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Application and Misapplication of Computer Programs for Accident Reconstruction

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ABSTRACT

Several computer programs are used by accident investigators to reconstruct motor vehicle accidents. These programs are seen as valuable tools by most investigators. However, it is also clear the programs are sometimes misused. This paper addresses five different types of computer programs used by accident investigators and discusses their proper and improper use. Most frequently, misuse is due to the lack of a thorough understanding of how the programs work. A series of recommendations is presented to help investigators properly use the programs.

MOTOR VEHICLE CRASHES are reconstructed by several types of agencies. For example, the federal government reconstructs accidents for statistical purposes and to fund or perform research on behalf of the general public. Vehicle manufacturers reconstruct accidents to help design safer cars and restraint systems. Insurance companies use consultants to reconstruct crashes to determine liability. And law enforcement personnel reconstruct accidents to determine if any laws were violated.

Computer programs have been used to analyze motor vehicle accidents since the early seventies [1,2,3]*. These programs were developed by large research institutes and were used by the engineers and scientists who developed them. With the introduction of the personal computer in the early eighties, these programs have become available for use by the general accident investigation community. Just as the level of skill varies among investigators, the level of understanding how the programs work also varies. When properly used, these computer programs are an invaluable accident investigation tool. When misused, these programs can produce erroneous results - and a misconception of what actually occurred during the accident.

All forms of analysis, including computer programs, can be misused. It is not the intent of the authors to criticize the programs or their users. Rather, the purpose of this paper is to describe how the various computer programs for accident reconstruction are used properly and improperly by field accident investigators. Although the number of programs described in this paper is only a portion of the total number of programs in use, many of the comments apply to other similar programs.

This paper begins by defining several types of programs, and evaluating each type separately. The evaluation includes the basic assumptions and limitations for each program, typical program applications, and ways in which the programs may be misused. The findings are summarized following the evaluation. Finally, a series of recommendations is presented to help investigators properly use the programs.

PROGRAM TYPES

Five types of computer programs have been defined and are currently popular within the accident investigation community. These types are:

- general analysis
- vehicle dynamics
- impact dynamics
- human dynamics
- photogrammetry

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*Numbers in brackets designate references at the end of the paper.

TABLE 1. General analysis programs.

BLAQQ BOXX [7]
C.A.A. System [8]
A-I-CALC [9]
C.A.R.S. [10]
COLLIDE [11]
CAR [12]

As with all forms of analysis, accurate input data are required to obtain accurate results. Proper data collection techniques are beyond the scope of this paper. The interested reader is referred to the literature [4,5,6] or a recognized training institute. A discussion and evaluation for each of the five types of programs follows.

1. General Analysis Programs

Several general analysis programs are shown in Table 1.

USE

These programs perform calculations, such as kinematics (position, velocity and acceleration as a function of time), conservation of energy, and conservation of momentum. The primary reason for using these programs is their ability to perform these important calculations quickly and accurately. The programs use particle dynamics; that is, the equations assume the motion can be considered to be a point mass. In addition, the acceleration is usually assumed to be constant.

MISUSE

The primary misuse of general analysis programs arises out of a misunderstanding of the application of the formulas they use. This section describes some of the more common misapplications.

The critical speed formula is frequently used because of its simplicity to determine how fast a skidding car was travelling while negotiating a curve. Implicit in the formula is the assumption that the vehicle is neither accelerating nor braking; cornering force is the only force present and causing tire marks. If accelerating or braking is present, the critical speed equation overestimates the speed.

Kinematic calculations are useful because they provide information about vehicle speeds. However, the equations used are general and can be applied to nearly any particle. Therefore, the programs expect a certain level of user understanding. For example, if given the wrong data, the equations will blindly compute things that are not possible, such as a vehicle acceleration of 41.3 ft/sec^2. It is up to the user to recognize that a problem exists.

The kinematic equations are also useful for estimating separation (post-impact) velocity, provided the vehicle travels a relatively straight path and does not rotate significantly between impact and rest and the deceleration is constant. If the vehicle rotates, the deceleration is normally not constant and the results may not apply.

The momentum calculations used in many of these programs assume the collision takes place in the first quadrant (that is, all scene measurements are positive). This assumption places a restriction on the coordinate system and may cause unchecked errors for some collision configurations. In addition, the equations are not valid for collinear (head-on and rear-end) collisions, and become extremely sensitive for near-collinear collisions. The user must insure the equations used by the program are valid for the particular collision configuration being studied.

The equations found in general analysis programs may be used to reconstruct an entire accident. However, because each of the formulas is used independently, there is no cross-checking between the equations. The compatibility checks between the impact and post-impact phase normally made by reconstruction programs (see *Impact Dynamics Programs*) are left up to the user, meaning the user must possess substantial skill and expertise to use these programs as a reconstruction tool. Inexperienced persons may reach erroneous conclusions.

2. Vehicle Dynamics Programs

Several popular vehicle dynamics programs are shown in Table 2. These programs vary in their level of sophistication, as indicated by some of the features shown in Table 2.

USE

Vehicle dynamics programs are used for studying the response of a vehicle to accelerating, braking and steering efforts by the driver. Accident investigators can use these programs to gain insight into how a driver may

TABLE 2. Vehicle dynamics programs.

Program Name	Load Transfer	Tandem Axles	Articulated Vehicles
EDSVS [13]	✓	✓	
EDVTS [14]	✓	✓	✓
SMAC [15,16]			
VTS [17]	✓		

have lost control of his vehicle as a result of excessive speed, braking, overcorrection, and other driver-related errors. The programs can also be used to study the general handling effects due to changes in friction, weight distribution, vehicle dimensions and other parameters. Since suspension effects (caster\camber change during jounce and rebound, dynamic wheel load related to unsprung mass, anti-dive suspensions) are ignored, the programs are most suitable for low friction regimes, where suspension effects are not as pronounced.

Vehicle dynamics programs are quite useful for illustrating how a vehicle will respond during over-correction and lane-change maneuvers. Thus, these programs frequently can be used to study the avoidability of an accident by evasive maneuvers.

An additional application for vehicle dynamics programs is the analysis of the post-impact phase of a collision, computing separation velocities. These programs will model the non-uniform deceleration caused by vehicle spinning between impact and rest.

All of these programs assume the vehicle is travelling over a flat, horizontal surface, although slight superelevations and grades may be analyzed by varying the friction coefficient. These limitations place restrictions on their use for research-oriented parametric studies. However, in accident reconstruction, where the primary goal is to illustrate what is possible and not possible by using a physical model, these programs are quite useful because their application is typically less rigorous.

MISUSE

All computer accident simulations have the useful property of being able to illustrate, using a physical model, what is possible and what is not possible. However, a single simulation should not be used as a basis to show the only way an event could have occurred. Several runs must be performed, changing the unknown or estimated parameters, to illustrate a range of possibilities.

Vehicle dynamics programs use a tire model to determine the lateral (cornering) forces as a function of vertical tire load, tire slip angle, coefficient of friction and the tire's cornering stiffness. The tire model assumes an inflated tire running on asphalt or concrete. If a tire is flat or debeaded, the model will over-predict the cornering force unless the coefficient of friction and cornering stiffness are greatly reduced. Unfortunately, there has been no study to provide recommended values for the parameters under these circumstances; the user must try a range of values to bracket the possibilities. For similar reasons, use of these programs must be restricted to hard surfaces; application to vehicles travelling on soft soil is untested and probably unjustified.

None of these programs is useful for studying the dynamics of a vehicle after it has rolled over. Since SMAC does not consider load transfer, rollover will not be predicted. However, VTS, EDSVS and EDVTS use a center of gravity (CG) height and quasi-static calculations (based on the current level of longitudinal and lateral acceleration) to compute the load transfer at each wheel. EDSVS and EDVTS will stop when a wheel lifts off the ground.

Application to accidents occurring on an unlevel surface may be permissible by varying the friction coefficient. However, a sensitivity analysis should be performed to confirm the effects of grade and superelevation. Use must not be extended to a vehicle driven into a ditch.

TABLE 3. Impact Dynamics Programs.

Program Name	Phases Analyzed		
	pre-impact	impact	post-impact
CRASH [18,19]		√	√
SMAC [15,16]	√	√	√
IMPAC [20]		√	

3. Impact Dynamics Programs

Three of the most popular impact dynamics programs are shown in Table 3. Although these models concentrate on the impact phase, some of them also analyze the pre-impact and/or post-impact phases as well.

USE

Impact dynamics programs are used for studying accidents which include vehicle-to-vehicle and vehicle-to-barrier collisions. The primary purpose of these programs is to estimate impact speeds and delta-Vs.

All of these programs assume the accident occurs on a flat, horizontal surface. However, they may be used for accidents occurring on minor superelevations and grades by varying the friction coefficients. A sensitivity analysis should be performed to confirm the effects of grade and superelevation. Load transfers and suspension effects are ignored, making them more accurate for low friction regimes.

All of these programs perform a significant number of lengthy calculations. However, the computer performs these calculations very quickly. As a result, the investigator is given the opportunity to make changes to the input and test the effect on the results. This *what-if* analysis makes these programs very powerful.

In many instances the program results may not apply directly to the subject investigation. However, it may still provide some valuable insight. This is where an experienced user can benefit from the use of the program without being led astray by it.

The following sections describe the individual programs, along with some of their applications and common misapplications.

CRASH - The purpose of CRASH is to estimate impact speed and delta-V for single and two-car collisions. It uses accident site and vehicle inspection data (impact and rest positions, tire/road friction characteristics and the vehicle damage profile) as input data. CRASH can be used to analyze multiple-car accidents by treating each impact individually, beginning with the last impact, and replacing the actual rest positions with *pseudo-rest* positions (the position where the vehicle would have come to rest had it not struck anything).

Several assumptions are made by CRASH, the understanding of which is essential if the program is to be used properly and effectively. These assumptions include:

- Flat, horizontal surface
- No load transfers during acceleration
- No driver control (active steering and braking)
- Linear exterior crush resistance
- Vertical uniformity of damage profile
- No sideswipes
- Negligible tire force during impact
- Typical vehicle data (some programs)
- Negligible restitution

The extent to which each of these assumptions affects the results must be evaluated on a case-by-case basis. When in question, a sensitivity analysis should be performed, varying the parameters of interest to determine the effect on the results.

A sensitivity analysis should be performed routinely to identify that information which, if varied slightly, can greatly affect the results. For example, in the case of a car making a left turn in front of an oncoming car, the speed estimate of the turning vehicle is normally quite sensitive to a slight heading change of the oncoming car. Conversely, the speed estimate of the oncoming car is insensitive to its heading change. This type of sensitivity analysis can be used to evaluate other input parameters, such as vehicle weights and moments of inertia, friction coefficients, wheel lockups, steer angles and path data (end of rotation and point on curve).

SMAC - The purpose of SMAC is to produce an accident simulation according the laws of physics. The program uses the investigator's estimates for the initial vehicle speeds, along with vehicle data, tire/road friction data, and driver control (acceleration, braking and steering) tables. The output is a simulated vehicle trajectory and damage profile for each vehicle. The objective is to find a set of initial speeds which produces the best match between the simulated and actual vehicle trajectories and damage profiles.

The resulting graphic output is used to illustrate an entire accident sequence. The trajectory data may also provide the basis for a general purpose graphical animation program (any animation not based on physics must be considered simply a cartoon).

One of SMAC's most useful applications is theory-testing. If one person believes an accident took place a certain way, while another person believes it took place a different way, both scenarios can be simulated. The scenario which produces the trajectories and damage most similar to the actual trajectories and damage is most plausible.

Several assumptions are made by SMAC which must be understood if the program is to be used properly. These assumptions include

- Flat, horizontal surface
- No load transfers during acceleration
- Linear exterior crush resistance
- Vertical uniformity of damage profile

The extent to which each of these assumptions affects the results must be evaluated on a case-by-case basis.

IMPAC - The purpose of IMPAC is to estimate delta-V for two-car collisions. It analyzes only the impact phase. It is similar to CRASH, in that it uses scene data as input. Like SMAC, it requires estimates of initial speeds as input data and uses these estimates to predict the separation conditions (velocity and direction).

Other assumptions made by IMPAC which must be understood if the program is to be properly used include:

- Negligible tire force during impact
- 2-dimensional motion
- Negligible restitution

The extent to which each of these assumptions affects the results must be evaluated on a case-by-case basis. When in question, a sensitivity analysis should be performed, varying the parameters of interest to determine the effect.

MISUSE

Impact dynamics programs are quite useful for studying motor vehicle collisions which, by their very nature, are extremely complex. These programs may also be the most misused. Again, the reason is often due to a lack of understanding about how the program works.

Each of these programs requires a substantial amount of accident site and vehicle inspection data. However, this same data is required for *any* reconstruction, regardless of the analytical technique. Some of this data is directly measured and some of it is interpreted. Data that must frequently be interpreted includes impact position, heading angle and sideslip, path between impact and rest, wheel braking, and some types of damage profiles. Misinterpretation of field data always affects the results to some degree. The investigator must interpret the data correctly.

Much of the vehicle data used by investigators comes from tables. However, table data assumes a typical vehicle. The extent to which a subject vehicle varies from the norm must be considered. For example, the listed curb weight should not be used if the vehicle was carrying five passengers and a trunk load of baggage. A good analysis requires good data. Errant or poorly estimated data always affects the results.

In some catastrophic collisions, a struck vehicle may actually break in two. Under these circumstances, none of these programs should be applied. The CRASH and SMAC stiffness coefficients are no longer valid, causing an overestimation of the delta-V. Similarly, the momentum equations used by CRASH and IMPAC, which assume two vehicle masses, not three, are not valid and the momentum-based results are erroneous. These programs are best-suited for studying collisions in the tested range for delta-V, approximately 10 to 40 mph. Results outside this range may be suspect.

Another potential misapplication is their use for articulated vehicle collisions. None of the validated programs accounts for the articulation degree of freedom. The effects of ignoring rotation about the kingpin may be significant and must be evaluated on a case-by-case basis.

Truck accidents must be handled with extreme caution. Although the physics may be correct for car vs truck collisions, potential problems exist. In situations where one vehicle outweighs the other by a factor of 10 or more, analysis will reveal the impact speed of the lighter vehicle is extremely sensitive to the scene and crush data.

The terrain boundary option is a useful feature of CRASH and SMAC. However, the boundary location is sometimes specified incorrectly. Users of CRASH should be aware that the specified boundary points actually result in *two* boundaries. One is specified directly by the entered points. The second is a mirror image of the first, but reflected about the X axis. After crossing the second boundary, the friction coefficient returns to its original value. (EDCRASH [19] and EDSMAC [16] have no second boundary.)

Another situation involving the terrain boundary arises out of a misunderstanding of the terms *primary* and *secondary* friction coefficient. The primary coefficient applies to the side of the boundary which contains the *origin*. The original program documentation has led some to believe that the origin is taken to be the initial location of the vehicles. This is not true. This origin refers to the origin of the earth-fixed axis system. Care must be taken to insure that the primary and secondary friction coefficients are properly selected.

The following section describes some of the more common misapplications of the individual programs.

CRASH - The CRASH program is a very useful program. However, it may also be the most misused, primarily because it is not fully understood by many of its users. Some of the more common misapplications are described below.

Investigators sometimes measure the damage profile for a specific vehicle and use CRASH to compute its delta-V by assigning the other vehicle as a barrier. A correct value for the damage-based delta-V requires entering the weights and damage profiles for *both* vehicles; otherwise, instead of obtaining the delta-V during the actual crash, the investigator calculates the delta-V which would have occurred if the vehicle struck a barrier (i.e., the equivalent fixed-barrier speed).

The combined speed formula (square root of the sum of the squares) is frequently used to compute the impact speed when the energy lost by sliding from impact to rest and the energy lost during impact are known. Some investigators have used the delta-V from CRASH in the equation as follows:

$$V_{impact} = \sqrt{V^2_{sep} + \Delta V^2}$$

This is a misapplication of delta-V. In the above formula, the equivalent fixed-barrier speed should be used instead of the delta-V.

In some less severe collisions, the driver may still be in control of his vehicle after a crash; he may actually drive (accelerate, steer and brake) his vehicle to its rest position. Any program, including CRASH, which does not consider driver inputs between separation and rest is not capable of handling this situation. Users should be aware of this possibility when investigating minor collisions.

Another problem lies with the virtual nonexistence of crush stiffness coefficients for trucks. Obviously, a typical truck exterior is very non-homogeneous and, therefore, may have grossly different stiffnesses at various locations. If CRASH is used, the most conservative assumption is to ignore the damage profile on the truck (i.e., assume it acts like a movable barrier and absorbs no energy).

Truck collisions frequently result in a phenomenon called bumper over-ride, wherein the damage is confined to the area above the bumper and other structural (frame) members. This results in an overestimation of damage energy. The stiffness coefficients should be reduced to account for over-ride. However, no research has been published which specifies the amount of reduction. In car-to-car collisions, the coefficients can be reduced until the magnitudes of principal force can be equalized. If the other vehicle is classified as a movable barrier, its principal force is not computed. Instead, it is automatically set equal to that of the other vehicle. When analyzing these collisions, a wide range of stiffnesses should be used to obtain the possible range of values.

The physics are sometimes incorrect for car vs unit (i.e., non-articulated) truck collisions because the tire force of the truck may not be insignificant. Consider the case where the truck weighs 50,000 pounds. The tire force may easily exceed 30,000 pounds, depending on the direction of impact. Yet the maximum impact force may actually be *less* than the tire force. The investigator must consider these factors on a case-by-case basis.

CRASH is useful for pole impacts, providing the pole did not break off. The pole is categorized as an immovable barrier. When measuring the vehicle's damage profile, induced damage should be included. Otherwise, the damage energy may be underestimated.

When CRASH is used for rollover accidents, the rolling resistance at individual wheels is meaningless, and this option should not be selected during the input session. Similarly, rotating and lateral skidding should not be specified because the empirical coefficients used by that procedure are based on test data which assume the vehicles remain on the ground. Under these guidelines, when used to study rollovers, CRASH simply uses the popular energy equation which assumes a constant deceleration between impact and rest. A proper estimate for the level of deceleration is critical for obtaining the correct separation velocity.

Another common misapplication of CRASH is misinterpretation of rolling resistance data. When table values for rolling resistance, such as those found in Taborek [21], are used, the values must first be divided by the coefficient of friction. However, the program also allows the user to interpret these data as percent of wheel lockup. Using that interpretation, the values should be entered without dividing by the coefficient of friction. The reason for this requirement becomes clear when one looks at the rollout equations [22]. The effect is small for dry roads, but can become significant for icy roads.

The following misapplications have also been found to reduce the integrity of the results:

- Use of default vehicle data instead of actual (measured or test) data
- Changing the weight without making a similar change to the yaw moment of inertia
- Increasing or decreasing wheel lock-ups without physical justification
- Using a point-on-curve without physical justification (i.e., accident site evidence)
- Use in cases involving severe override (damage confined above the belt line).
- Use in motorcycle and bicycle collisions
- Use in vehicle vs livestock collisions
- Use for accidents covering grossly unlevel terrain

SMAC - Misuse may involve a characteristic common to all simulation programs: A single simulation may not describe the *only* way an accident could have occurred. Experience has shown that it is sometimes possible to create vastly different scenarios by making small changes in the input data. A range of results should be presented.

Because SMAC expects all forces to be applied at the wheels after separation, it cannot be used to study rollover accidents.

SMAC uses driver input tables to simulate control (acceleration, braking and steering). These data must be correctly entered. Experience has shown that data entry errors or failure to understand how the tables work can lead to errant results.

SMAC is generally not useful for pole impacts. This is an algorithm limitation, associated with how inter-vehicle forces are computed. The resulting error may be small for minor collisions but becomes very significant as penetration of the pole increases.

The SMAC algorithm is not well-suited to barrier impacts because the depth of the barrier's damage profile is nil. SMAC becomes unstable when barrier stiffnesses (i.e., 10^6 lb/in^2) are entered. Users can get around this problem by entering stiffnesses on the order of 10^3. However, care and experience must be exercised in order to obtain valid results.

The physics in SMAC can be applied to unit truck collisions. Like CRASH, however, two potential problems exist with the stiffness coefficients. The first problem is the lack of stiffness data for trucks. The second problem is its non-homogeneous exterior. When SMAC is used for truck collisions, it is recommended a broad range of stiffnesses be used to test the effect on the results.

The following misapplications have also been found to reduce the integrity of the results:

- Use of default vehicle data instead of actual (measured or test) data
- Changing the weight without making a similar change to the yaw moment of inertia
- Increasing the integration timestep for the collision phase in order to speed up calculations (this is only recommended for preliminary runs)
- Increasing the inter-vehicle friction beyond its normal range
- Increasing or decreasing wheel lock-ups without reason
- Use in vehicle vs livestock collisions
- Use for accidents covering grossly unlevel terrain
- Not entering the smaller vehicle as vehicle no.1

IMPAC - Because the scope of analysis is limited to the impact phase, the IMPAC program tends to be misused less than other impact dynamics programs. However, the program does have some specific limitations. These are described below.

IMPAC requires good scene data as a consequence of its dependence on linear and angular momentum. It cannot be used to analyze a collision where only damage data are available.

The center of impulse must be estimated by the user. This point will influence the separation conditions, especially the angular velocity. This point is difficult to identify with precision. A range of values should be entered to identify the effect on the results.

Sideswipes can be handled by IMPAC. However, special parameters must be supplied. Specific data are lacking and these parameters are difficult to estimate. A wide range of values should be tried in order to establish the range of results. Using this procedure, the range may become very broad, thus placing a practical limitation on the use of the sideswipe feature.

When using IMPAC, the goal is to match the computed separation conditions (velocity, departure angle, crush energy) with those estimated using another means. Thus, if the basic estimates for separation velocity and/or crush energy are incorrect, the IMPAC results will be incorrect.

Investigators may focus on matching only the results of interest, ignoring other results. IMPAC will only produce correct results when *all* the target separation conditions match.

Like CRASH, or any program which ignores tire forces during impact, the physics are simetimes incorrect for car vs unit (i.e., non-articulated) truck collisions because the tire force of the truck may not be insignificant. The investigator must consider these factors on a case-by-case basis.

The following misapplications have also been found to reduce the integrity of the results:

- Use of the incorrect radius of gyration
- Use in motorcycle and bicycle collisions
- Use in vehicle vs livestock collisions

4. Human Dynamics Programs

Two human dynamics programs are shown in Table 4. These programs vary according to level of sophistication. Although not currently in widespread use, application to litigation involving the non-use of safety belts is likely to increase their popularity.

USE

Accident investigators can use these programs to determine how vehicle occupants and pedestrians become injured during impact. Occupant injury studies include the effect of interior design, the use or non-use of restraint systems, and the effectiveness of headrests. For pedestrian collisions, human impact simulators can be used to estimate throw distance for a given impact speed, as well as injury studies related to vehicle exterior design.

Human impact simulators use an impulse profile to describe the vehicle environment during the crash. CRASH and SMAC can provide this impulse. The profile from CRASH is very idealized and is not highly recommended for use in human dynamics programs. The SMAC profile, while still rather idealized in comparison to oscillographic traces from actual crash tests, provides a more realistic pulse shape.

TABLE 4. Human dynamics programs.

Program	Dimensions	Body Segments
MVMA-2D [23]	2	9
CVS-3D [24]	3	∞

MISUSE

Human dynamics programs have a characteristic common with all simulations: They normally do not describe the *only* possible outcome of an accident. Small changes made to any of the large number of estimated properties can cause significant changes in the results. Therefore, their use should be limited to parametric design studies and general illustrations of injury-producing mechanisms for forensic accident reconstruction. Detailed forensic injury studies are usually beyond their useful scope.

Another application beyond the useful scope of human dynamics simulations is the determination of who was driving in a complex rollover accident based on the rest positions of the victims within the vehicle. The applicability of a human impact simulation to a particular accident should be tested using a sensitivity analysis.

The accuracy of the simulation depends not only on the accuracy of the vehicle and occupant data, but on the accuracy of the impulse as well. If SMAC is used to generate the impulse, a thorough analysis of the human simulation will also require a thorough analysis of the impact simulation to insure the results are valid. Any other means of estimating the impulse must likewise be scrutinized for suitability to the particular accident.

5. Photogrammetry Programs

Four popular photogrammetry programs are shown in Table 5. The level of sophistication among these programs varies by the amount of analysis they perform on the data.

USE

Photogrammetry programs are used for locating information, such as skidmarks, debris and vehicle positions, from accident site photographs. To use photogrammetry, good photographs are required. The investigator matches the measured X,Y coordinates of four points found at the site with those same four points visible in the photograph. These four points, called calibration points, must be carefully selected to provide accurate results. In particular, no three points can lie on a straight line.

TABLE 5. Photogrammetry programs.

Program	Analysis? (Y/N)
TRANS4 [25]	Y
FOTOGRAM [26]	Y
AICALC [9]	N
EDCAD [27]	N

MISUSE

Successful photogrammetry requires that the calibration points be carefully selected. In particular, three of the four points must not lie on a straight line. Even if the points lie close to a straight line, the results will be extremely sensitive to small errors. For best results, the four points should surround the location of interest (debris, etc.).

The calibration points and all other points of interest are assumed to lie in the same plane. Misuse of photogrammetry arises most frequently from its application to non-flat surfaces. Potential problems include crowns and superelevations, elevated curbs and depressed ditches. One cannot place a limit on the permissible amount of crown, superelevation, or curb height, because the error may be small for a location 10 feet from the photographer and extremely large for another location 50 feet further away. Even those programs which analyze the data and provide an error estimate assume the error occurs on a flat road. To provide a basis for its use, the investigator should check the accuracy of his photogrammetry by comparing the results for a fifth point with its measured location. Without such a cross-check, there is no way to assess the validity of the results for a certain application.

The accuracy of photogrammetry is reduced as the location of interest moves farther away from the photographer. The effects of the loss of accuracy should be included in the analysis by using a range of values for the specified location. When there is a question, an assessment of accuracy should be performed. If necessary, additional (closeup) photographs should be used.

SUMMARY OF FINDINGS

The validation studies performed on computer programs used in accident reconstruction reveal they can provide accurate and useful results when used properly. However, the programs can be misused.

Good results are obtained when the programs are carefully used by trained professionals who understand how the programs work and use them accordingly - paying attention to programs' assumptions and limitations.

Most misuse is inadvertant, and often is due to a lack of understanding about the programs and the data they use.

No computer program should be considered as a black box which anyone without training can use to consistently obtain correct results. The skill of the investigator is an essential element in obtaining useful results with all computer programs. Investigators should carefully and thoroughly review the documentation and available literature which describes the calculation procedures before beginning to apply the program to field cases.

Misuse often arises when the investigator tries to compensate for missing or incorrect information, or for some important detail which has been overlooked.

RECOMMENDATIONS

The following recommendations have been developed to help accident investigators properly use the various computer programs for accident reconstruction:

1. **Understand the program** - Review the technical literature which describes the program *before* using it on individual cases. Training seminars help in this regard.

2. **Use it within its intended scope** - Do not apply the program to collisions that include significant factors not considered by the program.

3. **Run a series of analyses** - Test for potential sensitivities to determine how small measurement errors affect the results.

4. **Present the results as a range** - Use the series of analyses to show *all* the possible outcomes.

5. **Confirm your findings** - Whenever possible, do not rely upon a single means of analysis. Cross-check your findings through the use of independent methods.

6. **Present your results to a peer** - Unintentional misuse is frequently uncovered by a peer review of the analysis. During such a critical review, the application of the program to a specific accident is challenged to help insure the program assumptions are not violated, the input data are correct and results are applicable. Such a corroboration of the analysis is always valuable *before* writing a report or giving oral testimony.

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