%	26.0%	28.9%	27.5%		
02-BA	- 310	7.4%	13.3%	10.5%	22.5%	29.9%	32.4%	32.4%		
03/04-AB/BA	0	5.1%	7.3%	6.5%	15.6%	22.0%	22.5%	22.8%		
05/06-AB/BA	230	6.5%	8.3%	6.9%	17.6%	23.6%	25.4%	24.9%		
07-BA	490	5.5%	10.5%	7.4%	20.8%	27.9%	31.8%	32.5%		
08-BA	1,930	4.7%	12.7%	7.8%	20.9%	25.3%	25.6%	28.5%		
09-BA	3,890	8.3%	14.1%	10.0%	24.4%	28.3%	26.6%	30.3%		
10-BA	9,790	8.1%	14.1%	11.6%	26.7%	30.3%	31.4%	34.8%		
Pooled Data										
01-BA (08-BA)	- 1,495	4.3%	13.1%	16.0%	20.6%	28.4%	31.5%	33.5%		
02-BA (07-BA)	- 310	7.1%	13.2%	16.1%	22.8%	31.6%	34.5%	34.5%		
03/04-AB/BA	0	6.1%	12.0%	16.6%	21.6%	26.3%	28.8%	30.8%		
05/06-AB/BA	230	4.9%	8.7%	9.5%	18.2%	24.9%	26.0%	25.4%		
07-BA (02-BA)	490	5.6%	10.5%	13.2%	21.7%	29.9%	33.3%	35.0%		
08-BA (01-BA)	1,930	5.7%	14.6%	17.2%	25.3%	28.8%	31.3%	34.3%		
09-BA	3,890	8.3%	14.1%	10.0%	24.4%	28.3%	26.6%	30.3%		
10-BA	9,790	8.1%	14.1%	11.6%	26.7%	30.3%	31.4%	34.8%		

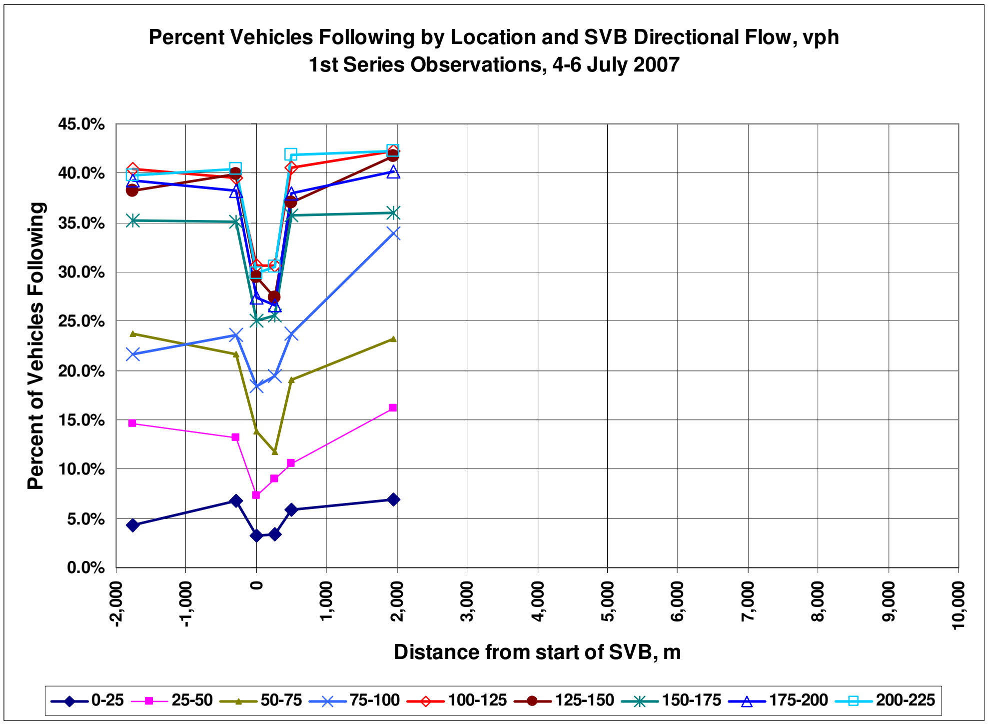


Figure 8 – Percentage Following Vehicles for Directional Flow Bands – 1st Series

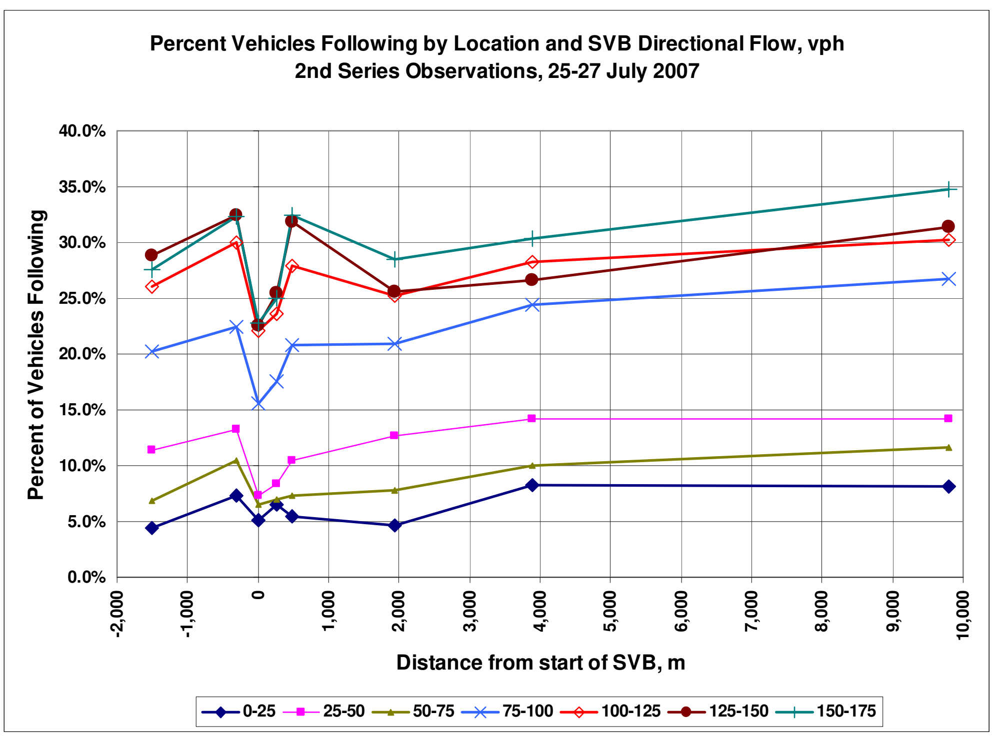


Figure 9 – Percentage Following Vehicles for Directional Flow Bands – 2nd Series

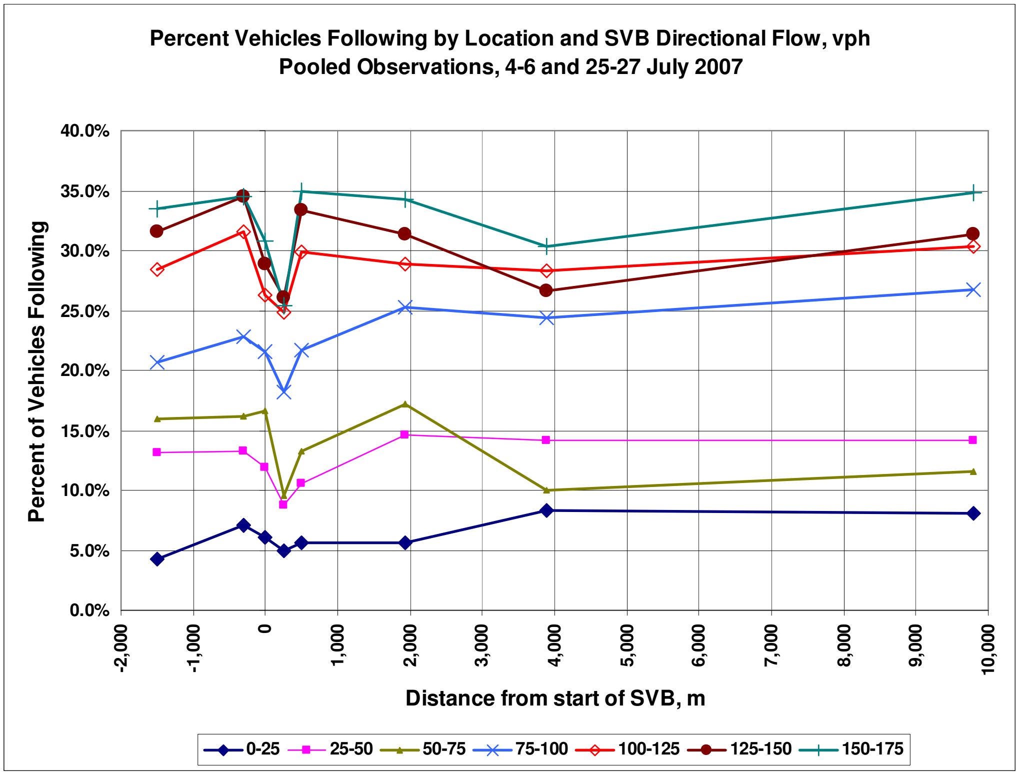


Figure 10 – Percentage Following Vehicles for Directional Flow Bands – Pooled Data

With a few exceptions, the same pattern repeats over each of the flow bands – the percentage following increases on the approach to the SVB over counters 01 and 02 (and as the road climbs up a grade); through the SVB if the two pairs of counters 03/04 and 05/06 are combined there is an apparent reduction in following – which is not directly comparable as it reflects an effective two lane situation; the counter at the end of the SVB (07) shows a slight reduction in % following to the counter immediately before the SVB; there is then a further drop in % following to the next counter (08) which is opposite to what would be expected and then the percentage following starts to rise to counters 09 and 10. Overall the change in vehicles following between counter 02 and 07 is only about 1.5 percentage points, or between 02 and 08 is 4.7 percentages points.

This is similar to the finding cited for Harwood & St John (1985) cited by Koorey and Gu (2001) who found a 2% reduction immediately downstream of a SVB and possibly another 4% in the following 450m. The possible explanation for this is that the overtaking vehicles have not had sufficient time to clear the overtaken vehicles and lie within the 5 seconds used to identify following behaviour in the study by Harwood and St John.

4.6 Change in Vehicle Speeds and Time Savings

It can be assumed that vehicles released from platoons will initially travel at the speed of single (unbunched) vehicles.

A comparison between the speed of single vehicles at counter 04 in the main traffic lane just after the start of the SVB and with the speed of slow vehicles in the SVB shows:

Table 5 – Mean Speeds along the SVB

	after start of SVB	before end of SVB
Single vehicles, counters 04,06 (alongside SVB)	83.8	91.2
All vehicles, counters 03, 04 (SVB users)	53.7	67.6
Difference, km/h	30.1	24.6

The speed of SVB users at the start of bay corresponds fairly closely to the 15%ile speed of all vehicles in the traffic stream at counter 02, just before the SVB. The speed of single vehicles corresponds to about the 57%ile speed.

Both SVB users and single vehicles using the traffic lane increase in speed over the length of the SVB, possibly due to coming over the crest onto a downhill section, and the speed differential between the two drops.

The mean speed of single vehicles at counter 02 (just before the start of the SVB diverge) was 82.2 km/h compared with 72.6 km/h for platoon leaders and 77.1 km/h for the whole traffic stream.

Overall it appears reasonable and possibly a little conservative to calculate the time saving benefits of the SVB from the mean traffic speed and the mean speed of slow vehicles that use the SVB. These mean speeds should be those corresponding to the length of road downstream of the SVB and will be influenced by terrain

4.7 Overtakings

Data has been provided by Opus on the estimated percentage of overtakings accomplished by matching vehicles in the parallel traffic lane against vehicles within ±8 seconds in the SVB and comparing the speed difference between both vehicles. It gives a pattern of overtakings rising with traffic volume up to around 20-25% overtakings at the higher volumes (above 135 veh/h in the treated direction). We have also carried out a similar analysis and obtain similar but slightly lower results.

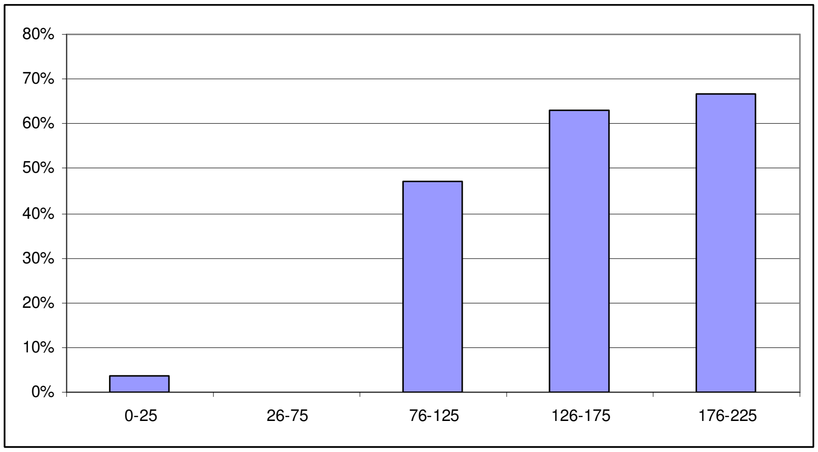
When calibrating the spreadsheet tool, some adjustments were made to the calibration factors to increase the overtakings to levels similar to those observed for a SVB of similar characteristics.

This was done primarily by adjusting the default traffic speeds for all approaching traffic and slow vehicle traffic and by adjusting the factor that reduces the speed of slow vehicles entering the SVB. This was originally set at 1.0 but has been reset to 0.75 to give a greater chance of multiple vehicles completing passing manoeuvres.

4.8 Proportion of SVB Users Using the SVB

Some further analysis has been made of the number of slow vehicle platoon leaders that do not use the SVB and are not overtaking other slow vehicles as a proportion of all slow vehicle platoon leaders. This indicates (**Error! Reference source not found.** below) that around half of these vehicles use the SVB apart from at very low flows, where data is probably unrepresentative.

Again, as part of the calibration process, we have set this parameter at 60% which is above the 45% suggested by Koorey and Gu (2001). This is to allow for some bias towards the vehicles that use the SVB being slower than the general run of slow vehicles. We have not included any volume effect as there is no evidence of any.



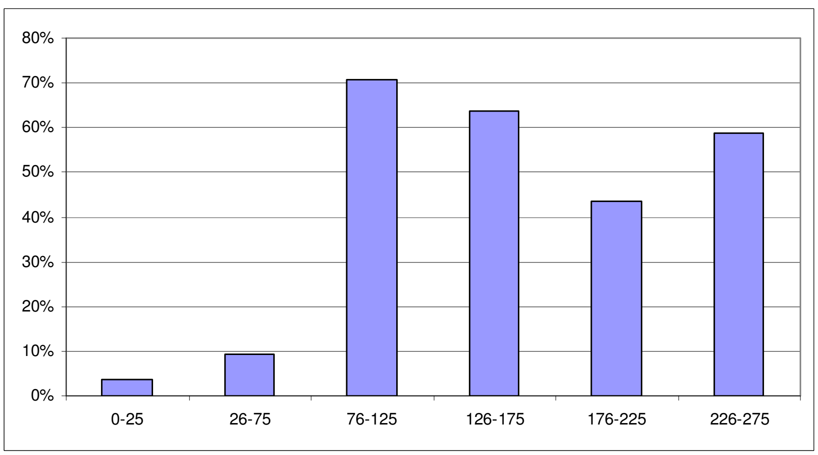


Figure 11 – Proportion of SV Platoon Leaders using the SVB, by Hourly Flow in the Treated Direction, 1st and 2nd Series

4.9 Zone of Influence of the SVB

The FHA(1987) guide provides some research data on the zone of effect of passing lanes down to 400m length. The zone of effect reduces with increasing traffic volume, as the time for released vehicles to catch up platoons further up the road reduces. For 400 veh/h in the treated direction and a 400m passing lane, the zone of influence is about 6 km and for 700 veh/h in the treated direction this reduces to about 3 km (small effects continue beyond this but at a very low level).

Koorey and Gu (2001) give an example for SVBs across the Kaimai range. In this case, counters at intervals of 3 to 5 km downstream of the SVB failed to detect any influence (in fact bunching was higher than the starting condition prior to the SVB) with the inference that all the platoon release effect had dissipated before the counter about 3 km downstream. This finding also appeared to be independent of directional traffic flow of up to 400/hour.

We have also reviewed the simplified simulation analysis carried out for the passing lane charts and graphs in the EEM. This was based upon simulating a light and heavy (slower) vehicle trajectory across about 1/3 of the State highway network, using a three dimensional coordinated road centreline. Results were categorised by length segmented by passing opportunities and the simulation run for a range of traffic flows. The result of this was zone of effect of 8 km at low flow (70- 140 veh/h/dir) tapering to 4 km at 350 veh/h/dir where passing opportunities were very limited (0% with PSD). Where there was passing sight distance for 50% of the road length, the zone of effect was about 5 km and did not vary with traffic volume. Where passing sight distance was high (90%), the zone of effect was near zero up to 140 veh/h/dir then increasing to 10 km at 350 veh/h/dir. This indicated that there is interaction between passing sight distance, terrain and traffic volume that contributes to effective length.

Clearly, if there is uninterrupted sight distance after a SVB, then its length of effect will be small, in the extreme limited to the length of the SVB if passing sight distance is uninterrupted downstream. If there is very restricted sight distance after a SVB then it will be more effective, but with increasing traffic volume the length of the effect will be reduced.

Turning to the data, Figure 10 indicates that the level of bunching had returned to that immediately before the SVB after 10 km. This is only a very rough guide to the effective length for two reasons: (i) it is not a before and after SVB installation situation that is being measured, but the length for the pre-SVB bunching to be re-establised (ii) the passing sight distance downstream of the SVB is not necessarily the same as that leading up to the SVB.

With these provisos, much of the bunching reduction appears to have dissipated by 4 km, and a 6 km length over which bunching is re-established would seem to be a reasonable estimate for this particular example. There is no evident variation in the length of zone of effect across the flow bands for this site and range of traffic flow.

In the absence of substantive data, we have constructed a set of relationships which appear reasonable but must be regarded as placeholders until results based more firmly on field research and/or modelling can be substituted. We would caution that using these relationships as they stand certainly risks inaccuracy.

The basic relationships are established for rolling terrain. For 100% PSD the length of effect of the SVB is limited to a nominal SVB length of 250m, with no variation with traffic volume. For 0% PSD the length of effect of the SVB is varied linearly from 6 km at zero veh/h/dir to 3 km at 500 veh/h/dir. Values for intermediate PSD are interpolated. Values for flat and mountainous terrain are these values factored by 1.5 and 0.5 respectively. This gives effective lengths between 3 and 5 km over the normal range within which SVBs are likely to be implemented, that is 0 to 30% PSD and 50 to 250 veh/h in the direction of treatment.

5 Spreadsheet Tool and Operation

5.1 Software and Layout

A stand-alone spreadsheet tool has been developed to implement the screening procedure. The procedure is implemented in Excel 2003 SP2. An introductory section, data entry, results, calibration data, intermediate calculations are ordered from the top down of the main worksheet. An additional worksheet contains look up tables used in the calculation.

5.2 Introductory Section

This sets out the general scope of the tool and the range limits of operation. It also refers to the MOTSM Guidelines on SVBs.

5.3 Data Entry

The data entry requirements are shown in **Error! Reference source not found.** below. Where the range of data entry is constrained the data validation function in Excel is used for selection of allowed values or else data outside of the range is rejected.

Data Entry - Enter values in the outlined cells

Name and Location of Project.. Sample Project, SH00 RS 23/4.123

	Item	Data Entry	Default Values	Values Used	Advice/Warnings
1	Vertical terrain classification downstream of SVB - flat, rolling, mountainous............	Rolling			
2	Trafficable road width, m............	7.0			
3	Percent Passing Sight Distance (PSD) for approach length (5km)............	20%			
4	Percent Passing Sight Distance (PSD) for downstream length (5km)............	20%			
5	AADT at time zero............	2,000			
6	Traffic growth rate............	2.0%			
7	Percentage of slow vehicles (HCVs + Light Vehicles Towing)............	15%			
8	Do you wish to enter vehicle speeds or use defaults for the terrain class ?............	Enter Speeds			
9	Mean traffic speed at start of SVB, km/h............	85	85	85	
10	Mean speed of slow vehicles at start of SVB , km/h............	50	55	50	
11	Does the road have high volumes of seasonal recreational traffic ?............	Yes			
12	Length of SVB excluding tapers, metres (MOTSAM min 60m, max 300m, data entry limits 50-400m)............	300			
13	Has a separate accident analysis been prepared ?............	No			
14	If yes, enter the discounted crash reduction savings in $............	$ -			
15	Time Zero for Evaluation (1 July of FY of submission for funding)............	2008			can be a future date, usually not more than 1 year
16	Base Date for Costs (1 July of FY in which evaluation is prepared)............	2007			cannot be after today's date
17	Date of Project Cost Estimate (must be at or before Base Year for Costs)............	2005			
18	Project Cost Estimate $............	300,000			cost estimate should include I&R and design if not already completed
19	Additional Maintenance Cost $ per year (at Base Year for Costs)............	3,500			

Figure 12 – Data Entry Requirements

1. Vertical Terrain Classification - Flat, Rolling, Mountainous are accepted
2. Trafficable road width in metres – for estimating capacity (EEM Appendix A3.11)
3. Percentage of approach length with passing sight distance – as a percentage between 0% and 100%, for use in calculation of % time following and % vehicles following (bunching)

4. Percentage of downstream length with passing sight distance – similarly for calculation of effective length downstream of SVB
5. AADT – range between 0 and 5,000 vpd accepted, above 2,000 a warning is given that this is outside Land Transport NZ's/Transit's MOTSAM and Transit's Draft SHGDM
6. Traffic growth rate, % per annum linear rate on the AADT
7. Percentage of slow vehicles in traffic stream
8. Specify or use default vehicle speeds – a switch that selects either user input or default values for the mean speed of the traffic stream and speed of slow vehicles at the start of the SVB; The next two cells provide for user data entry
9. Mean traffic speed at start of slow vehicle bay in km/h, required unless default vehicle speeds used
10. Mean slow vehicle speed at start of slow vehicle bay in km/h, required unless default vehicle speeds used
11. Rural or rural recreational route – determines which hourly traffic flow profile from EEM table A7.2 will be used; the profiles are in fact reduced to three flow periods, peak, daytime and night from the eight periods shown in the table.
12. Length of the SVB metres – 50 to 300m are the minimum and maximum MOTSAM limits, but up to 400m is accepted with a warning
13. Separate accident analysis – provides for crash saving benefits to be input from on external calculation, Yes/No answer required
14. Discounted value of crash savings if Yes to input 14.
15. Time zero for the discounting of costs, which is 1 July of the year in which the project is submitted for funding. This must be the current year or a future year, generally not more than 1 year ahead.
16. Base date for costs, which is the common base date to which benefit estimates and construction costs are adjusted, and is usually the current year.
17. Date of construction cost estimate, which is either the current year (as for 16) or an earlier year, the spreadsheet includes cost updating factors back to 2004.
18. Construction cost, $ in the year in which the estimate was made
19. Additional maintenance cost, $/year

5.4 Results

The results, shown as a table of discounted benefits and discounted costs for the SVB, together with the BCR are located immediately below the input data, and appear as follows in Figure 13

Results

Discounted Benefits	
Travel Time Savings	$ 424,519
Vehicle Operating Cost Saving	$ 42,452
Accident Cost Savings	$ 95,903
Reduced Driver Frustration	$ 77,600
Discounted Benefits	$ 640,473
Discounted Costs	
Implementation	$ 357,000
Maintenance	$ 33,338
Discounted Costs	$ 390,338
B/C Ratio	1.64

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Results

Discounted Benefits	
Travel Time Savings	
Vehicle Operating Cost Savi	
Accident Cost Savings	
Reduced Driver Frustration	
Discounted Benefits	
Discounted Costs	
Implementation	
Maintenance	
Discounted Costs	
B/C Ratio	

Results

Discounted Benefits	
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Maintenance	$ 33,338
Discounted Costs	$ 390,338
B/C Ratio	1.64

Figure 13 – Output Results

5.5 Calibration Data

The next data block (**Error! Reference source not found.**) contains calibration data for the procedure that should not be changed by the user. This and subsequent data blocks are hidden in the working version of the spreadsheet.

Calibration Data

U	**60%**	percent of platoon leaders user the SVB
Gt, s	**1**	clear time gap behind first, and ahead of last, passed vehicle
Ls, m	**12**	mean length of slow vehicle
St, s	**2**	time separation of passed vehicles
Lp, m	**6**	length of passing vehicle
Fvr, km/h	**0.75**	speed reduction factor for vehicles using SVB

Value of time	**23.25**	$/vehicle/hour, rural strategic,2002
Value of frustration benefits	**0.035**	$/vehicle-km of released platooning, 2002
Crash rate reduction from SVB	**11.1%**	of normal reported crash rate
Cost per reported injury crash	**555,000**	$/reported injury crash, 2006

VOC savings	**10%**	as percentage increment on travel time savings

Figure 14 – Calibration Data

- U - The percentage of platoon leaders that use the SVB – from research results discussed in the text, applied as a factor on the benefits if all platoon leaders used the SVB
- G_t – the time gap behind the first and ahead of the last passed vehicle for calculating overtaking time and distance requirements
- L_s – typical length of a slow vehicle, metres
- S_t – time separation between passing vehicles, or passed vehicles, if more than one vehicle can be passed in the SVB, for calculating overtaking time and length
- L_p – length of the passing vehicle
- F_{vr} – speed reduction factor for platoon leaders using the SVB; set to 0.75 (assumes SVB users reduce their speed on moving onto the SVB, and that they remerge into the main traffic stream without time penalty at the end of the bay)

5.6 Calculation Process

The next blocks are for intermediate calculations and will also be hidden from the user. They are:

- Calculations are run in parallel for the three flow period are columns down the page
- The first block calculates the directional flows and V/C ratio and uses look up tables reproduced from the EEM Tables A4.4a to A4.4c to obtain an estimate of percentage of time spent following, PTD%
- A factor (inserted as 0.85 as a calibration factor) is used to convert from PTD to percentage of vehicles following (bunching)
- The next block uses the Borel-Tanner formula to estimate the distribution of bunch sizes
- The next several blocks estimate, using vehicle speed, length and separation data, the number of vehicles that can overtake 1 vehicle or 2 vehicles in the SVB. In the majority of cases the result will be 1 vehicle only (and if there is insufficient speed differential it is possible that no vehicles would be able to pass)
- Using the percentage of SVB users, the bunch sizes and %bunching are calculated at the end of the SVB; this provides the data on the reduction in platooning for input to the benefit calculations (there is allowance for situations where more than one vehicle uses the SVB at a time and a calculation of how many vehicles could pass this extended block length – this has not been taken any further as other data to incorporate it are not readily available and the effect is anticipated to be minor);
- The last blocks convert the platoon release data into calculations of annual benefits, using the lookup tables on downstream length of influence of the SVB, hours per year annualisation factors, EEM unit parameter values for time, frustration benefits and crash reduction.
- The discounting of costs assumes that all construction costs are at time zero and that the benefit stream and any additional maintenance costs also start at time zero.

5.7 Printout

A print request generates two landscape A4 sheets, the first containing the introduction, range limits and caveats. The second sheet reproduces the data entry and the results block.

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Koorey G F(2002), *Passing Opportunities at Slow Vehicle Bays*, IPENZ Transportation Group Technical Conference, 2002