A motor vehicle accident causal system, from a human factors viewpoint, is presented. The system, or model, is based upon a cause and effect relationship: the "effect" being the primary failure or behavior which led directly to the collision situation; the "cause" being the reasons for the failure or behavior. Effects are described as information-processing failures of four types: (1) perception, (2) comprehension, (3) decision, and (4) action failures. The reasons for these information processing failures are categorized as (1) physical or physiological failures, (2) driver conditions or states, (3) experience or exposure factors, (4) conflicting behaviors or preoccupation, and (5) risk-taking behaviors. A causal reporting system for utilization by accident research groups is discussed in terms of primary or principal causes, severity-increasing factors, and relevant conditions. Two recent studies which used similar causal systems are described and findings from them are presented. A discussion of the possible benefits of such a system as results emerge is related to driver education and training techniques.

INTRODUCTION

The study of motor vehicle accidents has been ongoing almost since the inception of the automobile itself (Eames, Lee and Fell, 1970). From official police investigations and insurance reports to professional teams of researchers, a wealth of data has been gathered on accidents and on their supposed "causes". Reported causes such as alcohol, speeding, slippery roads, and vehicle defects have all been discussed frequently in the highway safety literature (Little, 1966; MacFarland, Moore, and Warren, 1955). Except in a few studies, investigation and reporting techniques or models have not been sufficiently developed nor applied in a way that would consistently determine the real, direct causes of motor vehicle collisions. How does alcohol itself cause a crash? Why is speeding considered a cause? More is needed to complete the picture of the collision situation in order to determine the direct failures in the system that produced the crash. With the exception of Baker's manual (1963) and a few research methodology reports (Fell and Tharp, 1969; Perchonok 1969; Tharp and Garrett, 1968; Treat and Joscelyn, 1971), the development of accident causal schema, as applied to accident investigation studies, has been limited. This paper, from the human factors standpoint, is an attempt to present such a scheme for accident investigation research studies.

Two similar causal systems or models which have been recently applied to produce significant results have been reported by Perchonok (1972) and the Institute for Research in Public Safety (1973). Perchonok's model (1969) was influenced by the Fell and Tharp (1969) methodology report, which was also the basis for the latter model development (Treat
and Joscelyn, 1971). This paper attempts to integrate and develop the best aspects of both models and more recent needs in the state of the art.

STATEMENT OF THE PROBLEM

In one national research program, professional multidisciplinary accident investigation teams, sponsored by the National Highway Traffic Safety Administration, prepare their in-depth case reports of accidents with a summary which gives identification information, briefly describes the accident, and lists the accident and injury causal factors for the case. Guidelines for both determining and reporting the causal factors (and appropriate recommendations) have been minimal, resulting in a wide variety of interpretations and language. All causal factors are classified according to a 9-cell highway safety matrix (Fell and Lee, 1970) which merely indicates what element of the system is involved (human, vehicle, or environment) in relation to the phase of the collision it is affected by (pre-crash, crash, post-crash). Other than these guidelines, factors are reported in a language determined by the individual teams, with little or no indication as to the extent of relevance of the factor or where the factor pertained to the sequence of events. This paper will deal only with the human pre-crash element of a collision, and is an attempt to define valid and consistent guidelines for reporting such factors. Once consistency in reporting is attained, valid data analyses can be performed with direct application to highway safety countermeasure programs.

APPROACH TO THE PROBLEM

The following is one approach to an accident causation system relative to the human elements involved (i.e., human pre-crash factors which contributed to the initiation of the collision). The system is based upon an analysis of the cause-and-effect relationships that form the last major link in the chain of human factors and events that lead to an accident. An “effect” is the primary failure, non-performance, or behavior which led to the collision; a “cause” is the factor or event that is the immediate reason for the failure, non-performance, or behavior. An example of a human causal chain is shown below along with similar chains for each major highway system element involved in a hypothetical crash.

Human Causal Chain

- Man fights with wife
- Late departure for work
- Aggressive driving
- Driver speed too fast for conditions
- Speed too fast for conditions
- Driver did not immediately comprehend danger of slower vehicle ahead around curve

Vehicle Causal Chain

- Faulty inspection
- Worn brakes not detected
- Worn brakes
- Increased stopping distance

Environmental Causal Chain

- It was raining
- Wet roadway
- Wet roadway
- Lower coefficient of friction on roadway

Human + Vehicle + Environmental Causal Chains = CRASH.

The system described in this paper will concentrate on human causes and human effects (i.e., vehicle and environmental factors that induce, produce, or combine with human effects will not be discussed in depth—but only to the extent necessary to show key interactions). Also, note that within a causal chain, effects (e) serve as the cause for the next step in the chain, and that between causal chains, the last “effect” (E) is considered to be one of the major factors in the overall chain of events leading to a crash (i.e., the last, or most immediate, ef-
fects (E) in the causal chains become the "causes" of the accident. The causes (C) (or reasons for) those last effects in the chain become the major or relevant conditions in the accident.

Effects

The human element in a traffic situation (be it a driver or pedestrian) is basically a processor and user of information. Information is constantly being fed to the human operator; he processes the information, makes decisions, compensates for conditions, and performs physical acts (Cumming, 1964). He is the most active and vital element in the driving situation (see Figure 1). When a critical situation arises (i.e., a collision course or its situational equivalent), the operator usually detects some information which alerts him to that situation and he compensates for it to avoid an unwanted collision. If he receives no information, ignores the information, makes an incorrect decision based upon the information, or acts incorrectly, a collision becomes imminent. Therefore, the "effect" of the human situation in driving is dependent upon how well the driver processes the pertinent information signalling him that he is on a so-called "collision course", and how he responds to that information.

Since we are dealing with human accident causal factors, the "effects" will be information-processing failures or nonperformances. Human information processing can be conveniently described as four distinct, yet interrelated, processes (Welford, 1960; see also Figure 1 adapted from Tharp, Calderwood, Downing, Fell, Garrett, and Mudrowsky, 1970):

1. Perception (sensing the information),
2. Comprehension (understanding or recognizing the information),
3. Decision (making a decision based upon the information), and
4. Action (performing some physical action based upon the decision).

In a traffic accident situation, these four

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**Figure 1.** The driver/vehicle/environment information flow in the driving task.
processes can be involved in an information failure in the following manner.

Perception (sensing; detection). The operator simply does not receive the danger signal or stimulus. It does not fall upon his senses, and so is not detected. In the visual mode, where more than 90% of the information used in driving occurs (Gioia and Morpeth, 1968), the signal is not in his field of view or it is blocked from his field of view. In the auditory mode, the stimulus is not heard or is physically not discriminated from other ambient noise (i.e., it is below the stimulus threshold). An example would be simply not looking in the direction of the other vehicle's approach. Another would be not "hearing" the ambulance's siren due to the vehicle windows being closed and the radio playing.

Comprehension (recognition). The signal or stimulus is within the sensing range of the operator, but for some reason he does not process the information as a danger signal. Examples of this failure involve too many stimuli bombarding the operator at one time, or a recognition failure due to a physiological defect such as visual acuity (e.g., he could not read the road sign). The information or stimulus falls upon the operator's senses, but is not recognized or comprehended as relevant to the situation.

Decision. A processing failure occurs here when the operator receives the signal, properly processes it (i.e., recognizes it), but makes an incorrect decision in his attempt to compensate for the danger. Examples would be making no decision at all (panic), blowing the horn instead of braking, misjudging the speed/distance of another vehicle, braking instead of attempting to steer, etc. The signal is perceived (detected) and comprehended (recognized) as danger, but an incorrect decision or judgment is made based upon it.

Action. This failure occurs at a point after the signal is received, comprehended, and a reasonable or proper decision is made. The operator merely physically acts or performs incorrectly. Examples here include a lack of action after a certain decision was made (again a "choking" or panic situation, but at a different point), an overreaction (oversteering), or an incorrect action physically (missing the brake pedal or the horn button).

Although not fully discussed in this paper, a vehicle-related "effect" would be a brake failure, wheel failure, tire failure, etc., that led directly to a collision. An environmental "effect" would be a bridge collapsing, a tree falling in the roadway, etc., that directly causes a collision.

Causes

Reasons for the above information-processing failures vary considerably. Certainly many reasons involve vehicle, highway, and ambient conditions. These, however, will not be dwelled upon here. Only human "reasons for" or "causes" will be described.

In a theoretical cause-effect relationship, the cause directly produces the effect, and the effect has a direct cause. In the real world of determining accident causation, many times the relationship will not be completely uncovered. The effect may be determined, but the cause may not be detected. Conversely, several causes may be discovered without positively knowing what the effect was. However, with some effort, the cause-effect relationship system can still be applied in most in-depth accident investigation research.

Therefore, the following categories describe human reasons for, or causes of, the effects (human information-processing failures) described earlier.

Physical or physiological failures. These failures are relatively rare, yet almost certainly cause some effect which produces an accident. These gross failures include heart attacks, seizures, strokes, falling asleep, etc., producing unconsciousness which virtually takes the
driver out of the system. The danger signal indicating a collision course is never perceived.

Conditions or states. These include physical or mental states which affect the driver's processing behavior. They may affect his attitude toward a stimulus and therefore his decision about that stimulus. They may affect his reaction and decision times, delaying them to the point of criticality. They may affect the operator's rationality. They may also affect his ability to discriminate and comprehend a stimulus as a danger signal. The examples of human conditions which can cause the information-processing failures are legion. They include probably the most frequent condition related to severe accidents, namely alcohol intoxication (Department of Transportation, 1968). Also, emotional conditions, drugs, mental pressure, fatigue, and handicaps could all cause certain human effects and would be considered under this category.

Experience or exposure. The human operator's past experience or exposure to similar situations many times affects the way he will process information. If the signal never indicated danger to the operator before, he may not comprehend it appropriately. If he has made previous successful decisions about the signal he may make the same decision again. If he hasn't been exposed to the signal, his decision time will probably be longer. His physical reaction could also be affected by his training and previous education. Examples of "experience" causes might be driving for only a short period of time, unfamiliarity with the vehicle and its handling properties, unfamiliarity with the surrounding area and roadway controls or deficiencies, and inexperience with night-time driving.

Conflicting behaviors or preoccupation. This category involves behaviors which interfere with the perception or comprehension of the stimuli. No real physiological failures or conditions are involved, but the operator is simply attending to some other information-processing task. Examples of this cause may be talking to a passenger, looking in the wrong direction such that a signal is missed, mentally processing several other stimuli so that the danger signal is lost in the "noise", and preoccupation with a radio broadcast. This category could be considered a "catch-all" reason when physical failures, conditions or states, and experience or exposure factors cannot be detected or were not included. Many times it is simply reported as "inattention", without specifically designating the reason.

Risk-taking behavior. This last category involves intentional risk-taking actions by a driver which ultimately affect his ability to process and compensate for danger signals. The risk-taking behavior, in effect, disregards "pre-danger-signal" information to the point that it is too late to react to the crucial stimuli. Examples of this quasi-intentional cause include speeding, violating stop signs and signals, making improper maneuvers, and following too close. The driver is typically aware that he is taking a chance with the risky behavior; however, for some reason or another (e.g., attitude, mental state, experience), he chooses to proceed with the action in hope that he will "get away with it".

Causal Reporting System

In many cases, these causes discussed above produce some effect described earlier. In a small number of cases, an effect may not be determined or, conversely, a cause may not be detected. In intensive, in-depth investigations, this should not occur with great frequency. However, the assurance that the cause-effect relationship uncovered in the investigation is the valid cause and effect of the collision will vary considerably. Therefore, degrees of assurance should be applied to each relationship. For example, the degrees of assurance, "possible, probable, definite", as defined by Treat and Joscelyn (1971) could be utilized.
This human causal system can be applied to an already developed and previously cited accident causation reporting system (Treat and Joscelyn, 1971) using the following definitions and descriptions.

**Accident causation (Primary or Principal cause).** This is defined as a factor or combination of non-performances acting together which were deemed by the investigating team as necessary to the occurrence of the accident, i.e., if the prime factor or combination of non-performances had not been present, then the accident would not have occurred.

This category definitely involves human effects, i.e., the information-processing failures, although it is termed as "causal" for convenience and basic clarity. Any perception, comprehension, decision, or action failure on the part of the operator which produced the critical event would have to fall in this reporting category. For example:

1. **Driver perception failure**—The driver did not see approach of another vehicle since he was looking to his left for other traffic.
2. **Driver comprehension failure**—A curve in the road was in driver’s field of view but he did not comprehend or recognize the situation as dangerous.
3. **Driver decision failure**—The driver misjudged speed/distance relationship of oncoming vehicle and thought he could make the turn safely.
4. **Driver action failure**—The driver oversteered to the left when he felt his vehicle drop off onto the right shoulder.

There may be inherent difficulties in determining whether a failure occurred at the perception or comprehension phases of processing. The two should be combined (i.e., perception/comprehension) when the determination cannot be made. Decision and action failures appear to be more distinctive.

**Severity increasing factor(s).** This is a factor or combination of non-performances determined by the investigating team to have increased the impact speed of the accident occurring, i.e., if the factors were not present the accident may still have occurred, but perhaps in a different manner or to a different degree.

This category would also include only human effects, but only those which were not so critical. For example:

1. **Driver perception failure**—The driver did not see the warning light on the dashboard indicating a hydraulic brake failure. Had he seen the light, he might have been able to apply the emergency brake or down-shift sooner (primary cause is brake failure—vehicle).
2. **Driver comprehension failure**—The driver did not realize low shoulder was a dangerous situation, i.e., driving onto the shoulder was an intentional act (primary cause is low shoulder inducing loss of control).
3. **Driver decision failure**—The driver panic-braked instead of pumping the brakes and attempting to steer out of the situation (primary cause was failure to perceive other vehicle approach due to traffic obstruction).
4. **Driver action failure**—The driver failed in the evasive maneuver attempted even though he detected danger, whereas braking would have lessened the collision severity (the primary factor was driver perception failure prior to point where a collision is physically impossible to avoid).

**Relevant Conditions.** This category is defined as a condition or state which caused or contributed to an accident factor or non-performance, thereby relevant to the effect of the crash situation. A relevant condition is one which the investigation team ascertains as the cause or induction of some non-performance or information failure which contributed to the crash.

It is obvious from the above definition that this category involves the human causes of the information failures. Although it is categorized as "Relevant Conditions", it still includes such causes as physical or physiological failures, experience or exposure conditions, conflicting behaviors or pre-occupation, and risk-taking situations. All of these causes can be thought of as existing conditions or behavioral states which induced or produced the human processing failures. For example:

1. **Driver physiological failure**—The driver fell asleep taking him "out of the system" and causing him to not detect his vehicle drifting off the road (primary factor was driver perception failure).
(2) Driver condition—The driver was intoxicated, thus changing his attitude toward speeding and slowing his processing and reaction times (primary factor was driver action failure).

(3) Driver experience—The driver had been driving only two months and had driven only 1609 km prior to the collision. This probably caused his decision failure to brake heavily on the ice instead of pumping and trying to steer (primary factor was driver decision failure).

(4) Driver preoccupation—The driver was conversing with and looking at a passenger when the danger signal occurred. He failed to perceive the other vehicle (primary factor was driver perception failure).

(5) Driver risk-taking behavior—The driver was proceeding too fast for conditions; by the time he comprehended the curve in the roadway, it was too late to react to it (primary factor was comprehension failure, i.e., danger signal (curve) transmitted to driver too late for him to recognize it, physically react to the situation, and slow down).

The above systematic application of a human factors model to an operational accident causal reporting system should provide the consistency and validity needed in this research area. Examples of its utilization follow.

SYSTEM UTILIZATION

The previously cited study by Perchonok (1972) involves an “accident descriptive system.” Part of his system involves “information failures” as precipitating collisions. One of the analyses reported in his study involved information failures in collisions as a function of driver age (see Table 1). As driver age increased beyond age 25, the proportion having information failures steadily increased; for drivers 65 or older, 60% were considered culpable due to information failures. Regarding particular types of information failures, the most extreme variations occurred in the oldest age group (65 or older) where so-called “recognition” and “projection” errors occurred with the highest frequencies.

As one can see from the definitions of his information failures at the bottom of Table 1, these are very close to the definitions presented in this paper. Perchonok’s “Presentation” failure corresponds with this author’s “Perception” failure; “Sensing” corresponds also with “Perception”; “Recognition” corresponds with “Comprehension”; and “Projection” failures correspond with this paper’s “Decision” failures. Perchonok did not have an equivalent of “Action” failure, per se, in his study.

This particular reporting and analysis technique described by Perchonok (1972) was performed on research accident reports, not police reports. However, information in many of the state police reports is sufficient to utilize Perchonok’s system of reporting.

Another study mentioned earlier where a similar system of accident causation has been utilized is the Indiana University’s Institute for Research in Public Safety (I.R.P.S.) study (1973). The methodological forerunner to this study was the Treat and Joscelyn (1971) report. In an analysis of over 150 in-depth collision selected on a representative basis (i.e., a representative sample of all accidents reported to the police over a specific time period), the percentage of human “direct causes” was determined (see Figure 2). In the I.R.P.S. scheme, “Decision Errors” correspond with this paper’s “Decision Failures”; “Recognition Errors” correspond with “Comprehension Failures”; “Performance Errors” with “Action Failures”; and “Critical Non-Performance” with “Physical or Physiological Failures”. The I.R.P.S. schema does not include “Perception” failures, per se. The I.R.P.S. findings indicate that decision and recognition errors about equally cause collisions (i.e., 40.4% and 45.7%, respectively). The “Definite Involvement” category means the investigation research team was sure (95% confidence level) that the error occurred and did cause the crash; the “Definite or Probable Involvement” adds the cases where the team was not so sure (it was “probably” a factor;
TABLE I

Information Failures* as a Function of Driver's Age

<table>
<thead>
<tr>
<th>Information Failure</th>
<th>20 or Less</th>
<th>21 to 25</th>
<th>26 to 35</th>
<th>36 to 55</th>
<th>56 to 65</th>
<th>65 or Older</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation</td>
<td>8%</td>
<td>7%</td>
<td>5%</td>
<td>8%</td>
<td>5%</td>
<td>8%</td>
</tr>
<tr>
<td>Sensing</td>
<td>7%</td>
<td>4%</td>
<td>11%</td>
<td>8%</td>
<td>9%</td>
<td>5%</td>
</tr>
<tr>
<td>Recognition</td>
<td>10%</td>
<td>5%</td>
<td>10%</td>
<td>10%</td>
<td>11%</td>
<td>20%</td>
</tr>
<tr>
<td>Projection</td>
<td>4%</td>
<td>1%</td>
<td>3%</td>
<td>5%</td>
<td>5%</td>
<td>15%</td>
</tr>
<tr>
<td>Unknown Type</td>
<td>6%</td>
<td>8%</td>
<td>6%</td>
<td>7%</td>
<td>11%</td>
<td>12%</td>
</tr>
<tr>
<td>(Subtotal)</td>
<td>(25%)</td>
<td>(25%)</td>
<td>(35%)</td>
<td>(36%)</td>
<td>(41%)</td>
<td>(60%)</td>
</tr>
<tr>
<td>No Information Failure</td>
<td>65%</td>
<td>75%</td>
<td>65%</td>
<td>64%</td>
<td>59%</td>
<td>40%</td>
</tr>
<tr>
<td>Total</td>
<td>168 (100%)</td>
<td>123 (100%)</td>
<td>109 (100%)</td>
<td>187 (100%)</td>
<td>56 (100%)</td>
<td>40 (100%)</td>
</tr>
</tbody>
</table>

* Information failures were defined in this study as consisting of four types: Presentation-information is not available to the driver (i.e., it never reaches his sensors); Sensing-information transmitted concerned areas of the driver but he is looking in another direction; Recognition-information received by the driver but not processed as danger cues; Projection-driver aware of information but does not draw valid conclusions about ensuing events (e.g., misjudgments associated with speed/distance relationships).

![Summary graph of the causal involvement of the first-level human "direct cause" categories, expressed as the percentage of accidents in which implicated.](image)

80% confidence level) the error was causal. In the columns, these percentages do not total 100% because there were multiple primary causes to many accidents, including vehicle and environmental factors.

SYSTEM BENEFITS

The benefits to be yielded from this system or model lie in two areas: (1) improving and better defining the state of the art of accident causation, and (2) the countermeasure impli-
cations to be derived from the results of using the system. In the first area of potential benefit, certain gaps and deficiencies of present systems can be rectified.

For example, the so-called “innocent” or “not-at-fault” driver can be directly reported in this system. In many accidents, the innocent driver may have had a chance to avoid the collision or at least lessen the severity of such. Information failures on his part can be reported in the “Severity Increasing Factor(s)” category.

This system also eliminates the single reporting of such general causal factors as “driver intoxicated”, “driver speeding”, and “driver inexperienced” by requiring the reporting of what the drivers did wrong, given these conditions and behaviors. It is generally agreed that “intoxication” and “speeding” do not directly cause accidents, per se. They are the inducement, in many cases, of some driver error which directly led to the collision. The “intoxication” does not directly cause a driver to drive off the road. However, a perception error, an incorrect decision about a curve in the road, and a failure to act, do directly lead to the collision. These information failures should then be reported along with the important “reasons for” them, in order for more sophisticated and meaningful analysis of accident causation to take place.

In the second area of benefit, as the purported system becomes more widely implemented and data become available in the crucial “information failure” area, multivariate analyses can be performed and the magnitude of information failures, or effects, associated with perception, comprehension, decision, and action can be determined. The potential of such findings as applied to specific countermeasures or emphasis areas in driver education courses appears to be promising (Fell and Esposito, 1974). Granted if perception problems dominate the findings, then the emphasis should be on correcting the environmental obstructions, clearing the driver’s view both inside and outside the vehicle, and reducing distractions. However, if comprehension failures are significant, and the I.R.P.S. (1973) findings seem to indicate just such a result, then perceptual pattern training and perceptual set theory could be emphasized in driver education as, for example, advocated by Marek and Sten (1972). The drivers should be taught the priorities in a given set of cues, both danger and non-danger cues, so that they can discern the proper information and adequately learn to filter the “noise”. If it turns out that decision failures are the major problem, then the emphasis in driver education should be on the cognitive selection of proper evasive maneuvers, instruction of principles on how to better judge speeds and distances, and the elimination of any incorrect practices in certain situations. Finally, if action failures constitute a great percentage of the errors, then the emphasis in driving courses should be on the teaching of skills, methods, on-the-road training, and performance in simulated emergency situations. The time devoted to the practice of steering out of situations, proper braking techniques, and other emergency maneuvers should increase in the driver education or training courses if the physical response or performance failure appears significant in the data.

Additionally, in the “reasons for” or causal area, the percentage of accidents involving driver physical failure (e.g., heart attack), driver conditions (e.g., intoxication), preoccupation or inattention, and various risk-taking behaviors (e.g., speeding) will be determined in a much more consistent and less ambiguous manner. Correlations between these “causes” and the various information failure “effects” will aid in identifying the areas where certain types of drivers need rehabilitation or retraining.

CONCLUSION

This accident causal system from the
human factors viewpoint should provide for more standardized reporting of the relevant human factors, while at the same time allowing for individual language differences and explanations by accident researchers. More detailed, valid, and structured analyses can be performed once the system is fully utilized and the data reliably reported, which should ultimately lead to better countermeasure development and allocation of resources. Certainly the findings by Perchonok (1972) and I.R.P.S. (1973) utilizing similar models provide this insight.

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