# EFFICIENT ROAD SAFETY RESEARCH THROUGH MULTIDISCIPLINARY CO-OPERATION

Address by E. Asmussen, Director Institute for Road Safety Research SWOV, at the opening of the Full Scale Crash Facility at the Research Institute for Road Vehicles TNO, Delft, 22 March, 1979

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The first part of the title of this speech broadly indicates the objective of the Institute for Road Safety Research SWOV: that is to say, to contribute to road safety by means of efficient scientific research. This notion of "efficient" must be considered in the light of the social objective of road safety research, i.e. to contribute towards the control of road safety by making it possible to weigh one countermeasure against another.

"Multidisciplinary co-operation" indicates the method SWOV has adopted to achieve its goal, based on the view that a multidisciplinary approach towards road safety problems would be the most effective. The knowledge available in the various disciplines will then have to be integrated by means of multidisciplinary co-operation.

At this official opening of the Full scale crash facility I regard it as my task to place the function of this crash facility, as a means of efficient road safety research, in the context of the interdisciplinary approach to road safety problems.

## The control of road safety

Before different countermeasures can be compared, we first have to agree on the answer to the question: What is it we want to control? At first, this question seems unnecessary. But further analysis shows that road safety is defined in many different ways, similarly to other well-being concepts such as health.

One thing is certain, however, that the lack of road safety must be regarded as an unintended side-effect of the transportation system which it will never be possible to eliminate. There is no such thing as absolute safety, at least as long as human acts play a major role.

From this point of view therefore, society will have to decide what degree of road hazards is still acceptable. But we must realise at the present time, when the discussion of well-being occupies such an important place, that it is no longer possible to pursue only the original goal of the transportation system, i.e. travel (quickly and comfortably), without bearing in mind that the side-effects such as road hazards will have to be kept within acceptable limits. The reverse case, in which road hazards as a side-effect are reduced at the expense of a large part of the original purpose of the transportation system is like "chucking the baby away with the bath water". From the well-being angle, it is not a good thing to drastically limit the number of journeys or greatly reduce comfort and speed. Again and again, it is a matter of comparing the effects of countermeasures both on the purpose and on the side-effects of the transportation system; in other words, it is a process of optimalisation.

## Risk

For this comparison to be adequate, a concept is required which gives information on the unsafeness of the transportation system, and also of road situations, vehicle categories, user categories, and so on. Such a concept is "risk". Risk analysis and risk assessment have already been applied in many fields in order to make negative effects, especially those caused by human action, comprehensible and tractable.

Risk is the (estimated) probability of an undesired coincidence of events multiplied by the (valuated) effects (loss).
Every human activity involves risk. This is certainly true in case of traffic, but it also applied to activities in and around the home and at work. Participation in these means the conscious acceptance of risks to a greater or less extent.

Risk comprises the following elements:
- the risk of events coinciding in an undesirable way;
- the nature of this undesired coincidence;
- the (valuated) effects of this coincidence.

In answering the question: "Is the risk in traffic acceptable?, it is necessary to be able to express this risk in figures. The total number of fatalities, casualties and/or accidents is unsuitable for this, but it will have to be supplemented with allocations

according to age groups, vehicle types, road categories and so on. Then, and then only, will it be possible, by making comparisons, to allot priorities within the transportation system, and also relative to other threats to life and well-being.
To give an example: the risk per year of dying from cardio-vascular diseases in The Netherlands is about twenty times as high as that of being killed in a road accident. This does not give an adequate picture of the threat from these two effects, because, for instance, they attack the various age groups very differently. Total mortality in the 15 to 24-year age group, for instance, relates for about 40 per cent to traffic fatalities. For this age group, therefore, the principal cause of death is road accidents, while cardio-vascular diseases hardly occur in it.
Another example: let us take the various vehicle types: over 40 per cent of all road fatalities are private car occupants. Here we must, of course, bear in mind that about 60 per cent of all traveller-kilometres are covered with private cars. Reduction of the risk to car occupants in some way or other can therefore be an important objective of road safety policy.

Now the question is how to achieve risk reduction as efficiently as possible. We must try and find out what countermeasures, what combinations of countermeasures, will give the highest cost/benefit ratio.

On the assumption that the "agent" (the necessary but not sufficient condition) of risk in traffic is the built-up energy, we can base search strategy for and classification of all the possible countermeasures on the following sequence:
As activities and/or actions have to be carried out in the transportation system (Phase 1) there is an energy build-up (speed, height on bridges, etc.) (Phase 2). This built-up energy can be released (in an undesired way) (Phase 3); we then speak of an incident or a conflict. This energy can come into contact (in an undesired way) with dead or living structure (material or human beings as the case may be) (Phase 4); we then speak of an accident. This contact may cause damage or injury (Phase 5). This damage or injury can spread (Phase 6).

Schematically, the control strategies are based on:

Phase 1. Limitation of activities;

Phase 2. Limitation of energy build-up;

Phase 3. Limitation of (undesired) energy release;

Phase 4. Limitation of (undesired) contact of released energy with dead or living structure;

Phase 5. Limitation of damage or injury to dead or living structure caused by contact with released energy;

Phase 6. Limitation of spreading of damage or injury to dead or living structure.

Countermeasures aimed at controlling road safety are not intended in the first instance to affect the objective of the transportation system. The more they do so, the more difficult will be the comparison on which a decision is based. It is clear that this affect is greatest in Phase 1 and least in Phases 5 and 6. The most efficient search strategy, therefore, is to deal with the sequence in reversed order.

Phase 6: Limitation of spreading of injury or damage

A number of factors play a part in this, such as first aid, transportation of casualties, but also warnings for and to oncoming traffic, removal of wreckage, and so on.

Phase 5: Limitation of injury or damage to living or dead structure caused by contact with released energy

As a rule, injury to living structures (human beings) weighs so much heavier than damage to material objects that strategies may partly be aimed at sacrificing material in order to protect people from injury. The ultimate endeavour is to keep the forces within the human tolerance wherever possible.

Some implications for traffic facilities in this context are:

- crush zones, seat belts, cage construction and so on in vehicles;
- break-away or slipconstructions for lighting columns, traffic signal installations, signposts, and so on;
- roadside safety structures, guiding vehicles with acceptable decelerations.

Phase 4: Limitation of (undesired) contact of released energy with living or dead structure

If it is impossible to prevent or properly limit injury and material damage upon contact with released energy, it is necessary to try and ensure that the energy released cannot come into (undesired) contact with living or dead structure. What this amounts to is that "segregation principles" must be applied, such as segregation in place (with either a space or a physical barrier in between) and segregation in time.

Besides application of segregation principles, creation of "emergency space" will also have to be considered; that is to say, when traffic facilities are provided space will have to become available for emergency manoeuvring, such as evasive action to avoid a crash.

Some implications for traffic facilities in this context are:

- traffic-category segregation with separate paths or lanes for pedestrians, cyclists, cars, lorries, etc.;
- segregation of traffic moving in opposite directions by means of wide central reservations and/or roadside safety structures in the central reserve;
- segregation of intersecting traffic with graded crossings or traffic signals.

The greater the energy build-up, for instance owing to higher speeds, the greater the need for these segregation principles. This strategy also includes shielding danger zones with physical barriers, such as roadside safety structures on shoulders. These are needed not only to shield rigid obstacles, but also steep slopes, or near bridges and so on.

Phase 3: Limitation of (undesired) energy release

If the foregoing strategies are insufficient, an effort will have to be made to influence traffic (manoeuvring) behaviour in such a way that the built-up energy cannot be released in an undesirable way. This phase is undoubtedly one of the most difficult in controlling road safety. Whereas human tolerance played a part in the previous phases, a major part is played in the present phase by human possibilities and limitations in observation, decision and action.

Traffic facilities will have to be designed and constructed so that on the one hand road users are not faced with tasks beyond their capabilities and on the other are not "tempted" to act in an "undesirable" way. We must therefore realise that countermeasures based on the idea that the surroundings, that is to say changeable external circumstances, can be isolated from the road users' characteristics and tasks, are doomed to failure.
As long as road users have so much freedom of action, it will be impossible to prevent the undesired release of energy. In that case complete automation is necessary. But if the design and construction of traffic facilities makes the fullest possible allowance for road users' characteristics, it should be possible to limit energy releases to a certain degree.

Phase 2: Limitation of energy build-up

If the foregoing strategy is also inadequate, then we shall have to go into the question of how this energy build-up can be limited. The principle will still have to be that the objective of the transportation system is affected as little as possible. Countermeasures in this phase relate to speed reduction, reduction of distances between destinations, the use of fewer cars for the same number of journeys (high occupancy rate) or the use of vehicles with less energy build-up, for instance bicycles.

Phase 1: Limitation of activities

Finally, it is, of course, also possible to reduce the number of activities (journeys). This really does affect the objective of the transportation system. This will always be a very difficult, political choice.

As matters stand, the principal starting point for countermeasures will be adaptation of the surroundings to human possibilities and limitations. On the one hand this relates to human capacity for observation, decision and action in using the road and on the other to human tolerance (Phases 5 and 6).

In the latter case, we generally speak of injury prevention and/or of crash research and countermeasures.

## Crash research

Research concentrating on the crash phase comprises a definition and explanation of all events as from the point at which a crash becomes unavoidable.
In the crash phase, the following elements can be distinguished which require attention both individually and in combination: man, the vehicle, the road and the surroundings:
- man, because of the demand upon his human tolerance (towards impact forces);
- the vehicle on account of the entirety of mechanical characteristics as regards the interior and as regards external characteristics;
- the road and the surroundings because of the danger zones and the various objects with which an impact can occur.

Two kinds of research are available for the purpose of specific countermeasures relating to crashes: accident research and impact simulation research.
The first, accident research, collects, processes and analyses only those accident data that relate to factors leading or contributing to injury (and damage). In the organization model for crash research (Figure 1) accident research is presented with the chain P (in-depth studies). These data form a means of ascertaining whether and, if so, where necessary improvements can be made in a road user's surroundings. Accident research is also a means of determining the effectiveness of crash countermeasures (modifying the risk of injury per accident).

Accident research P (on real accidents) can be supplemented with impact simulation research (research on part-phases of impacts, on proving grounds or in laboratories, whether or not by means of mathematical models).

There are two part-phases of impacts in the crash phase of an accident:
1. The primary impact: this is the impact of the vehicle with other objects (other road users, other road users' vehicles, road furniture and so on). The input variables of the primary impact are described in terms of vehicle speed, angle of impact, etc.;
2. The secondary impact: this is the impact of the road user with the inside of the vehicle, or with objects outside the vehicle, for instance if he is flung out of the vehicle or if he is riding a two-wheeler. The human body is then subjected to impact forces both internally and externally.

In the primary impact, the mechanical properties (forces in case of deformation etc.) of vehicles and, for instance road furniture, determine the output variables which can be summed up as decelerations of the vehicle body. These form the input variables for the secondary impact in which the mechanical properties of the vehicle's interior and supports (seat belt, seat, etc.) and the human body's mechanical properties (tissue properties) determine the ultimate injury.

Impact simulation research Q, regarding the primary impact, relates on the one hand to full scale impact tests on a proving ground or with the "crash facility" and on the other hand to mathematical models of the relation between speed, angle of impact, etc. and deceleration of vehicle, given certain mechanical characteristics of vehicle and obstacle.
The combination of accident research P and impact simulation research Q provides information on the relationship between decelerations of the vehicle and the probability of injury or injury patterns (R research). This R research can be subdivided into S and T research. The S research also being impact simulation research, relates to the secondary impact. Experimental research is done with the Full scale crash facility and dummies; the mathematical model concerns the relation of deceleration of the vehicle and forces on parts of the human body, given the mechanical characteristics of vehicle interior, support and human body.

The T research is purely biomechanical research, aimed at predicting (the probability of) injury (patterns) on bases of forces on parts of the human body, given the characteristics of the tissue of different parts of the human body.
Together with P research, and supplemented with other experimental research which can be represented by Q, R and S and of which (mathematical) simulations, for instance, forms a part, T research can provide the elementary criteria upon which crash safety measures have to be based.

The research results teach us what standards the characteristics of the vehicle, the obstacles and the vehicle interior must meet in order to reduce the risk of injury to a minimum.
It also indicates the practical and economic limits of crash countermeasures. On the one hand, this knowledge makes it possible to choose from among various countermeasures for instance shielding of obstacles, or making them compatible in impacts and so on; on the other hand it makes it possible to weigh crash countermeasures (Phase 5) against measures in higher phases (Phase 4, 3 and so on).
Obviously, this is possible only if the effectiveness of countermeasures in other phases is known.

Lastly, we can state that the social objective of every form of road safety research is to gain greater insight into the effects of countermeasures and combinations of countermeasures in order to make a better choice from among all the possible countermeasures.
The biased choice of certain countermeasures impedes a sound road safety policy. The efficiency of crash countermeasures is still fairly high. Yet unfortunately there is a certain resistance to them since they are described as "symptom abatement". The attitude "It is better to prevent an accident than to reduce its effects" is indicative of a limited vision about the notion "accident-risk" and the effectiveness of crash countermeasures. The reduction of injury and even damage by traffic accidents so that the effects are within acceptable limits seems more attainable than incident or even accident prevention, in view of the present state of the art. Furthermore,

for didactical considerations it is questionable whether emphasising prevention is really desirable, provided the consequences are to be considered as acceptable.
It is my view, therefore, that the Full scale crash facility, as an important means of crash research, can help to improve road safety. The widening of knowledge in this field of road safety, i.e. the crash phase, can be achieved more efficiently not only with such a Full scale crash facility. I should also like to point out the need for multidisciplinary co-operation. Knowledge of the effects of measures taken to improve road safety is rarely, if ever, obtainable within one discipline, in view of the complex nature of the problems. It is gratifying to note that the multidisciplinary co-operation between the Institute for Road Safety Research SWOV and the Research Institute for Road Vehicles TNO has already led to a number of results, such as the mathematical models for crash research. I trust that this co-operation will be continued and extended in the service of road safety.

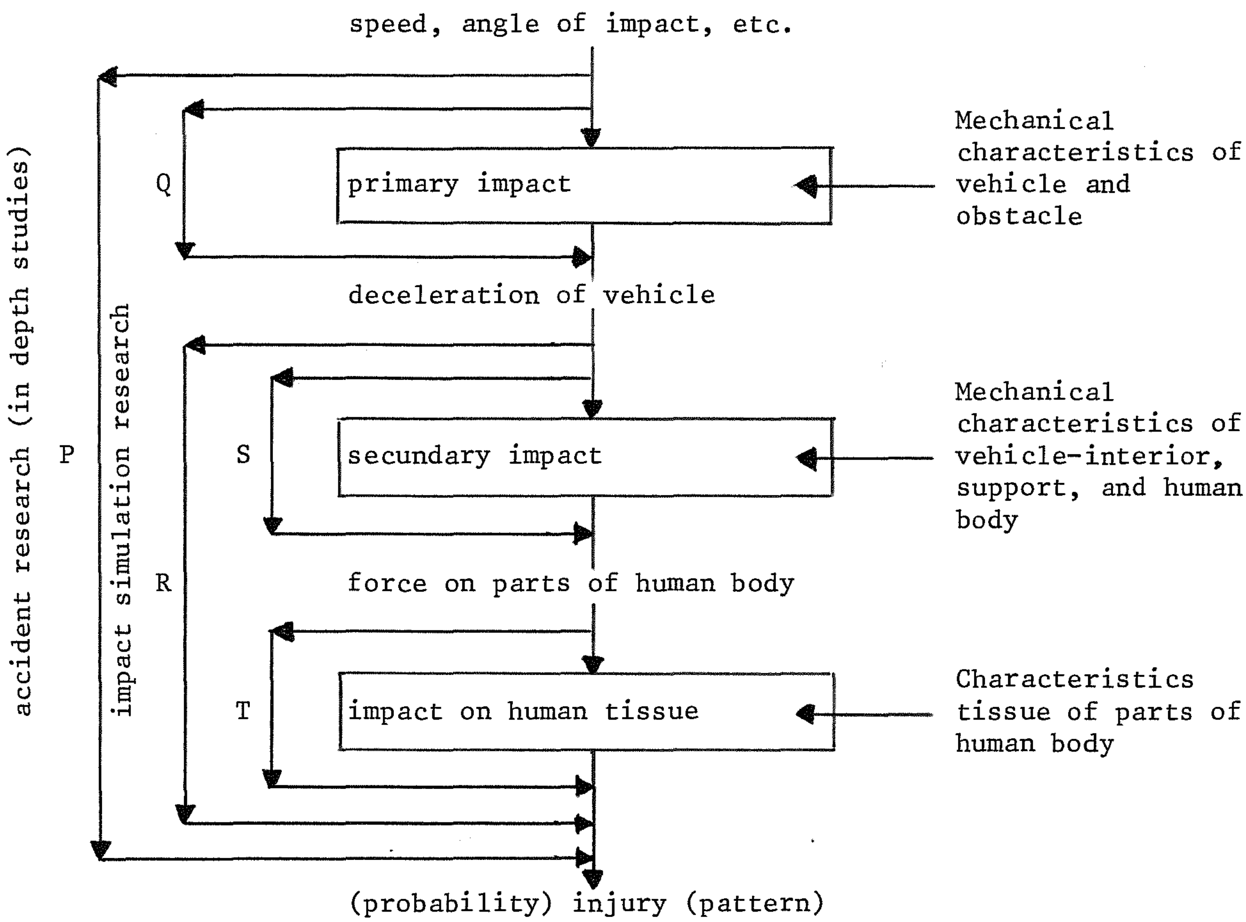


Figure 1. Organization-model for crash research