An Overview of Vehicular Accident Reconstruction

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21 December 2017

The Science

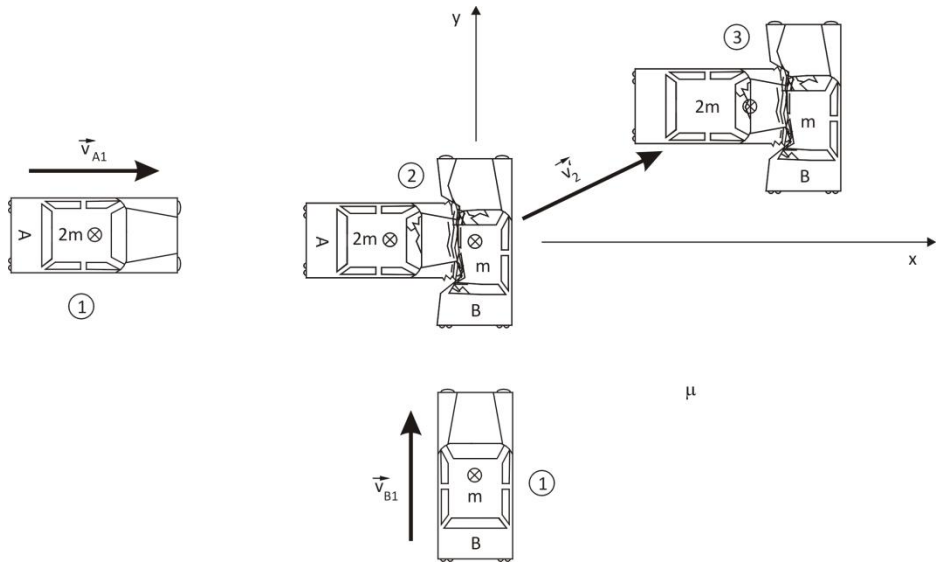
Vehicular accident reconstruction is a fascinating science. It is different from other engineering analyses in that an unplanned event, the collision, is the focus of the analysis. Things do not unfold in any planned sequence, and often evidence is missing or has many missing elements in it. So accident investigation often has a real cloak-and-dagger aspect to it.

The basic science of accident investigation is Dynamics, how physical objects move under the influence of forces. These objects—vehicles—must obey Newton's Second Law during their entire trajectories before, during, and after a collision. This sequence is carefully broken down into a time line (when what happened) and a location map (where the events in the sequence occurred). The problem is worked backwards in time and place, starting with the end resting position of the vehicles, working your way back to the point of collision, looking at the actual collision itself, and then working your way back from the collision to the point where the drivers of the vehicles recognized an impending collision and took evasive action.

More specifically, an analysis follows this line of reasoning:

1. Use skid marks and the Work/Energy Method to go backwards from the final resting position of the vehicles to find the velocities of the vehicles just after the collision.
2. Use the Principle of Impulse/Momentum to analyze the collision itself and calculate the vehicles' velocities just before they collided.
3. Use pre-crash skid marks and Work/Energy to calculate how fast the vehicles were going when the drivers recognized an impending collision.

By working backwards in this way, pre-event velocities can be determined, and blame can be attached to the offending driver's behavior.



From a Cal Poly Mechanical Engineering quiz, Winter Quarter 2013

The Work/Energy Method expresses the principle that energy can be neither created nor destroyed. In braking, friction takes the kinetic energy of motion from a vehicle and turns it into heat. Skid marks are the fingerprint of this energy conversion, so their length shows how much kinetic energy was dissipated in braking, both before and after the collision.

The Principle of Impulse/Momentum is an expression of Newton's Second Law, F = m·a, "force equals mass times acceleration". It is used instead of Work/Energy to analyze the crash itself because the energy dissipation in the crash is so sudden, chaotic, and unknown. Typically a crash lasts just 0.01 seconds. Even though the event is very short, Newton's Second Law still applies, so there is a definite connection between the post-crash and pre-crash velocities that can be determined by Impulse/Momentum.

Several analyses of vehicular collisions can be seen on our website at www.polyxengineering.com/AccidentReconstruction.html.

Specializations within Accident Investigation

The field of accident reconstruction can be divided up into a number of specializations. Vehicle dynamics, described above, is the heart of accident reconstruction. But there are other identifiable focuses that often show up in court. What happens to vehicle occupants in a collision is often important in a case. For example, in a roll-over accident, were the occupants of the vehicle wearing seat belts? In the case of an injury or fatality, what blow between the person and the vehicle caused the damage? I have seen a case where there was a dispute about who was driving a car with two occupants, one of whom died. The car was being driven in a very reckless manner. Was the survivor to blame for the accident or was he just a passenger in the car? In this case a very detailed map of the vehicle damage was made, and an analysis was done to match vehicle damage with the occupants' injuries.

Thus the human/vehicle interaction in a crash can be very important. A physician or a specialist in forensic medicine or biomechanics may be needed to establish cause.

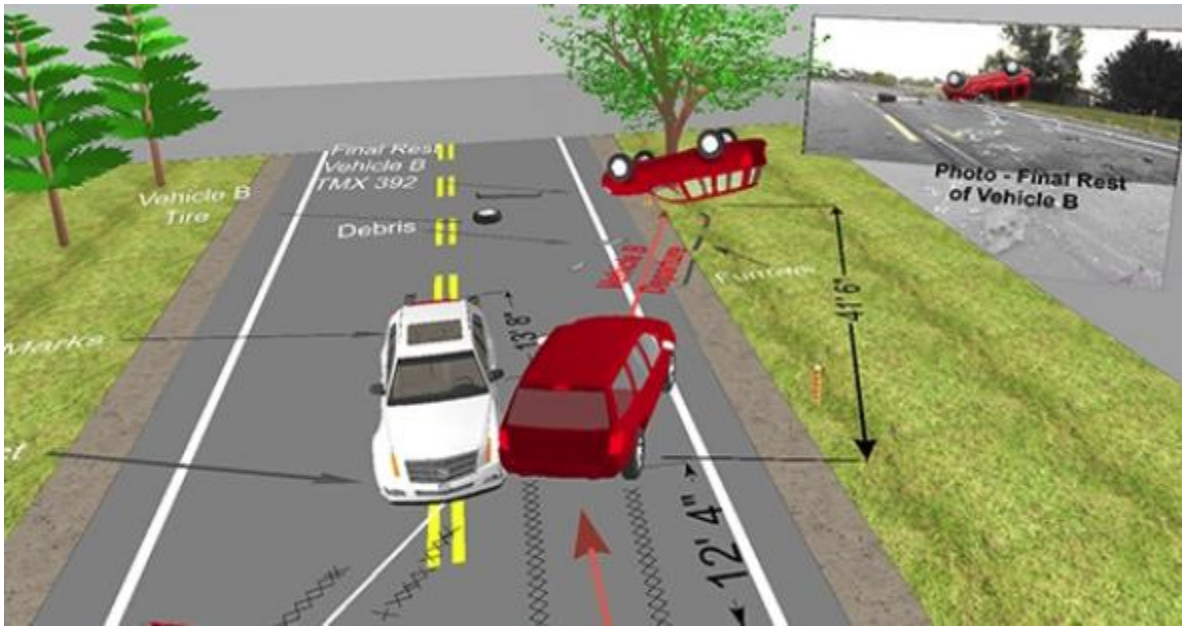
Scene documentation is also very important. Laying out an intersection and making drawings of a scene may require the services of a surveyor. Surveying nowadays has gone high tech, and there are laser measurement devices that can capture a scene quickly and with great accuracy. Laser measuring devices can be used to measure very precisely the damage to vehicles. The location of the damage on vehicles and how far they were pushed in can be used to determine the direction of the vehicles and their speeds at impact. This can be compared with the results from the vehicle dynamics analysis to confirm those results.

Because of the popularity of TV shows such as the CSI programs, juries nowadays expect a realistic portrayal of a collision. Software is available to analyze a crash. Software is also available to portray or re-create a crash. The two are different, and there is an entire, identifiable specialty in accident re-creation that is more like movie making. And as is often true in Hollywood, sometimes the script does not necessarily follow the constraints of reality, such as Newton's Second Law. But good graphics in themselves often have an impact on juries, even if what they portray is not possible. Thus there is an entire field of portrayal that has grown up with the software.

Tools for Accident Investigation

There are several good programs that can be used to analyze vehicular accidents. But it is too easy to believe blindly what comes out of a computer. So every analysis, even those done by computer, should be accompanied by a hand analysis that confirms the computer result. This is a "best practice" in every field of engineering that uses computers for technical calculations.

Computer software to perform an analysis runs the gamut from simple spreadsheet programs that contain canned formulae and vehicle data sheets to sophisticated 3D analyses that also produce animations that are true to physical constraints. A text-based program that is useful for organizing calculations and information on vehicle parameters is Accident Reconstruction Professional 11 by Dirigo Software. This program retails for $219. On the other end of the spectrum are programs like PC Crash and FARO® Zone 3D. PC-Crash retails at $4999. FARO® Zone 3D costs $2500 and up. Both of these programs have additional modules available for extra cost that focus on specialized components in the analysis.



Accident reconstruction and animation using FARO® Zone 3D.

Conventional accident reconstruction calculations are 2D calculations. This means that only the movement of vehicles on a plane is considered. A 3D analysis takes into account vertical motion also. If vehicles collide and one is launched vertically in the collision, this will not be captured in a 2D analysis. Also rollover accidents are 3D events.

The sophistication (and price) of the software runs parallel with its capabilities. An inexpensive package may only be able to analyze the collision of two vehicles in 2D. More sophisticated software would be able to handle many-vehicle accidents, like a pile-up on a fog-shrouded freeway. It might also be able to handle collisions involving articulated vehicles, like tractor trailers.

Another high-tech advancement in accident reconstruction involves documenting the crash scene. For this a *total station* is used. This is a surveying instrument mounted on a tripod. But nowadays the measurements are taken automatically. Sometimes a GPS system is integrated into the total station so that measurements can be taken when there is no line-of-sight between the instrument and the measured point. Even more sophisticated is a laser scanning device that takes all scene measurements automatically and recreates the scene digitally in 3D. The sophisticated accident reconstruction programs mentioned above accept input from these total stations to allow for scene re-creation in the analysis and simulation of the crash.

Yet another piece of technology that has revolutionized accident reconstruction is the use of Event or Crash Data Recorders (CDR) in modern vehicles. These devices sense collision events and deploy a vehicle's airbags if a crash is detected. But the CDR is also a vehicle's black box and records velocities just before and during a collision. This data can be downloaded from the CDR and compared with crash calculations to see if they are telling the same story. CDRs are under constant development and improvement and give ever more data as the technology matures.

Event or Crash Data Recorder under driver's seat

These advancements in technology allow the reconstructionist to satisfy a growing expectation of juries to see a simulation that clearly and graphically depicts the crash event. In a dispute, where one party utilizes these tools and the other does not, their use can be critical in determining the jury's decision in a case. It is also the case that private reconstructionists make greater use of this technology than does law enforcement. Thus your case can be helped if the money is there to support the use of these tools.

The Legal Interface with Accident Investigation

The most important legal constraint that arises in accident reconstruction is the *Daubert standard*. This governs admissibility of evidence from an expert, from the reconstructionist. It also governs the tools mentioned above for accident reconstruction. Daubert requires that the judge be the gatekeeper of admissibility. This means that it is not appropriate just to allow all evidence and let the jury decide on its soundness or relevance. Daubert requires that the methodology used by the expert be based on the scientific method and that this methodology be generally accepted as sound by the scientific community. Thus a new tool or a new analysis tact that has not been used before may be disallowed by Daubert.

As was mentioned above, it is possible to create an animation that portrays a collision graphically, but the sequence of events is impossible because it violates the Principle of Work/Energy or Impulse/Momentum. Thus in using animation in a case, an attorney and an expert must be aware of the consistency of the animation, how it is based on physical laws, and the technology involved in generating the simulation. Questions about the animation will come up and require explanation. The expert must be able to explain to the jury the analytical basis of the animation and how it is consistent with physical principles.

Regarding CDRs and the data contained in them, there have been disputes about whether this data is protected under privacy rules.

A very large, fuzzy parameter that often comes up in a traffic accident is the coefficient of friction between a vehicle's tires and the pavement. This coefficient describes how effectively the tires grab the pavement when trying to stop a vehicle. The coefficient of friction varies with pavement surface, with the age of the pavement and its condition, with whether or not the surface is dry, and also with the rubber used to manufacture the tire. Usually the best that can be given as a friction coefficient is a range of values. This affects the calculations of the post collision speeds and the initial speeds at the time that the drivers of the vehicles recognized an impending crash. Thus an attorney should not expect a single, precise estimation of vehicle speed but rather a range. If a single number is given by an expert, the attorney should worry about the credibility of the expert.

The Practice of Accident Investigation in California

The practice of accident investigation in California is not much different than it is in other states. The level of expertise available to local law enforcement varies quite a bit from jurisdiction to jurisdiction. The CHP has Multidisciplinary Accident Investigation Teams (MAITs) throughout the state. A MAIT is typically made up of several CHP officers who specialize in traffic accident investigation as well as a senior transportation engineer from Caltrans.

In the private sphere many accident reconstructionists are former law enforcement officers who retire and open their own businesses. Other reconstructionists are engineers, usually mechanical engineers, who know the field as a specialization of their engineering training.

In my opinion, accident reconstruction ought to be left up to trained engineers. Law enforcement officers usually do not have any engineering background and try to do accident reconstruction by taking specialized training courses that teach the canned use of established formulae to analyze an accident. This is a dangerous practice, in my opinion, since many things can happen in a collision that are not standard and that require a rigorous engineering analysis to arrive at a plausible sequence of events that follows the physical laws of motion.

In other areas of public safety the state licensure board for Professional Engineers has come down hard on people without an engineering background who are doing engineering calculations as part of their work. But in the case of accident reconstruction, the licensure board has had nothing to say. The result is that former law enforcement personnel are involved in accident reconstruction with a minimum of engineering understanding of motion, crash impact, or energy transfer in braking or in a crash. They attend these canned courses and come away with a formula sheet to perform complicated calculations. Their ability to explain the physical laws upon which a reconstruction or a simulation is based is very limited. So, admittedly biased, I would always recommend to an attorney to use an engineer as an expert in a traffic collision case instead of someone with no engineering background. A good example of a deposition that shows how a non-engineer expert can get in over his head can be seen on YouTube at http://www.youtube.com/watch?v=sYqXlRQrBN4.

There is a certification board, ACTAR (Accreditation Commission for Traffic Accident Reconstruction), that administers a test for reconstructionists. An attorney hiring an expert for an accident reconstruction should determine whether or not the expert is ACTAR-accredited. Engineering colleagues involved in accident reconstruction have told me that the lack of ACTAR certification has not hurt their creditability if they have a Professional Engineering license, since this is generally accepted as a higher certification than passing the ACTAR exam.

In the late 1990s a group of reconstructionists in California organized a professional organization, the California Association of Accident Reconstruction Specialists (CAARS). This organization has about 300 members, quarterly training, an annual conference to share ideas, and a quarterly newsletter (www.ca2rs.com).

California Association of Accident Reconstruction Specialists

Last, there is a built-in flaw in accident reconstruction that has to do with the documentation of a crash scene, and which renders an analysis more difficult than it needs to be. A collision occurs and is documented by the appropriate law enforcement agency. Often an expert is not engaged until some time after the crash. By that time, often much of the evidence—skid marks, for example—has been obscured or erased by other traffic on the roadway. Even the vehicles involved might have been repaired. Sometimes the evidence collected by law enforcement is good. Often it is not very good. It is astounding to me that now, in this day and age of digital photography, often no photographs are taken of an accident scene. And there is often so much pressure on law enforcement to get the roadway back open again, that evidence collection is rushed, and very big holes are left when trying to piece the scene back together again. What could be done about this is that scene documentation and data collection could be standardized so that egregious errors—like not taking any photographs—could be avoided.

The Author

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