FACTORS INFLUENCING THE OCCURRENCE AND OUTCOME OF CAR REAR-END COLLISIONS

– The Problem of Whiplash Injury in the Netherlands –

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Police based national accident data from the Netherlands show an enormous increase of both in number and in share of car rear-end collisions resulting in injury over the last 15 years. The average severity of those accidents remains low (illustrated by very low shares of occupants killed or hospitalised). However, the apparent increase in number of less severely injured as well as the personal and societal consequences of their injuries may well impose an increasing threat to the quality of life within the Dutch society.

Based on national accident data as well as other relevant injury and traffic exposure data, the current situation in the Netherlands is described. Differences with respect to gender unexpectedly suggest that female drivers have a higher risk of their car being hit from behind than male drivers do. Less unexpectedly, differences are found between males and females with respect to injury susceptibility. These differences are analysed using controlling factors such as type of car, type of road, and exposure to traffic.

It appears that not all of the indicators used point the same way; some of the increase mentioned may be due to registration biases. There is also a lack of adequate data with regard to the real number of whiplash injuries, their severity, and the longer-term consequences. Even if the total scope of the problem of whiplash injury in the Netherlands is still not fully known, the current estimate of societal consequences implicates a need for preventive measures. In the first place, accident prevention should be considered and a number of possible preventive measures (such as infrastructural improvement and application of ITS devices in cars to maintain distance in traffic) are discussed. Injury preventive measures (such as in car protection against whiplash) are already more generally available but still need much improvement.

Key Words: Rear-end collision, Whiplash injury, Traffic safety, Head restraint, Countermeasures

1. REAR-END ACCIDENTS, EVIDENCE FROM POLICE BASED DATA

1.1 Injury accidents

First we will look at the number of rear-end accidents, using the national police registration (called VOR-data in this article).

Like all police based accident registration, the Dutch traffic accident data are not complete and, which is worse, not representative for all (injury) accidents in the Netherlands.

Incompleteness is linked to less severe accidents and to accidents involving non-motor vehicles. However, in this article we focus on car-occupants, for whose accidents we consider the police registration as reasonably complete and representative.

The problem in this case is that the type of accident we are interested in (rear-end accidents) is generally not severe in terms of the number of casualties and their injury severity, another cause for underrepresentation. Bearing this in mind, we will look at the data available.

Though it is known that WAD (Whiplash Associated Disorders) may result from a variety of accident types (even non-traffic accidents), we will concentrate in this article on rear-end accidents of cars. There is evidence that this type of accident is responsible for the majority of all WAD (see also Section 2.3).

During the last 15 years it appears that injury producing rear-end accidents, as registered by the police, have considerably increased both in number and in share of all accidents. The total number of registered accidents remained more or less stable during this period at about 40,000; see Figure 1.

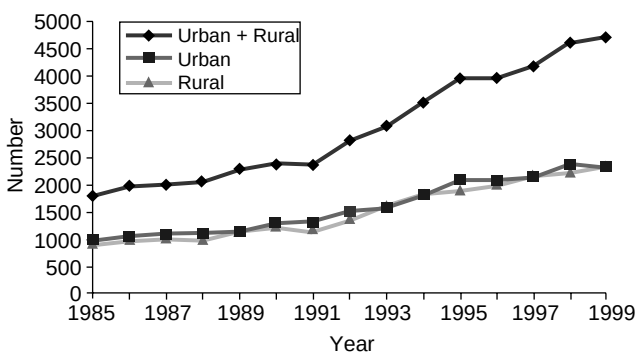

Fig. 1 Number of rear-end accidents concerning cars, according to built-up area, 1985-1999; VOR-data

Figure 1 shows the increase in the total number of rear-end accidents over the years, while it also makes clear that both in urban and rural areas the increase took place at about the same rate. Since most Dutch accidents occur in urban areas, the share of rear-end accidents is lower than those occurring in rural areas (9% against 15%). On highways, 35% of all accidents are rear-end accidents.

For this reason, and for the fact that this type of accident often occurs when traffic density is high (during rush hours) and disturbances have large economic consequences, official attention is often focussed only on highways. Recently, a Dutch national campaign was launched to influence drivers to keep a greater distance, and highway police are aiming by means of a specially designed camera system to identify and punish those drivers who keep a criminally short distance (of less than 0.5 seconds). The structural problem is that while a safe distance for a given speed (of say 100 km/hour) may be about 2 seconds (56 meters), gaps of that size (in dense traffic) will be immediately used by one or more car drivers hoping to gain time. In practice therefore, following distances of less than 1 second (28 meters at 100 km/hour) are very common in dense traffic, even though this is clearly not a safe distance in case of emergency stopping.

The main reason for the increase in the number of rear-end accidents is thought to be the fact that the car population on Dutch roads increased considerably over the period considered, while the available road length did not. Therefore the traffic density of cars on the majority of Dutch roads has increased, resulting in a far greater chance of meeting other traffic.

1.1.1 Injury severity

One of the reasons that rear-end accidents are not considered important at policy level, is the fact that they 'produce' almost no fatalities and far less hospitalised casualties than average, the standard criteria for the judgement of outcomes. While all accidents produce 28% of severe outcomes, rear-end accidents 'only' produce 14%. Most other types of collisions, such as frontal and side collisions are far more serious than average, not to mention collisions of cars against fixed obstacles.

This is one of the reasons that SWOV (SWOV Institute for Road Safety Research) has recently started a research project aiming at the development of a system to measure the (long-term) consequences of traffic accidents. The results of this project would be used as an additional element to describe the severity of traffic accidents.

This way, consequences of accidents such as rear-end accidents, that are normally considered to be of minor severity (the severity of whiplash injury is often coded as minor in terms of life-threatening) would be based on other aspects describing quality of life etc.

1.2 Damage accidents

While the number and proportion of rear-end injury accidents have been steadily increasing over the years, the proportion of damage-only rear-end accidents has more or less remained at the same level of about 15% as is shown in Figure 2.

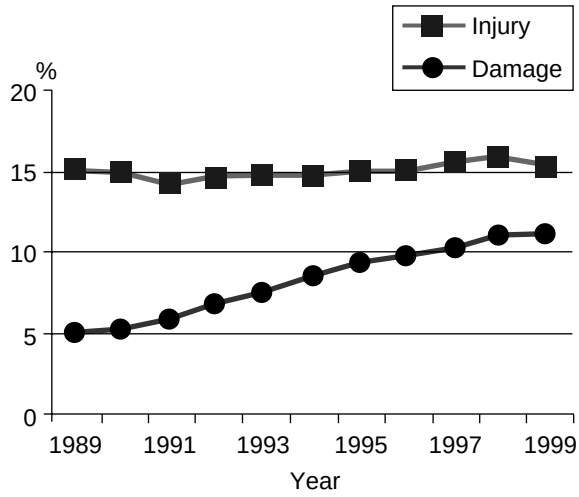

Fig. 2 Percentage of rear-end injury and damage-only accidents related to all accidents, 1989-1999; VOR- data

This is contrary to what was expected. It was expected that both the shares of injury and damage-only accidents would have increased considerably, since the mechanism thought to have caused the increase in injury rear-end accidents is equally applicable to damage-only accidents (increased traffic density). It is possible therefore that the registration of injury producing accidents with regard to rear-end accidents is partly biased by police policy in this matter, due to increased public and official interest regarding the problem of whiplash injury. This possibility is illustrated by the fact that the police in some districts gave people involved in rear-end accidents written pre-printed forms, advising them to ask for medical diagnosis regarding neck injury. In reality, a fair amount of these accidents would have been damage-only.

An additional explanation is underreporting of rear-end accidents in the police registration with regard to non-serious damage-only accidents, such as most rear-end accidents probably are. Some preliminary information on

this subject was recently provided orally by police officials to SWOV. Police explained that from the annually reported 600,000 traffic accidents (nearly 2,000 each day), received through the national emergency telephone number (1-1-2), police was able or willing to send a police (registration) team in about 300,000 cases. As we know, some 40,000 of these are registered as injury producing accidents, while the remaining 260,000 are registered as damage-only, of which about 40,000 are car rear-end accidents (the 15% mentioned in Figure 2). So, all kinds of possible biases may be introduced when the police decide for reasons of priority not to pursue or register an accident reported by telephone, the most apparent of these biases being estimated accident severity.

Even if some of the accidents registered by police as injury rear-end accident should have been damage-only, the reverse may be equally true, or even more so. This is due to the fact that according to medical literature, in many cases those involved in rear-end accidents may not experience complaints until afterwards, sometimes days or even weeks after the accident; so the police would not know that an injury had occurred.

Still another explanation for the fact that we find an increase in injury producing rear-end accidents and not much increase in rear-end damage-only accidents, may be that collision speeds have increased, along with the mass of cars, thereby causing a greater risk of injury, in the case of a rear-end accident. Evidence for this hypothesis is derived from several sources: Dutch national statistics point out that the average car mass (kerb weight) of both individual car models and the car fleet as a whole, has been steadily increasing over the years and will probably continue to do so. Car mass is found to be a major influence regarding the outcome of accidents, including rear-end accidents[1].

Evidence that driving speeds have steadily increased (despite the increased traffic density) is derived from regular local, regional and national surveys. It is probable that collision speeds may have risen as well, also due to the fact that the average engine capacity of cars has steadily increased over the years, allowing still higher driving speeds and far greater acceleration capacity than before.

1.3 Gender differences

Not unexpectedly, the proportion of injured female car-occupants from rear-end accidents is higher than the proportion of male occupants. This phenomenon is very often found in studies concerning neck-injury and is explained by the biomechanical fact that the female neck is structurally more vulnerable than the male neck. In case of the Dutch data, the difference was established in more detail for car drivers only, and appeared independent of car-mass/size (women tend to drive smaller cars than males) and area (women tend to drive more often in urban areas than males)[2]. It was found that injury-risk of female drivers was twice as high as injury-risk for male drivers. Injury risk was expressed as the number of injured drivers divided by the number of kilometres travelled. The influence of car mass (or size) is illustrated in Figure 3.

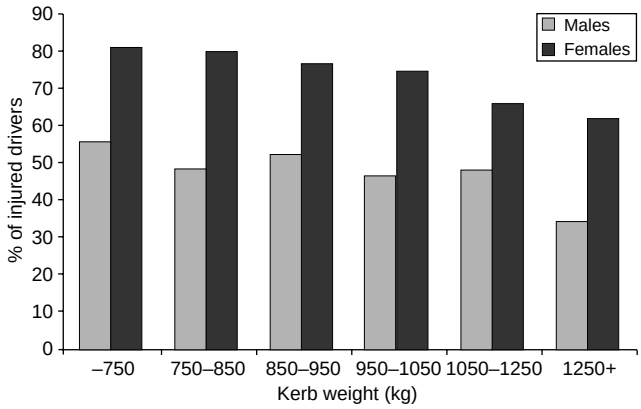

Fig. 3 Percentage of injured male and female drivers of cars involved in rear-end accidents, dependent on kerb weight of their car; VOR/ vehicle data 1996-1997

Figure 3 illustrates that car mass (expressed here as kerb-weight) influences injury risk (the risk is higher in smaller cars). At the same time, women drivers are injured more frequently than male drivers regardless of car mass.

A different matter appeared to be that female drivers are more involved in rear-end accidents than male drivers. This is suggested by the fact that the total number of female drivers (injured and not injured) is higher than the total number of male drivers involved in registered rear-end accidents, while the share of male drivers in the total accident population is always higher than the share of females.

So, assuming that the registration regarding rear-end accidents was not biased with respect to gender of casualties or drivers, it is possible to conclude that female drivers have a higher risk of rear-end accidents.

A preliminary explanation for this phenomenon might be that women drivers tend to drive more carefully and are more law-abiding compared with male drivers. For instance, if women tend to stop as soon as traffic

lights turn to orange/red, and male drivers would not, this might be the cause of rear-end accidents. The data available however are not sufficient to support further speculations about different traffic behaviour of male and female drivers.

2. INJURY DATA

The Dutch Ministry of Transport officially uses data from specific injury sources (such as mentioned under Section 2.1 and 2.2) to calculate the real annual amount of traffic casualties. A method for this purpose was established in a joint venture of the Ministry and the Central Bureau of Statistics, while SWOV acts as advisor.

2.1 Whiplash and hospital data

LMR (National Medical Registration) is the name of the Dutch database containing discharge data of all hospitalised people in the Netherlands, including annually some 19,000 traffic casualties. Injury data and external causes of injury are coded according to the ICD9-CM (9th Revision of the International Classification of Diseases, Clinical Modification, of the World Health Organisation). Whiplash injury is formally coded as a sprain of the neck (ICD9-code 847.0). It appears that in 1998 only some 140 traffic casualties were discharged, having at least a sprain of the neck (in most cases this was their most important injury as well).

The data reveals that 80% of these people were car-occupants; 53% were females. Both were a far higher proportions than average, since 28% of all hospitalised traffic casualties were car-occupants and 40% of all hospitalised traffic casualties were females.

Though these data and proportions clearly confirm that whiplash injury is mainly a matter of car accidents and is more prominent with females than with males, the total number of diagnosed whiplash cases is very small indeed.

Apparently, whiplash cases are normally not admitted to hospitals at all, and we have to look at other injury sources for relevant data.

2.2 Whiplash and A&E data

One of these other sources is called LIS (Injury Information System). This source is based on a representative sample of 17 hospitals having a 24-hours A&E (Emergency Treatment) Department (representing about 14% of all Dutch hospitals). Relevant data of all casualties (of all types of accident and disease) admitted to these A&E Departments are coded and transmitted to the Dutch Consumers Association in Amsterdam, which is responsible for the management of the data on behalf of the Dutch Ministry of Public Health.

Annually about 120,000 traffic casualties are counted at population base (the sample itself counts about 16,000 traffic casualties), including fatalities and hospitalised. Excluding these two specific groups, the data contains information about some 105,000 traffic casualties (the officially published number for 1998).

Traditionally, cyclists account for the majority of traffic casualties in the Netherlands, in view of the fact that nearly every Dutch man, woman, or child owns a bicycle. The distribution of casualties according to vehicle type therefore shows roughly a share of 50% cyclists against 25% car-occupants, the remainder being mainly moped-riders and pedestrians.

In Figure 4 some details of the injuries of the 1998 A&E casualties are shown, concerning cyclists and car-occupants.

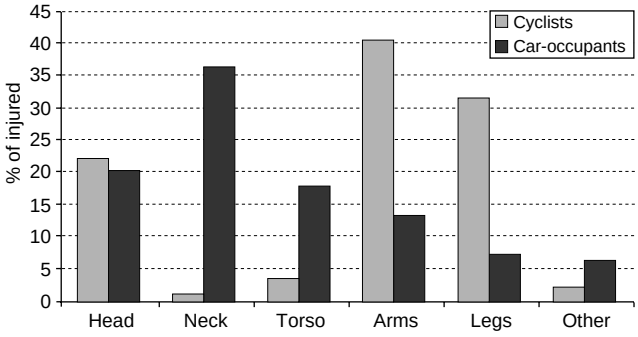

Fig. 4 Percentage distribution of injured body parts concerning the most important injury, for cyclists and car-occupants; LIS data 1998

Figure 4 shows considerable differences with regard to distribution of injured body parts for two different road users (shown is the distribution regarding their most important injury). While cyclists suffer mainly from injuries to their extremities (their share amounting to 70% of all injuries), emphasis with car-occupants is on head and neck injuries (55% of all injuries).

Whiplash injuries are of course included under 'neck' shown in Figure 4; however, with regard to the actual type of injury they are found under different headings in the system.

Since there is no specific code for whiplash injury, the majority of the neck-injuries (77%) have been coded

as 'superficial' (contusion), while some 18% were coded as 'muscle/tendon'.

From the descriptive text adherent to every case it becomes apparent that the majority of these injuries are described as 'pain in the neck', 'contusion of the neck', 'muscle pain in the neck', 'complaints of the neck,' etc. The word 'whiplash' is used in few cases.

Also, in most of these cases some additional description of the accident is given, such as rear-end accident. Using these descriptive data as an entrance, neck-associated injuries amount to about 1,000 cases in the sample or to almost 8,000 at population level.

Clearly, neck injury is one of the major concerns in case of car-occupants, even if not all of these injuries may be considered whiplash associated.

A&E treatment for injuries sustained in traffic accidents occurs (in the majority of cases) soon after the accident has happened. Since, as already referred to, whiplash complaints may often develop some time after this moment, it is to be expected that the number of neck-injury cases reported by the system (some 8,000 cases regarding car-occupants) underrepresents the real scale of the problem. Even if not all of these 8,000 cases may be counted as whiplash cases, we find that at the level of the A&E treatment, several thousands of potential cases are added to the total whiplash toll.

2.3 Whiplash and enquiry data

In the previous paragraphs we found evidence of possible whiplash cases at the in-patient level and at the A&E level.

We are still missing the level of what probably represents the majority of cases of whiplash injuries, namely those casualties who at first do not seek medical treatment at all, and those who visit their own GP (General Practitioner) and who may consequently get medical treatment from specialists, physiotherapists etc.

Some indication that we are considering a large group of casualties may therefore come from the world of GP's. However, up to now no systematic source of this type of medical data is available in the Netherlands. There exists however an alternative:

OIN (Accidents in the Netherlands) is the Dutch name of a periodical national telephone enquiry concerning a sample of the Dutch population (about 60,000 people have been asked) with regard to 4 different types of accidents: traffic, sport, work and home/leisure. The enquiry aims primarily at Dutch people having experienced injury from an accident during the last 3 months. Distinction is made between medically treated and not-medically treated casualties. Medical treatment involves all treatment by medical professionals; non-medical treatment includes all treatment by non-professionals and no treatment at all. The study is repeated almost every 5 years, the most recent results[3] are from 1997/1998.

Weighed for the population and on an annual base, some 2 million medically treated accident victims are counted, of whom about 266,000 are traffic casualties (averaged over the years 1997 and 1998). Fifty percent were cyclists and 23% of those were car-occupants. Since the sample relating to traffic casualties in this recent study was rather small, only detailed information about these two casualty groups (cyclists and car-occupants) is reliable from a statistical point of view.

Considering the nature of the survey, though all injury severities are included (apart from fatalities), a large proportion of medically treated casualties in the survey (some 40%) was treated by a GP only. Another large proportion (also some 40%) was treated either at A&E departments or by specialists in hospitals.

In Figure 5, the same type of information as given in Figure 4 is now shown for the casualties in the survey.

Fig. 5 Percentage distribution of injured body parts concerning the most important injury, for cyclists and car-occupants; OIN 1997/1998

Figure 5 shows clearly that neck-injuries are the main source of concern for car-occupants. The overall distribution of body parts is not much different from the one in Figure 4, though the share of arm and leg injuries for cyclists are reversed (i.e., in the survey appears more leg injuries than arm injuries).

2.4 Consequences of whiplash injury

Strictly speaking, whiplash itself is already a consequence of injury, the reason why it is originally described as a sprain of the neck. Whiplash or WAD is known to be a variety of different complaints of pain, lack of concentration, functional loss regarding the use of the arms, shoulders etc.

During the last OIN-enquiry, a second target group

are people who were still suffering from an injury sustained from a previous accident (at least prior to the 3-month period).

From this additional group of traffic casualties (weighed around 304,000 people!) some 42% (128,000 people) were car-occupants and 25% (76,000 people) cyclists. As we see, the shares of these two major traffic modes have been reversed, compared to those who were involved in a recent accident (within the 3-month period) as discussed in Section 2.3. Apparently, accidents involving car-occupants are far more serious in terms of injury-consequences than accidents involving cyclists.

It should be noted that no factual information is available about the real date of the accidents of the casualties considered. Some are from very long ago (years); some may be from more recent times; all are at least 3 months old. This lack of information prohibits for instance to calculate the total number of these casualties on an annual population base, leaving their number at the level of 304,000 Dutch people over the 3-month period considered.

Comparable to Figures 4 and 5, in Figure 6 the distribution of injured body regions is shown, again only for cyclists and car-occupants.

Fig. 6 Percentage distribution of injured body parts concerning the most serious injury, for cyclists and car-occupants, still suffering from injury sustained in a previous accident; OIN 1997/1998

Figure 6 shows that car-occupants involved in previous accidents have an even higher proportion of neck-injuries than those from recent accidents (Figure 5).

Of all 128,000 car-occupants mentioned earlier, 50,000 reported having 'permanent' complaints related to neck-injury. The wording 'permanent' was indeed used in the enquiry, though no time reference was given or asked for. These permanent complaints ranged from pain, etc. to immobility and are to be considered typical for (long-term) whiplash effects. So some 50,000 Dutch people are suffering 'permanently' from WAD.

2.4.1 Short summary of data concerning rear-end accidents and data concerning neck-injuries

Even though police based accident data do not contain any information about the type of injury, the data concerning rear-end accidents and injury severity point to a 'large-scale' traffic safety problem. It is expected that this problem may increase in scale because of the expected increase in traffic density. Even though most of the sources of injury data do not specify the type of accident, it has become clear from the short descriptions given by the casualties that whiplash injury and car rear-end accidents are closely associated.

The following table provides an overview of the relevant numbers of accidents and casualties already given in previous paragraphs:

Considering the numbers of casualties suffering from any type of neck injury, the annual toll of 25,000 people (given in the second last line of the table) overlaps (includes) all of the previous numbers of casualties. As discussed in the previous paragraphs, the majority of these neck-injuries could be considered as being whiplash-associated.

The number of people given in the last line of the table (i.e., 50,000) permanently suffering from a neck-injury from previous accidents, could be considered to be additional to the 25,000 from recent accidents. Though the time bases are different, it is expected that the number of these 50,000 cases would have only been slightly higher on an annual basis. Even more than is the case for casualties from recent accidents, neck-injuries from previous accidents should be considered as whiplash-associated.

Type of source	Type of event	Number	Time base
Accident data, injury	Rear-end accident	4,000	Annual
Accident data, damage	Rear-end accident	40,000	Annual
Hospital data (LMR 1998)	Car-occupant, having whiplash injury	140	Annual
A&E data (LIS 1998)	Car-occupant, having neck-injury	8,000	Annual
Survey data (OIN 97/98)	Car-occupant from recent accidents, having neck-injury	25,000	Annual
Survey data (OIN 97/98)	Car-occupant from previous accidents, having neck-injury and permanently suffering from neck-injury	50,000	3-month period

3. DISCUSSION ABOUT SOLUTIONS

3.1 Accident prevention

The first line of defence is to prevent rear-end accidents from occurring at all. In view of average Dutch traffic density, especially during rush hours, the risk of becoming involved in a rear-end accident is high and preventive measures should be considered for all aspects of the traffic system.

3.1.1 Road design

Specifically for highways and probably applicable to some other types of rural roads, systems have been developed based on monitoring actual traffic density and give advance warning to drivers 'up-stream'. These warnings may be given literally as written electronic messages on announcement boards mounted over the roads ('traffic jam ahead'), or better still, they may give pertinent information about a safe local driving speed. Contrary to what (Dutch) drivers still often think about these speed announcements, they should immediately be followed, not being a free suggestion, but prescribed speeds.

These systems are of course linked to specific stretches of road in areas, where traffic jams are frequently occurring and where local, regional or national authorities are willing to finance these solutions.

Both for reasons of finance and feasibility, it will be difficult to apply such systems to other stretches of roads; systems would therefore have to be developed that act independently of a given local road situation (see also 3.1.2 Vehicle design).

SWOV has launched a new concept called Sustainable Safety, in which road design (as well as car design and environment) automatically 'force' drivers to maintain safe driving conditions, mainly dependent on the type of road. This asks for a considerable investment in research and redesign of the transport and road system in the Netherlands, even though it is already considered safer now than in the majority of other European countries. Sustainable Safety as accepted by the Dutch Ministry of Transport, is also needed to reach the traffic safety goals that the Dutch Ministry of Transport has set for the coming 10 years. The most important of these goals being a 50% reduction in the number of traffic fatalities and a 40% reduction in the number of traffic injured, both goals respective to the numbers in the mid-eighties.

In the meantime the traffic safety problem keeps asking for various practical (if sometimes temporarily) safety solutions. One of the problems of safe road design is that in the Netherlands there are as many road owners as there are local authorities, and then some. It still appears very difficult to get all these different authorities pointed in the same direction, especially since the Ministry of Transport has been deregulating much of their responsibility for traffic safety to lower authorities (12 provinces and 500 cities).

It is hoped that the current problem of rear-end collisions will ultimately be solved by means of sustainable safety measures even though the Dutch authorities are far less interested in the less severely injured (such as whiplash cases are still considered) than in fatalities and seriously injured.

Specific junctions in urban areas may be improved considerably by better design of the junction itself, and in case of traffic lights, by enhancing visibility of those lights. According to a recent Canadian study[4], an effectiveness of 30% to 45% less rear-end collisions has been reached at a number of locally improved sites in British Columbia.

3.1.2 Vehicle design

In terms of vehicle measures, we may think of properties enhancing visibility, especially of cars when braking. For this purpose European legislation has been introduced recently, requiring a third (higher mounted) stopping light in all new vehicles (in Holland since 1999).

Of course, much is expected from application of new electronic devices in cars. According to manufacturers of these devices, as well as the car industry itself, devices controlling both longitudinal and lateral movement of cars, may be introduced on a large scale at the end of the current decade (near 2010). However, there is still much debate about almost all aspects of the future intelligent vehicle (IV), including especially the feasibility (the reality) for any system of being able to control interacting traffic streams instead of individual cars in demonstrations.

However, future developments may include automatic (electronic) stopping, since at the moment warning systems for drivers who come too near the rear of another car are already available. These are intelligent or adaptive cruise control systems automatically maintaining a pre-set driving speed and a pre-set distance (or follow-time in seconds) and will apply the brakes if necessary. It is clear that these systems are not meant for high density traffic and are only meant for comfortable driving under more or less quiet traffic circumstances, such as on highways outside rush hours. (Therefore, this might not generate the solution for the urgent problem

under discussion in this article.)

'One step further' is anti-collision radar that would sense any obstacle or vehicle in front and side of the car driven, and acts (steers or stops) accordingly.

From a research point of view it is still far too early to expect practical application of such measures in the near future, since there are so many questions still to be answered. The safety of the whole traffic system is one of them.

3.2 Injury prevention

3.2.1 Car design

Technical solutions, involving the design of the car, its structure or its safety applications, are subject to European legislation, prepared at Brussels (so-called Directives) and Geneva (so-called Regulations). These legal requirements however are minimum requirements (primarily designed to decrease trade barriers), to which all manufacturers have to comply, before they are allowed to sell their cars in any of the 15 current EU countries.

It is as well that car manufacturers voluntarily provide a lot of extra safety (devices), or if not voluntary, based on the demands of the market.

Extra safety is not only provided by the well-known airbags meant for additional protection in frontal collisions and side collisions, but also by the less visible pre-designed collapsible structures at the front as well as the sides.

3.2.2 EuroNCAP, the ultimate solution?

As in the US and Australia, also in Europe a test program has been developed and applied to test new cars at a safety level beyond the requirements of the current directives. The European consumer associations initiated this program, called EuroNCAP (European New Car Assessment Program). It is already joined by a number of national authorities, research institutes and car manufacturers; the European Commission is funding part of the costs. The program is considered to be 'helping' car manufacturers to improve the passive safety features of their cars, especially of cars that do not fully comply.

All results are published at regular intervals, after they have been discussed with manufacturers, who are even given an opportunity to apply improvements if test results are at first negative. Though car rear-end design (including head restraints) is not yet part of the program, there are however several indications that this will soon be the case. An important supporter of this point of view, is the EU itself, represented by DG TREN (Directorate General for Energy and Transport), awaiting the results of several current EU projects concerning head restraints and test methods to be incorporated in EuroNCAP.

3.2.3 Head restraints

During previous years, providing proper protection against the consequences of rear-end collisions has not been a priority of car manufacturers, despite consumer association's reports on the various poor designs of individual head restraints, including their impossibility to be adjusted to the proper height and the proper horizontal distance.

Availability of head restraints in new cars has been required only recently, though it must be said that in most new cars availability of head restraints has been almost 100% for a long time, at least on front seats. The particular problem in the Netherlands was (and still is!) that Dutch males may not be protected properly as far as height of head restraints is concerned, even if the restraints comply with the only recently adjusted European Directive pertaining to this matter[2].

It appeared that while the Dutch government (advised by SWOV) was trying very hard to convince the European Community to improve vertical adjustment height, other European countries (supported by their industry) were opposed, in most cases, for financial reasons. It is only a small consolation that the situation in the US is even worse[5].

The scope of the Dutch problem of vertical height adjustment is clearly demonstrated in Figure 7.

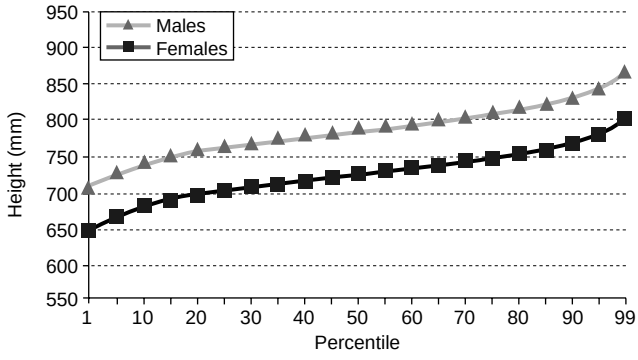

Fig. 7 Cumulative frequency of required minimum head restraint height for adult Dutch males and females, by percentile

Figure 7 shows that though all Dutch females would be properly protected, still 35% of Dutch males would not be properly protected by head restraints conforming

to the latest European requirements (i.e., minimum height = 80 cm).

Injury prevention may be enhanced by means of far better head restraints than are currently available. Drawbacks of current head restraint designs are well documented. From periodic Dutch road surveys, it appears that still about half of all drivers and front-seat passengers do not adjust the vertical distance properly even if they can.

Sustainable solutions should include at least the whole of the seat considering seat back and restraint as one structure. Further developments must also include the structure of the rear-end of the car much the same way as the front-end and sides of cars has become part of the passive safety structure. Incorporating a properly developed test in EuroNCAP as stated above, may well result in sustainable solutions.

4. SUMMARY AND CONCLUSIONS

4.1 Accident data

- According to accident data from the national police registry, the number of injury producing rear-end accidents of cars, the collision type thought to be highly associated with whiplash injury, has been increasing considerably over the last 15 years in the Netherlands. Also, the share of these accidents increased considerably, from less than 4% in 1985 to more than 11% in 1999, the total amount of these registered accidents remaining more or less the same at the level of 40,000 per year.
- The cause of the increase is mainly the increased traffic density (far more cars, not more roads). Since traffic density will probably continue to increase, especially due to the expected further growth of the car population, a further increase in the number of rear-end accidents is also expected.
- Contrary to expectation, the number of damage-only rear-end accidents did not increase much over the last 10 years. The share remained at a constant level of about 15% of all registered damage-only accidents in the Netherlands, the total annual number of these accidents being around 250,000.
- Typical properties of all rear-end accidents are their more frequent occurrence during rush hours than outside these hours; their severity is generally far less than all other types of collisions with cars, illustrated by the very low number of people killed or severely injured in these accidents.
- On rural roads, and especially on highways, the proportion of rear-end accidents is considerably above average, up to 40% of all accidents on these road types. However, the absolute number of these accidents is the highest in urban areas.
- Females involved in rear-end accidents are injured more often than males. This result was analysed in more detail in previous studies, where female drivers were compared with male drivers. Even after controlling for differences in severity of the accident, and mass/size of their cars, females are more often injured than males. Assuming that the injuries sustained in rear-end collisions are mainly neck-injuries (an item not available from police based registration), this finding points to some structural difference regarding injury susceptibility of the female neck compared to the male neck.
- There is also evidence that female drivers are more frequently *involved* in rear-end accidents (where their cars are hit from behind) than male drivers, regardless of injury. No clear explanation for such a difference can be based on analysis of the available accident data.

4.2 Injury data

- Whiplash injury is not a matter associated with hospital in-patients. Only about 1% of all traffic casualties admitted has been given this diagnosis. At the level of A&E treatment however, whiplash injuries, or rather injuries associated with this diagnosis, are found to be more than 30% of all car-occupants.
- From survey data, concerning casualties from all types of accidents in the Netherlands, it was found that annually 25,000 car-occupants suffer neck-injury. Most of these may be considered whiplash related.
- From the same source, it was found that 50,000 Dutch people (car-occupants, involved in a previous accident) are suffering permanently from neck-injury complaints, most of which are definitely whiplash-associated.

4.3 Lack of link

While accident data point to a major traffic safety problem, they lack detailed information about the type of injury. While detailed injury data point to a major problem concerning whiplash injury and its consequences, these data lack almost all detail about the accident, the damage etc.

The combination of these sources (through matching or linking) could give a better way to further understanding of the whiplash phenomenon. It is recommended to carry out this type of study on a statistical basis, ensuring numbers of cases are large enough for real-world analysis of this increasing social problem.

4.4 Remedies

4.4.1 Accident prevention

- There is evidence that road improvement may well influence the occurrence of rear-end accidents. Promising are systems influencing driving speeds at potentially dangerous stretches. On Dutch highways some of these systems already prove their quality and usefulness in cases of pending traffic jams, a factor closely associated with the occurrence of rear-end accidents. From a Canadian study it also appears feasible to reconstruct crossings and traffic lights with emphasis on visibility, thereby preventing the occurrence of rear-end collisions.
- It is also expected that further development and application of intelligent in-vehicle systems to prevent accidents may reduce the scale of the problem. Available already are high mounted stopping lamps, and on a very small scale intelligent cruise control systems that react, or at least warn the driver, when the distance to traffic in front is becoming dangerously close. However, far more studies and experiments are needed to develop and optimise intelligent systems that will function and interact safely when applied in the whole car fleet.

4.4.2 Injury prevention

- Head restraints are still considered to be the number one remedy against the occurrence of neck injury. It is therefore very disappointing to conclude that even the European legislation lags behind concerning basic demands i.e., height requirements appropriate for most of the population. Even though Dutch people are bigger (i.e., taller) than average, it is not clear why 50% of Dutch males would not be protected by head restraints conforming to the existing legislation.
- From various recent developments however, it might be concluded that neck protection is becoming a major issue. Some car manufacturers advertise newly designed 'anti-whiplash' seats, including reclining seat backs and proper head restraints. Several European studies are being carried out to improve head restraints, seats, and the regulations surrounding this aspect. Recently the European Commission promoted the use of EuroNCAP for this purpose. One could imagine that through the combined forces of governments, EU Commission, manufacturers, insurers and researchers there is still hope that in the near future less whiplash cases will occur.

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