London City Police Cruiser Rear-End Collision - Review of Physical Evidence & Potential Analysis

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An accurate reconstruction of a motor vehicle collision requires the analyst's correct interpretation of the physical evidence, and proper application of analysis, before conclusions can be drawn. It is with this in mind that Gorski Consulting reviews a reported rear-end impact of a London City Police cruiser in downtown London, Ontario.

News media reported that, on the afternoon of Sunday, July 13, 2014, the police cruiser was westbound on Queens Avenue in London and had come to a stop at a red traffic signal at the intersection with Colborne Street.

Figure 1 shows a photo from the London Free Press newspaper. It shows a view, looking generally westbound along Queens Avenue, with the two vehicles at their final rest positions. What should be apparent is that this rear-end impact does not appear to be of a severity that would be expected on the streets of a city's downtown. Assuming that a striking vehicle's initial speed was 50 km/h and that the impacted vehicle was of a similar stiffness and mass, and that about a 50% overlap existed between the contacting vehicles, a change in velocity of something less than 25 km/h for each vehicle could be expected. But the damage to the vehicles, as shown in Figure 2 (also from the London Free Press) demonstrates a change in velocity that is higher than that. Figures 3 and 4 also show that there was a substantial post-impact motion of both vehicles and that there was substantial clockwise rotation of the impacting blue van. These facts led us to explore the incident a little further.

On the afternoon of Monday, July 14, 2014 we attended the site to examine the remaining physical evidence of the crash. Figure 5 shows a westward view along Queens Avenue from several hundred metres east of the intersection with Colborne Street.

Queens Avenue is a one-way street with two westbound lanes. One can appreciate that it is straight and level for a substantial distance on approach to the area of impact. Given this fact the driver of the van should have had this time and distance to observe the stopped cruiser, provided that the cruiser was in fact stopped there throughout that time. The reality is that the physical evidence cannot provide that information, it may only give an indication of the cruiser's location for only a brief time before impact. Evaluation of the momentum and energy in the system may also provide valuable information. However it is sometimes misunderstood, and not appreciated, that the ability to interpret the meaning of the physical evidence is essential to any further analysis. Thus we will review this evidence in detail before discussing approaches toward analysis.

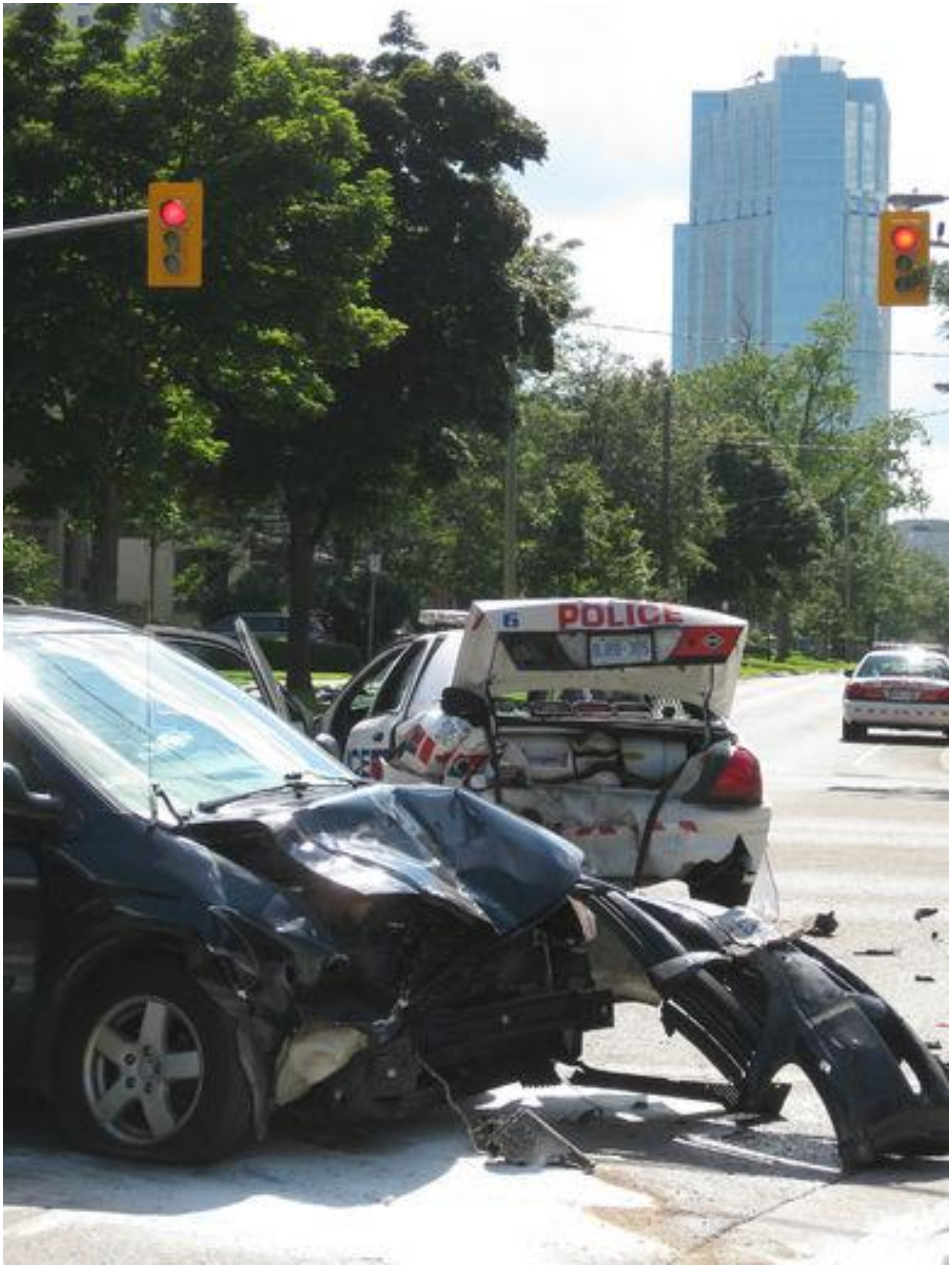

Figure 1: View, looking generally westward along Queens Avenue at the intersection of Colborne Street in downtown London, Ontario where a London City Police cruiser was rear-ended.

Figure 2: View of the substantial crush to the left portion of the rear end of the London City Police cruiser.

Figure 3: View, looking south-east at the final rest positions of the vehicles.

Figure 4: View of the post-impact travel distance of the Police Cruiser.

Figure 5: View, looking west from several hundred metres east of the accident site.

As we approach closer to the accident site we begin to appreciate that there is a lack of pre-impact skid marks from the van, as demonstrated in Figure 6.

Figure 6: Westward view showing lack of pre-impact skid marks.

The telltale signs of the point of impact between the vehicles is clearly indicated in Figure 7.

Figure 7: View, looking west at the physical evidence just east of the traffic stop bar for westbound traffic on Queens Avenue.

In many major collisions gouges to the road surface are a good indicator of the point of impact (POI). This is particularly so in head-on collisions of two vehicles approaching from opposing directions. In intersection collisions where vehicles approach from 90 degree angles such road surface scrapes may be displaced a short distance from the "point" of impact.

This could also be true for some major rear-end impacts where both vehicles are in motion. However this is less true in cases where the rear-ended vehicle is stopped. For this reason the evidence in Figure 7 can provide some useful probabilities about the vehicle pre-impact motions.

If one looks closely into the middle of the right lane one should be able to detect some scrapes in the pavement that are parallel to the length of the lane. These were caused by one the vehicles at impact. More interesting is the commencement of a fluid trail that curves from that POI somewhat toward the north-east. Such fluid trails are typically caused by the explosive bursting of the contents of the engine compartment of the impacting vehicle, but not always. Yet the point where this fluid trail begins is consistent with the police cruiser being stopped at the stop bar and the van being offset to the left of the cruiser at the initial contact. This overlap is consistent with the area of direct damage that exists to the rear end of the cruiser.

If we look at the trail of fluid again, as shown in Figure 8, we might come to the misguided belief that, after the initial contact, the van moved in a north-easterly direction, as indicated by the curve of the fluid trail. That is not the case.

Figure 8: View of fluid trail extended to show the van's final rest position in the background.

One can refer to Figures 1 and 3 to recall that the van rotated abruptly, clockwise, after the initial contact. Thus the motion of the van's centre-of-gravity during and after impact was relatively parallel to the road length but the escaping fluid was at the perimeter of that rotating mass and therefore followed the noted curved path to rest.

The commencement of this fluid trail is in conformity with the cruiser being stopped at the stop bar when it was struck. We can move further westward along the path of the fluid trail toward the final rest position (FRP) of the van as shown in Figures 9 and 10.

Figure 9: View looking west along the fluid trail caused by the front end of the van.

If we look within the bounds of the two white lines that form the zone of the pedestrian crossing we can see a long, narrow, curved scrape in the pavement just to the left of the fluid trail. If we look at Figure 3 we can see that the left front tire of the van has come off of its bead and the rim is contacting the road surface. So the long narrow scrape was caused when the tire came off its bead and the rim contacted the pavement.

As we look in Figure 10, to the right end of the pedestrian crossing zone, we can see some white-coloured fluid trail that has flowed toward the curb. This whiter stain is typically from the engine coolant and it was deposited at the final rest position (FRP) of the front end of the van.

Figure 11 shows the same area but from north of the FRP and looking south. There are dark and light coloured stains here and the fluid has drained toward the curb in the foreground. Such evidence is typical of what one would see at the final rest position of the front end of a vehicle that has sustained substantial front end damage.

In Figures 12, 13 and 14 we follow the curved scrape caused by the rim of the left-front wheel of the van. As we approach the midpoint of the scrape we can see in Figure 13 that there are two yellow dots painted there. These are police markings to identify the rest position of the two front wheels of the van.

Figure 10: View looking west toward the final rest position of the van.

Figure 11: View, looking south at the markings at the final rest position of the van.

Figure 12: Closer view of the start of the scrape produced by the left front rim of the van.

Figure 13: Yellow paint indicates the final rest position of the two front wheels of the van.

Figure 14 shows a southeasterly view of the yellow-painted markings used by the police to identify the front wheels of the van. In the middle of the figure we can clearly see how the scrape ends abruptly at the yellow line where the police marked the stopped position of the left front wheel.

Figure 14: View, looking south-east at the markings at the final rest position of the van. The scrape in the middle of the view ends abruptly where the police have produced a yellow line to signify the rest position of the van's left front rim.

Figure15 shows a view looking north at another set of two, yellow lines that identify the final rest position of the two rear wheels of the van.

Figure 15: View, looking north, toward another set of yellow lines that mark the rest position of the two rear wheels of the van.

Similar to the situation with the left-front tire, the left-rear tire also came off its bead as the vehicle rotated and therefore the rim contacted the pavement and produced a scrape. Figure 16 shows a view looking east, from just west of the rest position of the left rear tire and it should be possible to see the scrape which ends at the yellow line which identifies the wheel's rest position.

Figure 16: View, looking east from just west of the rest position of the left-rear tire of the van, and showing the scrape that was caused by that tire as the tire came off of its bead.

Having completed our description of the markings caused by the van we can now turn our attention to the evidence related to the police cruiser. Figure 17 provides an overall view, looking southwest, toward the rest position the police cruiser. Yellow lines have also been painted on the road to identify the rest position of the cruiser's wheels.

In Figures 17, 18 and 19 we move progressively in a south-west direction, into the intersection, where we find the four yellow lines which identify the final rest position of the police cruiser. We can recall from looking at the cruiser at its rest position in Figures 1 through 4 that it was stopped at angle with the front end pointing generally in south-west direction. This angle is confirmed in the yellow lines that we see in Figure 19.

If we look slightly further, beyond the yellow lines in Figure 19, we should be able to see a dark stain, roughly between the lines that identify the two front wheels. Figure 20 provides a closer view of the stain. That dark stain is located approximately where the front end of the cruiser was located at final rest. It is not very common to see fluid escaping front the front end of a vehicle that has only been struck in the rear. Of course none of the on-site photos actually show a view of the front end of the cruiser so we cannot know if any further damage might exist there.

Figure 17: View looking southwest toward the final rest position (FRP) of the police cruiser.

Figure 18: View looking southwest toward the yellow lines that identify the four tires of the police cruiser at its FRP.

Figure 19: View, looking south-west toward the four yellow lines at the police cruiser's FRP.

Figure 20: View of dark fluid stain located just ahead of the front wheels of the cruiser at its final rest position.

It is possible to follow the path of the cruiser from impact to rest by observing that the left rear tire left a visible mark as it moved from impact to rest, as shown in Figures 21 through 24. However that mark is not a black transfer but a light-coloured one that is often made when a road surface is wet. Therefore this leads to further questions.

Figure 21: View of faint tire mark produced by the left rear tire of the police cruiser as it moved toward its rest position.

Figure 22: View of tire mark caused by the left rear tire of the cruiser as it moved toward its rest position.

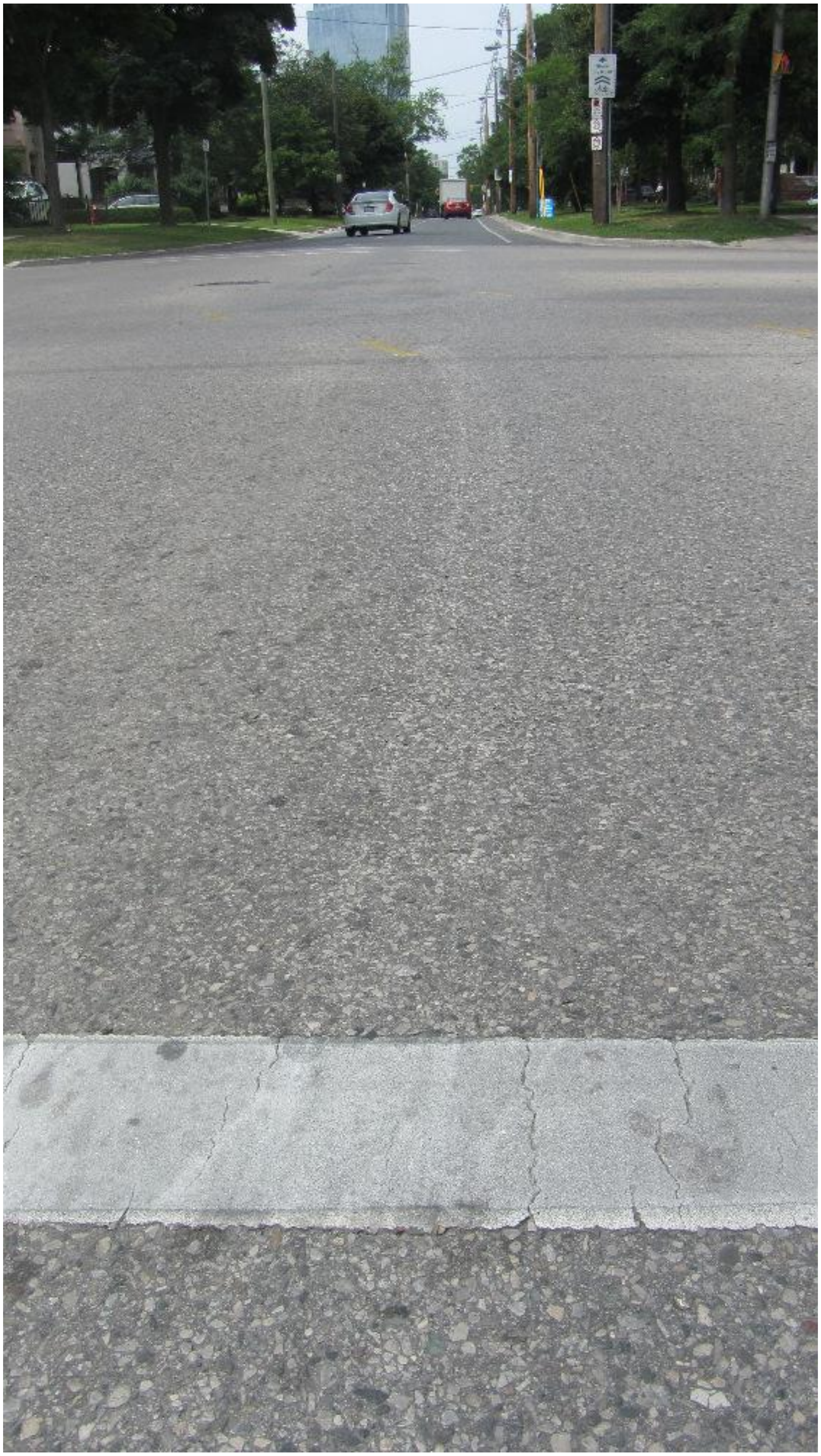

Figure 23: View of tire mark produced by the left rear tire of the cruiser as it moved toward its rest position.

Figure 24: View of the tire mark, caused by the left rear tire of the police cruiser, as it reaches the yellow line at its rest position.

Approaches Toward Analysis

In a real-life case where an analysis is required for civil litigation or defense against criminal or traffic act prosecution the approaches toward analysis can be as varied as the reasons for needing it.

In an initial article in the London Free Press provided the following basic information about the crash:

"The cruiser was travelling westbound on Queens Ave. when it was rear-ended at a red light Sunday afternoon, said Const. Jane Crosby. A male driver in a minivan struck the cruiser from behind around 3:15 p.m., Crosby said. There were no passengers in the van, and both drivers were taken to hospital by ambulance. "The officer is injured," Crosby said. "At this point they are assessing his injuries." Neither had injuries that were life-threatening. Crosby said the officer was conscious when police arrived on scene. The ages and identities of the two men have not yet been released .It's too early to determine a cause of the crash, Crosby said, but the police investigation will continue."

Subsequently it was indicated that the driver of the van was charged with "...impaired operation of a motor vehicle by drug causing bodily harm". It is often assumed that impaired driving means alcohol impairment but that may not be the case. Even a situation where a driver takes a prescription drug for an aliment he could be charged with an offense if his actions were negligent by, for example, knowing that his state of being would affect his driving. The issue whether a driver was impaired or not would not normally trigger a requirement for a deep investigation of the collision facts, although every situation is unique.

As a theoretical exercise we will take the assumption that the driver was not impaired and that there is an allegation by the defendant that unusual actions by police caused him to collide with the cruiser. Such a scenario might also be common if the struck vehicle was not a police cruiser but simply a civilian vehicle and there is a dispute amongst two drivers as to where the liability for the collision should lie.

From the outset, a rear-end impact like this would, with a high degree of probability, lead to the driver of the striking vehicle (the van driver) being deemed liable for the collision. For the situation to be otherwise the van driver would have to argue that something occurred that was unforeseen or unusual in the driving of the cruiser or because there were other events in the vicinity that complicated the situation.

A common failure of the justice system is that it relies too much on subjective evidence. The most common form of subjective evidence comes in the form of personal statements. These statements may come from anywhere: drivers, passengers, supposed "independent" witnesses", or from official parties who have come to investigate and analyse the circumstances. In the 21st century, it would seem that our technical expertise and the tools we have available to us, would allow us to move further away from such subjective evidence and rely on those less arguable, objective, scientific facts that are developed from our advanced technologies. Unfortunately, that progress is exceeding slow and we continue to "burn Salem witches" for their obvious sorcery or we exonerate criminals because their "references" dress them in clean white suits.

Despite the irritation that is caused by police when they close a roadway for their investigation, it is during this process that the most important, objective evidence has the opportunity to be gathered. In fact, it is even before the closing, but during the most early moments after a crash that evidence needs to be secured before it is altered or destroyed. Often it is not the most dramatic evidence that is of most importance. Small pieces of debris, faint tire marks, and similar evidence can often provide the most compelling information that can invert the application and focus of the investigation.

Thus, even in this rear-end impact scenario, it is vitally important to document evidence precisely at the earliest opportunity.

The use of total stations to map the evidence is now turning toward laser scanners. Now a robotic scanner is placed at the accident site and its head rotates 360 degrees to capture all of the evidence within a short range. The scanner's capabilities can be adjusted to a maximum of almost a million measurements per minute. The device is then taken to another area of the site and the process is repeated, as many times as it is necessary to document the whole area of interest.

A scanner can also capture the precise crush and damage to each of the vehicles, whether the vehicles are at their rest positions, or later in a towing yard.

In situations where a scanner or any similar instrument was incapable of being used to document the evidence, there is computer software available to capture objective evidence. For example, in the case where a witness has taken a photo of important evidence and that evidence became destroyed, software such as Photomodeler, can be used to obtain valuable information, such as the location of the evidence.

Whatever methods are used, the objective is to create a scale diagram of the site with all the relevant evidence precisely notated. Popular drafting software such as AutoCAD can accomplish this while there are also various less sophisticated products available that are focused on accident reconstruction. Once the site diagram is available then the true "analysis" portion of an assignment can begin.

Analysis has been made easier in some respects due to the progressively larger number of vehicles that contain event data recorders ("Black Boxes") that capture a small segment of time before, during and sometimes after an impact and copy the status of certain instruments to an electronic module during that time. An example set-up for downloading is shown in Figures 26 & 27) Officially, General Motors Corporation began installing EDRs with the ability to capture pre-crash data as early as 1999. Since then the U.S. National Highway Traffic Safety Administration (NHTSA) has mandated that effective in 2013, all light vehicles must be equipped with the capability of recording a list of 15 parameters if a manufacturer equips a vehicle with an EDR. There was also a loose requirement that the data from such EDRs be made accessible for downloading by the general public. The result is that there is a proliferation of EDRs out in the vehicle population even though the general public cannot, in practice, obtain their data, nor can the general public turn off the EDR's capabilities.

Figure 25: Example of a laser scanner set-up at an accident site.

Figure 26: Example of a typical set-up to download the data from an EDR using the Crash Data Retrieval (CDR) toolkit.

Figure 27: View of CDR Diagnostic Link Connecter (DLC) cable being attached the DLC port to allow communication between the downloading equipment and the EDR module.

In general, EDRs will store information in the range of 5 to 10 seconds before impact. That information might contain the vehicle's speed, and certain actions of the driver such as steering, braking and throttle application. Seat belt use is another item that is documented. The severity of an impact is also documented as acceleration over a certain range of milli-seconds. The acceleration pulse in many severe, head-on collisions can be completed in just over 100 milli-seconds (1/10th of a second) however some collision scenarios can produce much longer pulses, even approaching 500 milli-seconds. Such EDRs are also capable of storing information about 2 or 3 impacts in short succession. There is also a capability of storing information about less severe impacts (Non-Deployments) that do not require the triggering of a safety device such as an air bag or seat-belt pre-tensioner.

Even though EDRs exist, they are not infallible and an analyst is required to check the data for any signs that it is not what it is expected to be. Thus we might believe that the recorded speed of a vehicle is the actual speed at which the vehicle traversed the landscape when in fact it may only indicate the rotation speed of a wheel from which the speed is derived. Thus, theoretically, a vehicle could be in stopped position with its wheel not touching the ground and spinning a an incredible rate and the EDR might indicate that the vehicle was travelling at an incredible land speed.

Other errors also appear when there is a disruption to the electrical system of a vehicle which prevents the data from being properly and fully recorded. Similarly there can be certain software or hardware problems in the modules, sensors or recording capabilities that require the analyst to be able to detect those problems. This is why analysts are still required to complete the actions of a reconstruction and compare the results to the EDR data although in many instances that is not necessary.

The form and direction of analysis of a traffic incident varies greatly depending on the agency involved and the reason for the analysis. "Reconstruction" to some persons takes on the narrow definition of finding the speed of a vehicle and then "closing the books". In reality reconstruction has a much broader meaning in the wider world.

In our rear impact example the issue of interest may be a safety-related defect that might have caused the driver of the van to be incapable of braking the vehicle. In North America this might involve an investigation by groups such as NHTSA and Transport Canada or investigators from vehicle and component manufacturers.

A reconstruction might involve a medical condition whereby the drug manufacturer failed to warn the drug user of certain side effects of a drug. It might be necessary to examine the collision events to compare the actions of the driver to what would be expected from a non-impaired driver.

A reconstruction might involve the assessment of the injuries to the vehicle occupants to determine whether certain safety features such as air bags or seat-belts performed properly or were somehow disabled.

A reconstruction might involve the assessment of road geometry, signage or maintenance that could have contributed or caused the collision. Thus, if our van driver attempted to brake but his vehicle slid on an unusual surface that was too slippery that factor would need to be evaluated.

Many analyses require that the motions and positions of the impacting vehicles be established before further analyses are carried out. Traditionally, before the advent of the digital computer, a momentum analysis was the preferred method, though to some degree, the system energy had some useful applications.

A momentum analysis derives its basis from the theoretical observation that, in a vacuum, the pre-impact momentum of two colliding particles was equal to their post-impact moment. Or, in other words, momentum was conserved. This concept was applied to motor vehicle collision reconstruction via several simplifying beliefs. One, that a vehicle can be substituted for the point mass without significant degradation of the principle. Another simplification is that angular momentum (rotation) could be ignored and that linear, translation, motion was all that needed to be evaluated. Another simplification was that the pre and post-impact conditions immediately "before" and immediately "after" the impact could be accurately established. Another is that nothing of significance needed to be considered during the short time of contact between the vehicles such that the collision pulse could be viewed as instantaneous.

In practice, a momentum analysis involves calculating the post-impact velocities (speed and departure angles) of the vehicles from the point of impact (POI) to the final rest positions (FRPs). Multiplying the velocity and mass of each vehicle causes the analyst to determine the post-impact momentum. To repeat, the total post-impact momentum is the post-impact momentum of both vehicles combined. Then according to the theoretical principle, the post-impact momentum must be equal to the pre-impact momentum. In order to establish the pre-impact momentum the analyst must make some reasonable assumptions about the angle at which the vehicles approached the POI - and this is where some of the "art" of the science comes into play. Because, in many cases, the angle of approach is assumed but not verified through objective, physical evidence. Regardless, by assuming the angles of approach the closed system becomes a rather simple, mathematical process leading to the pre-impact velocities of both vehicles.

The momentum analysis became unnecessarily difficult to visualize due to the insistence of the majority of analysts on writing out their solutions using trigonometry. In some way we believe this was a way of keeping the mystery of the process in the few hands that knew its mystery while preventing those who really needed to know the truth from finding the truth. Anyone seeing this trigonometric description of the analysis must either have had a good grounding in it, and the theory of momentum, or simply become lost. Those judges and juries who encountered the material could not possibly understand it.

An equivalent method of displaying momentum analyses is to use vector diagrams. Vectors are lines whose length and angle are used to indicate the speed and travel direction of a vehicle. This is equivalent to using trigonometry except that the vector diagrams provide a better visual indication of the procedure and therefore persons unfamiliar with technical analysis, such as judges and juries, have an easier time understanding the methodology.

In about the mid-1970s the use of energy evaluation in reconstruction became more popular as researchers such as K. L. Campbell ("Energy Basis for Collision Severity") demonstrated that there was a relationship between the magnitude of crush and the energy dissipated in that process. It was possible, via long and time-consuming hand calculations, to go through this procedure of calculating energies at impact and incorporating then into the post-impact calculations.

A "Damage Analysis" procedure that was incorporated into a computer program called CRASH soon became popular as investigators began taking crush measurements to determine the collision severity and ultimately determining the pre-impact speed of vehicles in a collision. Interestingly, the CRASH program was developed with the ability to conduct independent Momentum and Damage analyses and then compare the results to each other. It became a very useful tool and so it ushered in the next big step in collision reconstruction - the use of digital computers.

Figure 28: Example of a CRASH output from the EDCrash program, circa 1984

In fact CRASH was only a pre-processor to a larger analysis tool call SMAC which was actually developed just prior to CRASH. SMAC was to be a simulation program in that it allowed the analyst to position "replicas" of vehicles on a site diagram and then run the replicas toward impact, cause the vehicles to respond from the impact, and then make the vehicles move to their final rest positions. The idea was to keep re-running SMAC until the inputs caused the vehicles to reach their rest positions while being in conformity with facts of the case.

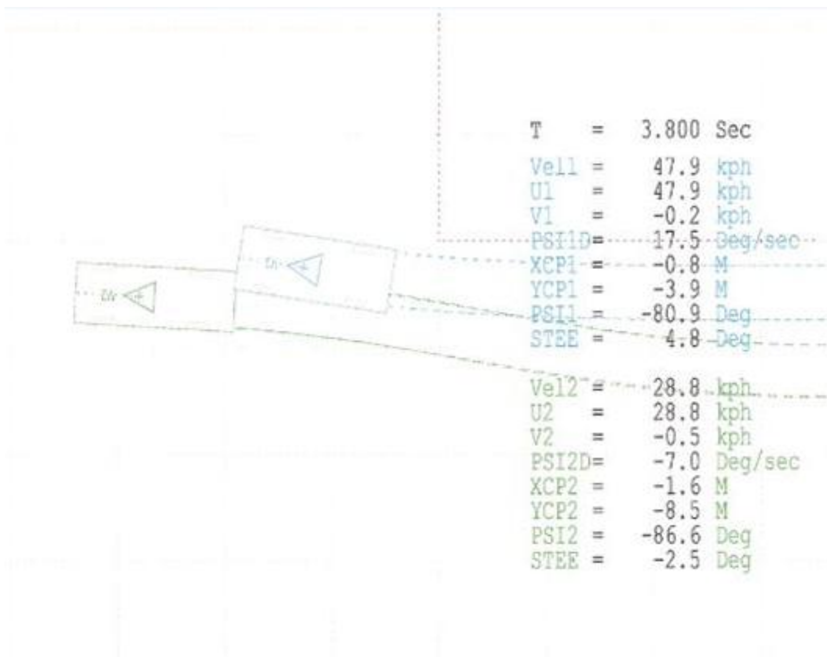

Figure 29: Example of a rear-end impact SMAC simulation at a time of 3.8 seconds from the start of the simulation.

So, in our rear-end collision example, the analyst would set-up a SMAC scenario from a time of 5 seconds before impact. At this start time the analyst might assign a forward speed of 70 km/h for the van and 0 km/h for the stopped cruiser. The analyst would also assign various inputs such as braking/acceleration/steering that would be applied to each vehicle at, for example, every 1/10th of a second. Once the analyst presses the "run" button the SMAC program would begin to provide a visual indication on the computer screen of the vehicle motions at the 1/10th of a second time increments (as per the example in Figure 26). So the analyst could watch as the van approached the cruiser and made contact. The forces of impact are modeled in such a way that the vehicles shown on the computer screen sustain crush to their perimeters and separate toward their final rest positions.

As mentioned earlier, reconstruction does not just involve calculation of speeds. For example, the analyst of a rear-end collision may have very little interest in ground speed. Most analyses of rear-end collisions involve attempts to determine the severity of the impact and how the occupants of the struck vehicle sustained their injuries. Injury assessments cannot be performed however until the motion of the vehicle in accurately determined. And the vehicle motion cannot be determined until it is tied to the physical evidence on the road. Thus, a hierarchy of procedures exists.

To repeat, first the vehicle exterior is tied to the site evidence. Next the vehicle is tied to the other striking vehicle, if one exists. Next, the occupant is tied to the vehicle interior. And finally the occupant's interior organs are tied to the body. It is this hierarchy and prioritization that has to take place in its proper order. There is computer software such as MADYMO that is specifically designed to examine the motion of the occupant within a digital vehicle interior while also having the capability to mimic the responses and acquire data of an advanced anthropometric dummy.

In the present day there are numerous computer-based reconstruction, simulation and animation programs being sold by various vendors. Their sophistication and accuracy vary and require an analyst familiar with the technology to understand the difference. Motor vehicle accident reconstruction is a special case in science in that large monetary rewards and penalties are the consequence of any findings. Thus as new tools arrive there is a tug-of-war between those who glorify and vilify them, that can sometimes have little to do with science or sound logic. In our experience it is not often the tool that is at fault but the human that controls how it will be used.

In the same way, physical evidence can be nonsense in the hands of the inexperienced or unethical analyst. However, a proper procedure, based on extensive experience and relevant training, will provide a proper interpretation and that interpretation can provide the basis for an accurate analysis and valid conclusions.

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