VEHICLE ACCIDENT RECONSTRUCTION
"AN EXACT SCIENCE"
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Speed Evaluation

In vehicle accident reconstruction, the speed of the vehicle is often of primary importance. Speed becomes a factor because of its:

- legal significance relative to the posted speed limit,
- physical role in the damage to the vehicles and the injuries to the occupants,
- effects on the movement and maneuvering of the vehicles,
- effect on a driver's visibility, perception and response to the developing accident.

There are a variety of ways a reconstructionist can evaluate a vehicle's speed. Different mathematical formulas are used in these methods. While these may at first appear intimidating, the actual math is usually basic algebra and geometry. The formulas can be found in any of references 1-4 and information on data collection in references 5 and 6. The greater difficulty is understanding the underlying physics and deciding exactly how the equations are applied to a particular situation. Hopefully, you can gain some insight into the logic of the physics and some understanding of the type of information which the reconstructionist will need to perform an accident speed evaluation.

The evaluation of speed will usually be conducted with one or more of the following methods:

1. **Momentum/Energy Analysis**
2. **Damage/Energy Analysis**
3. **Centrifugal Force Analysis**
4. **Launch, Fall or Vault Analysis**
5. **Geometry and Timing Analysis**
6. **Event Data Recorders**

Each of the methods will be outlined briefly along with some of the restrictions and limitations.

1. MOMENTUM/ENERGY ANALYSIS

For our purposes, linear momentum can be defined as the vehicle ***weight*** multiplied by the vehicle ***speed*** in a certain ***direction***. The basic premise of a momentum analysis is that the linear momentum immediately following a collision is the same as the linear momentum immediately preceding a collision. Any momentum "lost" by one vehicle is "gained" by the other. The application of these principals can be observed in any billiard game. ***Each*** vehicle has a weight, speed, and a direction going into the collision and a weight, speed, and direction coming out of the collision. There are a total of 12 numerical values in the two vehicle, two dimensional momentum analysis. ***The analysis will solve for any 2 of the 12. All others must be assumed or evaluated by some other means.***

The typical linear momentum/energy analysis has the following phases:

- The reconstructionist must obtain the weights of the vehicles. Since, in most cases the weight of the vehicles will not change appreciably during the collision, this information is sufficient for 4 of the 10 required values.

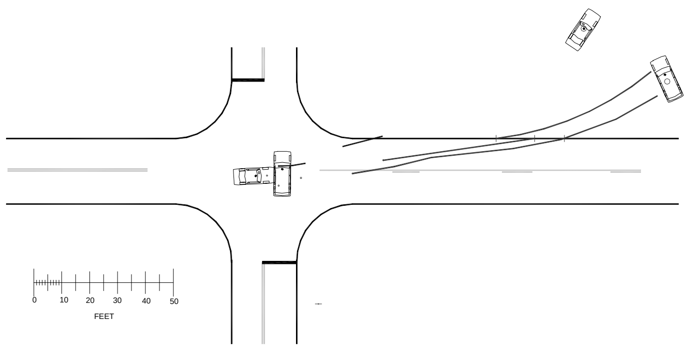
- The impact location and rest position of the vehicles is determined.

- The postimpact direction is obtained from the physical evidence, e.g. tire marks, gouges at the accident site or the general direction from impact to rest.

- The decelerations from impact to rest are evaluated. The evaluation is based on postimpact braking, rotation, terrain, contact with brush, etc. encountered from impact to rest. The postimpact speeds can then be determined from the evaluated decelerations and the travel distance to rest. This is the energy portion of the analysis.

- At this point, if the preimpact direction for both vehicles is "known", the momentum equations can be solved to yield the speed for each vehicle. Alternatively, if the incoming speed and direction for one vehicle is "known", the speed ***and*** direction for the second can be calculated.

- The final portion of the analysis is another energy phase (braking or skidmark length) which takes into account any preimpact deceleration.



Accidents where the momentum analysis has limited or no applicability include:

- head-on or rear end collisions (In these cases the analysis reduces to one dimension and can only solve for one unknown speed ***or*** direction.)
- collisions with fixed objects or between vehicles with large weight differences
- collisions where deceleration values cannot reasonably be determined
- collisions which are not short in duration such as sideswipe of a trailer

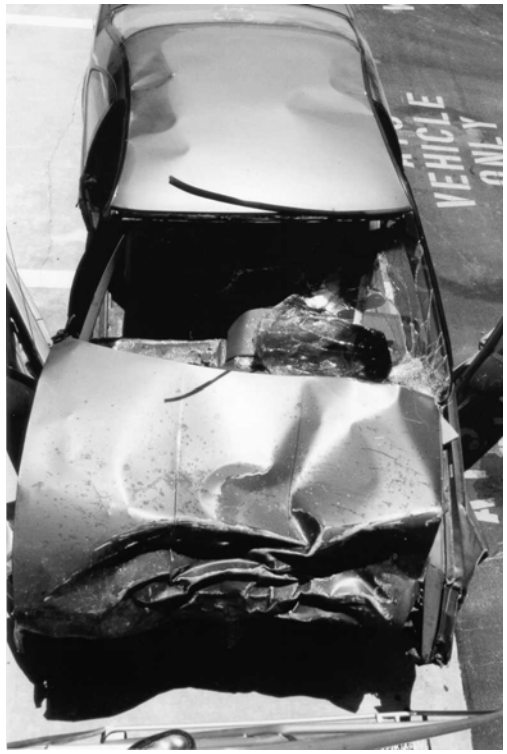
Although, it is not used as frequently, angular momentum is also conserved during a collision. Therefore, any angular momentum lost by one vehicle is gained by the other. The principles of angular momentum can also be observed in a billiard game. When "English" is imparted to a ball, it is given a spin. When it subsequently strikes another ball, some of the spin will be transferred to the struck ball. Also like "English" in billiards, angular momentum is more difficult to apply to reconstruction than linear momentum. There are two basic reasons for this difficulty. First, while linear momentum requires the weight of a vehicle, angular momentum requires the rotational inertia. Rotational inertia values are significantly more difficult to obtain than weights. In addition, the angular deceleration must be evaluated. Reasonable values for the rotational deceleration can be very difficult to obtain and usually require extensive computation. The easy way to handle the computation is with a computer and angular momentum is evaluated in some reconstruction software.

2. DAMAGE/ENERGY ANALYSIS

The basic premise in a damage analysis is that the forces causing the collision damage can be evaluated analytically by comparing the damage profile of the accident vehicle with the damage profile produced by a controlled test. Verification of the basic premise is well documented. The difficulties lie in three general areas.

a) Staged tests are usually conducted with a collision into the proverbial "brick wall". This produces a nice flat damage profile which is easy to measure. Real collisions may involve profiles which are more difficult to measure.
b) The vast majority of staged tests are frontal collisions at approximately 15, 30 or 35 mph. Real accidents involve a variety of angles and speeds. Impact areas are often on the side or rear where the comparison data is sparse.

c) Real collisions usually involve another vehicle. The data on staged collisions with another vehicle is also sparse.

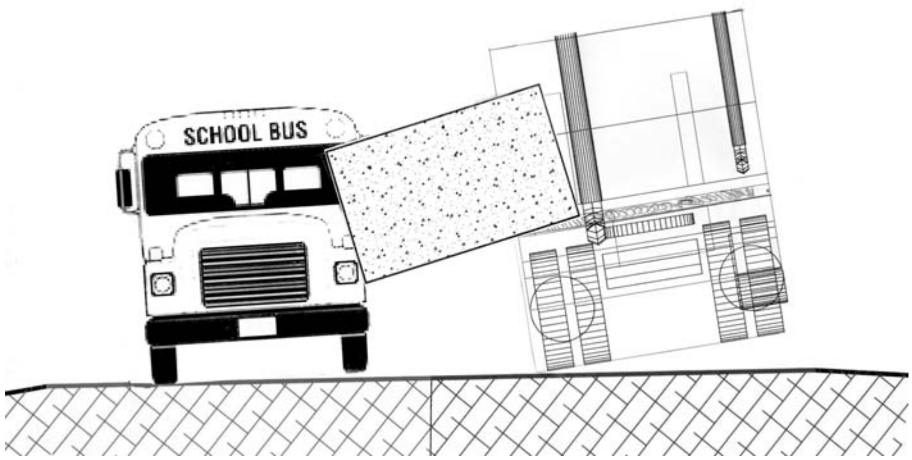


A good candidate for damage analysis

Even with these complications, analysis from damage data is often superior to the momentum analysis and has wider application. Damage analysis can be applied to collisions with fixed objects such as large trees or bridge columns. It is also very useful when analyzing collisions between automobiles and large trucks.

A point of considerable confusion over this type of analysis is that the damage analysis only evaluates the ***change*** in velocity (speed and direction) of a vehicle during the collision. The postimpact speed and the speed prior to impact must be calculated independently. Usually, these calculations are made with energy methods in the same manner as outlined for the momentum analysis.

2. CENTRIFUGAL FORCE ANALYSIS



The forces generated as the tractor trailer rounded a curve dislodged the load

Centrifugal forces are created whenever a vehicle is not traveling along a straight path. Therefore, this analysis technique is usually applied in accidents which occur on curves or as a result of evasive maneuvering. As a vehicle travels along a curved path, the centrifugal forces increase as the speed increases or the radius decreases. This type of analysis could be used for a truck overturn or to evaluate speed from "yaw marks". It is very useful for establishing a maximum speed around a curve. The important points to remember here are that steering, braking and suspension components can significantly effect the speed at which control is lost or a vehicle overturns. A sudden steering input can reduce the radius of the turn. It will also create a "weight shift" which may initiate an overturn. Braking will reduce the speed at which the tires begin to leave "yaw marks". Also, when braking is involved, it is important to distinguish between skidmarks which curve as a result of vehicle rotation and yaw marks which are created by lateral movement.

4. LAUNCH, FALL OR VAULT ANALYSIS

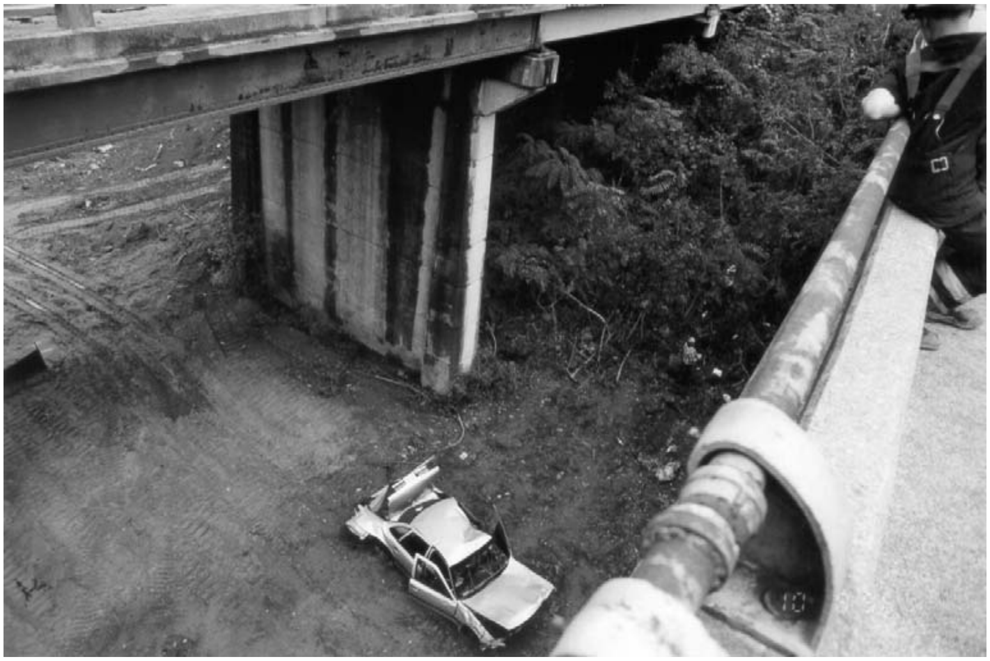
When a vehicle or an object loses support from the ground it is "launched". It then travels horizontally at the same horizontal speed at which it was "launched" until it "falls" back to the ground. The "fall" may start as an initial upward, level or downward movement.

These techniques are a favorite of the reconstruction schools. The principal reasons are: the equations can be readily set up and solved; the principles can be easily demonstrated and the solutions can be very accurate. Unfortunately, the amount of effort and time associated with the equations in the schools is far out of proportion to their actual utility in speed evaluation. Relatively few accidents involve significant "flights" of vehicles or objects. However, there are occasions where this type of analysis is useful. These include a) pedestrian impact, b) motorcycle/rider separation, c) vehicle travel over an embankment or into a body of water, d) travel over a ditch or a steep grade, and e) rollovers. The basis of the analysis is that once a vehicle or object separates from the ground, it will follow a ballistic arc while in the air. All that is required to calculate the speed at which it left the ground are:

- Identification (measurement) of the point where it was "launched" and the point it first contacted following the "fall". This provides the horizontal travel distance.

- Difference in elevation of the launch and contact points.

- The angle of launch.



A fall from this height is readily analyzed

As typically used, these equations make several assumptions which may influence the results. The equations ignore the effects of wind and air resistance. In most cases these effects will be negligible but they may be significant for very high speed accidents or objects which are not as dense as vehicles and people. A factor which will likely be significantly greater is the accuracy of the launch angle and the horizontal distance. If the vehicle left the ground while traveling over uneven terrain or as a result of contacting an object such as a curb or guardrail, the launch angle may be difficult to evaluate. Vehicle rotation and suspension movement can also effect the evaluation of the distance from launch to contact. These will be especially important if the horizontal travel is not several times the length of the vehicle.

5. GEOMETRY AND TIMING ANALYSIS

With the advent of antilock braking systems, the traditional momentum analysis combined with preimpact skidmark evaluation is not as reliable as in the past. Skidmarks from ABS are much fainter or non-existent. Analysts are relying more heavily on visibility and timing considerations to evaluate speed. To illustrate the application of these techniques, consider an accident in which an automobile driver rounds a curve and observes a pickup backed across the roadway. The driver of the automobile states, "as soon as he came around the curve, he saw the pickup, applied brakes and skidded to impact". If the automobile left 50 feet of skidmarks prior to impact, a momentum analysis could be used to determine the speed at collision and an energy analysis (skidmark length) to determine the speed at the start of braking. However, if the automobile had antilock brakes there may be little or no skids to measure. In this situation, the speed at impact could still be evaluated with a momentum analysis but the speed at the start of braking would have to be evaluated on the basis of the available visibility and the timing considerations of perception/reaction and deceleration.

You may note that it is appears the result will be less accurate than the analysis with the measured skidmark. However, it is possible that it will be more accurate. One of the principal problems with the skidmark is that, when it is present, it tends to become the controlling factor in the analysis. Many accidents involve significant braking before any skidding occurs. This results in a general trend toward the conservative evaluation of a vehicle's speed. If we reconsider the speed analysis with the skidmark and also perform a visibility and timing analysis, it may indicate that the driver of the automobile could have begun braking 125 feet prior to impact. Therefore, it could be concluded that the automobile was either traveling faster than the damage and 50 feet of skidmarks would suggest, or the driver was not paying attention as he rounded the curve. Visibility and timing considerations may therefore be important even in situations where there is sufficient information to evaluate speed by other methods.

6. EVENT DATA RECORDERS

Event Data Recorders were introduced into automobiles as a byproduct of airbag implementation. The airbag has to deploy in time to protect an occupant during a collision. A variety of sensors collect information which is processed in an electronic module. When some combination of the inputs exceeds the designated threshold, the airbags are activated. The systems are designed to retain portions of the input data in electronic memory. Following an accident, the automobile manufacturer can download the data. Some manufacturers are pursuing at least some public access to this information. Equipment to download and electronically interpret the data from General Motor's and some Ford vehicles is commercially available.

The type of information stored will depend upon the vehicle model and the nature of the accident. Useful information for reconstruction is unlikely in vehicles earlier than the mid 1990's. As an example, late model General Motors' vehicles store information on the engine speed, vehicle speed, brake status and throttle position for up to 5 seconds before the airbag deployment. The accelerometer data is converted to a delta V for the event. The status of the airbag warning indicator and the driver's seat belt is also included.

At the present time, the data available is relatively limited because of the small amount of electronic storage available in most of the devices. As with all things electronic, the storage capacity will likely increase rapidly. Other limitations are associated with the focus of the system on the airbag deployment. Frontal airbags are designed to deploy in collisions where the occupants would move forward relative to the automobile. The sensor data is concentrated on the detection of a frontal event. If the accident under consideration is a rollover, it is unlikely that the data would contain much useful information. Further advances such as side airbags require additional sensors which may provide more useful data for this type of accident.

Event Data Recorders are essentially storage devices for the measuring instruments the manufacturer has chosen. These can provide an accurate description of the accident. However, there are a number of limitations. The limitations include:

- Acceleration data is usually limited to the longitudinal axis, therefore the delta V's only reflect the component parallel to the vehicle.
- Because of the limited storage space, storage occurs at discrete intervals. What happened between the storage intervals could be important.
- The stored data is a reflection of the sensor readings. These may or may not be accurate. Bad sensors will give bad data.
- The sensor data may be accurate, but not a reflection of what is really happening to the vehicle. For example, the speed data would presumably come from the drive train. If a drive wheel left the ground it could provide a falsely high speed to the sensors.
- Much of the sensor data simply reflects an on/off condition.
- The devices are electronic with some mechanical interfaces.

Electronics can be influenced by age, contamination, deterioration, electromagnetic fields, etc. In most cases, this would produce no results. However, inaccurate results are possible. The results should be consistent with the other aspects of the accident. A traditional reconstruction is required to confirm or refute the recorded data.

SUMMARY

The techniques which were discussed will cover most of the situations encountered in accident reconstruction. There are other analysis techniques which may be applicable and appropriate for a particular accident. All of these also have their advantages and limitations. The general objective is to provide the best evaluation represented by the data, verify the result with other methods if possible and consider the reasonable range of the results. With a general understanding of the analysis and its limitations, you should be able to determine whether this has occurred.

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