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Forensic Engineering Studies Using Exemplar Vehicles and Surrogates in Vehicle Impact Cases

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Abstract

As part of their event reconstruction, accident reconstructionists often inspect exemplar motor vehicles. "Exemplar" means a vehicle of the same model, production series, etc. in terms of the vehicle of interest. In the analysis of the injury aspects of vehicular collisions, biomechanics experts can also benefit from exemplar studies, especially when a surrogate (individual of the same gender, age group, body stature, etc.) is incorporated into the study. This is often an important activity since available physical evidence is often limited. For example, photo documentation may focus almost exclusively on the outside of the subject vehicle, whereas the injury event(s) often occur within the vehicle. Also, providers of vehicle specifications typically provide limited (if any) vehicle interior information. Finally, depositional information may be very limited, providing few details on events and conditions that may have contributed (or not) to claimed injuries. Thus, exemplar/surrogate studies can provide a wealth of information in the analysis of what injuries may (or may not) have occurred knowing the physics of the accident reconstruction and the resulting occupant kinematics, geometric considerations, claimant characteristics, and the associated injury mechanisms. A series of situations will be presented as examples of how exemplar/surrogate studies can be useful in injury analysis, including seat belt issues, rear-end collisions, and pedestrian/vehicle incidents. General protocol considerations will also be presented.

Keywords

Exemplar vehicle, surrogate, vehicular impact, occupant kinematics

Introduction

In order to be an effective expert in the areas of vehicular accident reconstruction and injury causation related to vehicular collisions, one has to first understand the incident of interest in detail and then be able to communicate one's findings. While the analysis tools and associated methodologies may be well established in terms of the accident reconstruction in itself, the understanding and subsequent communication of the occupant motions and how this relates (or does not relate) to any claimed injuries may be more challenging. This cannot be accomplished easily from just "math and physics"; one often has to understand how a unique individual can interact with a geometrically-restricted environment (usually the vehicle interior) given the physics of that happened to the vehicle. While conducting such an analysis, it is important to appreciate the uniqueness of the event and not rely extensively on a "one size fits all" mentality[1,2]. In an ideal world, one places the claimant in the actual undamaged vehicle and

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literally recreates the incident, memorializing the process by some quantitative means. Such recreations are simply not possible for many reasons, including scientific, legal, ethical, and psychological points. However, a variety of investigative activities can still be conducted that move in this direction.

One such investigative tool that can be very useful in such analysis is the use of exemplar vehicles and surrogates. This approach will be explored as a way of facilitating such an analysis and the subsequent presentation of the analysis conclusions. The general effectiveness of such exemplar/surrogate studies has been noted by others (for example, Van Kirk[3]). The Accident Reconstruction (ARC) Network website (www.accidentreconstruction.com) presents case studies that employed exemplar/surrogate approaches. However, peer-reviewed publications of exemplar/surrogate methodologies is currently minimal. This approach is discussed below, including the motiviation to conduct such studies. To further illustrate the potential effectiveness of this approach, a number of actual examples will be presented that illustrate various aspects of this type of tool and the types of information and insights that may be provided to the investigator (and subsequently presented to others, including juries).

As already noted, the methodology to understand the physics of a vehicular collision is well established. Parameters such as impact speeds, change in velocity, principle direction of force, and other relevant parameters involving rates and accelerations (both linear and angular) can be estimated using a variety of commonly employed approaches. In a more complicated analysis involving a vehicle with extensive damage, the accident reconstructionist may incorporate the use of an exemplar vehicle. Van Kirk (2001) defines an exemplar vehicle as:

> *A vehicle of the same make, model year, and accessories that the collision vehicle had at the time of the accident. It is meant to represent as closely as possible the actual collision vehicle.*

Such exemplars are useful for a variety of situations, including assisting the accurate determination of crush deformation. Comparing the actual crash vehicle with the exemplar can be done using standard manual techniques or more sophisticated software products such as PhotoModeler (Eos Systems, Inc.). One must have sufficient information such as the VIN to establish the exact model of the crash vehicle. Then the investigator can use a variety of on-line approaches to locate an appropriate exemplar vehicle. Many dealers will provide easy access to their inventories (including used cars) via their web sites. Also, both dealers and private sellers may advertise on a variety of web sites such as AutoTrader.com and Yahoo! Auto. Such websites allow searches that are very specific geographically, i.e., the searches can focus on “local”. The ARC Network website provides a comprehensive list of such web sites and also includes exemplar vehicle location assistance providers. In locating a suitable exemplar vehicle, it is often advisable to consult the *Sisters and Clones* database to determine if any flexibility is present regarding the subject vehicle. For example, a particular model vehicle of interest may be a part of a production run that lasted several years, thus locating the same make/model may be easier since there is flexibility in the exemplar production year.

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The situation becomes more complicated when one seeks to understand injury causation issues related to vehicular collisions. In such situations, the use of an exemplar vehicle may be appropriate since the actual crash vehicle may be unusable due to extensive damage or may not be available at all. Lack of availability is unfortunately a common situation, reflecting the time frames involved (the actual vehicle was sold, scrapped, etc.) or legal obstructions (opposing counsel simply denies permission for any occupant studies using the actual vehicle). The use of a surrogate, basically a human "model" of the same gender and comparable body stature as the person claiming injury, may also be necessary since the actual person involved in the incident of interest may not be available due to legal constraints, extensive injury, or fatality. Again, the underlying principle is to obtain incident-specific and person-specific information as accurately as possible; recreating the actual event using an exemplar vehicle and surrogate model is certainly moving in this direction.

Information necessary to determine the needed surrogate characteristics (particularly height and weight) is usually available from medical records. In many crash scenarios, the height may be more critical than the weight since the ultimate issues may relate more to geometrical considerations. For example, in the analysis of a frontal collision and the relationship of seat belt usage (or lack thereof) to claimed injuries requires an understanding of the distances between anatomical reference points and vehicle interior surfaces. These distances are a strong function of the person's height and less dependent on weight.

In conducting any exemplar/surrogate studies, it is critical to understand in detail the physics of the collision of interest and any associated damage to the actual vehicle. Important factors include:

- Type of collision (frontal, rear-ending, lateral, etc.) and principle direction of force (PDOF)
- Detailed position, velocity, and acceleration histories, including vertical and/or angular (if relevant)
- Force of impact
- Extent of vehicle rotation
- Extent and location of compartmental intrusion
- Air bag deployments

Understanding such factors allows one to determine probable body movements in response to what is happening to the vehicle. Occupant kinematics simply cannot be explored in the absence of such information.

It is also critical to understand the occupant's positioning at the time of the impact of interest. Important factors include:

- Seat geometry (seat back angle, head rest positioning, etc.)
- Seat positioning (front/back)
- Positioning of upper and lower extremities, especially if one is focusing on the driver
- General body orientation at the time of impact

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It is also important to know if a restraint system were in use (or not). "General body orientation" may reflect preferences (as known) of the subject of interest. Some drivers rest one arm on some interior surface; some drivers keep their head close to the headrest. "General body orientation" also relates to "normal" positioning characteristics and so-called "out of position" characteristics. Some occupants were unaware of the impending impact and generally looking forward. The person may have been leaning to the left to observe oncoming traffic while in a right turn lane. The person may have been attending to a child in the back seat. Some front seat passengers rest their feet on the dashboard. Conducting an exercise that assumes "normal" seating position when the person was in fact out of position (or vice versa) will only be of limited use and may lead to the wrong conclusion.

Finally, one has to understand relevant details of the vehicle of interest. This often relates to interior design. It is usually the interior geometry as set by the vehicle construction in combination with the positioning of the occupant that establishes the possible extent of occupant trajectories in response to the accident vehicle dynamics. These trajectories may or may not involve possible contact with various interior surfaces or structures. An exemplar/surrogate study may identify possible contact points or demonstrate that such contacts are not probable under certain circumstances (often important in seat belt issues).

Other crash scenarios will require appropriate modifications and extensions. Examples of such scenarios are multiple impacts, situations where occupant-occupant contacts may be an issue; and roll-overs.

Figure 1
Exemplar/surrogate investigation of a frontal collision involving a seat belt issue. This involved a 45 mph impact with a PDOF of -10°; no compartmental intrusion was present on the passenger side. The female front seat passenger (5' 0", 105 pounds) sustained femoral head and acetabulum fractures. The female surrogate was 5' 0" tall and weighed 110 pounds. The claimant testified that she was restrained.

Application examples

Seat belt issues

For the first example, the occupant of interest (a front seat passenger) was in a vehicle involved in a 45 mph frontal collision, slightly from the left; the PDOF was -10 degrees. There was no significant compartmental intrusion on the passenger side. The occupant was a female who was 5' 0" tall and weighed approximately 105 pounds. She sustained left femoral head and acetabulum fractures, but no knee injuries. The basic question regards whether the seat belt was in use (plaintiff theory) or not (defense theory). An exemplar vehicle was located and a female surrogate 5' 0" and 110 pounds was recruited. The surrogate (unfamiliar with the purpose of the study) was instructed to position herself per her personal preferences in the front seat passenger seat; otherwise, no instructions were given. In this position,

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various measurements were obtained, including distances from the surrogate's knees to the dash (various locations) and distance from the ankle or toes with the leg fully extended to the firewall. Measurements were obtained with and without seat belt use. Figure 1 presents a view of the surrogate's "comfortable" positioning within the exemplar vehicle. The surrogate was later instructed to move the seat to the full back position and 3 other positions more forward to explore the influence of seat position variability (it was later determined that the surrogate's "comfortable" positioning closely matched the seat positioning from actual vehicle photos). As illustrated in Figure 1, there is considerable distance from the surrogate's knees to the dash (approximately 11-12 inches). Also, with the seat belt in use, the surrogate was unable to touch the firewall with her legs fully extended forward. It was concluded that the claimant's injuries were a direct result of lack of seat belt use; the documented injuries would most likely not have occurred had the claimant been using the available functional restraints.

For the second example, the occupant of interest (the driver) was in a vehicle involved in a 37-38 mph frontal collision, slightly from the left; the PDOF was -10 degrees. The vehicle was not equipped with an airbag. The collision caused 1-2 inches of compartmental intrusion on the driver's side (this included the dash moving inward). The driver was a male 5' 0" tall and weighed approximately 155 pounds. He experienced right knee injuries that required surgery; there were no other injuries. The driver claimed to have been using the restraint system, but put the shoulder harness behind him while driving due to a prior (unrelated) left shoulder injury. The issue: whether this "improper" use of the restraint system was related to the claimed injuries; the plaintiff theorized that there was no relationship; the defense theorized that the injuries were a result of the "improper" usage. In this case, the actual plaintiff was used in an exemplar vehicle along with a surrogate of the same height and 150 pounds weight. The surrogate (unfamiliar with the purpose of the study) was instructed to position himself within the vehicle as if he were the driver; no other instructions were provided initially (later, the surrogate was instructed to position the shoulder harness behind him as per the original incident conditions). Various measurements were obtained, including distance from knees to dash. Figure 2 shows one view of the study (this one involves the surrogate). The study was repeated using the claimant, who did not witness the earlier surrogate study. The surrogate positioning was very similar to that of the claimant. As indicated in Figure 2, the knee-to-dash distance is very short (1-2 inches). Considering that 1-2 inches of compartmental intrusion occurred, it was concluded that the "improper" usage of the restraint system had no bearing on the outcome.

Figure 2
Exemplar/surrogate investigation of a frontal collision involving a seat belt issue. This involved a 37-38 mph impact with a PDOF of -10° that caused approximately 2 inches of compartmental intrusion. In the actual crash, the male driver (5' 0", 155 pounds) used the lap belt, but placed the shoulder harness behind him while driving. Right knee injuries were documented. The male surrogate was 5' 0" tall and weighed 150 pounds.

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As a third example, the occupant of interest (the driver) was in a vehicle involved in a 29-31 mph far-side (passenger side) impact to the front passenger door area; the PDOF was 90 degrees. There was outside door crush, but no compartmental intrusion. The driver was a female 5' 3" tall and weighed approximately 125 pounds. The driver experienced a closed head injury that included a contusion to the top of her head; there were no other injuries. The plaintiff claimed to have been using the restraints. The defense theorized that no restraints were in use and that the injuries were a direct result of lack of use. An exemplar vehicle was located and a female surrogate recruited who was 5' 4" tall and weighed approximately 130 pounds. The surrogate (unfamiliar with the purpose of the study) was instructed to position herself within the exemplar vehicle per her normal driving positioning with the restraint system in use. She was then instructed to lean to her right (it was previously determined that the driver would move to her right as a result of the far-side lateral impact). Figure 3 presents a photo of this part of the study. As illustrated in the photo, the surrogate could not contact the passenger door with her head; the distance was approximately 16 inches top of head to door (it was also previously hypothesized that such head-door contact was the relevant injury mechanism). Conclusion: the claimant was not using the available functional restraints.

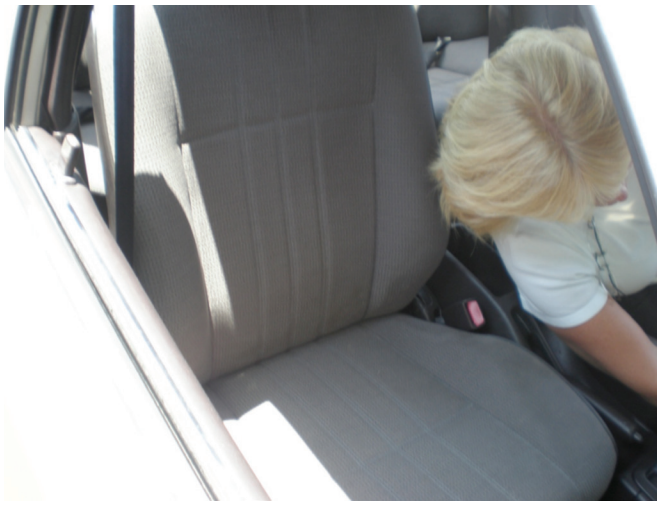

Figure 3
Exemplar/surrogate investigation of a far-side lateral impact involving a female driver (5' 3", 125 pounds) claiming to be restrained. The impact velocity was 29-31 mph with a PDOF of 90° (impact centered on the front passenger door, no compartmental intrusion). A closed head injury was claimed (a contusion to the top of the head was documented); no other bruising was observed. The surrogate was 5' 4" tall and weighed about 130 pounds. Her instruction was simply to lean to her right while restrained.

Rear end collisions

As a rear end example, the occupant of interest (the driver) was in a vehicle that was rear-ended while stopped (no subsequent impacts). The delta-v for the target vehicle was determined to be 2.2. – 2.4 mph and there was no offset. The restrained driver was a young male 5' 8" tall and ap-

Figure 4
Exemplar/surrogate study of a rear-ending of a stopped vehicle where the restrained male driver (5' 8", 165 pounds) claimed cervical injuries. The delta-v of the target vehicle was 2.2 – 2.4 mph; there was no offset regarding the bumper-to-bumper collision. The surrogate was 5' 8" tall and weighed 155 pounds. He was instructed to position the driver's seat as if he were the driver per his personal preferences while restrained.

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proximately 165 pounds. Cervical soft tissue injuries were claimed; no other injuries were involved. The claimant's counsel claimed that the injuries were causally related to this collision; defense counsel took the opposite viewpoint. An exemplar vehicle was located and a male surrogate recruited who was 5' 8" tall and weighed about 155 pounds. The surrogate (unfamiliar with the purpose of the study) was instructed to position himself as the driver per his preferences; no other instructions were provided other than to use the available restraints. Figure 4 presents a side view of the surrogate's positioning. As illustrated in the photo, the surrogate's head was actually resting on the headrest; the headrest itself, because of its general design, would easily prevent any significant extension movement of the driver's head/neck complex. It was concluded that no injury mechanisms for cervical injuries such as claimed were not established to any significant degree in this collision.

As a second rear-ending example, the occupant of interest (the driver) was involved in a rear-ending of a stopped van. The delta-v for the target vehicle was 4.0 – 4.4 mph and there was no offset. The restrained 56 year old male driver was a long-time construction worker who was 6' 5" tall and 245 pounds. Lumbar soft tissue injuries were claimed; no cervical involvement was claimed or documented in the post-incident medical records. The claimant's counsel claimed that the injuries were causally related to this collision; defense counsel took the opposite viewpoint. An exemplar vehicle was located and a male surrogate recruited who was 6' 5" tall and weighed about 220 pounds. The surrogate (unfamiliar with the purpose of the study) was instructed to position himself as the driver per his preferences; no other instructions were provided other than to use the available restraints. Figure 5 presents a photo of the exercise. It became evident that the van (the actual was a 1994 van) was equipped with a poorly designed seat in terms of head/neck protection; in fact, for all practical purposes, there was no headrest. This problem was exacerbated by the claimant's height. As the Figure 5 photo illustrates, the upper shoulders, neck, and head are forward from the seat back (2-3 inches at shoulder level) and the top of the seat is approximately shoulder level. Translation: the head/neck is basically unprotected in terms of any extension movements such as those typically observed in rear-end collisions. However, the same seat ("Captain's seat" style which has a reasonable amount of padding) maintains good lumbar region/seat contact, especially when the restraints are used. As noted above, it is curious that there were no cervical issues given the poor seat design and driver orientation. It was concluded that no injury mechanism for lumbar injuries of the type claimed were established to any significant degree in this collision.

Figure 5
Exemplar/surrogate study of a rear-ending of a stopped van where the restrained male driver (6' 5", 245 pounds) claimed lumbar injuries (no cervical issues). The delta-v of the target vehicle was 4.0 – 4.4 mph; there was no offset regarding the bumper-to-bumper collision. The surrogate was 6' 5" tall and weighed 220 pounds. He was instructed to position the driver's seat as if he were the driver per his personal preferences while restrained.

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Pedestrian-vehicle impact

As a pedestrian-vehicle example, a pedestrian claims to have been injured as a result of a BMW hitting him while the BMW was backing up in a valet parking zone (he was crossing behind the BMW, walking perpendicularly to the BMW backward movement). Witnesses estimated the BMW speed was about 3-4 mph, although descriptions of the pedestrian body motions during the impact were highly variable, including one witness testifying that he was "bumped" and otherwise kept on walking and one who said he was not hit at all. The 5' 11", 205 pound male claimed lumbar injuries as a result of being thrown onto the rear trunk decklid and contacting the rear windshield. No other injuries were documented, including any lower extremity issues. The claimant's counsel advocated for a direct relationship between this impact and the claimed injuries; defense counsel thought otherwise. An exemplar BMW was located and a 5' 11" male surrogate weighing 210 pounds participated in the study. Figure 6 shows a photo where the surrogate is standing sideways (this would be the claimant's approximate position in the actual incident) and just contacting the rear of the stationary exemplar BMW. As the photo shows: 1) the first contact would be between the bumper and the right knee area (no evidence of such contacts); and 2) the surrogate's center of gravity is at/below the level of the top of the trunk lid. Also, if the surrogate's right arm were "down", there may have been arm/vehicle contacts as well (again, no evidence of such contacts). The claimed movements and final positioning are not probable given the geometrical relationships as shown. It was concluded that the impact as described by the claimant was unlikely and that no injury mechanisms for lumbar issues as claimed were established to any significant degree.

Figure 6
Exemplar/surrogate investigation of a pedestrian-vehicle impact. In the actual incident, a BMW backs up at 3-4 mph and contacts a male pedestrian (5' 11", 205 pounds) who was crossing behind the BMW. The claimant testified that he ended up on the rear trunk decklid and also contacted the rear windshield, causing lumbar injuries (no lower extremity injuries or any other injuries were documented). The 5' 11", 210 pound surrogate was instructed to stand as shown while just touching the rear of the stationary BMW.

As a second pedestrian-vehicle impact example, a female claimed injuries as part of a relatively complex series of events (as described by the claimant). The plaintiff was initially the driver of a vehicle that rear-ended another vehicle, setting off a series of impacts involving vehicles that were ahead. These impacts all occurred within the inside lane of a multilane roadway next to a grassy median. The plaintiff exits her Cadillac Escalade, leaving the driver's door open approximately half way, and proceeds to move in the direction of the vehicles ahead that were involved in the collisions. While roughly even with the front tire of the Escalade (she's only a foot or so away from the driver's side of the vehicle), she claims to have been hit by a pick-up truck that was apparently driving around the accident vehicles, being thrown up onto the hood of her Escalade, then falling to the ground. There was no damage to

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Figure 7
Exemplar/surrogate investigation of a pedestrian-ve hicle impact. In the actual incident, the claimant (5' 8" 135 pound female) is walking along the side of her Cadillac Escalade after exiting the vehicle, leaving the door open. While at the approximate position as shown, she claims that a vehicle approached from behind and hit her, forcing her onto the top of the Escalade hood. She then fell to the ground. A closed head injury was claimed; no other injuries were documented. The 5' 8" 145 pound surrogate was instructed to stand as shown; no other instructions were given.

the Escalade other than the frontal damage due to the rear-ending. The 5' 8" 135 pound woman claimed a closed head injury; no other injuries were documented. None of the scene witnesses (there were many) saw the vehicle that supposedly hit the claimant; none saw any of the claimant's motions as described. Plantiff's counsel attributed the claimed injuries to the "phantom" vehicle impact; defense counsel had a variety of issues with the case, claiming that the impact never occurred at all. An exemplar Cadillac Escalade was located and a female surrogate recruited who was 5' 8" tall and weighed about 145 pounds. The surrogate (unfamiliar with the purpose of the study) was instructed to position herself next to the Escalade facing forward (this attempts to recreate the plaintiff's self-reported positioning); no other instructions were provided. Figure 7 shows a photo of this investigation. As the photo illustrates, there are many problems with the plaintiff's claim of what happened. This includes: 1) how the truck, approaching from behind, could contact her, given the door positioning; 2) how she could end up on the trunk of the Escalade given the height of the Escalade front hood relative to her center of gravity (the hood height is approximately mid-upper arm level); and 3) the total absence of injuries indicating a vehicle-body contact, body-roadway contact, etc. No experts presented supporting information on the plaintiff side. The case did not resolve very well for the claimant.

Discussion

A number of factors and issues should be considered by the investigator when conducting an exemplar/surrogate study, including:

- As possible, the surrogate should match the physical characteristics of the actual person, including gender, height and weight, although in many situations height is more important than weight.
- Surrogates should be unfamiliar with the purposes of the investigation, i.e., should not in any way be biased (therefore, helping to refute possible accusations of the overall study being biased). Any instructions should be clear and minimal. Using investigator staff, legal counsel staff, or others who may be interpreted as having a vested interest in the case may not be prudent.
- Extensive measurements should be conducted and documented using an appropriate protocol. The NHTSA crash test dummy documentation protocol employed in occupant crash protection research is one example (FMVSS Standard No. 208 testing protocol, form TP-208-S-1b). In parallel to such documentation, adequate photography documentation should occur.

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- Explore variability in key assumptions. As examples, if the seat positioning is uncertain, explore a range of seat positioning. If the degree to which the driver is turning to the right is uncertain, include a variety of body positioning in the investigation. Any uncertainty in the PDOF should be considered in exploring occupant kinematics.
- When securing access to exemplar vehicles (especially if the vehicle is otherwise on commercial property), it is important to provide a comfort factor to the vehicle owner that there are no ulterior motives to conducting the study (i.e., the dealership is not itself being investigated).
- Weigh your subjects using your scale and measure the height of your subjects using a stadiometer. Self-reported heights and weights are usually inaccurate. Also, driver's license information may be inaccurate or dated.
- Always maintain healthy skepticism, i.e., let the physical information guide your analysis, not your own preconceptions and biases. Sometimes what one thinks occurred did not. Sometimes new insights emerge from the investigation. Maintain objectivity and open-mindedness. The investigator is trying to determine truth, independent of the cause being represented.

As the application examples illustrate, conducting exemplar/surrogate studies can provide many insights into what may or may not have occurred in relation to an injury-causing event that involves a vehicle. Such investigations show strong motivation on the part of the investigator to really understand what happened (or did not) beyond simple "virtual" math/physics analysis. Such investigations are consistent with a "unique event, unique person" type of mentality, which is more scientific than a "one size fits all" basis. When such studies are documented photographically, subsequent communication of the investigation conclusions can be very effective.

References

1. Lee, W.E. III. Biomechanical analysis and injury causation: an individual-specific and incident-specific approach. 43rd Annual Proc. AAAM: 438-439, 1999.
2. Lee, W.E. III. Forensic engineering case analysis in biomedical engineering. J NAFE 24(1): 11-22, 2007.
3. Van Kirk, D.J. *Vehicular accident investigation and reconstruction* CRC Press, 2001.