

Offtracking of 23m  
HPMVs compared to  
Standard Vehicles

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# INTRODUCTION

When a combination vehicle travels along the road the trailers do not follow exactly in the path of the truck. The offset distance between the path of the axles at the rear of the rear trailer and the path of the steer axle of the truck is called the off-tracking.

There are three main mechanisms which produce off-tracking but they can occur in combination. The three types of off-tracking are called:

- Low speed off-tracking
- High speed steady off-tracking
- High speed transient off-tracking

In the report we will explain the three types of off-tracking and compare the off-tracking performance of 23m HPMVs with that of standard legal maximum sized vehicle for some representative turns.

The analysis shown here has been done using the computer simulation software based on the Yaw-Roll package developed at the University of Michigan Transportation Research Institute. This software has been extensively validated by comparing its results with experimental measurements and we can be confident that the results are reasonably accurate.

# OVERVIEW OF OFF-TRACKING

## Low Speed Off-tracking

When a vehicle travels around a turn at low speed the rear wheels track inboard of the steer axle. For a long combination vehicle the magnitude of this effect can be quite large. Various standard manoeuvres can be used to characterise this effect. Figure 1 shows the results of modelling a 20m long 4-axle truck towing a 4-axle while executing a 90° turn with an outside radius of 12.5m at 5km/h. This is reasonably representative of a left turn out of a t-junction.

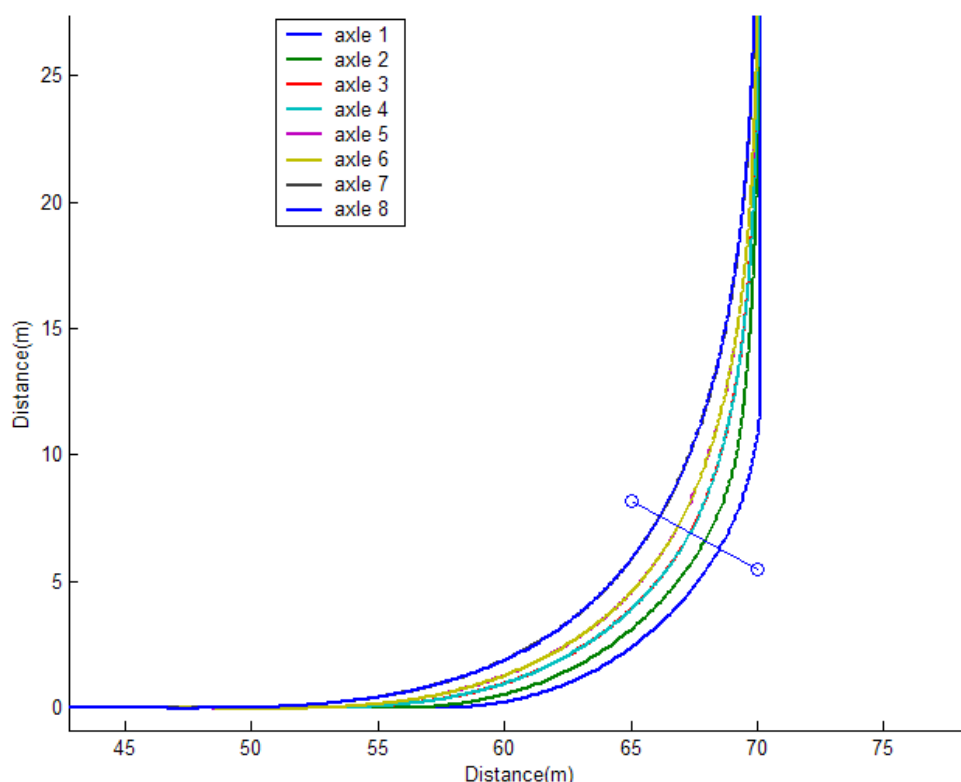


Figure 1. Low speed off-tracking.

The lines show the paths of the centre of each of the axles. The transverse line with the two circles on the end shows the maximum width required and this is the distance between the path of the right front corner of the truck and path of the leftmost wheel on axle 8.

For this vehicle on this turn the maximum width required is 5.63m. This is more than 3m greater than the width of the truck itself (2.5m). The maximum off-tracking, which is the offset between the path of the centre of the steer axle and the centre of axle 8, is 2.69m.

The amount of low speed off-tracking depends on the radius of the turn and the angle turned through. Thus, for example, on a right turn at a small roundabout, the angle turned through will be greater than 90° and the off-tracking will be more. However, as the turn radius increases the off-tracking is less.

The amount of off-tracking also varies with vehicle configuration. Generally more articulation points reduces the off-tracking which is why a truck and trailer off-tracks less than a semi-trailer even though it is longer. The size of the offset between the hitch position and the rear axis of the towing vehicle also affects off-tracking which is one of the reasons truck and trailers off-track less than B-trains.

## High Speed Steady Off-tracking

When travelling on highways at open-road speeds the curves have much larger radii and turn through much smaller angles and so the low speed off-tracking becomes negligible. However, with higher speeds, negotiating curves generates a sideways force on the vehicle. This force is resisted by the tyres and as a result the rear of the truck and the trailer will track outboard of the steer axle. Some types of suspensions will magnify this effect slightly because the body roll of the vehicle will cause the suspension to steer the vehicle outwards a small amount.

The standard manoeuvre that we have used to illustrate this effect is a 393m radius turn which the vehicle is negotiating at 100km/h. This combination of radius and speed produces a sideways force of 0.2g which is typical of the sideways force experienced when negotiating a higher speed curve at the advisory speed.

Figure 2 shows the paths of the axles during this turn and clearly at this scale it is impossible to see the off-tracking effect. However, if we zoom in on a section of this path as shown in Figure 3 we can see that all the axles are tracking outboard of the steer axle. The magnitude of this off-tracking is 0.37m. This means that in the curve the road width required by the vehicle is approximately 2.9m rather than 2.5m.

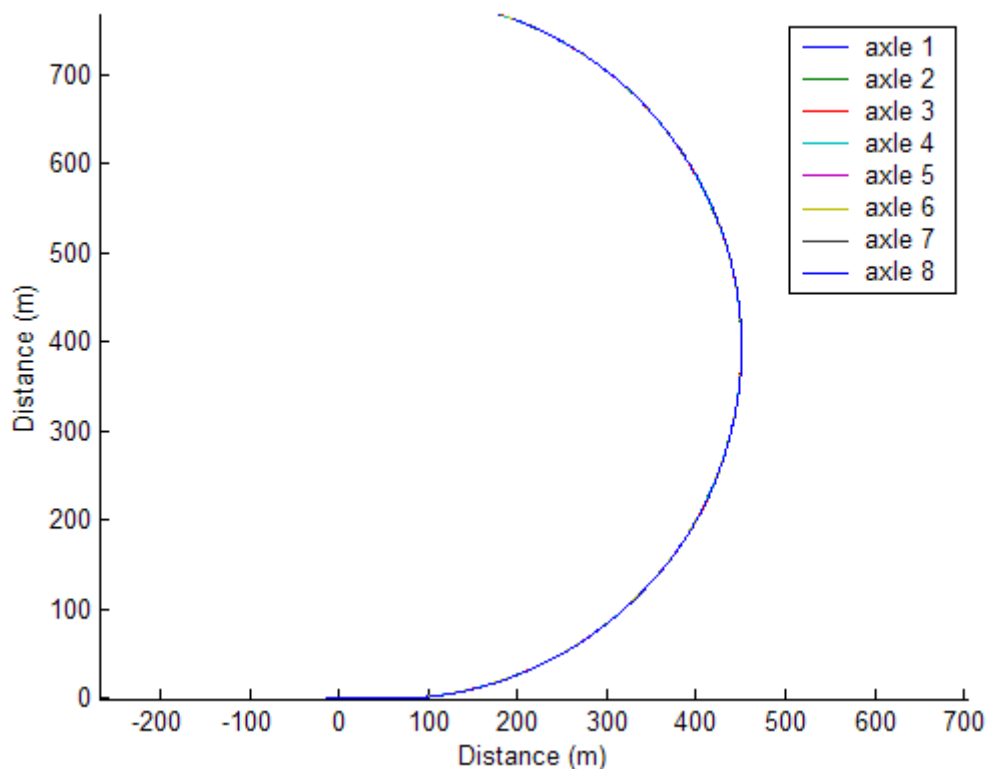


Figure 2. High speed steady off-tracking.

This high speed steady off-tracking effect also occurs on straight roads because of the road camber. A crossfall of 4% results in a sideways force of 0.04g on the truck which is resisted by the tyres. Clearly this sideways force is only 20% of the sideways force experienced in the cornering manoeuvre shown and so the off-tracking will similarly be only about 20% as high but it can combine with other effects.

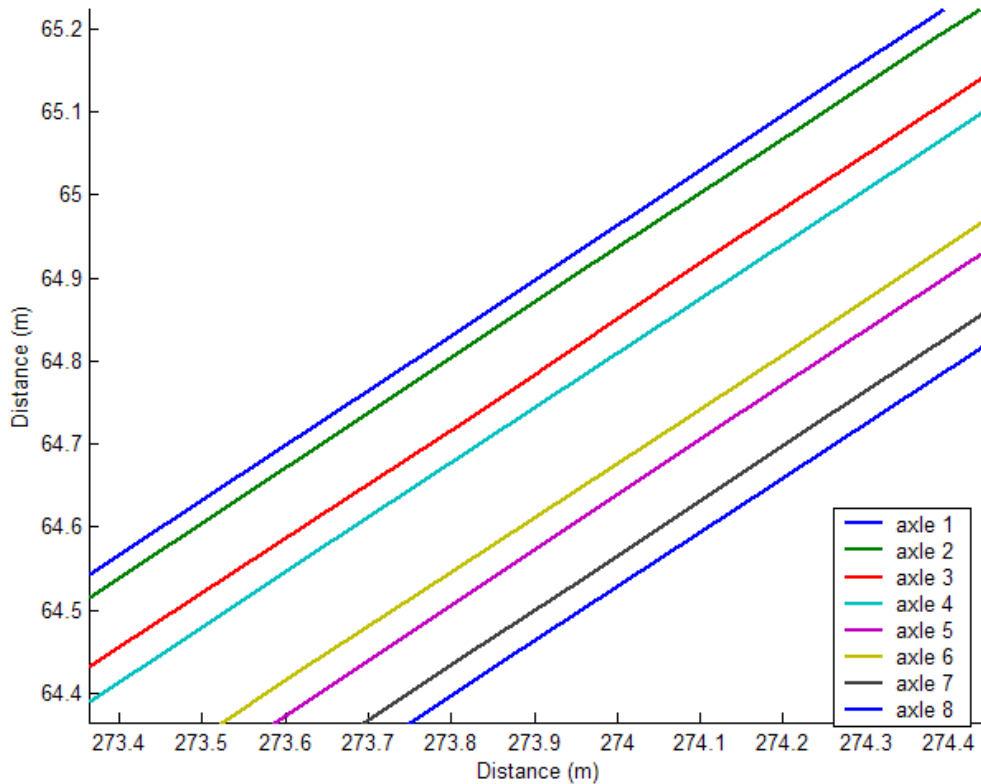


Figure 3. High speed steady off-tracking - close up.

## High Speed Transient Off-tracking

When a truck executes an evasive manoeuvre, for example to avoid a vehicle that has pulled out of a side road, there is a “tail whipping” effect where the trailer experiences higher sideways forces than the truck. As a result of this the path of the trailer will overshoot the path of the truck before eventually coming back into line. The standard manoeuvre that we use to characterise this effect is the SAE lane change. In the manoeuvre the vehicle executes a 1.46m lane change in 2.5s at 88km/h. Figure 4 shows the paths of the axle centres when executing this manoeuvre. The maximum off-tracking is shown and is 0.41m. Note that the x and y axes are no different scales and so the off-tracking as shown is exaggerated.

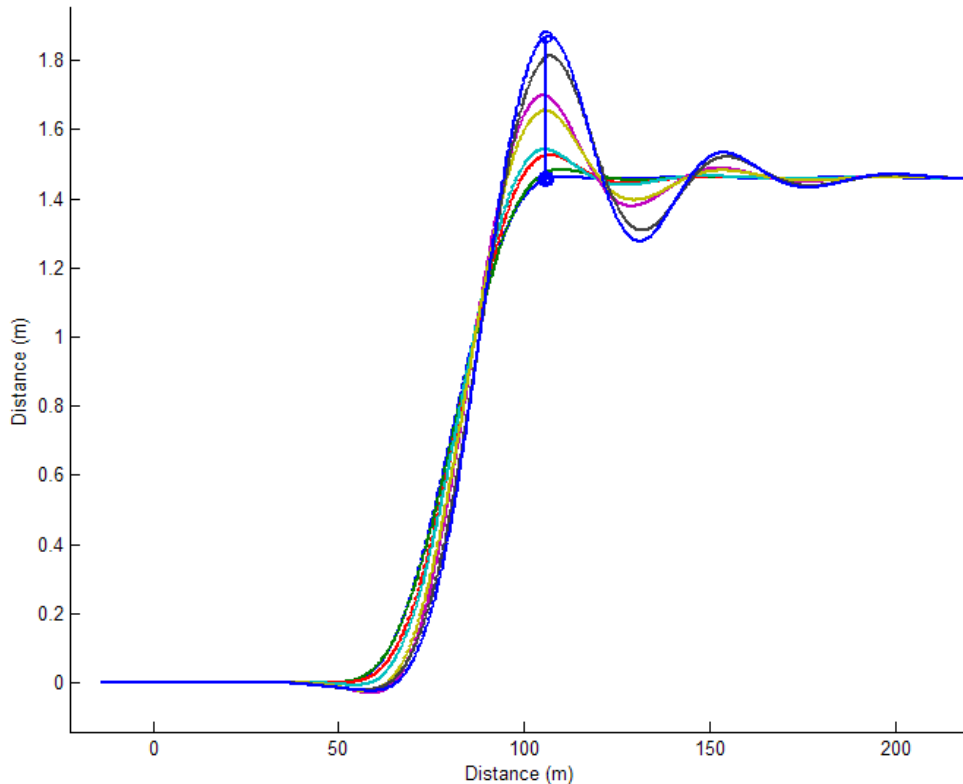


Figure 4. High speed transient off-tracking.

## Combined Effects

The different kinds of off-tracking do in certain circumstances combine. In some cases they cancel each other out resulting in reduced off-tracking while in other cases they add together to make things worse.

As mentioned low speed off-tracking reduces as the curve radius increases and the turn angle reduces. Thus for a 25km/h advisory speed curve, the low speed off-tracking will be less than it is for a 90° turn at an intersection. Also because the speed has increased there will be some high speed steady off-tracking as well which will lower the total off-tracking further. Thus the total off-tracking for highway curves is a combination of low speed off-tracking (resulting from vehicle geometry) and high speed off-tracking (resulting from sideways forces). At low speeds, the high speed off-tracking can be ignored while at high speeds the low speed off-tracking can be ignored. For intermediate speed curves both effects occur. Typically the crossover point is about 60km/h, so that for curves that would normally be negotiated at speeds below 60km/h there will be inboard off-tracking while at higher speeds there will be outboard off-tracking. At the crossover speed the off-tracking will be approximately zero.

Also as noted, the road camber will produce some high speed steady offtracking. If we then superimpose an evasive manoeuvre on top of this the effects will combine. So, for example, if the evasive manoeuvre is made to the right and the vehicle then goes over to the right hand side of the road where the cross-fall also goes to the right, the amount of off-tracking will be increased.

# COMPARISON OF HPMVS WITH STANDARD LENGTH VEHICLES

## Manoeuvres

In this analysis we have been asked to compare the off-tracking performance of HPMVs with that of standard vehicles in real world turning situations. Specifically we were asked to consider a 12.5m radius turn, a 25m radius turn, a 50m radius turn and a 100m radius turn. As already mentioned the off-tracking depends not only on the turn radius but also on the turn angle and the vehicle speed.

For this comparison we have simulated a 90° turn for each radius value. For the 12.5m radius turn we have set the vehicle speed to 5km/h and thus for this turn the sideways force is minimal. For the 25m radius turn we have set the speed to 25.2km/h, for the 50m radius turn we have set it to 36km/h and for the 100m radius turn we have set it to 50km/h. In all three cases, these speeds will result in a lateral acceleration (sideways force) value of about 0.2g.

For this study the turn path as described is the target path for the centre of the steer axle. This is different from some PBS manoeuvres where the target path is sometimes the path of the outside of the outer steer tyre or the outside front corner of the truck.

## Vehicles

Selecting vehicles to compare is quite difficult. Within the standard legal dimensional limits, a wide range of geometric configurations is possible and different applications have different requirements. A truck and trailer used for tipper applications transporting bulk materials like gravel will generally have quite a different geometry from a truck and trailer that is used for linehaul operations with general freight.

In terms of low speed off-tracking, the poorest performing standard vehicle is the 19m quad axle semi-trailer with a single castor steer axle at the rear. This vehicle was used to set the benchmark to which the pro-forma HPMV designs are referenced and so this vehicle is included in this study.

The most widely used combination vehicle in New Zealand is the truck and full trailer. Thus we considered two truck and full trailer configurations. The “standard” vehicle was based on data we had for a milk tanker. This is a 4-axle truck towing a 4-axle full trailer with an overall length of 20m. The spacing from the first-to-last axle was 17.63m. For comparison we used the worst case dimensions for the 23m pro-forma truck and full trailer design using a 4-axle truck and a 5-axle trailer. The worst case dimensions are those that produce the most low speed off-tracking. The first-to-last axle spacing for this vehicle was 20.45m. Thus it meets the requirements of the proposed 50MAX HPMV which requires a minimum spacing of 20m to achieve 50 tonnes GCW.

The final vehicle considered was the 23m B-train 50MAX HPMV. There are several variants of this vehicle but they all have similar off-tracking performance and so we are reporting the results for the 5700mm tractor option only. This vehicle has a first-to-last axle spacing of 20.02m and thus meets the 50MAX requirements for 50 tonne operations.

## Results

With the conventional performance-based standards (PBS) analysis, the off-tracking is determined by the offset between the path of the steer axle and the path of the worst-case rear axle. This worst case axle is not always the rearmost axle as, in some instances, the second-to-last axle produces more off-tracking than the last axle. Nevertheless, comparing the path of the axles in the rearmost axle group with the path of the steer axle allows the off-tracking to be calculated for the conventional low speed and high speed off-tracking manoeuvres. However, in this analysis, the 25m radius, 50m radius and 100m radius manoeuvres all generate a mixture of low speed and high speed off-tracking and the largest offset is not necessarily given by the steer axle and the rear axle group. This is illustrated in Figure 5 which shows the paths of the



axles of the 23m pro-forma truck and trailer during the 100m radius turn. In this case the off-tracking width is not determined by the first steer axle or the rear trailer axle group.

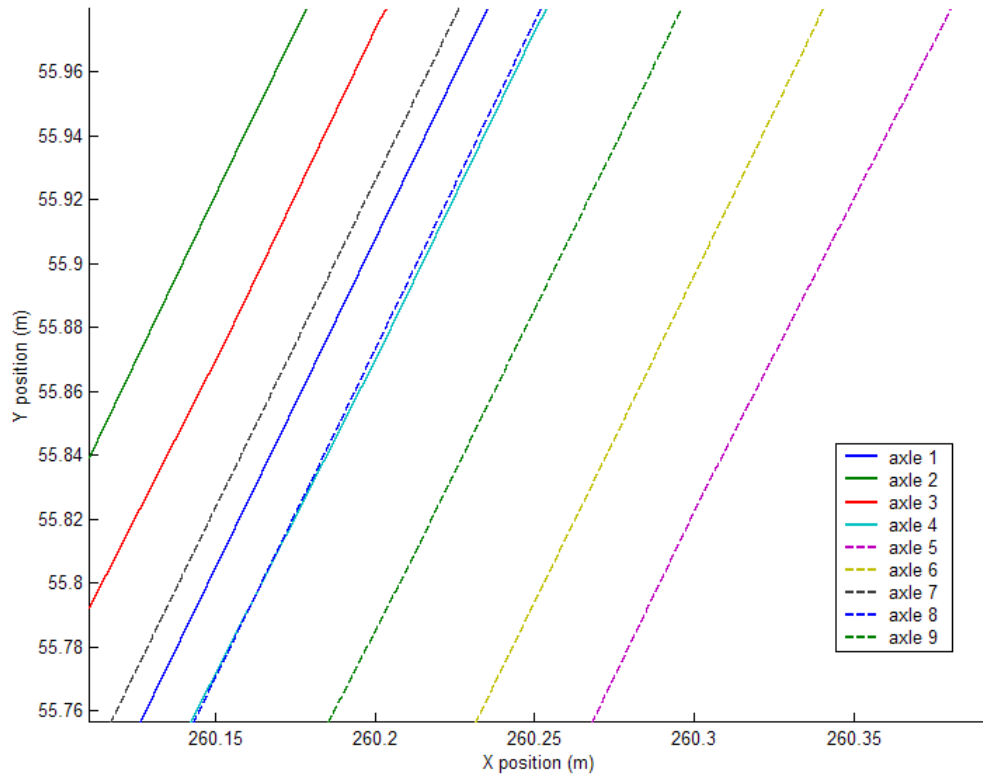


Figure 5. Path of axles of 23m pro-forma truck and trailer during 100m radius turn.

To address this issue we have defined the off-tracking as the maximum offset between the innermost and outermost axle during the specified turn. This quantity essentially represents the additional road width that the vehicle requires during the turn.

The results of simulating the four vehicle configurations through each of the three turning manoeuvres are shown in Table 1. The 23m HPMV truck and trailer has greater low speed off-tracking than the standard 20m truck and full trailer and is slightly better but similar in performance to the quad semi-trailer. The 23m HPMV B-train is slightly worse but also similar to the quad semi-trailer. This is as expected. The quad semi-trailer was used as the reference for low speed turning performance and the worst case pro-forma design was based on being no worse than the reference vehicle. The turning manoeuvre used here is different to that used for the pro-forma design process which is why there are small differences.

Table 1. Off-tracking of the three vehicle configurations for different turning radii.

Vehicle Configuration	Off-tracking (m)			
	12.5m radius	25m radius	50m radius	100m radius
19m quad semitrailer	3.95	1.81	0.74	0.22
20m 4-axle truck and 4-axle trailer	2.90	1.02	0.31	0.16
23m HPMV 50MAX truck and trailer	3.94	1.61	0.56	0.18
23m HPMV 50MAX B-train	4.07	1.51	0.49	0.09

For the higher speed turns, the 50MAX vehicles are better than the quad-axle semi-trailer although slightly worse than the standard truck and trailer. As outlined earlier the off-tracking for these curves is a mixture of high speed and low speed and thus the differences between the vehicles are quite difficult to interpret.

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## CONCLUSIONS

The basic criterion used for the development of the HPMV pro-forma designs was that their low speed turning performance should be no worse than that of the worst case standard legal vehicles. Once this criterion was satisfied the designs were tested to ensure that they performed satisfactorily in all other respects. In the case of the 50MAX design, additional criteria based on infrastructure impacts were also applied.

The analysis undertaken here considers several turning manoeuvres that were not part of the original assessment process. Reassuringly, the performance of the pro-forma design is comparable to that of the reference vehicle in these turning manoeuvres. It is, however, worse than that of standard length truck and full trailer particularly for small radius turns.

This does mean that operators will have to consider the operating environment when deciding whether or not a 50MAX HPMV is a suitable vehicle for a particular freight task. This consideration happens now. B-trains and semi-trailers are not currently used for milk collection from farms because they are difficult to manoeuvre through farm gates on narrow country roads.

It should also be noted that the 50MAX configurations analysed in this report are worst case configurations in terms of low speed turning performance while the reference vehicles are typical vehicles for that configuration. It is possible to configure 50MAX vehicles with considerably better low speed turning performance within the dimensional limits allowed by the pro-forma design specifications.