Passing Bays: a Cost-effective Solution to Reconcile Agricultural Vehicles with Through Traffic on Major Roads?

Catharinus F. Jaarsma[1)], Hielke D. Regnerus[1)], Raoul Beunen[1)]

[1)] Wageningen University, Land Use Planning Chair, Gen. Foulkesweg 13, 6703 BJ Wageningen, The Netherlands, E-mail: Rinus.Jaarsma@wur.nl

Introduction

Although drivers of agricultural vehicles (AVs) mainly use minor rural roads, it is not always possible for them to avoid arterial highways (two-lane roads with one carriageway and forbidden to bicycles and mopeds). These arterial highways are designed for large volumes of through motorized traffic with high speeds. A slow-moving and relatively heavy AV is an "intruder'' here because it creates safety risks and delays for other motorized drivers.

In order to reduce these problems, measures to separate motorized and AV traffic on arterial highways should be considered if re-routing the AVs along minor rural roads is impossible. Several separating measures, such as paved or sealed shoulders (Brannolte 1989; Ogden 1997) or extra (climbing) lanes (TRB 1994) as parallel roads (Wegman 1997), have recently been proposed. However, already in 1965, the US "Highway Capacity Manual" mentioned the passing bay (PB) as a traffic separating measure for AVs. A PB is a third lane that runs over a short distance, directly beside the carriageway and exclusively for AVs. AVs are obliged to use the PB in order to give the vehicles from the platoon the opportunity to pass. At the time of recommendation, general criteria for the application of PBs "cannot be given; each case needs to be analysed separately, because strategic location of the bays is highly important" (HRB 1965: p. 100). Later elaborations of the PB focus on improving the level of service (TRB 1994) and on alternatives for climbing lanes for summer recreational routes (Voyer 1998). Jaarsma *et al.* (2005) investigated the impacts of PBs on delay and passing manoeuvres for the other road users. Their study covers current practice in most European countries, where AVs cannot avoid the use of some arterial highways with considerable traffic volumes and simultaneously cause specific problems there.

The aim of this paper is to present the PB as a small scale alternative for separation of mixed traffic flows and to illustrate its effectiveness in reducing delays and safety risks.

Differences in speed and consequent impacts

Differences in speed and weight on roads with mixed traffic are an important road safety issue. Direct safety risks occur when the faster driver does not decelerate in time for the slower vehicle. Furthermore, the passing process itself is an extra safety risk. When prompt passing is impossible, the experienced delay and the need to stay behind the AV might increase frustration among the faster drivers and cause unsafe behaviour. Therefore, the mix of speed and weight has two interrelated aspects: delay and direct safety risks as well as indirect safety risks, which Figure 1 conceptually presents. Jaarsma *et al.* (2005) studied both aspects to assess the effects of PBs. In their study, they calculated the number of vehicles affected by the trip of the AV, the number of passing manoeuvres, the total delay and the average delay per vehicle involved.

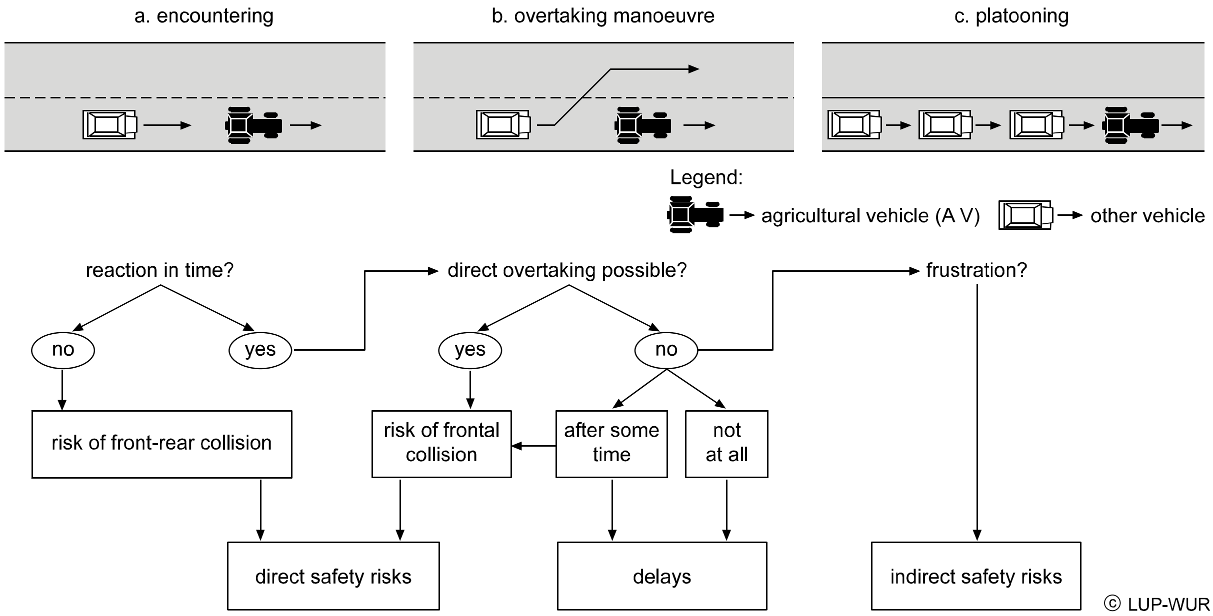

Figure 1. Conceptual framework for the problems caused by a slow moving agricultural vehicle on an arterial highway (Jaarsma *et al.* 2005)

The calculations are based on an analytical macroscopic model, ELOVO, developed by Botma (1988). Using the AV's speed and trip length, the traffic volumes and speeds in both directions, the truck percentage and the availability of passing sight distance, the characteristics of the resulting disturbance of the traffic flow are determined. There is a general relation between the trip length of the AV and the characteristics of the disturbance, if all other input variables are kept equal. The number of affected vehicles, the duration of the disturbance and the maximum length of the platoon depend linearly on trip length. The delay increases quadratic with trip length. It is this property that makes it possible to reduce delay by dividing a trip of an AV into smaller parts, for example, by the construction of PBs.

Passing Bays: design and effects

A PB for AVs is sited directly beside the main road and separated by a narrow verge. Signs order the AV to use it and to give way when leaving it. Figure 2 shows the PB and the necessary traffic signs. Research by the Ministry of Transport, Public Works and Water Management (MTPW 2001) shows that special attention should be given to the design of the

PB entrance. The AV should be able to drive into the PB easily, so that it avoids breaking on the arterial highway. Moreover, the PB should be long enough to reduce speed and provide space for at least two AVs. Jaarsma *et al.* (2005) propose a length of 150 m. In the Netherlands, in actual practice, a length of 100 m is applied (MTPW 2001).

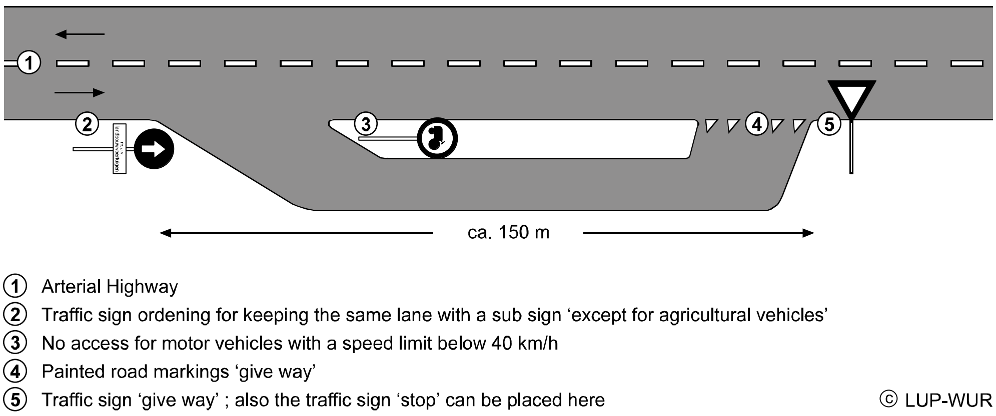

Figure 2. A rough sketch of a passing bay for agricultural vehicles alongside an arterial highway (Jaarsma *et al.* 2005)

Another important aspect of the PB is its location. A location just downstream of a signalized intersection is advisable. This enables the AV to get on the road again more easily if the traffic on the main road must stop for a red light. It is also important to determine where AVs most frequently leave the arterial highway to avoid putting PBs near these places. Communication with local farmers is advised to determine the proper locations for PBs (Jaarsma *et al.* 2005).

In their study, Jaarsma *et al.* (2005) made calculations for two characteristic trips of AVs. First, a trip of 10 km with a speed of 30 km/h is considered. This type of trip is representative of mechanized agriculture and it is consecutively split into two, five and ten equal parts. A second type of trip represents activities such as ground transport with dumpers, with a higher speed (40 km/h) and on somewhat longer distances (16 km). The latter type is split into two, four, eight and 16 parts. Because the general picture for both types is the same, we restrict ourselves to the first type in this paper. We further restrict to arterial highways with a passing sight distance of 50% (i.e. road sections with no-passing zones cover 50% of the trip length).

Figure 3 shows the delay as calculated with the ELOVO model in relation to two-way traffic volumes for the original trip and the trip split by PBs. Figure 3A shows that the total traffic delay caused by one AV under these circumstances will stay below 5 hours for two-way volumes below 600 vehicle/h. Such an amount of time seems disproportional to the expensive measures that need to be implemented to avoid this problem. However, for higher volumes the total delay increases rapidly and the effect of the split becomes significant, even for only one AV. Of course, one should realize that the total delay increases linearly with the number of AVs making a trip of this type.

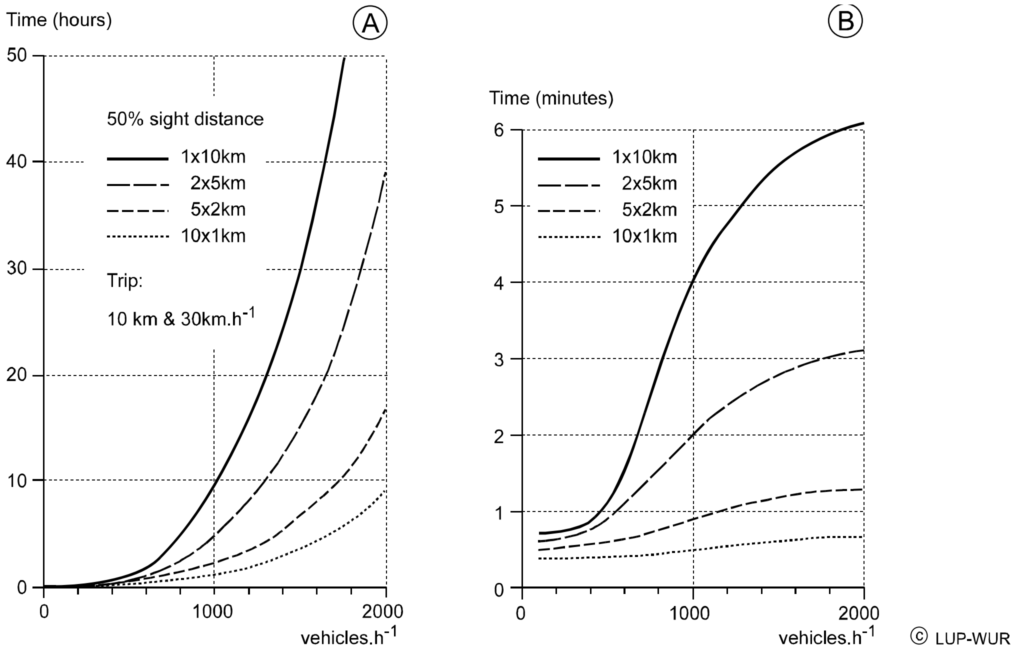

Figure 3. Delay as calculated with the ELOVO model caused by one AV trip in relation to two-way traffic volume for an original trip and a trip split by PBs. A. Total delay (hours). B. Average delay per hindered vehicle (minutes) (Jaarsma *et al.* 2005)

Regarding the number of hindered vehicles (to be used as an indicator for the direct safety risks), the results from Jaarsma *et al.* (2005) show that this number hardly changes when the trip is split. This is expected, however, because the number is determined by the length of the trip of the AV. The trip length is hardly reduced when the split trips use the PB instead of the arterial highway.

Another indicator of the direct safety risks is the number of passing manoeuvres. For 50% passing sight distance, the maximum (53 passing vehicles) is reached at a volume of 600 vehicle/h. In a situation with PBs, fewer passing manoeuvres are made, up to 25 maximum. This is a positive however small contribution to traffic safety.

Jaarsma *et al.* (2005) consider the average delay per drive a better indication for safety risks because the longer drivers have to stay behind the AV, the stronger their wish to pass, and if this is impossible, the greater their frustration. Figure 3B shows the average delay per hindered vehicle related to the hourly two-way traffic volume. Figure 3B is derived by dividing the results from Figure 3A by the calculated numbers of hindered vehicles (not presented in this paper; see Jaarsma *et al.* 2005).

Figure 3B clearly illustrates that the average delay per hindered vehicle is strongly reduced if PBs are applied to divide the trips of the AV into parts. This figure also illustrates the impact of different spacing between the PBs. With a spacing of 5 km, the average delay will exceed 2 minutes when volumes exceed 1000 vehicle/h. A spacing of 2 km allows for an average delay just above 1 minute, even for a high volume of 2000 vehicle/h.

Discussion

Given the computational results of Jaarsma *et al*. (2005) showing that PBs can significantly reduce delays caused by AVs, it is important to know under which circumstances PBs may be considered as an effective solution compared to alternatives.

The choice of a parallel road is a final solution for the mix of speeds and weight on the arterial highway. However, it is an expensive solution which needs a good amount of space. This alternative is only advised for heavily loaded arterial highways (above 2000 vehicle/h) and/or intensive flows of AVs. Instead of parallel roads, alternatives on the regional network of minor roads should be investigated (Jaarsma and Mijnders 2000; Jaarsma *et al*. 2003).

Comparing the PB with high-standard rural roads with an extended road surface (Brannolte 1989) or sealed shoulders (Ogden 1997), a vehicle carrying out a passing manoeuvre must still use the opposing traffic's lane. Therefore, these alternatives will only be effective for low volumes. Furthermore, a wider road profile may run up against objections from a landscape and/or ecological viewpoint.

When a temporary measure is needed to precede long-term plans for a more drastic change in the road network and/or to introduce passing restrictions because of the area’s accident history or because of field observations that indicate an excessive amount of dangerous passing manoeuvres, PBs are an applicable provisional measure.

From their computational results, Jaarsma *et al*. (2005) propose a spacing between PBs of 2 to 4 km. A smaller spacing will give a further (but limited in absolute numbers) reduction of delay and frustration, but at the same time a smaller spacing has the practical objection that AVs have to break their trip too frequently. This also implies that PBs are not a feasible solution in situations where AVs make only short trips on the arterial highway. Research of the MTPW (2001) shows that the driver of the AV realizes the delay being caused for other drivers and therefore accepts the small discomfort experienced in using the PB. This experience again underlines the importance of good communication with local farmers.

Conclusions

Differences in speed and weight on roads with mixed traffic are an important road safety issue. PBs do not change these differences in themselves, but they do positively reduce average delay per hindered vehicle. This, in turn, will reduce the risk of frustration and road rage, especially for more heavily loaded arterial highways, and hence improve road safety.

The PB can be a small-scale, cheap and therefore cost-effective solution, especially in situations where a) two-way volumes exceed 600-800 vehicle/h but are below 2000 vehicle/h, b) AVs make trips with lengths exceeding 2 km, and c) AVs pass more than incidentally, but not very frequently. In such situations the PB may reconcile the use of the arterial highway by both through traffic with belonging speeds and slower moving AVs.

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