

TRAFFIC SAFETY OF HEAVY VEHICLES, (ACCIDENT ANALYSIS, ACCIDENT RECONSTRUCTION)

KÓFALVI Gyula – IbB Hungary
VINCZE-PAP Sándor – AUTÓKUT
#244

1. ABSTRACT

This paper provides an overview of safety situations of commercial vehicles on the basis of databank concerning more than 4500 accidents. Different safety points of view are analysed and evaluated. A special accident reconstruction program (CARAT) is interpreted which is able to solve the traffic and accident questions in practical approach. It summarises conclusions and proposals on road safety of heavy vehicles in Europe.

2. PRELIMINARY

Presently, the European Union has 15 member states, but the future membership of central and east European countries is on the current agenda, whose general level of development, transport infrastructure and road safety situation are significantly different from each other. It is natural that efforts are made for creating uniformity in each field, including the accident statistics as well.

The IRU has been regularly dealing with general road safety, focusing primarily on one part of this issue, namely on the accidents of commercial vehicles and the safety thereof. The number, the transport performance and the accident situation of commercial vehicles justify clearly this special attention, since they have a major impact on the general road accident situation of a country or region. In addition to the general data, the IRU needs special information and correlations for the fulfilment of the tasks stipulated by it in this area that it could correctly appraise the safety situation, monitor the changes thereof, identify the unfavourable trends in due time and design its own actions, the necessary counter measures aimed at the enhancement of safety (publicity, education, training, new provisions, etc.).

3. MAIN AND SPECIAL OBJECTIVES OF ROAD TRANSPORT AND ACCIDENTS

3.1 Vehicle Fleet

The next two tables show the collected motor vehicle fleet data of 41 countries in a breakdown for the years of 1990 and 1997 and estimated data in 2001.

| | 1990 | 1997 | 2001 |
|-------|------|------|------------------|
| EU | 484 | 499 | 505 ¹ |
| CEC | 250 | 246 | 255 ¹ |
| Total | 734 | 745 | 760 ¹ |

Table 1. Number of Buses and Coaches (*1000) / EU and Central and Eastern European Countries / ¹estimated

| | 1990 | 1997 | 2001 |
|-------|-------|-------|--------------------|
| EU | 15689 | 19666 | 20300 ² |
| CEC | 2074 | 3085 | 3700 ² |
| Total | 17763 | 22751 | 24000 ² |

Table 2. Number of Commercial Vehicles (*1000) / EU and Central and Eastern European Countries / ²estimated

3.2 Heavy vehicles (trucks and buses, coaches) accidents in Europe for the period 1990-1999

The first question in this respect is the data of what accidents can be collected. In most European countries the statistical data collection system is such that there is only an estimate about the total number of road accidents. As a rule, only the parameters of those accidents are included in the official statistics during which one or more persons were injured, therefore no official and reliable information are available about the accidents involving a damage only.

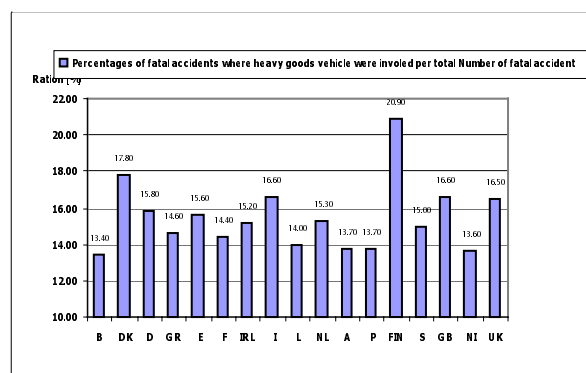


Figure 1. Percentage of fatal accidents where heavy commercial vehicles were involved per total number of fatal accidents

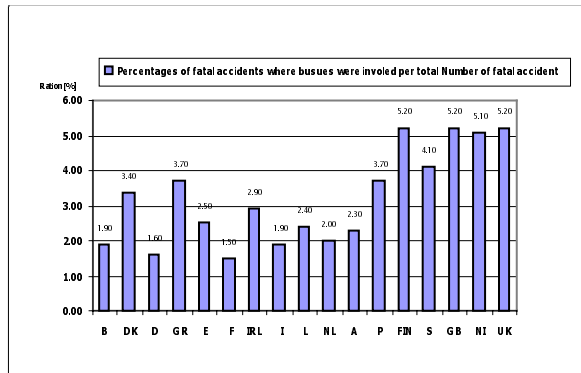


Figure 2. Percentage of fatal accidents where buses and coaches were involved per total number of fatal accidents

The proportion of commercial vehicles involved in fatal accidents in the EU Member States was 15.4%, and of buses and coaches was 2.4%.

3.3 Fatality on the road

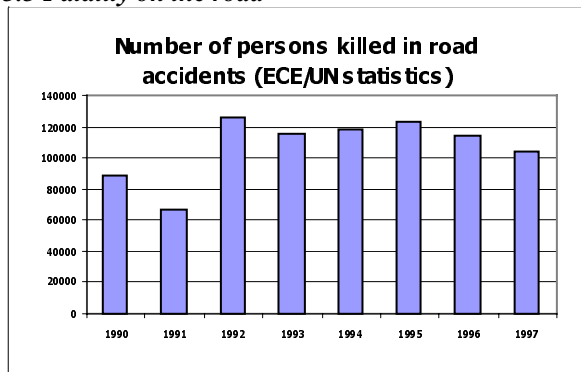


Figure 3. Number of fatal accidents (1990)

This statistics contains 35 European countries concerning the year 1990. Adding them up we learn that this year a total of 88,663 persons died as a result of a road accident in the listed 35 countries. In the same 35 countries 69,189 persons were killed in road accidents in 1997, which figure represents a 22% decrease.

3.4 Efficiency analysis

This section contains the analyses of accidents involving commercial vehicles over the past 15 years performed by the IbB and a comparison with credible accident research conducted abroad from a similar perspective. IbB's accident registration form sets out some 100 questions, divided into sub-groups.

The data evaluated give a good overview primarily of the nature and features of European utility vehicle accidents. The fatigue and falling asleep of the utility vehicle drivers play an important role in statistical analyses because this may cause accidents with very serious aftermaths. The efficiency analysis of the

vigilance control equipment named REACON, which is used widely for the first time in Europe (1,000 trucks) was also performed using the initial version of this accident statistics programme. The main definition of the vigilance analysis at scientific level will be covered later on. The majority of the utility vehicle accident analyses known to us (HUK/GDV, INRETS/Fr., ROBINSON/GB, DEKRA/D) applies to one country or one region. This data base contains trucks with Hungarian marking plates participating in international transport on the one hand, and in the case of accidents that involve more than one vehicles, it deals with the various means of transport of the given country. Based on the above, IbB's data base, supplemented with the nearly 30 years of experience of the analysts in accident research and analysis and vehicle accident expertise, provides results that are appreciable also at European level.

3.5 Impact points

The distribution of truck-passenger car impact points is a good indicator of the high proportion of frontal (65-78 %) and rear underrun (9-25 %) collisions.

Therefore it is important to fit appropriate front and rear underrun protection with suitable deformation characteristics to trucks (corresponding ECE and EU regulations) which prescribe such protection.

The accident participants in accidents involving commercial vehicles are predominantly passenger cars and trucks. With respect to the former, injuries to the less protected other participant are usually more severe, while in the latter category, the similarly large mass is the source of danger. The proportion of other accident participants is insignificant, therefore it is primarily those two categories of traffic participants that need more attention.

3.6 Causes of rollover accidents

Based on our analysis of 164 accidents involving the rollover of the vehicle, the main reasons for the accidents were as follows:

| | |
|----------------------------|------|
| Error of the driver | 56 % |
| Technical reason (vehicle) | 22 % |
| Exterior error | 22 % |

3.7 Non-effect of cargo

56.28% of accidents occurred with a full load, 28.14% occurred empty. The decisive majority of loads (93.89%) consisted of piece goods. The proportion of ADR loads (1.68%) is low. Severity was also below the average.

The cargo was featured as a causative factor of the accident in 1.83% of cases, which is far below the average. The GB statistics referred to above featured a 5.5% figure.

During the road control conducted in Germany (DVR) mostly utility vehicles participating in international transport were checked: in 27% of cases loading was correct, 34% showed minor mistakes, but in 39% there were grave deficiencies that threatened with an accident.

The demand for a greater fixing force arising out of the spreading of combined transport methods especially calls for a more thorough analysis and investigation of this issue.

In the accidents caused by load shift, the most common deficiencies with the restrain systems used were:

- Insufficient number of restraining devices used
- Edge protectors not used
- Not lashing parts of load independently of other parts
- Non-checking the security of the load during a journey
- Using a slippery load platform
- Balking not used, or not used properly.

3.8 Number of cases of environmental cause and percentage of all accidents

Heavy vehicles:

| | |
|---------------------------|--------|
| Human | 60,0 % |
| Technical | 15,0 % |
| Other (road, environment) | 25,0 % |

Accident causes:

| | % |
|-------------------------------|------|
| Speed | 8,7 |
| Falling asleep | 0,42 |
| Alcohol | 0,08 |
| Infringement of traffic rules | 68,3 |
| Other | 22,5 |

Table 3. Influencing factors of accidents

The human, technical and other influencing factors were summarised out of the answers included in the above data form, and the rounded data of these are provided. Technical components include mostly so-called technical and maintenance shortfalls. Naturally, these could also be grouped according to a different logic, but in this case proportions would also be in a 60-15-25 distribution. The former proportions also show differences by accident type. For instance, in the cases of collapse and loss of stability the participation of the road may reach 40%.

Following a careful analysis of traffic accidents, it can be clearly stated, that the weakest link in the control system „driver-vehicle-environment” is the driver of the vehicle. 80 to 90 % of all traffic accidents are attributable to human error. One of the causes for such

driving errors is the excessive flood of information, to which the driver is exposed to.

3.9 Number of accidents involving drivers by various age groups

| Age groups of drivers % | | | | | | |
|-------------------------|-------|-------|-------|-------|-------|-------|
| Year | 1993 | 1994 | 1995 | 1996 | 1997 | 1999 |
| 25-30 | 8,55 | 12,59 | 11,25 | 8,82 | 11,21 | 7,97 |
| 30-35 | 13,65 | 12,77 | 9,77 | 9,42 | 8,79 | 8,64 |
| 35-40 | 27,8 | 25,91 | 25,9 | 17,43 | 13,62 | 13,29 |
| 45-50 | 26,64 | 27,37 | 26,75 | 36,87 | 34,66 | 33,55 |
| 50-55 | 15,13 | 12,96 | 16,77 | 19,44 | 20 | 23,26 |
| 55-60 | 8,22 | 8,03 | 9,55 | 7,41 | 11,55 | 11,96 |
| 60-65 | 0 | 0,36 | 0 | 0,6 | 0,17 | 1,33 |

Table 4. Influencing of age

3.10 Distribution of accidents by time and distance

Not dealing with different environmental effects (restricted visibility, fog,...) only the accidents time-table distribution is emphasized.

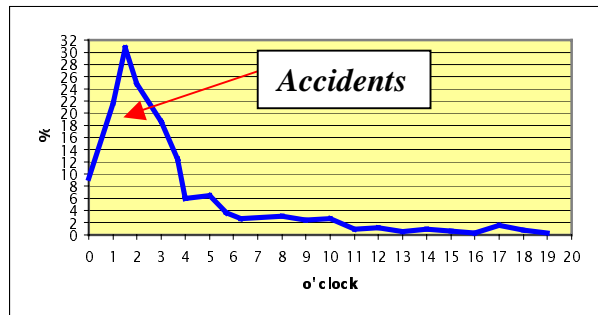


Figure 4. Accidents o'clock

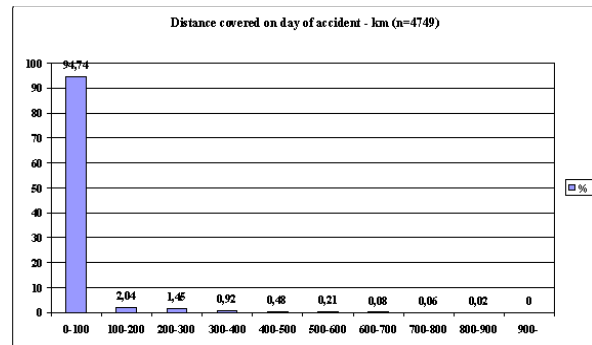


Figure 5. Distances covered on day before accidents

The high incidence of accidents in the *first two hours* after setting off is definitive.

With respect to the days of the consignment, the decisive proportion of accidents (46%) occurred in the first two days and the decisive majority (94%!) of

accidents happened within the first hundred kilometres, on the first day of the trip.

This raises questions as regards the system of launching consignments and the level of conditioning of drivers when they start work. The relaxed condition is pseudo feature, because of the previous nervousness (previous day's occupation, loading, administration,...). The drivers get into the cabins in stress condition.

3.11 Braking or not braking

The very high proportion of accidents with no braking (62 %) suggests lack of competence of the drivers. It can be driven back to the lack of the necessary training, education and certainly to the physical conditions of the drivers.

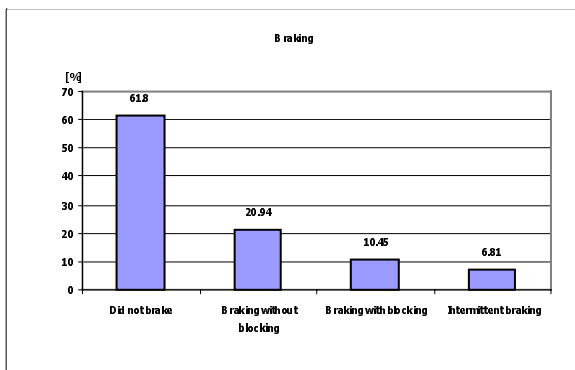


Figure 6. Braking for accidents

Certainly many other effects (road surface, road visibility, other environmental causes, vehicle defects, alcohol influence, ...) could be featured and analysed yet.

4. RECONSTRUCTION OF ACCIDENTS

A deep-in analysis of an accident is not accomplished without accident reconstruction and without computer aided accident reconstruction. The accident expert needs the plotting of streets, roads and trees, buildings. He needs kinematics and kinetics of vehicles or to check the vehicle mobility on off-roads. We use the CARAT 4.0 software for this aim.

4.1. CARAT 4.0

This program (Computer Aided Reconstruction of Accidents in Traffic – CARAT) is able to solve the traffic and accident questions in practical approach. It integrates a *high-efficiency drawing module* for drawing, kinetics and kinematics. It has a special network which makes easier to set a scaled, dimensioned drawing about the plot. (DXF-drawings and bmp-files can be used from any other program.)

The 3D kinetics program is available for complete analyses of braking, drifting, acceleration or normal manoeuvre process of vehicle. The front-wheels can

be steered, other wheels can be governed by deformations. The most important element of the mathematical simulation is the tyre-model. It uses the IPG-TIRE static model. The break-load partition can be arbitrary and the adhesion is changeable by wheels. The steering movements, (brake, gas) pedal-forces are also arbitrary in time-function. Special investigation is the analysis of braking process in different surface to every wheel.

The part of kinematics handles the vehicles in arbitrary 2D track with arch-movement simulation. (E.g. "Ackerman" requirement.)

The vehicles can be examined with 6 degrees of freedom for rollover or other complex process too. The calculations can be supplemented with diagrams of time, road, velocity, acceleration.

Additionally the user can choose among different technical data-bases of vehicles, 2D and 3D drawings of buildings, trees, vehicles.

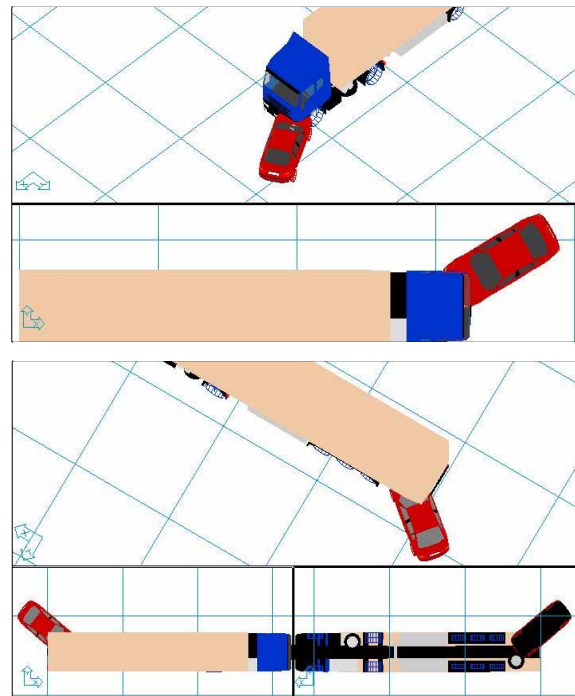


Figure 7. Front- and rear oblique impacts in 2 views.

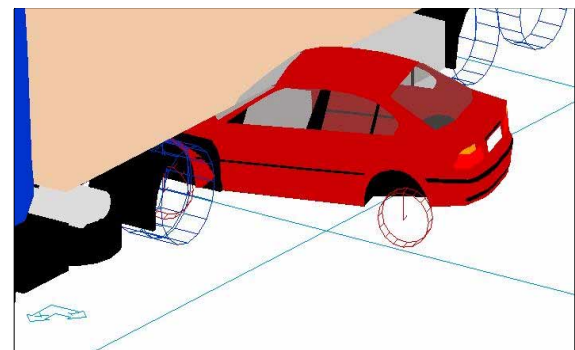


Figure 8. Side impact of automobile with truck.

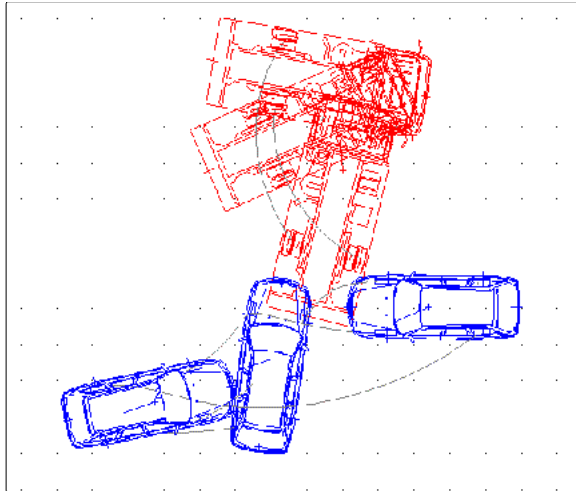


Figure 9. Motion analysis (per 0,5 seconds) of rear-side impact of truck with passenger car.



Figure 10. Front underrun accident reconstruction of small automobile with truck.

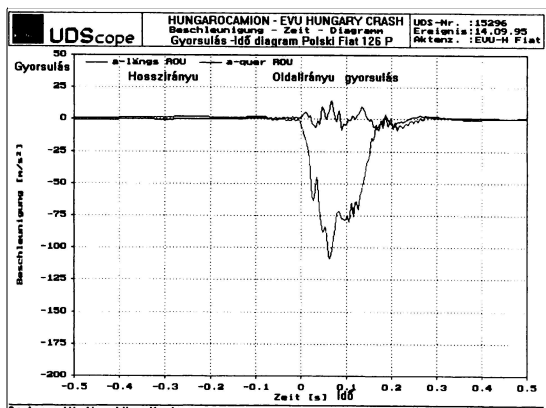


Figure 11. The measured longitudinal and side accelerations at previous front underrun accident-test.



Figure 12. Real truck-automobile side impact reconstruction test.

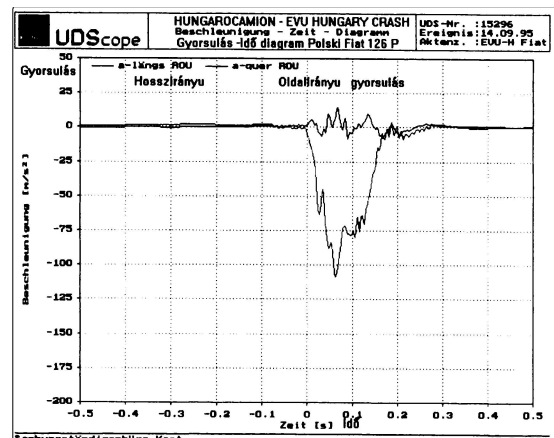


Figure 13. Measured longitudinal and side accelerations at side impact of automobile with truck.

5. SUMMARY, CONCLUSIONS

5.1 Conclusions

- 1) The proportion of accidents caused by high speed with passenger cars is comparatively low (cca. 55%). As regards speed, there is a high proportion of accidents that occurred at low speeds.
- 2) Although accidents arising out of falling asleep or driving under alcoholic influence are represented insufficiently in the analysis, both fields require strict control.
- 3) Defects (total) of engine/power transmission (20%) and brake systems (56 %) are the definitive components. Roughly seven per cent of the HGVs involved had some kind of defect which contributed to the accident.
- 4) Distribution of accidents by time of day, the decisive majority of accidents happen between 6 a.m. and 2 p.m. Cyclic distribution corresponds very highly with the so-called performance-

availability cycle in the case of accidents involving falling asleep.

- 5) The distribution of truck-passenger car impact points is a good indicator of the high proportion of frontal and rear (underrun) collisions. The distribution of driver impact points within the cab indicates the direction of development for passive safety.
- 6) Road types, main roads are in first place (59.13%), with the majority having one lane in each direction (64.4%). Road surface, high quality asphalt (75%) and concrete (23.63%) predominate. Among road surface conditions, dry one dominates (56.68%), but lower traction wet surfaces (22.97%) and icy surfaces (12.48%) account over 35% collectively. More than a third of all accidents occurred on such surfaces. Road incline: predominantly no incline (76.83%). At road visibility the good visibility predominates. Weather: the proportion of accidents occurring in clear weather is decisive (54.41%). Rain and fog show relatively smaller proportions (8.31% and 3.9% respectively), but accidents occurring in such conditions were more severe than the average. Wind was not a causative factor in over 95% of accidents.
- 7) Driving experience, a definitive peak is observable with drivers aged 18-20, while distribution by experience at the company showed peaks at drivers with 1-2 years and 10-12 years of experience. Among those, it is particularly the high incidence of accidents with drivers who have up to two years of experience with the company they drive for that requires the implementation of effective driver training in harmony with the company vehicle pool and control system.
- 8) Rollovered vehicles in the entire database: the proportion of overturned vehicles is max. 2%, while among the 1073 accidents included in the detailed analysis, the corresponding proportion is 15%.
- 9) Although the proportion of accidents where the vehicle is turned over and leaves the road is relatively low compared to all accidents (10-15%), they deserve special attention and analysis due to the volume of financial damage generated and the high probability of personal injuries (ejected out of the cab).
- 10) Cargo: 56.28% of accidents occurred with a full load, 28.14% occurred empty. The decisive majority of loads (93.89%) consisted of piece goods. The proportion of ADR loads (1.68%) is low. Severity was also below average. Relationship between cargo and accident, the cargo was featured as a causative factor of the accident in 1.83% of cases, which is way below

average. The GB statistics referred to above featured a 5.5% figure. General accident statistics usually do not contain accidents stemming from the movement or incorrect fixing of the cargo. Thus, it is possible to deduce conclusions primarily from the expert investigations on individual accidents about the fact that the fixing of the cargo plays a dominant role in about 15-25% of lorry accidents. In the absence of international regulations various national requirements and recommendations are demanded on the fixing of cargo.

- 11) With respect to the days of the consignment, the decisive proportion of accidents (46%) occurred in the first *two days*. This raises questions as regards the system of launching consignments and the level of conditioning of drivers when they start work.
- 12) The decisive majority (94 %) of accidents happened within the first hundred kilometres, on the first day of the trip.
- 13) The high incidence of accidents in the *first two hours* after setting off is also definitive.
- 14) The very high proportion of accidents with no braking or steering manoeuvre (61.18% and 69.11% respectively) suggests lack of competence in the drivers.
- 15) The proportion of jack-knifing with articulated lorries (7.93%) shows a favourable tendency. That indicates that the braking and directional stability characteristics of the vehicles have improved significantly. The primary reason is the widespread use of ABS and EPS.

5.2 Proposals

- *Driver training*: Special- defensive - safety training (not only for the transport of dangerous goods).
- *Management training*: IRU - Road Safety Management Program.
- *Vehicles technical systems*:

In summary, the requirements of **passive safety** are as follows:

- introduction of enhanced front under-run protection (and bumper) systems with energy absorbing properties;
- improvement of rear under-run protection systems for truck and trailers ;
- introduction of closed, large-area protection on the side of trucks and trailers keeping the distance to the road surface as low as possible ;
- improved protection in the truck cab, particularly by increasing the structural

stiffness of the cab based on real accident situations;
increase in the percentage of truck passengers wearing seatbelts;
granting of a weight bonus for vehicles featuring safety devices.

At **active safety** equip the trucks with:
adaptive cruise control systems (ADC);
electronic braking systems (EBS);
electronic stability program with rollover stabilisers (ESP);
driving lane assistance systems;
conspicuity of the truck at darkness (ECE-R 104 retroreflective markings).

- *Systems to help drivers to comply with regulations:*
 - speed governors;
 - tachographs (new digital tachograph).
- *Road infrastructure:*
 - road design, construction and equipment (dimension-weight-drivers sight line, kinetic energy affect road construction, spraying of water by heavy vehicles, guard-rails are not always equally effective for lorries and car, emergency stopping lanes);
 - ancillary infrastructure (service areas, parking places for heavy vehicles, freight terminals).

Forecasting the future, we say that, the intelligence crash avoidance systems and the different technical developments ,in strange mode, have slight influence onto the accidents in the practice. Not only the less developed countries, but the more developed EU countries will struggle with the same daily problems in the near future too. The previous unsolved tasks will alive further.

REFERENCES

- [1] Kőfalvi, Gy.: Heavy vehicle transport and environment protection in Europe
OECD- Symposium 1993. Budapest
- [2] B.J.Robinson: Fatal accidents involving heavy goods vehicles in Great Britain, 1988-90.
- [3] Kőfalvi, Gy.: Turnover of commercial vehicles examination-improving those under way stability characteristic. The Second International Conference on Road Safety October 7-10. 1991 Tel-Aviv
- [4] DVR-Website: Ladungssicherung – Strassenkontrolle 1999 www. dvr.de
- [5] Road Accident Statistics CARE- Database EC DG TREN E3 –06/07/2000
- [6] Statistics of Road Traffic Accidents in Europe and North America. United National Publication. 1990-2000
- [7] Eurostat- Statistics 2000, CARE database 2000