Expert report – DGvGM

CASE No. 02-215/BIO

VULNERABLE ROAD USER CRASH
IMPACT BIOMECHANICS

The Hermitage, Coed Pella Road, Colwyn Bay, LL29 7BA, United Kingdom

“The Centre of Excellence That Offers Future Safe Mobility”

Prepared for: CAT, Scottsdale, Arizona, USA

Prepared by: E. Clive Chirwa, BEng (1st Hon.), MSc(Auto. Trans.), MSc (Auto. Struct),
PhD (Struct. Dyn.), FZIE, MSAE, UK

Hermann Steffan, Univ.Prof. Dipl. Ing. Dr., TUG, Graz, Austria
Table of Contents

Executive summary ........................................................................................................... 3

CHAPTER I: INTRODUCTION ......................................................................................... 4

Preamble ............................................................................................................................ 4

Characteristic of the pedestrian crash on 04 October 2002 ........................................... 4

CHAPTER II: DOCUMENTATION AND VEHICLE ASSESSMENT ............................. 8

Documentation ................................................................................................................. 8

Assessment and photo analysis ....................................................................................... 8

The Assessment ................................................................................................................. 9

Injuries to Rev. David Geist ............................................................................................. 12

CHAPTER III: BIOMECHANICS - INJURY MECHANISMS ......................................... 13

Primary Impact ................................................................................................................ 14

Secondary Impact ............................................................................................................ 16

Estimation of injury risk without a towing hook .............................................................. 17

Suggested frontal design of the Chevrolet Blazer with respect to pedestrian protection ................................................................................................................................. 18

CHAPTER IV: DISCUSSION AND REMARKS ............................................................ 20

CHAPTER V: CONCLUSIONS ......................................................................................... 24

CHAPTER VI: REFERENCES ............................................................................................. 25
Executive summary

From the police report based on this work’s objectives, we will be assessing only the accident between WF’s 1995 Chevrolet Blazer with the pedestrian DG. According to the police report, the contact was made when DG was retrieving some items from his parked VW Beetle car boot or trunk of VIN No. 3VWBT21C91M412725. The incident happened along Haddon Avenue when the Chevrolet Blazer travelling Northbound suddenly changed trajectory to impact DG who was still standing behind his VW Beetle.

The 1995 GM SUV Chevrolet Blazer chassis No. 1GNCT18W4SK236460 that impacted DG on 04 October 2002 has the front structure that is rigid with very high stiffness, unnecessarily strong with a high aggressivity Index. It is unsafely designed for pedestrian protection.

The front protruding hook located in the undesirable place caused DG’s leg amputation.

If the hook did not exist or it had been designed differently, DG would have suffered some limb fracture that would have required wearing plaster and later make full recovery.

According to all the facts presented herein, the only explanation for the amputation of the left lower leg is that of a full contact with the towing hook, which is seen as extremely pedestrian unfriendly design. Indeed, this is a design fault.

If a pedestrian safety design of the frontal area was to be realised, where the hook is moved to a more pedestrian friendly location, or covered nicely underneath the bumper, the amputation would have been prevented. Left leg injuries that would have been attributed from this accident would have been moderate similar that on the right leg.

The left leg injuries are not caused by DG being squashed between the two vehicles, but by the towing hook slicing DG’s leg.
CHAPTER 1: INTRODUCTION

Preamble

In this report an accident between three vehicles and a pedestrian that occurred in the 600 block of Haddon Avenue within the Borough of Haddonfield on 4th October 2002 at 04:49 pm is being analysed in order to offer an expert opinion on how the 1995 Chevrolet Blazer [VIN No. 1GNCT18W4SK236460] driven at the time of the accident by WF struck DG standing behind his legally parked car. In addition it assesses the likelihood of the towing hook and overall aggressivity index of the frontal structure of the Chevrolet Blazer precipitating the serious leg injuries that resulted in DG losing one lower limb on spot and fracture of the other lower limb.

Characteristic of the pedestrian crash on 4 October 2002

From the police report based on this work’s objectives, we will be assessing only the accident between WF’s 1995 Chevrolet Blazer with the pedestrian DG. According to the police report, the contact was made when DG was placing or retrieving some items from his parked VW Beetle car boot or trunk of VIN No. 3VWBT21C91M412725. The incident happened along 600 block of Haddon Avenue when the Chevrolet Blazer travelling Northbound suddenly changed trajectory to impact DG who was still standing behind his VW Beetle.

The accident topology diagrams in the police report are given to show the following points:

1. We believe vehicle \( V_1 \) is thought to have made contact first with the pedestrian then with the VW car. That is why the VW was pushed by 18 ft \((5.5 \text{ m})\) from the point of impact. The pedestrian landed a couple of feet away (pool of blood) from the point of impact (shoe sole or the beginning of the VW skidmarks), see Figure 3.

2. Because the Chevrolet Speed after impact of the pedestrian and the VW beetle was not equal to zero, Vehicle \( V_1 \) progressed on to hit vehicle \( V_3 \) in the side and it is at this moment in time its final velocity became equal to zero.

3. Therefore, the police calculated impact velocity between \( V_1 \) and the pedestrian is conservative. The minimum speed must have been a combined one that takes the sliding speed, the impact speed with pedestrian/VW and the sliding speed that took \( V_1 \) into \( V_3 \). According to details taken from the photographs and using the police data collected
at the accident scene, the minimum velocity at the time of the impact between \( V_1 \) and the pedestrian is larger. Indeed, WF the driver of vehicle \( V_1 \) admits in his statement provided on 7 October 2002 that he was accelerating at the time he hit DG.

Since the pedestrian DG is far much lighter than the SUV \( V_1 \), he has little effect upon its speed. The car \( V_1 \), however, very rapidly increased DG’s speed from zero to the impact speed of \( V_1 \). The time taken for this is about the time it took for the \( V_1 \) to travel a distance equal to DG’s calves that measure between 6 – 8 inches (150mm – 200 mm). If we use the conservative police data that the impact speed was 20 mph (8.94 m/s) and the impact duration was 0.025 seconds, we can determine DG’s minimum acceleration in that short time to be \( \frac{8.94}{0.025} = 358 \text{m/s}^2 \) (1174.5 ft/s\(^2\)). We know DG weighs 200 lb = 90.72 kg. Then the minimum force he experienced is a product of his mass and his acceleration, \( 90.72 \times 358 = 32477.76 \text{N} = 32.48 \text{kN} \) (7301 lbf). This means DG experienced a weight of nearly two \( V_1 \) SUVs in the region of contact about 2 inches or 5 cm below the knee.

![Skidmarks showing vehicle \( V_1 \) trajectory](image)

**Figure 3. Chevrolet Blazer skid marks**

The impact point and the landing location after contact was made between DG and the vehicle \( V_1 \) plus \( V_2 \) can be described from Figure 4 as follows:
4. The shoe sole that detached itself from one of DG’s shoe due to the friction load developed between the shoes and the road as he was impacted with a minimum load of 32.48 kN indicates the approximate location where he stood before the accident.

5. The skidmarks of the locked right rear wheel show clearly the beginning of the VW push once contact with the SUV driven by WF had been made. DG was first struck by the SUV, then sandwiched between the SUV and the VW during the first critical stage of the collision. This may have saved his life but the load was so severe that it sheared both lower limbs. This severity is precipitated by the high aggressivity index and the unfriendly towing hook that protrudes at near knee point and that makes the first contact with the lower limb that slices DG’s left leg and later crushes the right leg between the two vehicle bodies V₁ and V₂.

![Figure 4](image.png)

**Figure 4.** The pedestrian impact history showing the point of contact and location of landing after impact

6. Due to momentum, DG’s body was carried for a couple of feet and landed in a location where there is a pool of blood. While the vehicle VW continued to slide further by hitting the kerb and then change trajectory to its final position as shown in Figure 4.
7. Figure 5 shows another angle of the final position of vehicle \( V_1 \). This angle clearly shows with reference to the shoe sole that the first contact vehicle \( V_1 \) made by the towing hook on DG’s legs then became sandwiched between the Chevrolet Blazer and the VW.

![Figure 5](image)

Figure 5. Showing the final position of vehicle \( V_1 \) with respect to the accident topology

The forensic analysis and the reconstruction carried out however shows that the injuries sustained by DG could only have been attributed if at the time of impact DG was facing the incoming vehicle. He could have been alerted by the either the skidding tyre noises or by raving of the Blazer since WF was actually accelerating just before impact.
CHAPTER II: DOCUMENTATION AND VEHICLE ASSESSMENT

Documentation

To facilitate the analysis, CA provided the following documentation for perusal:

1. The State of New Jersey Haddonfield Police Department Traffic safety Unit Motor Vehicle Accident Report No. 02-215;
2. The New Jersey police crash report form attachment to 02-215;
3. The Cooper Health System report MRN#04509895;
4. The Haddonfield EMS Incident report form compiled on 4 October 2002 by the emergency unit;
5. The Virtua Mobile Intensive Care Program patient report No. 104038;
6. Vehicle damage report, claim No. 30-V595-322;
7. Images of the accident topology and the deformed vehicles;
8. Supporting information related to the accident.

In addition to the above provided documentation, Professor Clive Chirwa travelled to inspect an exemplar in Southampton, UK. The inspection was carried out within the period of 19th April and 30 April 2006 between 09:15 am and 05:30 pm. This included necessary measurements that facilitated the understanding of the accident and the deformations associated therewith.

Assessment and Photo Analysis

<table>
<thead>
<tr>
<th>CASE</th>
<th>-DG v GM - Case No. 02-215</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASSESSMENT DATE</td>
<td>- 19 April 2006 – 30 April 2006</td>
</tr>
<tr>
<td>TIME OF ASSESSMENT</td>
<td>- 09:15 AM TO 05:30 PM</td>
</tr>
<tr>
<td>WEATHER</td>
<td>- N/A</td>
</tr>
<tr>
<td>ASSESSMENT TYPE</td>
<td>-Qualitative from photos</td>
</tr>
<tr>
<td>ASSESSMENT APPARATUS</td>
<td>-N/A</td>
</tr>
<tr>
<td>ASSESSED VEHICLE</td>
<td>-2000 Chevrolet Blazer (Black ) V₁</td>
</tr>
<tr>
<td>VISUAL DOCUMENTATION</td>
<td>-Accident Report, medical report, and still images</td>
</tr>
<tr>
<td>OCCUPANTS AT THE TIME OF ACCIDENT</td>
<td>-WF (Driver)</td>
</tr>
</tbody>
</table>
| CASE | -DG v GM  
| Case No. 02-215 |
| ASSESSMENT DATE | - 19 April 2006 – 30 April 2006 |
| TIME OF ASSESSMENT | - 09:15 AM TO 05:30 PM |
| WEATHER | - N/A |
| ASSESSMENT TYPE | - Qualitative from photos |
| ASSESSMENT APPARATUS | -N/A |
| ASSESSED VEHICLE | -VW Beetle (White ) V₂  
| Chassis No. 3VWT21C91M412725 |
| VISUAL DOCUMENTATION | - Accident Report, medical report, and still images |
| OCCUPANTS AT THE TIME OF ACCIDENT | - No occupants (stationary car)  
| DG (Pedestrian) |

**THE ASSESSMENT**

The vehicle V₁ geometry and deformation patterns were assessed from the images and particularly from Figure 6. The collected data were compared with those on the exemplar model in Figure 7.

![Figure 6. Chevrolet Blazer 1995 Model deformed front](image-url)
This later model 2002 still shows the aggressiveness of the front and the protruding hook that is lethal.

Figure 7. The exemplar vehicle V₁ inspected and measured on 24 April 2006

The undeformed hook that protrudes and makes contact with the tibia at a point below the knee (2 inches = 5 cm) for an adult when standing close to it.

Figure 8. The undeformed hook of the exemplar Chevrolet blazer
Figure 9. The side view of the underfomed hook of the exemplar Chevrolet blazer showing the protruding poor design

The side view showing the extent of the hook protruding and if standing close to the bumper you will feel the hook making a forceful contact to the calf flesh in the tibia region.

Figure 10. The hook of the 1995 Chevrolet blazer showing the deformation it sustained in shearing the tibia of DG

The hook that sheared DG’s tibia just below the knee at about 2 inches (5 cm). It is in its final deformed shape.

Human biomaterial
Figure 11. The 2001 VW Beetle that acted as the front barrier sandwiching DG with the Chevrolet front post the hook slicing

Injuries to DG

According to the reports DG suffered a left above the knee amputation and open reduction internal fixation of the right tibia. According to the witnesses the left leg was completely separated from the body immediately after the accident.

The whole biomechanics topology is described below giving the insight knowledge of what exactly happened and quantifying the injuries sustained by DG when he was first struck by the towing hook and then by the front of the Chevrolet Blazer that sandwiched him to the VW.
CHAPTER III: BIOMECHANICS – INJURY MECHANISMS

Images depicted in Figures 3, 4, 9, 10, 11, showing the point of collision can be used in the reconstruction without any difficulty. Figure 3 shows the tyre marks of the Chevrolet Blazer just behind its resting position. This same picture also depicts a rather sharp change in direction of the right front tyre mark. This change in direction indicates the action of an external force, namely the crash force. Hence after understanding the topology, the point of collision can be reconstructed [12, 13].

The analysis of Figure 3 also indicates that the Blazer moved a little bit more than one time its wheel base from the location of collision to the point it came to rest. This is slightly more than 100 inches (2.54 m).

Due to the deep described curvature of the tyre marks a slightly reduced brake deceleration of approximately 0.6 g is assumed in this analysis. This is a realistic value based on the dry road conditions and the road surface texture.

Assessing from point of view of the collision between the Chevrolet and the Nissan, the collision speed between these vehicles can be estimated to approximately 10 mph according to the deformations measured on both vehicles.

Inputting these data into the equation of motion, the speed of the Blazer immediately after the impact is calculated as 14 mph.

Furthermore, from the equation of conservation of momentum, taking into account the masses of both vehicles as well as the positions of the vehicles at contact, the collision speed of the Chevrolet Blazer is estimated as 25 mph.

According to all witnesses DG was standing facing in the direction of his vehicle behind his car, just before he was hit, he turned to face the incoming Chevrolet. As can be seen from figures 4 and 11 the trunk must have still been open when the first collision occurred. This is due to the fact that the door of the trunk appears undamaged, while the frame of the trunk is severely damaged.

From a biomechanical viewpoint it can be stated that a complete separation of a full or a part of an extremity can be found due to several reasons:

The most common way for a full separation is the high tensioning and shear forces which can occur at very high speed collisions. In these cases the extremity is accelerated from point of contact with the vehicle within a very short contact time of typically less than 50 ms to the vehicle speed. The other
body parts, being not in contact with the vehicle have to be accelerated to the same velocity within that very short time. Due to inertia, this effect creates very high forces. In certain cases, these forces can be high enough to separate body parts. From accident investigations it is well known that this requires an impact velocity of similar magnitude to that of 25 mph for the separation of different body parts.

**PRIMARY IMPACT**

Therefore, in order to simulate or reconstruct DGt’s accident we must look at bumper and hook designs. For the current accident the legs and the upper body must have been first contacted by the Chevrolet Blazer, as shown in the figure 12.

![Fig. 12 Simulation results of First contact of Blazer Bumper to leg](image)

The sequence of impact as depicted in Figure 12 is as follows:

- The first contact the Chevrolet Blazer made with DG is its bumper impacting a location near the knee;
- Then followed by the towing hook that sheared the both legs and especially the left leg that was loaded heavily;
- Then DG upper body rotated on the Chevrolet to create the indentation in the bonnet and front grill area;
- This was followed by the Chevrolet Blazer moving forward with DG’s body wrapped to its front, to impact the parked VW rear;
- Due to momentum of the Chevrolet and the impact velocity that was still high, the impacted force into the VW was so great that it pushed the VW to a distance of 18 feet (5.5 m).
Fig. 13 Testing an adult lower leg under impact loading [18]

Fig. 14 Test and simulation results of an adult femur under impact loading [18]

|---------------------|------------------|-------------|

(a) Experiments vs. FE simulation
(b) Max. Principal Strain vs. Deflection (mm)

Figure 15: Comparison between the FE simulation and experimental results for dynamic three-point bending of femur: (a) force vs. deflection curves and (b) the maximum principal strain (close to the impactor) vs. deflection curves. The experimental results are from UVA Tests 2.1, 2.2, 2.5, 2.6, and 2.8 (Funk et al. 2004) scaled to the 50th percentile male.

Table 9. The maximum bending moment at the mid-leg location in three-point bending tests of the femur

<table>
<thead>
<tr>
<th>FE Simulation-exact (Nm)</th>
<th>FE Simulation - from reaction forces (Nm)</th>
<th>Test Data (Funk et al 2004) (Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>392</td>
<td>426</td>
<td>463 (+ 117)</td>
</tr>
</tbody>
</table>

Fig. 14 Test and simulation results of an adult femur under impact loading [18]
In order to understand the degree of injury severity sustained by DG, we had to consult peer reviewed research papers that have been carried out on adult femur and tibia under bending loads that are instantaneously applied, hence impact loads. These are similar to the boundary conditions that loaded DG through the towing hook.

Figure 13 illustrates a FE schematic plan of the bending test set-up. This set-up is identical to the one used on three human adult femurs (Figure 14) and tibia/fibula (Figure 17), whose results are presented [14-18].

The three-point dynamic bending tests were simulated in order to quantify and verify the material properties of the cortical bone. The two ends of the femur for instance were fixed in roller supports. The orientation of the femur in the cups was decided by allowing the bone to lie flat on its posterior surface and pushing the medial side of the specimen against the wall of the bone cup.

The dynamic load was applied at the mid-shaft in the posterior/anterior direction using a 16 mm diameter impact moving vertically with the velocity reaching 1.5 m/s in 5 ms. Yamada [14], Ehler et al. [15] and Mather [16] performed experimental tests on femurs and tibia/fibulas from cadavers. Untaroiu et al. [18] simulated the femur and tibia/fibula based on mechanical properties of human biological materials taken in femur and tibia/fibula regions. The validations of the results in [17] were compared with experimental test results in [14-16] the agreement is good.

The results in Figure 14 show the behaviour of the femur as compared to the simulation. From the graph we can deduce that the maximum impact load the human femur can take in bending is between 3.5 kN and 4.2 kN with a deflection of between 12 mm and 22 mm.

Correlating these results to the accident data from DG’s case, we can say that his legs were loaded by 32.48 kN which is 7.7 to 9.3 times the load that requires to fracture an adult femur. This tells us that DG was impacted by a very high force that was mainly concentrated in the towing hook and that did not encounter any difficulty in slicing the lower limbs.

SECONDARY IMPACT

Once the initial impact or primary impact phase between the Chevrolet and DG was complete, DG’s body wrapped around the Chevrolet continued to move to a secondary impact with his parked VW as shown in Figure 15.

The secondary impact occurred well after the towing hook had already sliced the lower limbs of DG. Therefore the sandwiching effect of DG could not have caused more severe injuries than already had.
ESTIMATION OF INJURY RISK WITHOUT A TOWING HOOK

When assessing the contact situation as shown in Figure 16, a very symmetric loading of both legs can be expected with a good distributed loading on DG’s body. The distributed load will cover the entire contact region, hence when sandwiched between the two vehicles; the body will be under distributed compressive load. This is a far less severe loading condition to that of a towing hook applying a concentrated load that is localised. The injuries here are squashing of the body regions including the lower extremities.

According to the bumper orientations between the two vehicles, the forces on both legs would have been very similar when the hook is not protruding as in the case of the Chevrolet. Therefore we would have seen quite similar injuries on both legs. In this case the fracture mechanism like that occurred on the right leg could have been expected. This could have been treatable with full patient recovery. With a softer bumper, even lower injuries could have been expected.
SUGGESTED FRONTAL DESIGN OF THE CHEVROLET BLAZER WITH
RESPECT TO PEDESTRIAN PROTECTION

It is well known that all kinds of localised punching loads result in severe forces due to the fact that they cover a small contact area. In the frontal part of the Chevrolet Blazer, protruding functional components such as towing hooks are injury risks to pedestrians. These lethal functional components that do not take part in transferring load for the well being of the vehicle structure should be eliminated and thus providing pedestrian safety.

In addition, the frontal structure has high stiffness and strength that is attributed from over design. All stiff components must be protected by damping materials or removed from the vicinity of high risk to pedestrian.

It is well known that SUVs, based on the principle design, are not pedestrian friendly due to the increased height of the front bumper to the legs are not nicely supported in the lower leg area, which results in a high risk of damage to the knee and lower extremities. In Europe and Japan, this is nowadays evaluated through specific type approval tests for all vehicles brought into EC and Japanese markets.

In addition the bonnet is elevated in SUVs than is the case in passenger cars. This increases the pelvic load significantly.

Further to these general design rules that need to be adhered to in any design, there are many visible design faults/problems in the front of the Chevrolet Blazer. These are as follows:
1. The two hooks on left and right side are not protected at all. In addition they are protruding in the region beyond the spoiler by at least 2 inches (50 mm);

2. The hooks are not retractable. They should be made to go inwards behind the bumper when not in use. As it is, the hook design is very aggressive and a great hazard to pedestrians;

3. The Bumper Structure is still made of steel and not covered with plastic;

4. The surrounding Spoiler leaves a wide gap around the hook. This facilitates the pedestrian legs to go round the hook and get locked for easy slicing process;

5. The spoiler seems to fracture and break leaving rather sharp corners, which are dangerous for cuts;

6. Due to the increased bumper height of the SUV there is a high probability that the hook gets in direct contact with the bumper of another vehicle, which even increases the risk for sandwiched/squeezed pedestrian;

7. Injuries due to pedestrians squeezed between vehicles are reported on a regular basis especially at low speeds. The injury mechanisms are that of lacerations of the flesh and twisted ankle. To a lesser degree you get fracture of the bone. All these injuries are treatable for a pedestrian to resume normal life after treatment.

Fig. 17 Test and simulation results of an adult tibia/Fibula under impact loading [18]

Comparing the front design of the Chevrolet Blazer to a typical frontal design of an appropriate vehicle it can be estimated that due to the extreme positioning of the towing hook, injuries to DG can be expected even at low contact speeds. The injury risk is more than double when contact is between the hook and the leg.
CHAPTER IV: DISCUSSION AND REMARKS

Based ONLY on the evidence provided to us that is presented below:

- The State of New Jersey Haddonfield Police Department Traffic safety Unit Motor Vehicle Accident Report No. 02-215;
- The New Jersey police crash report form attachment to 02-215;
- The Cooper Health System report MRN#04509895;
- The Haddonfield EMS Incident report form compiled on 4 October 2002 by the emergency unit;
- The Virtua Mobile Intensive Care Program patient report No. 104038;
- Vehicle damage report, claim No. 30-V595-322;
- Images of the accident topology and the deformed vehicles;
- Supporting information related to the accident.

Plus reference to supplementary material on the accident obtained from CA, below are the comments on the DG pedestrian accident that occurred on 04 October 2002.

Overall the front and rear final collapse patterns of the 1995 Chevrolet blazer chassis No. 1GNCT18W4SK236460 and the 2001 VW Beetle chassis No. 3VWBT21C91M412725 respectively, plus the pedestrian DG whose left leg was completely sliced and the body sandwiched between the two cars can be summarised using Figures 6 to 15 as follows:

(i) Figure 6 shows the collapse behaviour of the SUV 1995 Chevrolet blazer driven by William Firman at the time of the accident. The deformation pattern on the right of the vehicle is that caused by the pedestrian DG and by the interaction with the VW Beetle. While the left side deformation was caused by impacting the third vehicle, the Nissan, after the collision with DG and the VW had occurred.

The accident history between DG and the Chevrolet Blazer can be described as:

(a) Just before the accident DG was standing behind his parked car putting something in the trunk. As he heard the tyre skidding noise he turned to face the incoming Chevrolet Blazer. The time was extremely short for him to escape the accident and moments later after a few milliseconds he was struck.

(b) Through assessing the extent the towing hook, point 3, protrudes from the front of the Blazer. This from the geometry was the first contact DG’s body made with vehicle V;
(c) As the towing hook pushed and sliced through DG’s left leg in the process shearing and crushing the two lower limbs at about 2 inches or 50 mm from the knee joint, the upper body was by now making contact with the front grillage at point 2 applying a distributed load from the pelvis to the lower part of the thorax. As the Chevrolet continued to move forward, the left arm and left shoulder joint was thrown forward rotating about the stomach pivot point to impact the bonnet nose at point 1, hence the deep indentation that in the process caused the fracture of the left arm;

(c) The frontal structure deformation pattern, Figure 6, in the location that impacted DG, shows the extent of the accident severity. Assessing the depth of the deformation of the vehicle V₁ upper body structure, the picture becomes clear that the speed calculated by the police is conservative. From the deformation the vehicle was travelling at a speed above that. The reason for this argument can be substantiated if measurements from the 1995 Chevrolet blazer driven by William Firman were made and using energy equations to calculate the velocity at impact;

d) The bending deformation of the hook downwards as shown in figure 6, point 3, and in Figure 10 is caused by striking first DG then the VW Beetle at point 2 in Figure 11. This happened as the load equal to 32.48 kN mainly concentrated in the hook impacted DG’s lower legs. For good comparison with other people’s peer reviewed research work, Figure 17 shows the experimental and FE simulation results of the lower leg, with a tibia and fibula. The boundary conditions were exactly the same as shown in Figure 13.

The experimental results show the Fibula fracturing first at 1.9 kN that is just under 2.0 kN after a displacement of 37 mm. The tibia fracture at about 3.8 kN after a displacement of about 44 mm. In general the lower leg fibula breaks fist around 1 to 2 kN and the tibia at around 2.7 kN to 4 kN.

As the Chevrolet continued to advance the vehicle accelerated according to WF’s own testimony that he pressed the accelerator rather than the brake pedal. Note this is a common phenomenon that causes many accidents in elderly population above 70 years old. In English towns with a high population of elderly over 70, accidents have been recorded with driver’s own admission that they pressed the accelerator and not the brake pedal hence causing the accident.
The hook during this moment in time acted as a shearing device cutting through the calf muscle and then the fibula and tibia with some crushing mechanism and then once the slicing of the leg had completed the Chevrolet had still some velocity to carry DG and later enable the hook to indent the legally parked VW Beetle at point 2 in Figure 11 and push it for about 18 feet (5.5 m) from where DG lay bleeding.

(e) The right leg was hit in the area around the corner of the Chevrolet as WF attempted to make some late corrective action by turning hard the steering wheel to the left. By this time the full force of the Chevrolet was already imparted into DG and the parked VW Beetle.

(ii) Figures 7, 8 and 9 show the exemplar 2002 Chevrolet found in Southampton in the South of the UK. The front structure and location of the hooks are still the same and have never been changed despite numerous calls by the EURONCAP and Australian NCAP results to remove bull bars and any sharp protruding objects in the front of SUVs in order to protect pedestrians.

The frontal structure of the SUV Chevrolet Blazer is stiff, excessively strong and has parts in the contact zones that are dangerously harmful to pedestrians. In compatibility engineering, the front of this SUV can be categorized as aggressive. To assess how aggressive this front structure is to pedestrians we need to look at the aggressivity index.

In simple terms, aggressivity index is a function that is related to the stiffness and energy absorption capability of the front structure in relation to injuries perpetrated by that front structure on pedestrians in contact. The SUV 1995 Chevrolet Blazer has a number of different aggressivity indices throughout the front face. That means locations in the front face can absorb different pedestrians energy. This is known as the reference value defined as a ratio of energy absorption capability of ideal material/structure to stiffness of ideal material/structure. Therefore, the aggressivity index can be defined as a ratio between local energy absorption capacity and the product of reference value with local stiffness.
Local Energy Absorption Capacity

Aggressivity Index = \[
\frac{\text{Reference Value} \times \text{Local Stiffness}}{\text{Local Energy Absorption Capacity}}
\] [1]

This shows that the hook will have a high Aggressivity Index because the energy absorption capacity is very small as seen from the final state of the hook (Figure 10) that has not deformed efficiently. While in the bonnet at point 1 in Figure 6, the deformation is apparent and energy was absorbed, although not high enough to have protected the arm from fracture. Overall if we add up all the aggressivity indices in all the locations in the front face of the 1995 SUV Chevrolet Blazer we see that the vehicle is aggressive.

(iii) Figures 11 shows the VW Beetle deformed shape after the accident. The lower part at point 2 depicts a deep indentation followed by a fracture. This was caused by the rigid hook after it had in a short period of time sliced DG’s lower limbs at about 2 inches or 5 cm below the knee. The upper part of the VW Beetle show some deformation at point 1 that was caused by DG’s upper torso and thereafter contact with the SUV area around the right light.
CHAPTER V: CONCLUSIONS

1. The 1995 GM SUV Chevrolet Blazer chassis No. 1GNCT18W4SK236460 that impacted David Geist on 04 October 2002 has the front structure that is rigid with very high stiffness, unnecessarily strong with a high aggressivity Index. It is unsafe designed for pedestrian protection.

2. The front protruding hook located in the undesirable place caused DG’s leg amputation.

3. If the hook did not exist or it has been designed differently, DG would have suffered some limb fracture that would have required wearing plaster and later make full recovery.
CHAPTER IV: REFERENCES

3. EURONCAP; [www.euroncap.com](http://www.euroncap.com)


