The influence of avoidance manoeuvres on the lateral throw distance in accidents involving pedestrians – the tangential throw

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The "dent offset" and the "lateral throw distance" are fixed reference points commonly used in accident reconstruction. But neither the dent offset nor the lateral throw distance can be determined solely on the basis of the pedestrian's speed of movement. A small series of tests was carried out to investigate more closely the influence of avoidance manoeuvres on the pedestrian's trajectory, i.e. the lateral throw distance.

1 Introduction

When reconstructing an accident involving a pedestrian, the main focus tends to be on capturing the impact velocity. In practice, however, the pedestrian's dynamic movement right up to the moment of the collision has a much greater influence in terms of both time and travel.

When considering whether the accident was avoidable or not, it makes relatively little difference whether the collision velocity was 30 kph or 35 kph, for example. Far more important is the speed at which the pedestrian was moving prior to the impact and what happened to the pedestrian in the actual collision phase. The pedestrian's dynamic movement during the actual collision phase has a significant influence on the dent offset and the lateral throw distance. If the pedestrian stepped into the road from a standstill and was stationary when the collision occurred, the resulting time period is longer than for a pedestrian moving at a constant speed. Based on the time from when the pedestrian steps into the road until the collision occurs, certain conclusions can be drawn regarding the car driver's actions before the collision, such as whether he was travelling too fast or whether he was slow to react. In this context, the warning/signal position also constitutes an important parameter [1].

2 Influencing factors

In [2], important conclusions regarding the dent offset and lateral throw distance were drawn from an extensive series of tests. Up to collision velocities of around 45 kph, information about the dent offset and the lateral throw distance can be an important factor for establishing the pedestrian's movement velocity at the point of impact. In this context, it is an established fact that the lateral throw distance is not an absolute value in relation to the movement velocity, as it depends on the car's front structure, the impact angle of the pedestrian's body, the pedestrian's height and in particular the bonnet length. It is not possible, for example, to establish the exact movement velocity to within 3.0 m/s based on the dent offset and the lateral throw distance – there will always be a tolerance of about 10%. As a rule, trying to narrow down the speed based on witness statements only makes things harder.

If, for instance, a stationary pedestrian is hit centrally by a car travelling straight ahead, there will be no meaningful dent offset and no meaningful lateral throw distance, as demonstrated in the test illustrated in Figure 1. In this crash test, the pedestrian was hit at an unbraked speed of 40 kph while standing side-on to the vehicle.

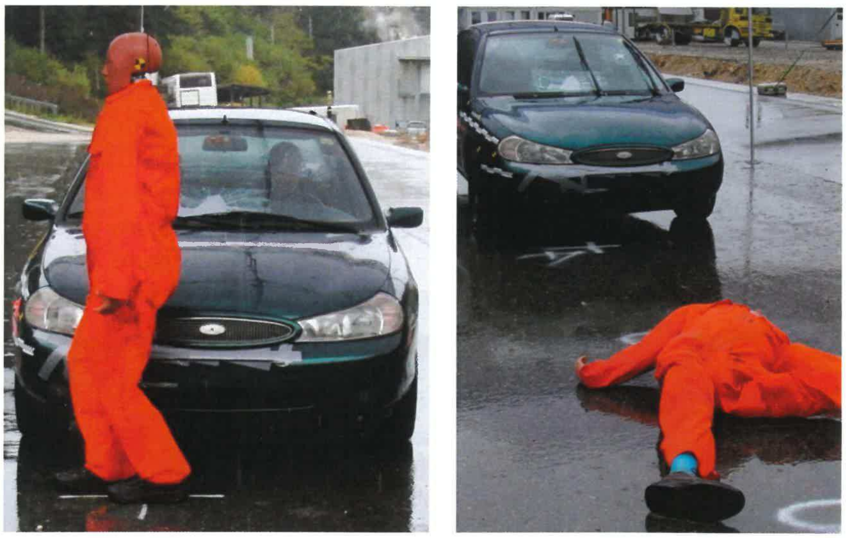

Fig.1 DTC crash test at 40 kph impact and final position

There is practically no lateral throw distance. Test series [2] was conducted in 1995. Since then, car front designs have become more wedge-shaped and vehicles tend to have a flat bumper. Today, if a pedestrian is hit even slightly off centre, but at almost the same speed as in the test in **Figure 1** (used for comparative purposes), a lateral throw distance of about 3 m occurs solely due to the different shape, see **Figure 2**.

If the initial speed is appreciably higher than the collision speed, the driver's actions prior to the collision constitute another factor that could potentially influence the lateral throw distance.

If a pedestrian moves into the road from right to left from the driver's perspective, and if the driver spots them 1.5 s before the collision, then there are at least 0.5 s available for the driver to swerve away from danger – i.e. to the left – instinctively, without a complex thought process. This is exactly what happens in many cases, albeit not always.

3 Practical tests

A small test series was conducted to investigate more closely the influence of an avoidance manoeuvre (normally a sudden swerve) on the pedestrian's trajectory (i.e. the lateral throw distance). In all four tests, the car was unbraked and the pedestrian dummy was hit side on. The car travelled at two different speeds of approximately 25 kph and 35 kph. In two tests, a specific radius was chosen to produce a lateral acceleration of about 2 m/s^2. The other two tests were conducted with a lateral acceleration of approx. 4m/s^2.

This relatively small lateral acceleration range was chosen because the time that elapses between end of reaction and collision does not normally exceed 0.5 - 1 s. This means that during the phase leading up to the actual collision, the lateral acceleration also has to build up first. Only in the rarest of cases will the lateral acceleration limit be reached by the time the collision occurs.

Figure 3 and **Figure 4** show two of these tests. The first one was conducted with a lateral acceleration of about 2 m/s^2.

Fig.2 CTS crash test at 37 kph impact and final position

Fig.3 CTS crash test at 32 kph impact and final position

There is almost no dent offset on the vehicle. The lateral acceleration during the second test was 4 m/s^2. Despite the car's slightly slower speed, the dent offset on this car is clearly visible. In **Figure 5**, both vehicle fronts are shown side by side to demonstrate the difference in dent offset. Their final positions in relation to the impact location and the radii in which the cars travelled are shown in **Figure 6** for a lateral acceleration of 4 m/s^2 and in **Figure 7** for a lateral acceleration of 2 m/s^2. The test conducted at the higher collision velocity produces a lateral throw distance of about 2 m. A clear dent offset is also evident.

However, in this test the dummy was stationary at the point of impact. The test that was carried out at low speed but with high lateral acceleration only produced a minimal lateral throw distance but a very large dent offset. The dummy was also stationary in this test.

In the test with the lower lateral acceleration, this relationship is reversed. At the slower speed of

32 kph, the lateral throw distance is 2.25 m. However, the dent offset is effectively zero. At the higher speed, there is only a small dent offset.

Once again, the dummy was stationary during these tests.

These tests demonstrate that the car's lateral acceleration at the point of impact affects both the dent offset and the lateral throw distance.

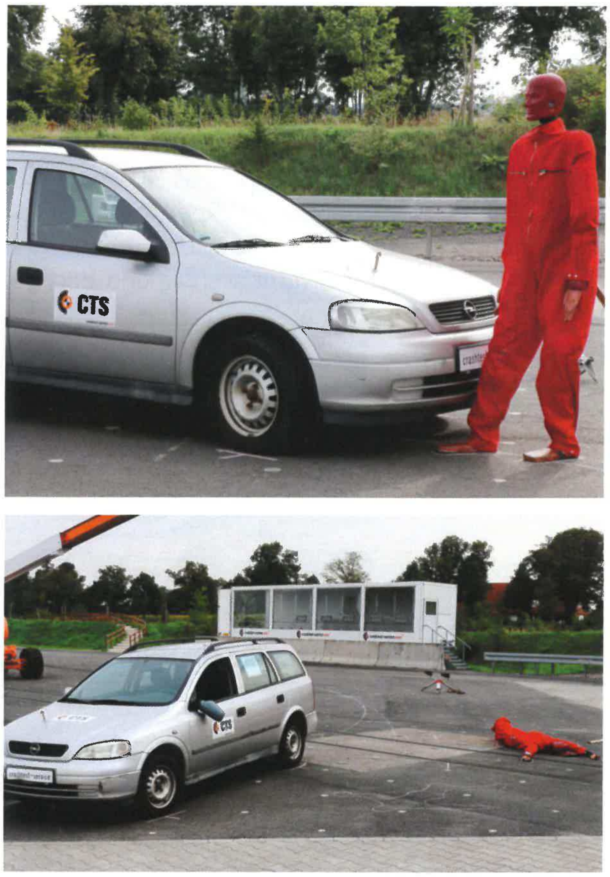

Fig.4 CTS crash test at 28 kph impact and final position

The following example illustrates the above problem. If the accident location is known from the accident report, for instance from clear shoe abrasion marks, and if the pedestrian's final position (see **Figure 8**) is also known, but if there is no information on the car's final position immediately after the impact and there are no abrasion marks left by the car, normally a basic scenario based on the above situation (such as in **Figure 9** or **Figure 10** on page 40) will be used, taking into account the physical point of impact with the car. This inevitably implies that the pedestrian is moving at a significant velocity at the point of impact. The test described in **Figure 2** has already shown that certain car shapes can cause high lateral throw distances even if the pedestrian is stationary (see **Figure 10**). The scenario depicted in **Figure 11** on page 40 shows the impact of the driver swerving to try and avoid a collision.

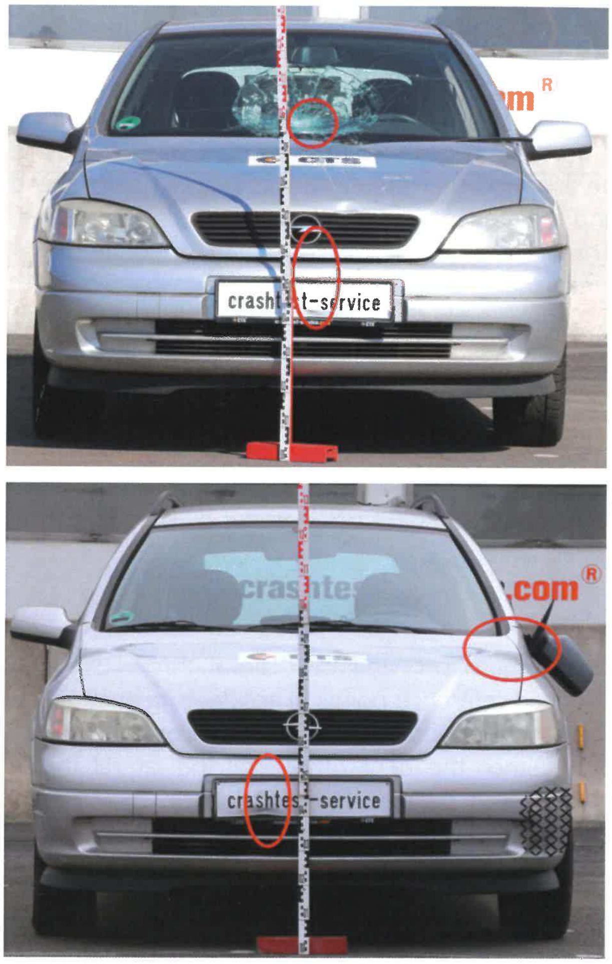

Fig.5 CTS crash test: comparison of the dent offset between Figures 3 and 4

In this case, the pedestrian was stationary at the point of impact.

The final step involved verifying the test results using a computer simulation, as shown in **Figure 12** on page 41.

The influence of the different scenarios becomes clear when carrying out a detailed accident investigation from an avoidability perspective. **Figure 13** (page 41) shows the correlation between travel and time for an accident in which a pedestrian moving at the relatively fast speed of 8 kph was hit while crossing the path of a car travelling parallel to the carriageway. Due to the speed at which the pedestrian was travelling across the car's direction of travel, the impact causes the pedestrian to be thrown onto the opposite carriageway. In this scenario, the signal position occurs 1 s before the collision as the pedestrian steps into the road. The available time of 1 s is too short for the car driver to initiate an effective avoidance manoeuvre.

In the case of a tangential throw, the scenario depicted in **Figure 14** on page 42 is also feasible. The stationary pedestrian (for example a pedestrian under the influence of alcohol) is hit as the car carries out a strong avoidance manoeuvre and, as a result, the direction of the pedestrian's trajectory is not caused by the pedestrian's own speed but by the direction of the car's swerve. It must therefore be assumed that the car driver reacted beforehand and initiated an avoidance manoeuvre to the left. This could imply an excessive initial speed and may mean that the accident could have been avoided if the speed limit (in this example 50 kph) had been observed (see red and green curves).

In conclusion, if the case is reconstructed on the basis of a tangential throw, the accident may have been caused by excessive speed, meaning that the car driver could have prevented it by keeping to the speed limit.

4 Summary

The "dent offset" and the "lateral throw distance" are fixed reference points in accident reconstruction and can be found in every textbook on the subject. But neither the dent offset nor the lateral throw distance can be determined solely on the basis of the pedestrian's speed of movement. For example, if the pedestrian is visible on the carriageway for longer than the time required for the car driver to react, the car driver will often perform an instinctive avoidance manoeuvre. If an avoidance manoeuvre is initiated, the pedestrian is hit obliquely by the car, causing them to be thrown tangentially. In this case, the resulting lateral throw distance is not due to the pedestrian's speed of movement but to the car driver's sudden avoidance manoeuvre. This can significantly alter the avoidability of the accident.

Further research is recommended involving comparable tests using the new biofidelic dummies which provide even more realistic movement behaviour (see [3]). However, since both the vehicle's contours and the contact area at the front of the car also have an influence, it may be helpful to carry out specific crash tests for the reconstruction of particular accidents.

References

[1] Hoger, T.; Schimmelpfennig, K.-H.: "Darstellung von Wampunkt und Signalposition"; Ureko-Spiegel 17 (2015).

[2] Rohm, M.; Schimmelpfennig, K.-H.: "Einfluss der Bewegungsgeschwindigkeiten beim Pkw-Fußgängerunfall"; Verkehrsunfall und Fahrzeugtechnik 5 (1995), pp. 122 - 128.

[3]: Kortmann, A. : "Comparing crash behaviours in crash tests – The new biofidelic dummy", IMPACT Spring 2018 Vol. 26 No. 1

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See Figures 6 -14 on pages 39 - 42

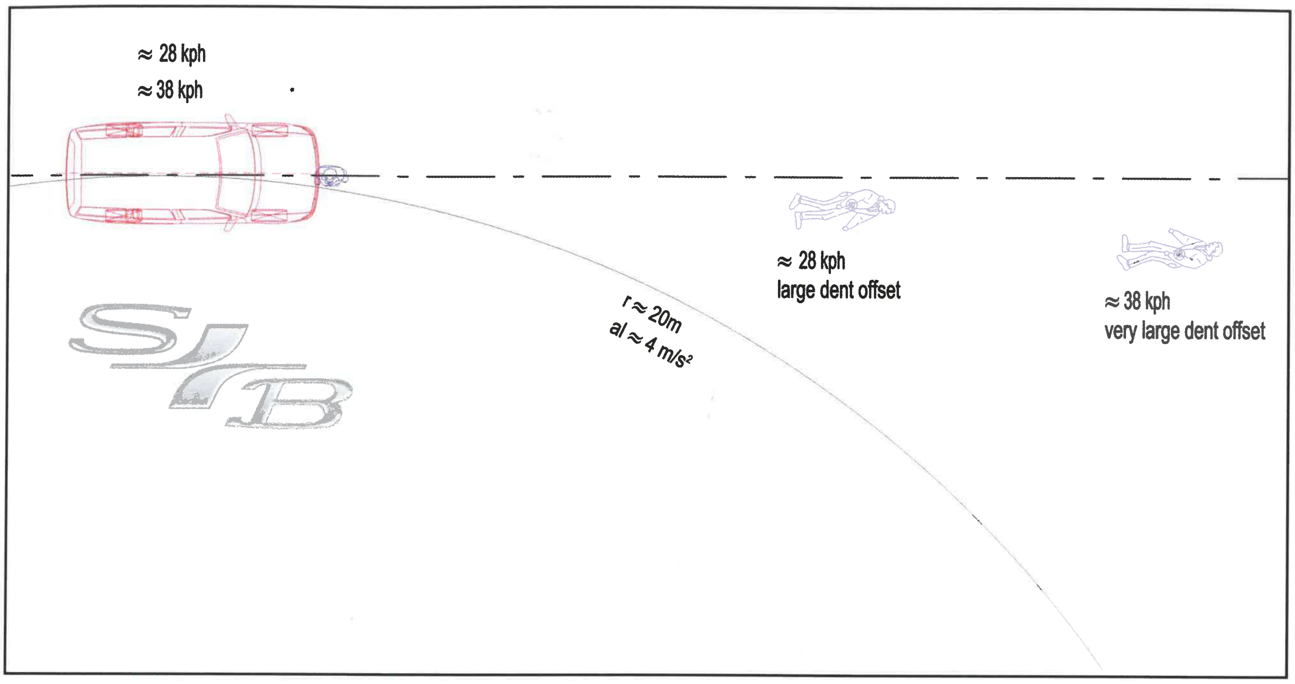

Fig.6 CTS crash test: comparison of lateral throw distances in tests at 4 m/s^2

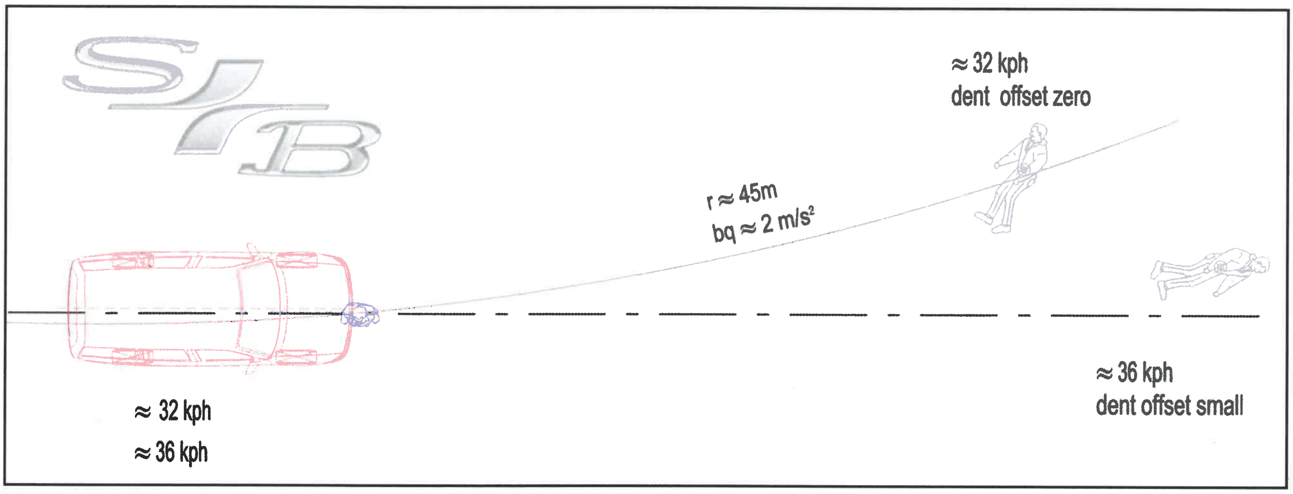

Fig.7 CTS crash test: comparison of lateral throw distances in tests at 2 m/s^2

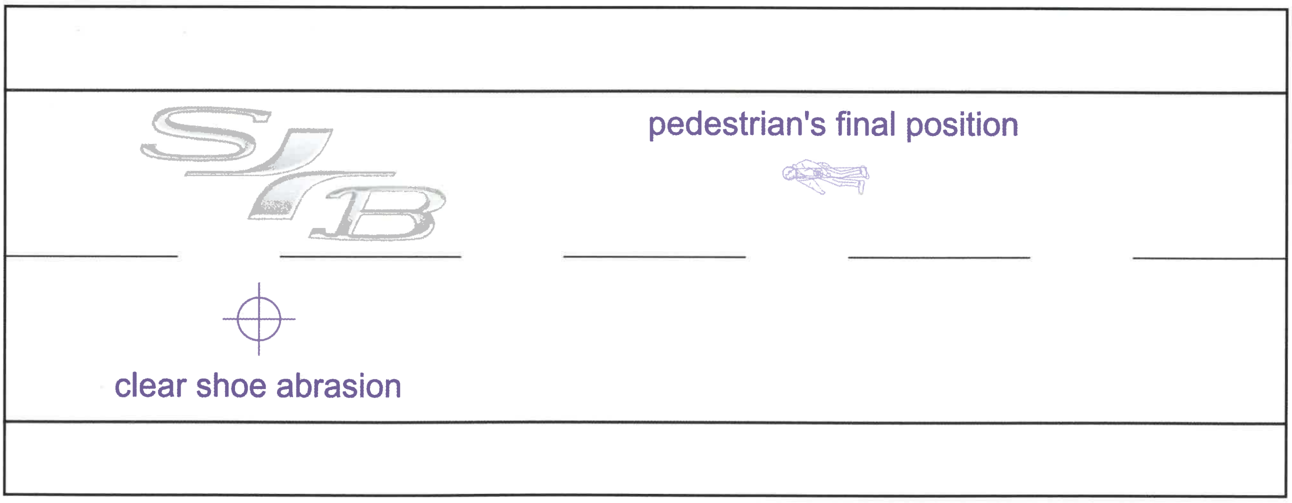

Fig.8

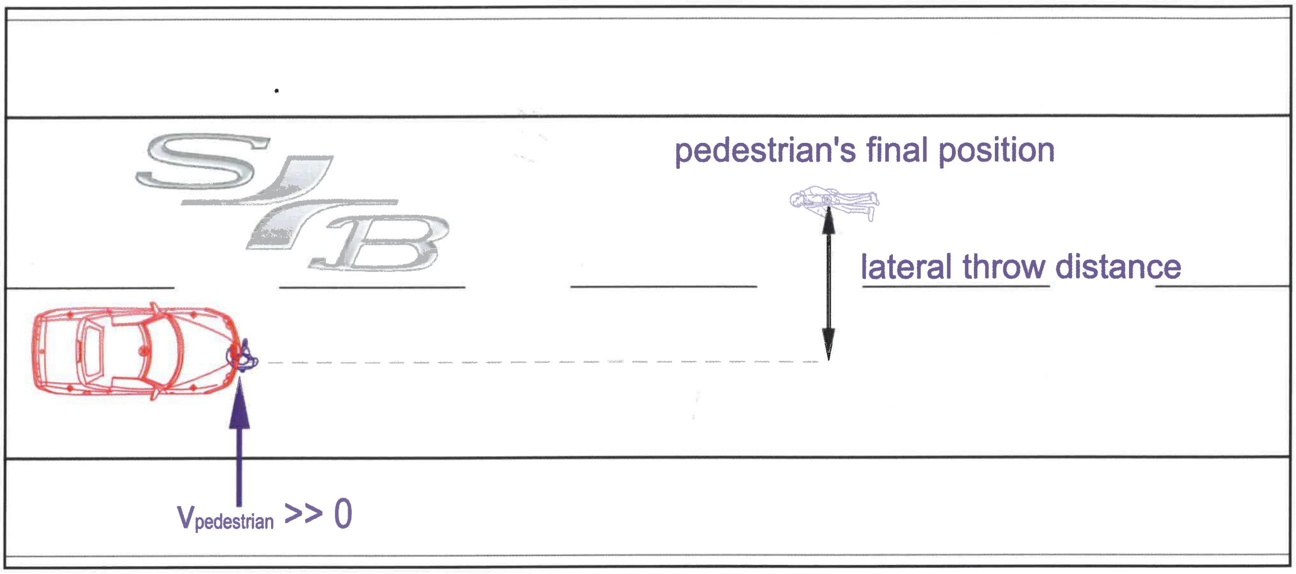

Fig.9

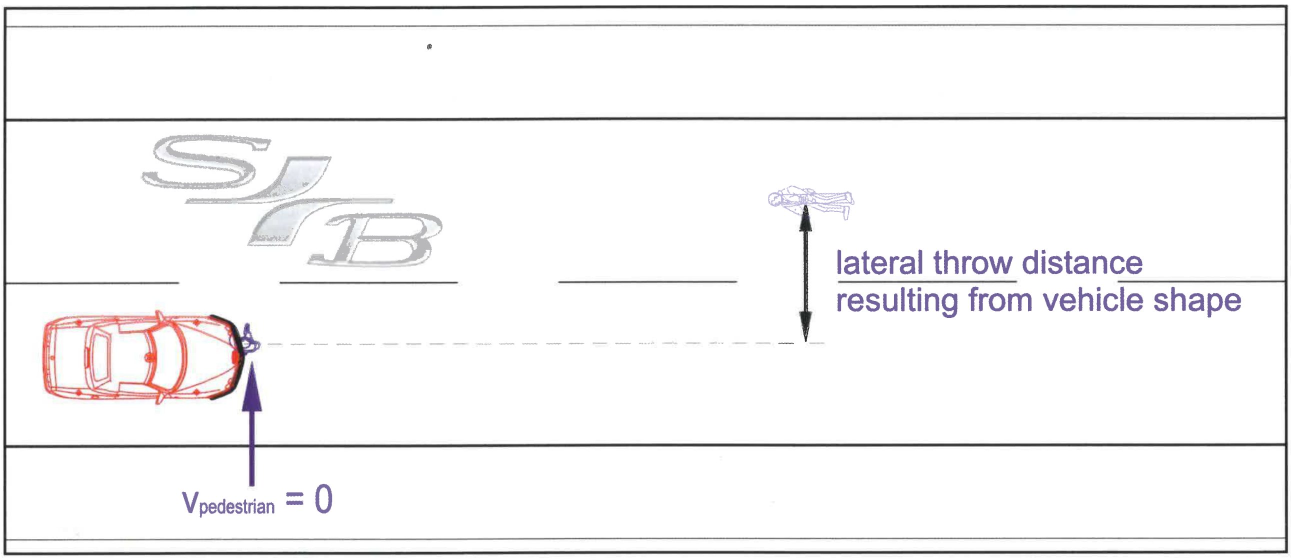

Fig.10

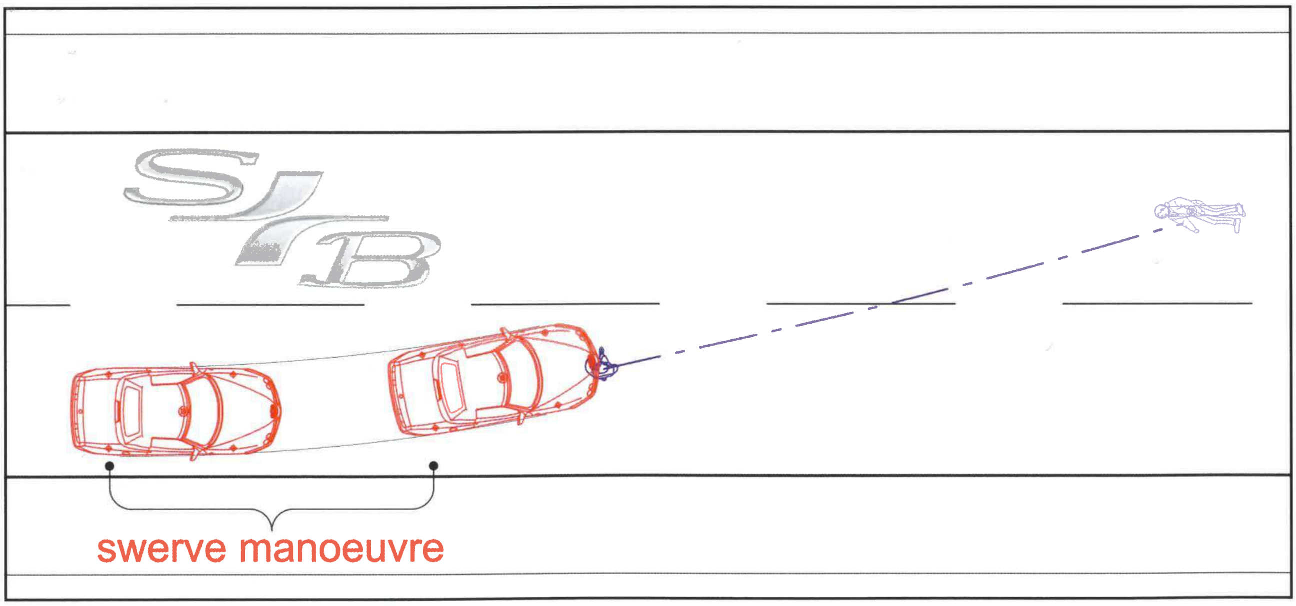

Fig.11 A car performing a strong avoidance manoeuvre hits a pedestrian

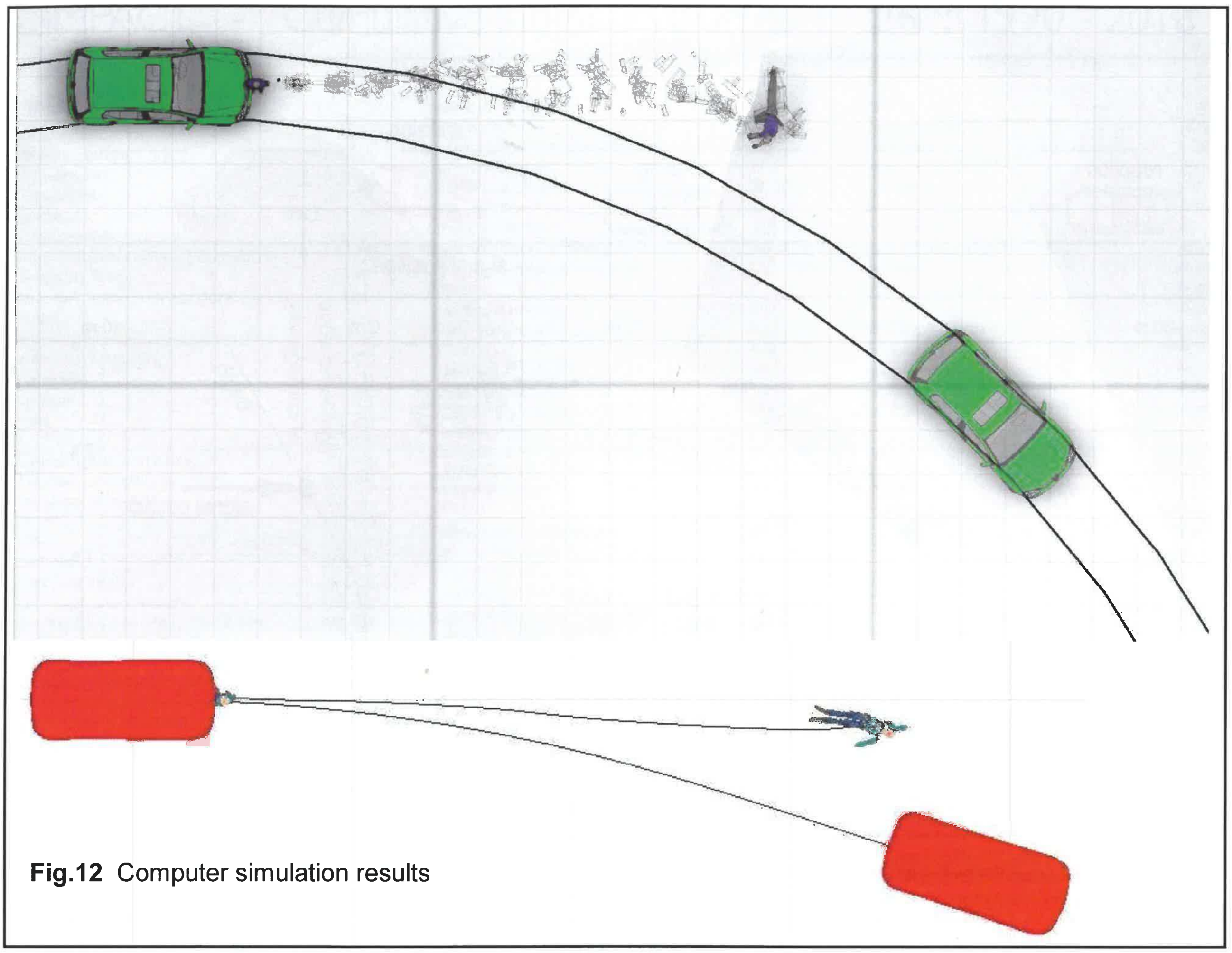

Fig.12 Computer simulation results

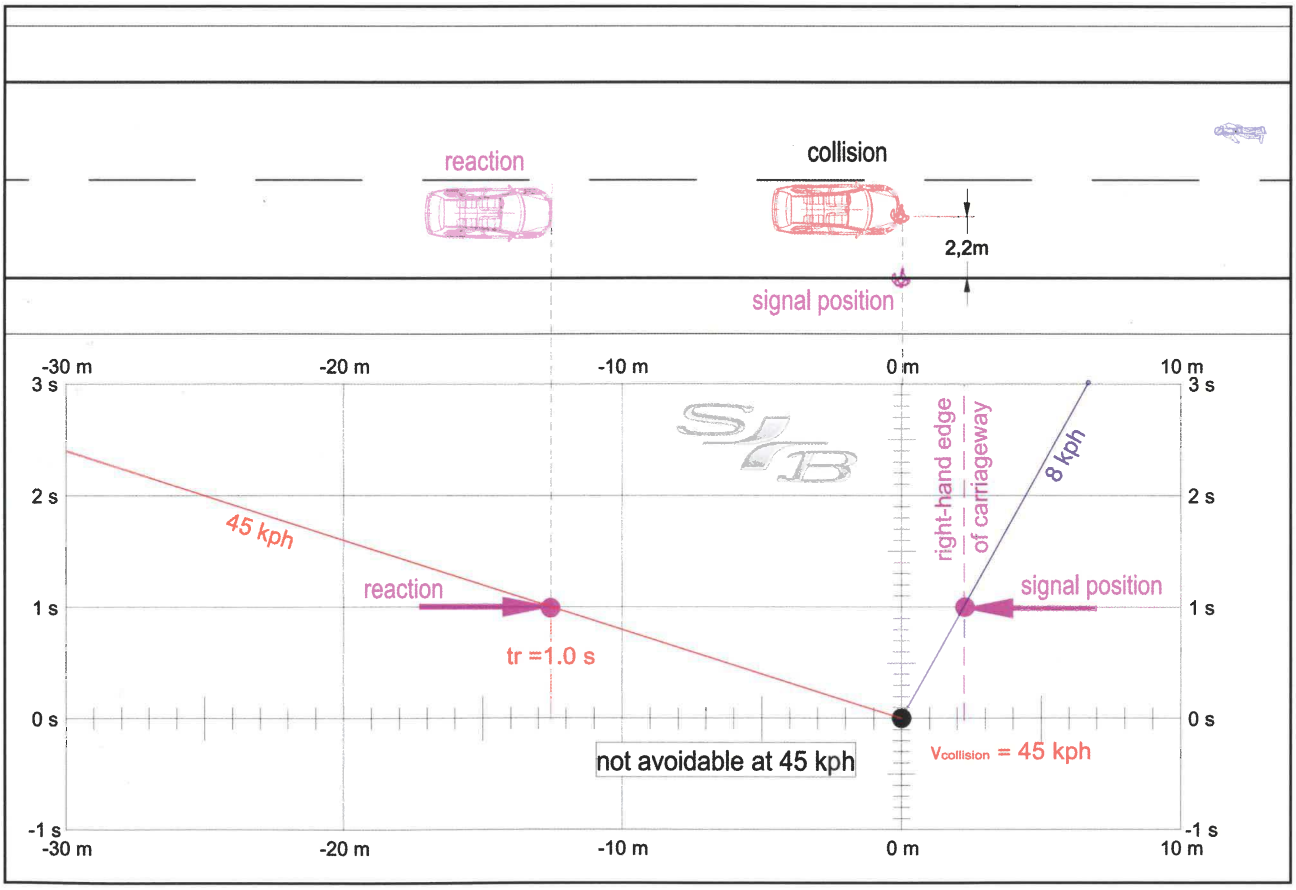

Fig.13 Travel and time based on Figure 9

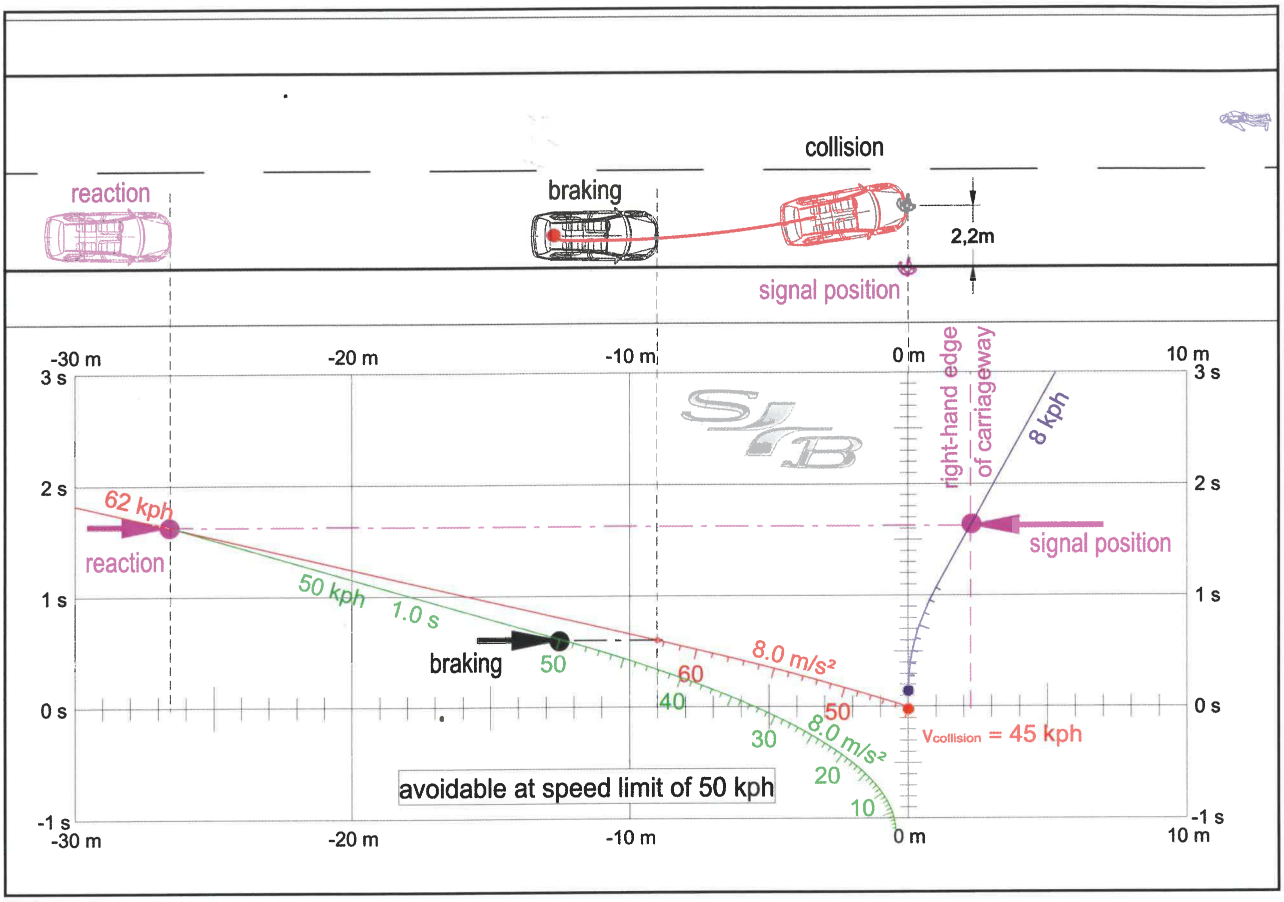

Fig.14 Travel and time based on Figure 11