GEOMETRIC CONSIDERATIONS FOR THE TRACTOR-SEMITRAILER MAKING A 90 DEGREE RIGHT-HAND TURN

J.R. Billing
Automotive Technology and Systems Office
Transportation Technology and Energy Branch
Ontario Ministry of Transportation and Communications
1201 Wilson Avenue,
M3M 1J8
(416)235-5010

March 20, 1987

1/ INTRODUCTION

Critical stability and control characteristics of the tractor-semitrailer are largely determined by trailer wheelbase and overhangs. During low speed turning, the wheelbase determines offtracking of the trailer, hence the space needed to turn around any particular curb. The overhang in front of the trailer kingpin, and the overhang behind the turn centre of the trailer present potential intrusions into the space of other vehicles driving the turn [1,2].

This note summarizes some computations carried out at the request of Mr. J.R. Pearson of RTAC, on behalf of the CCMTA/RTAC Vehicle Weights and Dimensions Study Implementation Committee. The results were obtained by brute force using the MTC low speed vehicle offtracking program, as there is no simple way to compute directly either offtracking or outswing for a 90° right-hand turn.

2/ THE VEHICLES

All vehicles used a tractor with a front axle of overall width 2.286 m (90 in), to the outside of the tires, and a tandem drive axle with 1.524 m (60 in) spread and overall width 2.44 m (96 in). Three tractor wheelbases were used: 3.6, 4.9 and 6.2 m (142, 193 and 244 in). The fifth wheel was assumed to be at the centre of the drive tandem, zero offset.

The trailers used wheelbases of 6.5 to 12.5 m (21.3 to 41.0 ft), with rear overhangs between 0.1 and 0.5 of the wheelbase. The front overhang was always 1.2 m (4 ft). The trailer body width and overall axle width were both 2.59 m (102 in). The trailer tandem axle spread were always 1.524 m (60 in).

The combination of seven trailer wheelbases with five rear overhangs and three tractor wheelbases resulted in 105 separate runs.

3/ THE TURN

The turn was a 90° right-hand turn of 14 m (45.93 ft) radius, with a tangent approach and exit. This was used by MTC to develop the current design standard for the stop condition curb, and is either the same or close to that used in the RTAC turning templates.

The vehicle was positioned so that the outside edge of the tractor's left front tire followed the 14 m radius. This means that on the straight approach to the turn, the outside edge of the trailer's left rear tire, and the body, were 0.152 m (6 in) to the left of the path of the left front tire.

4/ SPACE REQUIRED FOR TURNING

The space envelopes required for turning are illustrated in Figure 1.

The swept path is defined on the left initially by the trailer's left rear wheel, because it's axle is wider than the tractor front axle, and then by the tractor's left front wheel. The swept path is defined at the right by the right rear wheel of the trailer. Offtracking is measured along a normal to the specified path of the tractor's left front wheel, between the path of the centre line of the tractor's front axle and the path of the centre line of the trailer's rear axle.

Outswing of the body to the left of the tractor wheel path is in three phases, shown in Figure 1. There is an initial outswing as the trailer begins to change heading but before it has developed significant offtracking. For a fixed rear overhang dimension, outswing is exaggerated as wheelbase is reduced because the change in trailer heading is proportionately increased, as shown in Figure 2. The outswing is of concern because the left rear of the trailer may not be visible to the truck driver, and if the turn starts with the trailer left wheel on the lane stripe the left rear corner of the trailer can intrude into the space of traffic in the adjacent lane. The height of the left corner of a trailer poses a clear hazard to automobile traffic. As the turn proceeds, trailer offtracking develops and the left rear corner of the trailer moves inside the path of the tractor. The steer angle causes the left front corner of the tractor to protrude beyond the path of the left front wheel of the tractor. At a later time when the tractor has essentially straightened up in the exit lane, residual trailer offtracking leave an articulation angle and the left front corner of the trailer protrudes beyond the path of the left front wheel of the tractor. Neither of these latter two cases occurs until the truck is well into the turn. Since this is quite some time after the driver initiated the turn, it may be presumed the driver would not have started the turn if these protrusions would give rise to any hazard as the driver can see the points on the truck. Alternatively, other traffic would have sufficient time to avoid conflict with the truck. These cases are therefore not considered a serious traffic hazard.

5/ RESULTS

The results for both offtracking and outswing are presented in Table 1.

The offtracking results are shown in Figure 3. They may be summarized approximately for long trailer wheelbases by the relationship.

$$\text{Offtracking} = 0.283\,T + 0.522S - 2.331 \qquad (1)$$

where T = tractor wheelbase (m)
S = semitrailer wheelbase (m)

This relationship is specific to the vehicle and turn used in this analysis. It is similar to one derived by UMTRI during the technical phase of the Weights and Dimensions Study [2]. Since the offtracking of the MTC WB 17.5 Design Vehicle in the same turn is 5.239 m, all vehicles which satisfy the relationship

$$0.283\,T + 0.522\,S \leqslant 7.57$$

have offtracking not in excess of the design vehicle . This may be rewritten as

$$S + 0.54\,T \leqslant 14.5 \qquad (2)$$

For practical purposes the coefficient 0.54 could be replaced by 0.50, so that a performance criterion stating that

"the sum of trailer wheelbase and one half the tractor wheelbase shall not exceed 14.5 m"

should ensure that all vehicles turn no worse than MTC's design vehicle, which is typical of current equipment (S = 11.5 m, T = 5.5 m). Note that the above criterion would limit tractor wheelbase to 4 m with a 12.5 m wheelbase trailer.

The outswing results in Table 1 show that outswing increases with both trailer wheelbase and rear overhang ratio. It decreases modestly with increased tractor wheelbase, because this starts trailer offtracking sooner and reduces its heading angle. The outswing results for 3.6 m tractor wheelbase are presented in Figure 4. Outswing may be summarized by the approximate relationship

$$\text{Outswing} = 0.057\,(r^2 - 0.224r + 0.005)(S^2 - 7.876S + 24)(1-0.042T) \qquad (3)$$

where S and T are as defined above
and r = semitrailer rear overhang/wheelbase, $\geqslant 0.2$
Outswing is zero for $r < 0.2$.

This relationship is again specific to the vehicle and the turn used in this analysis. It was derived in a rough manner, yet gives results for outswing within 0.025 m (1 in) for all entries in Table 1 with $r \geqslant 0.2$.

Figure 4 shows that outswing does not exceed 0.3 m for any wheelbase for a rear overhang ratio less than 0.4, and does not exceed 0.2 m for any wheelbase for a rear overhang ratio less than 0.34.

Trailer overall length is a significant measure of vehicle productivity. Trailer length is given by

$$\text{Length} = S(1 + r) + F \qquad (4)$$

where S and r are as defined above,
and F = semitrailer front overhang (m).
This trailer length relationship is shown in Figure 5 for a front overhang of 1.2 m
Outswing and length limits could be imposed upon Equations 3 and 4, in a similar mananer to that imposed on Equation 1 to generate Equation 2. Equation 2, 3 and 4 could then be evaluated to generate an envelope of acceptable vehicle configurations.

Rear overhang ratio, in practice, is a function of trailer front overhang, and tractor and trailer axle loads, for the critical case of a uniformly distributed load on the trailer. These relationships are presented elsewhere [3].

6/ CONCLUSIONS

This work has examined the trailer dimensional considerations of wheelbase and rear overhang, which affect space requirements for turning, and overall length, which affects productivity, for the tractor-semitrailer vehicle. Relationships have been developed for turning based upon a 90° right-hand turn of 14 m radius at the outside of the tractor left front wheel. The relationships presented should permit development of vehicle dimensional limitations based upon performance criteria.

7/ REFERENCES

[1] Ervin, R.D. and Guy, Y., "The Influence of Weights and Dimensions on the Stability and Control of Heavy Trucks in Canada," CCMTA/RTAC Vehicle Weights and Dimensions Study Technical Report No. 1, RTAC, Ottawa, July 1986.

[2] Ervin, R.D. and Guy, Y., "Axioms Relating Size and Weight Constraints to the Response of Trailers in Combination Trucks," Paper presented at International Symposium on Vehicle Weights and Dimensions, Kelowna, B.C., June 1986.

[3] Billing, J.R., "Dimensional Relationships for Uniformly Loaded Semitrailers," Ontario Ministry of Transportation and Communications, Transportation Technology and Energy Branch, Working Paper, March 23, 1987.

Table 1/ Trailer Outswing and Offtracking

TRACTOR WHEELBASE (m)	TRAILER WHEELBASE (m)	OUTSWING (m) FOR TRAILER REAR OVERHANG RATIO					OFFTRACKING (m)
		0.1	0.2	0.3	0.4	0.5	
3.6	6.5	0.000	0.004	0.017	0.050	0.104	2.218
	7.5	0.000	0.006	0.028	0.073	0.149	2.667
	8.5	0.001	0.009	0.039	0.102	0.209	3.145
	9.5	0.001	0.012	0.050	0.137	0.277	3.647
	10.5	0.001	0.017	0.069	0.179	0.360	4.168
	11.5	0.001	0.022	0.087	0.227	0.456	4.705
	12.5	0.002	0.027	0.111	0.282	0.565	5.256
4.9	6.5	0.000	0.003	0.015	0.043	0.090	2.617
	7.5	0.000	0.005	0.023	0.061	0.132	3.052
	8.5	0.000	0.008	0.033	0.090	0.187	3.514
	9.5	0.001	0.010	0.045	0.121	0.251	4.000
	10.5	0.001	0.014	0.060	0.156	0.328	4.505
	11.5	0.001	0.018	0.076	0.206	0.420	5.027
	12.5	0.001	0.023	0.098	0.255	0.526	5.563
6.2	6.5	0.000	0.003	0.013	0.037	0.080	3.093
	7.5	0.000	0.004	0.019	0.055	0.118	3.512
	8.5	0.000	0.006	0.029	0.080	0.169	3.958
	9.5	0.000	0.009	0.039	0.108	0.229	4.428
	10.5	0.001	0.012	0.053	0.144	0.300	4.919
	11.5	0.001	0.016	0.068	0.186	0.389	5.426
	12.5	0.001	0.020	0.087	0.234	0.492	5.948

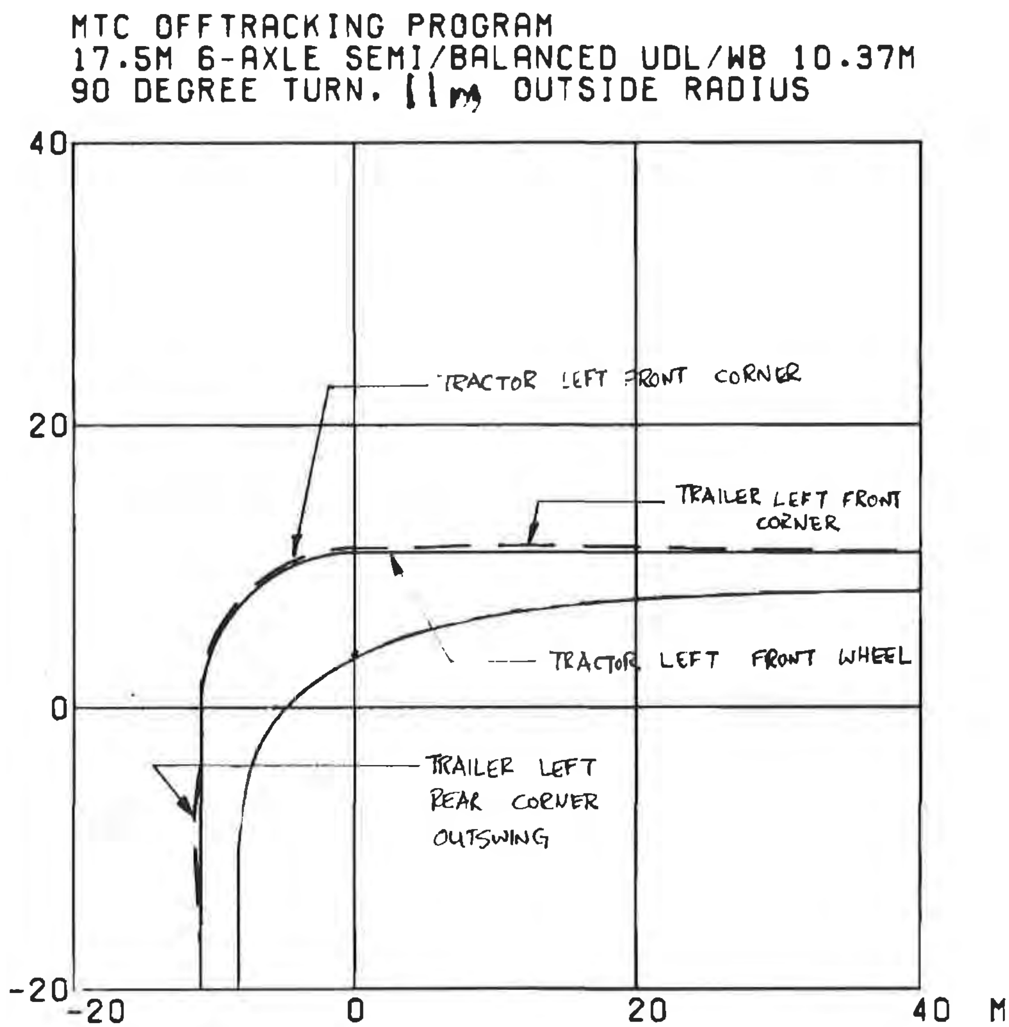

Figure 1/Outswing during 90 degree Right-Hand Turn

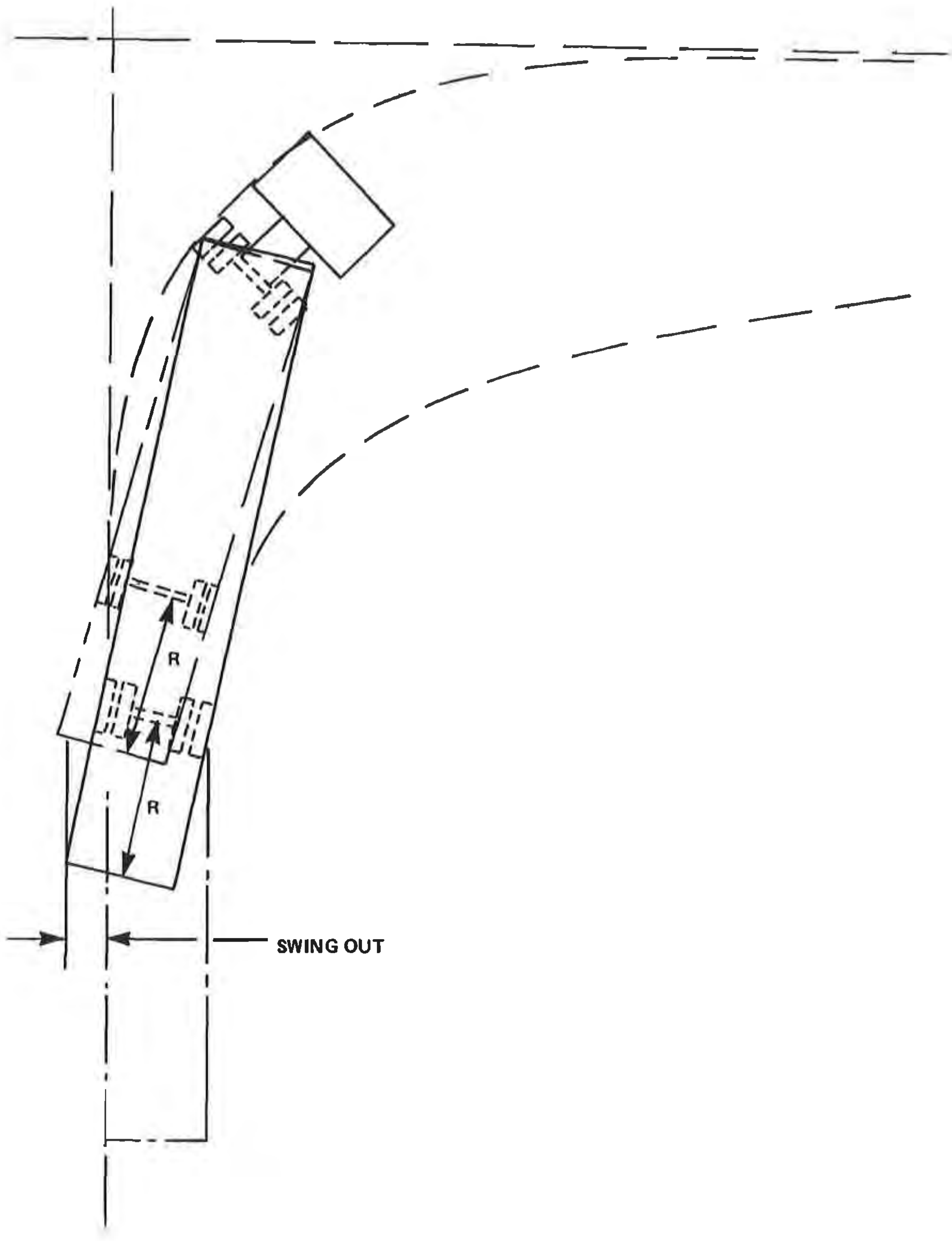

Figure 2/ Effect of Wheelbase on Swingout for Same Rear Overhang

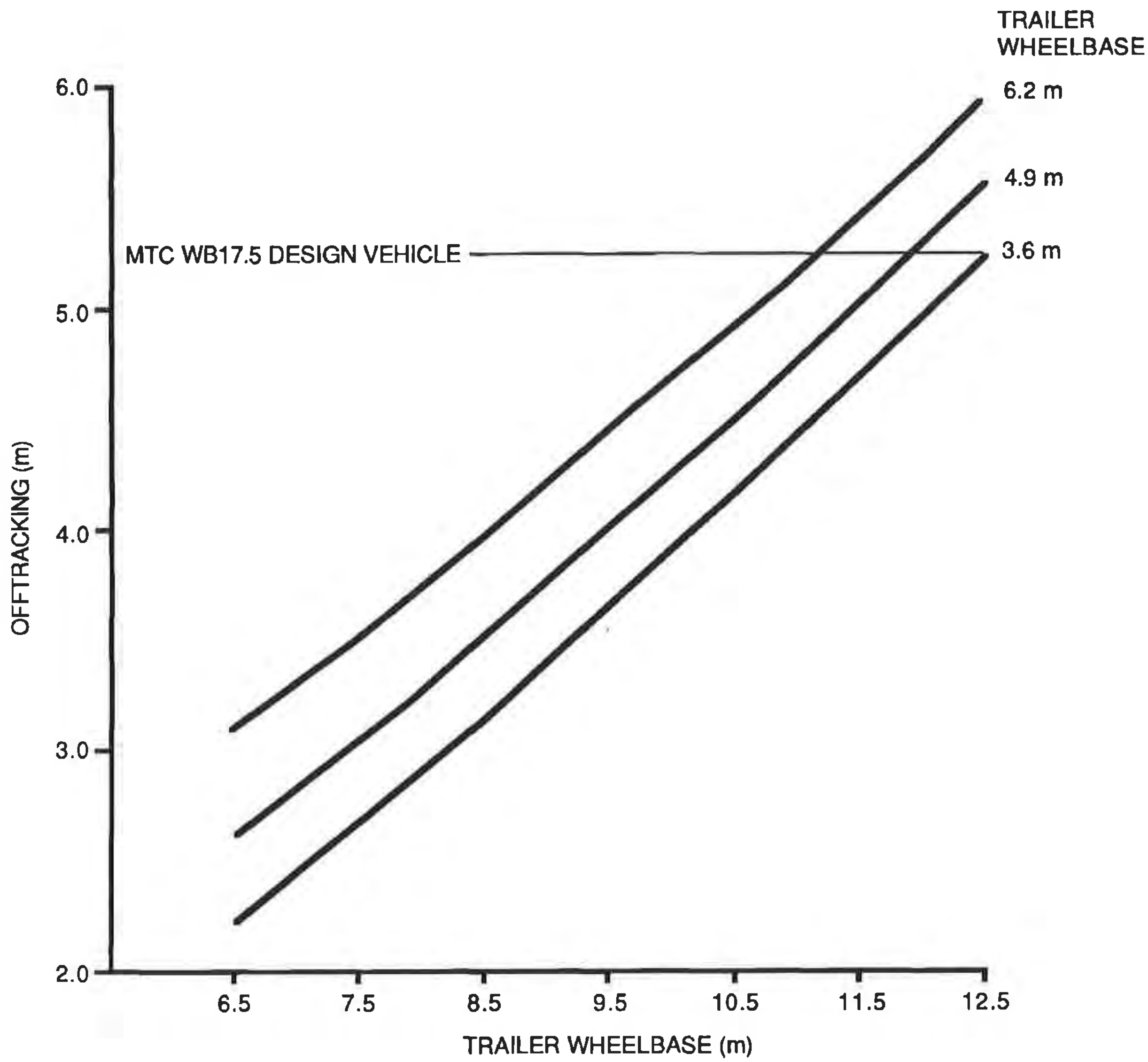

Figure 3/ Offtracking

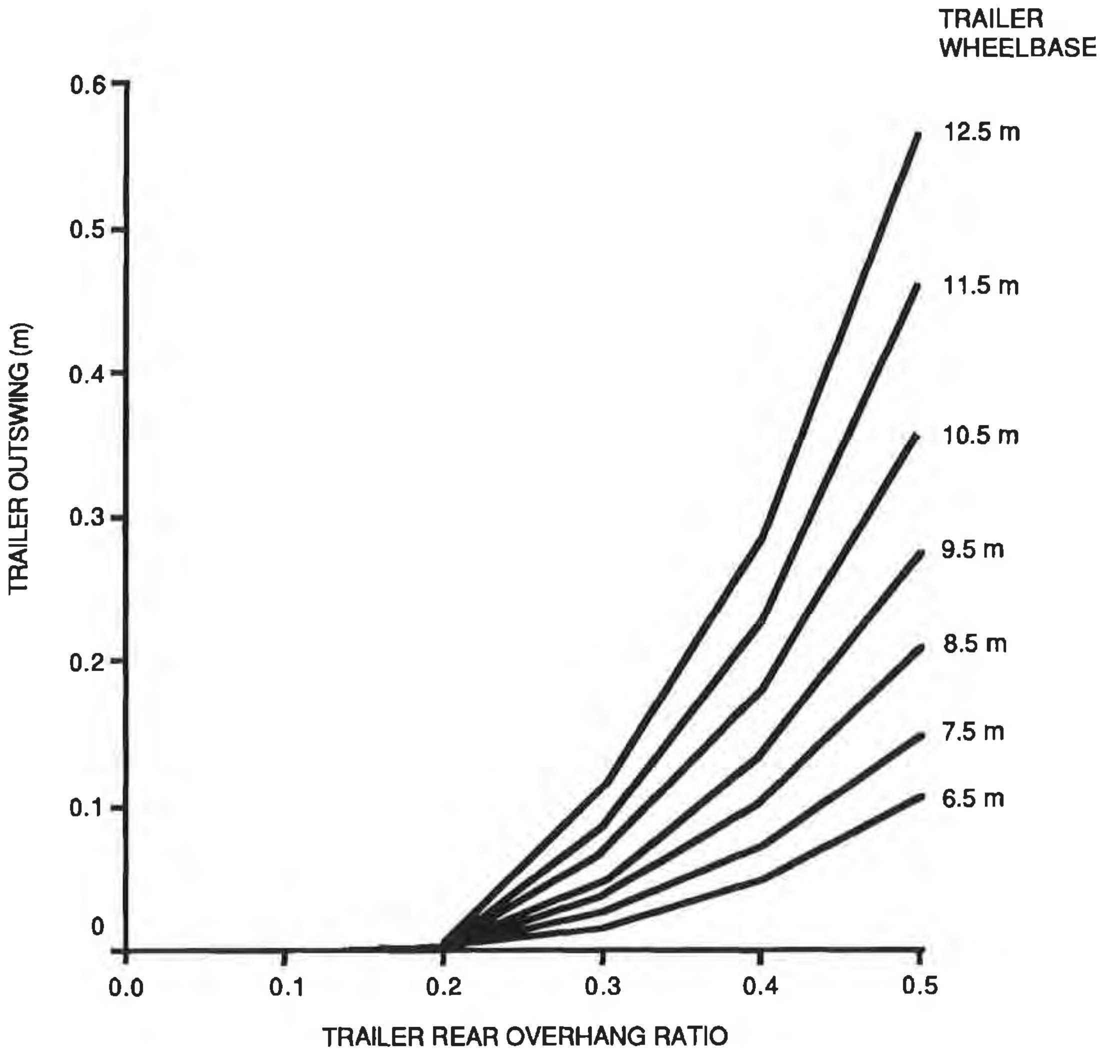

Figure 4/ Trailer Outswing for 3.6 m Wheelbase Tractor

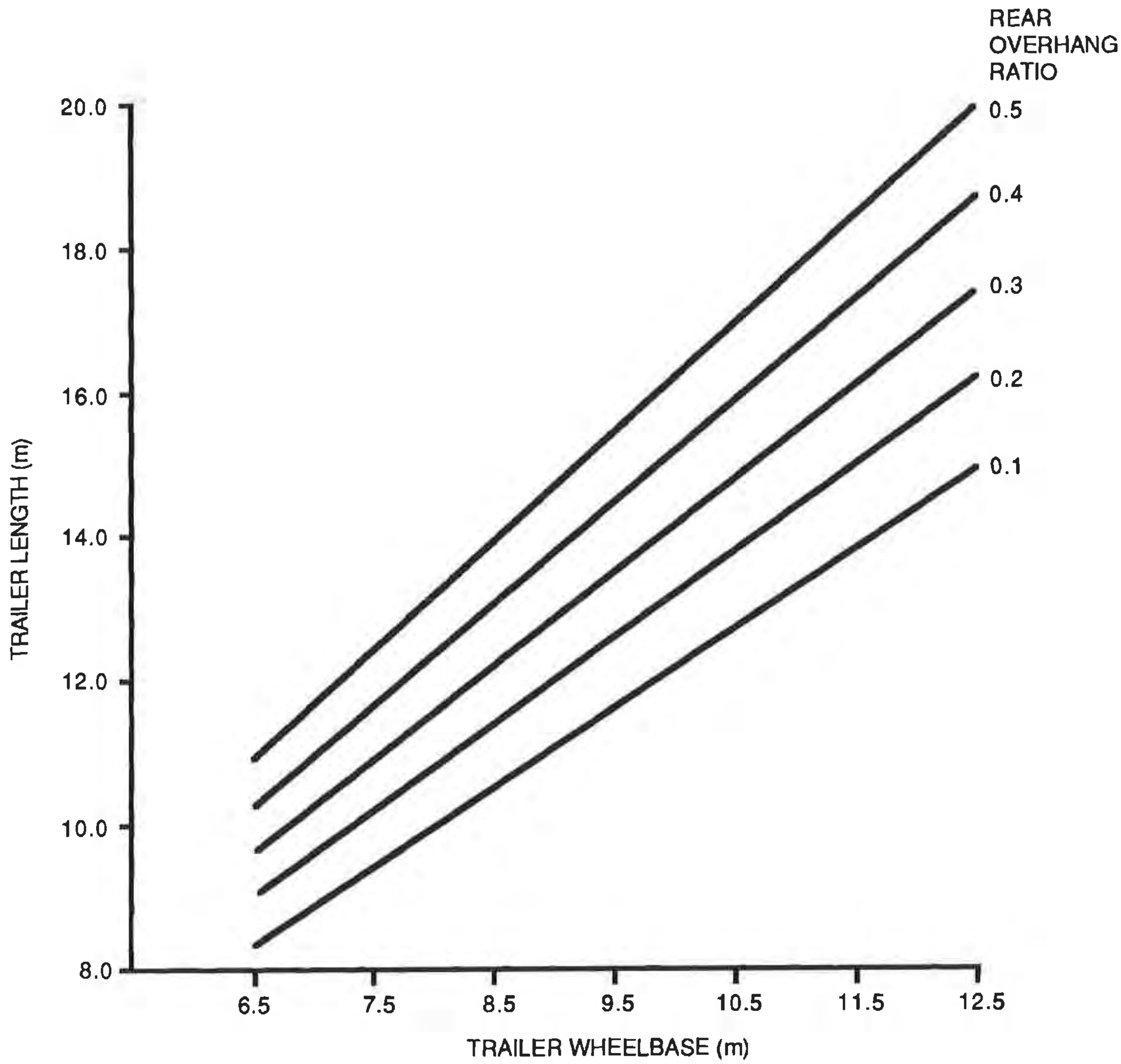

Figure 5/ Trailer Length for 1.2 m Front Overhang