THE INVESTIGATION OF ACCIDENTS INVOLVING RESTRAINED CHILDREN AS PART OF THE CREST PROJECT - CHILD RESTRAINT SYSTEM FOR CARS - FUNDED BY THE EUROPEAN COMMISSION

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ABSTRACT

The objective of Workpackage I of the CREST research programme is to acquire knowledge on injury mechanisms through an in-depth investigation of some 400 accident cases involving children using child restraint systems. These cases meet selection criteria of front or side impact, age of child and severity of injury of occupants.

The information gathered and the various methods of investigation of accident cases will be described.

A summary of information collected to date includes the number of children by injury severity, type of restraint and age and example cases will be presented.

THE OBJECTIVE OF WORKPACKAGE I (WP I) of the CREST research programme is to acquire the necessary knowledge on injury mechanisms through an in-depth investigation of some 400 accident cases involving children using child restraint systems. The database will contain cases which meet specific criteria that are relevant to the CREST programme. The database will not, therefore, be representative of the real-world accident scene. From this database cases will be identified and

approximately 45 reconstructions and 200 sled tests undertaken by Workpackage II of the CREST project. Workpackage III of the programme concentrates on the development of improved child dummies and numerical simulation. The outputs of WPs I, II and III will be used by Workpackage IV to propose improved test procedures (test and dynamic conditions, updated biomechanical criteria and improved dummies) which will determine the effectiveness of child restraint systems. Innovative designs of child restraints will be developed and will undergo the new test procedures in order to demonstrate the feasibility for industry to meet them.

THE CREST PROGRAMME

CREST - Child Restraint System for Cars, is an EC EUCAR project under the Standards, Measurements and Testing (SMT) Programme. The project (number SMT4-CT95-2019) was launched by Directorate General XII in January 1996 and is of 54 months overall duration. This paper therefore describes the activities of WP I during the first $2^1/_2$ years of the programme.

The CREST programme involves 8 Partners, 3 Associated Partners and 2 subcontractors from 6 European countries involved in four Workpackages. The partners are presented in Table 1. The four Workpackages are further subdivided into Tasks, in order to facilitate the entire work programme, as described below:

WP I: Accident Cases
WP II: Dynamic responses of the dummies
- Task 1 Accident reconstructions
- Task 2 Sled tests for parametric variation studies

WP III: Design and instrumentation of the dummies
- Task 1 Crash test dummy improvements
- Task 2 Numerical simulations of dummies and child restraint systems
- Task 3 Evaluation of dummy improvements

WP IV: Innovative child restraint system prototypes and test method definition
- Task 1 Proposal of test methods to evaluate the effectiveness of child restraint systems
- Task 2 Development of three prototype innovative child restraint systems
- Task 3 Validation of the prototype innovative child restraint systems

ORGANISATIONS INVOLVED IN WP I

The five organisations involved in WP I will ultimately deliver a CREST database of approximately 400 documented cases. These cases will meet selection criteria, as described later in this paper, of the type of impact, age of child, method of restraint and severity of injury.

The role of Workpackage Leader is fulfilled by the Laboratory of Accidentology and Biomechanics (LAB). The LAB, based in Nanterre, France, is common to PSA Peugeot Citroën and Renault. The personnel involved in the case investigations are 3 engineers and 4 accident investigators. The LAB is also responsible for the management of the CREST database.

Table 1 - Partners of the CREST Programme

Organisation (in alphabetical order)	Involvement	Country
BASt, Bundesanstalt für Strassenwesen	Partner	Germany
FIAT Auto SpA (ELASIS SEpA)	Partner (Subcontractor)	Italy
GDV, Gesamtverband der Deutschen Versicherungswirtschaft e.V. Institut für Fahrzeugsicherheit.	Associated Partner with RENAULT	Germany
INRETS, Institut National de Recherche sur les Transports et leur Sécurité - LBSU (Laboratoire de Biomécanique et Sécurité des Usagers)	Partner Workpackage Leader WP III.3	France
MHH, Medizinische Hochschule Hannover, Accident Research Unit	Associated Partner with the BASt	Germany
PSA Peugeot-Citroën	Partner Workpackage Leader WP I	France
RENAULT Biomechanical Department	Project co-ordinator Workpackage Leader WP II	France
TNO, Nederlandse Organisatie voor Toegepast Natuurweten- schappelijk Onderzoek, Crash Safety Research Centre	Partner Workpackage Leader WP III.1 and WP III.2	Holland
TUB, Technische Universität Berlin	Partner	Germany
VSRC, Vehicle Safety Research Centre of RICE, Research Institute for Consumer Ergonomics, Loughborough University	Partner	UK
VTI, Swedish National Road and Transport Research Institute, Crash Safety Croup	Associated Partner with TNO, Workpackage Leader WP IV	Sweden

The Accident Analysis Team of ELASIS is involved in WP I on behalf of FIAT Auto SpA, Italy. The ELASIS accident unit has 7 personnel: 2 engineers and 5 technicians, all of whom are involved in the CREST case investigations. The medical information is collected by the Second University of Naples. ELASIS is also responsible for the development of the CREST database.

Gesamtverband der Deutschen Versicherungswirtschaft e.V. (GDV), Germany is involved in WP I as an associated partner to RENAULT, France. GDV is an association in which most German insurers have joined together and has 474 member companies of which 124 are motor insurers. At the Institute for Vehicle Safety in Munich scientific research is performed in all areas of vehicle safety including accident analysis, biomechanics, injury assessment and prevention and the development of safety standards in close co-operation with the German traffic ministry and European Authorities. The CREST case investigations are undertaken by engineers, medical experts and project assistants from the department.

The Accident Research Unit of the Medical University of Hannover (MHH) is involved in WP 1 as an Associated Partner on behalf of the Bundesansstalt für Strassenwessen (BASt), Germany. The CREST case investigations are undertaken by engineers, medical experts, project assistants and students from the department, under the supervision of a medical expert.

The Vehicle Safety Research Centre of RICE (the Research Institute for Consumer Ergonomics, Loughborough University) is an organisation specialising in accident investigation and crashworthiness based in England. The CREST vehicle examinations are co-ordinated by one dedicated accident investigator and undertaken by any of a team of 6 accident investigators. The collection and coding of medical information is the responsibility of a team of 3 and the interviewing, case co-ordination and CREST project management is undertaken by an ergonomist.

The objective of WP 1 is to investigate 392 accident cases that meet the criteria. This total number of cases is divided between the 5 organisations and will be investigated during 4 years of the project. The co-ordination of the CREST project as a whole has necessitated a revision of the original allocation of cases and the intention of all of the groups is to condense the period of accident investigation as far as this can be achieved within the operational constraints of each organisation.

The schedule has proved to be difficult to meet in the light of (i) the CREST criteria, (ii) the number of accidents that meet these criteria and (iii) the effort involved in pursuing those cases that prove not to meet the criteria. Each organisation is making efforts to increase the number of potential cases and the situation will continue to be closely monitored and revised in the light of progress.

METHODOLOGY

The methods of case investigation and the sources of information vary between the organisations and include on-scene or post accident vehicle examination and different procedures for notification and access to medical records and personal information. However, common to all the investigators must be information about the vehicles, the circumstances of the accident, information about the occupants and their injuries and details of the restraint system being used. It was necessary therefore to develop a standard CREST form in order to ensure that the content, format and terminology used are common to all. The CREST form is an enhanced version of the ISO/FDIS 13218 report form [1]. Case criteria have been established and fine tuned in order to meet the overall objectives of the CREST project and make the case investigations as effective as possible. These criteria were confirmed in May 1997, are summarised in Table 2.

Table 2 - The case criteria for CREST.

One child or more under the age of 12 years appropriately and correctly restrained. At least 1 child up to the age of 12 years correctly restrained in a child restraint system (CRS) or adult seat belt. (Note: cases with misuse of CRS, such as inappropriate type of restraint for size of child or incorrect fitting of restraint into the vehicle, will be included if the misuse can be well defined).
Either the child or another restrained occupant severely injured. Frontal or lateral impact with at least one severe injury (AIS 2+) or fatality observed in the accident; eg. AIS 0 or AIS 1 for restrained occupants and a severely injured restrained child (AIS 2+) or AIS 2+ for other restrained occupants and children with no CREST relevant injuries (AIS 0 or AIS 1)
Frontal collision - ΔV >40 km/h Frontal collisions with ΔV >40 km/h even if restrained children receive no CREST relevant injuries (AIS 0 or AIS 1)
Lateral impact - intrusion >200 mm Side impacts with intrusion >200 mm, even if a child restrained on the struck side by seatbelt or CRS receives no CREST relevant injury (AIS 0 or AIS 1)
Car-to-vehicle or car-to-fixed-obstacle accident Case vehicles are cars and passenger vehicles designed to seat up to 9 occupants. Only frontal and side impacts are to be investigated for reconstruction. Multiple collisions and roll-overs can be selected only if the injuries are related to a single impact.

The LAB investigates cases all over France and with the support of the police and hospital staff conduct a technical examination of the vehicles involved, obtain a medical description of the injuries and endeavour to find out about the child restraint system (CRS) used. The LAB increased its notification systems and now has four sources of information:

- the area of investigation in the west of Paris in which all passenger cars with injured occupants are systematically analysed;
- the two areas (Normandy and Picardy) in which accident causation related investigations are carried out on the spot in real time;
- the reports by the Police (Gendarmerie) of all accidents with injuries occurring in both country and small city areas;
- the information coming from the medical emergency teams acting all over France.

The investigations of ELASIS are based on an agreement with the Italian Traffic Patrol [2]. The accident unit are alerted to accidents from all over Italy in which at least one person is injured and there are child occupants. They immediately contact the local police to verify whether the accident satisfies the CREST criteria, to obtain all the data

collected by the police officers at the scene of the accident and to arrange the in-depth investigation regarding the vehicles, injured people and the road infrastructures. The vehicles are then inspected by ELASIS, standard measures of deformation taken and impact points of the occupants with the vehicles recorded. Further investigations are carried out with regard to the site of the accident and the road infrastructure. All medical data are collected. Every accident is then reconstructed in detail using the data collected and D.U.R. procedure (Dekra Unfall Reconstruction). The experience to date has highlighted the relatively low frequency of accidents involving restrained children. This is believed to be a consequence of the low rates of child restraint use. In order to increase the sample of accidents ELASIS will monitor the police database for all accidents involving children throughout Italy and will then follow up specific accidents.

The methodology of GDV is significantly different to those of the LAB and ELASIS. Case investigation is retrospective, on the basis of insurance claims of the German motor insurers [3]. The database of retrospective cases which is being trawled for cases that meet the CREST criteria contains 18,000 accidents with personal injuries in Germany during 1990 and 1991. The insurance claims contain the following main documents: a Police report, an expert's report (which is sometimes an accident reconstruction), medical data and witness evidence. There is, therefore, a lot of information about the cause(s) of the accident, the chain of events, the vehicle damage, safety systems and the resulting injuries. On consideration of all of this information a retrospective analysis is undertaken by the engineers and medical experts in the team.

The investigations undertaken by MHH are both retrospective and current. The retrospective cases [4] are taken from the ARU's database according to the CREST criteria. The biomechanics and kinematics of injury pattern, the child restraints used and other information is analysed in detail. A proportion of these cases have required further contact with the vehicle occupants in order to establish details of the child restraints used. In addition to the examination of retrospective cases procedures have been established to investigate current cases involving restrained children. The investigation area of MHH extends from the urban to the rural regions of Hannover with a radius of approximately 60 km. However, this area has been enlarged in order to increase the number of potential CREST cases. Since April 1997 police reports of all car accidents with injured children in the region of Lower Saxony are sent to MHH. Those which meet the CREST criteria are selected for a comprehensive investigation and sampling of information.

The methodology employed by the VSRC at RICE is based on the in-depth accident investigation procedures developed for the UK Co-operative Crash Injury Study (CCIS) established in 1983 [5]. It involves detailed retrospective examinations of crashed vehicles which are then correlated to occupant injury information obtained from hospital records, post mortem reports and postal questionnaires. For the CREST study all police notifications from the East Midlands catchment area (that is Nottinghamshire, Leicestershire and Derbyshire) are considered. All of those which meet the CREST criteria are investigated. During the first year of the project it became clear that the number of potential cases from the established sampling area was insufficient. Methods have now been established for the notification and investigation of accidents from the

West Midlands sample area of BARC, the Birmingham Accident Research Centre. Additional areas of accident notification are being investigated.

The existing procedures of the partners did not all yield sufficient information about the child restraints and details of their use. Where possible, therefore, the partners obtain additional information from the parent, guardian or driver of the case vehicle. This is achieved by face-to-face interview in order to elicit information about each child restraint used, its history, fitting, use and possible misuse. Measurements and photographs of the child and child restraint are taken and, when appropriate, the child restraint recovered. Where possible observation is made of the restraint being fitted into the vehicle and the child into the restraint. In some cases those involved do not wish to be interviewed, but will give information over the telephone. This information cannot be as complete as that obtained during a personal visit, but can nevertheless provide a basic level of information about the CRS. A direct approach to families is not made in cases involving a fatality or very serious injury. In these circumstances (and in cases where those involved have not responded to contact from the research team) the co-operation of the police dealing with the accident is invaluable. The police officer, on behalf of the research team, returns to those involved and obtains basic information about the child or children, the method of restraint or the type of child restraints used. Alternatively they will establish whether a direct approach by the research team is welcome.

The partners endeavour to obtain information of the highest quality that is possible from all sources. Each case is considered by all of the partners in WP I and a collective decision is made about whether to include the case in the database and recommend it for reconstruction.

RESULTS

THE DATABASE of accident cases is the deliverable of WP I which will be used both to identify cases for reconstruction by WP II and as a database for future analysis. The database is not representative of the real-world accident scene as the accidents contained in it have been selected on the basis of the criteria documented in Table 2. The database structure has been developed by ELASIS in Access 2.0. It contains related forms in a hierarchical structure, as illustrated in Figure 1 and described below:

Form 1 Tb_IdentAccident : one record for each accident.
This form contains 20 variables and 1 illustration (drawing of the accident) recording the details of the accident and relating to the number of vehicles involved, the type of collision, the angle of impulse, overlap, etc.

Form 2 Tb_CarsDescr : there is one record for each of the vehicles involved.
This form contains 40 variables and 1 photograph relating to the make, model, mass, ΔV, etc.

Form 3 Tb_Occupant : there is one record for each occupant involved.
This form contains 3 variables that are common to the child and adult occupants: position, age, weight.

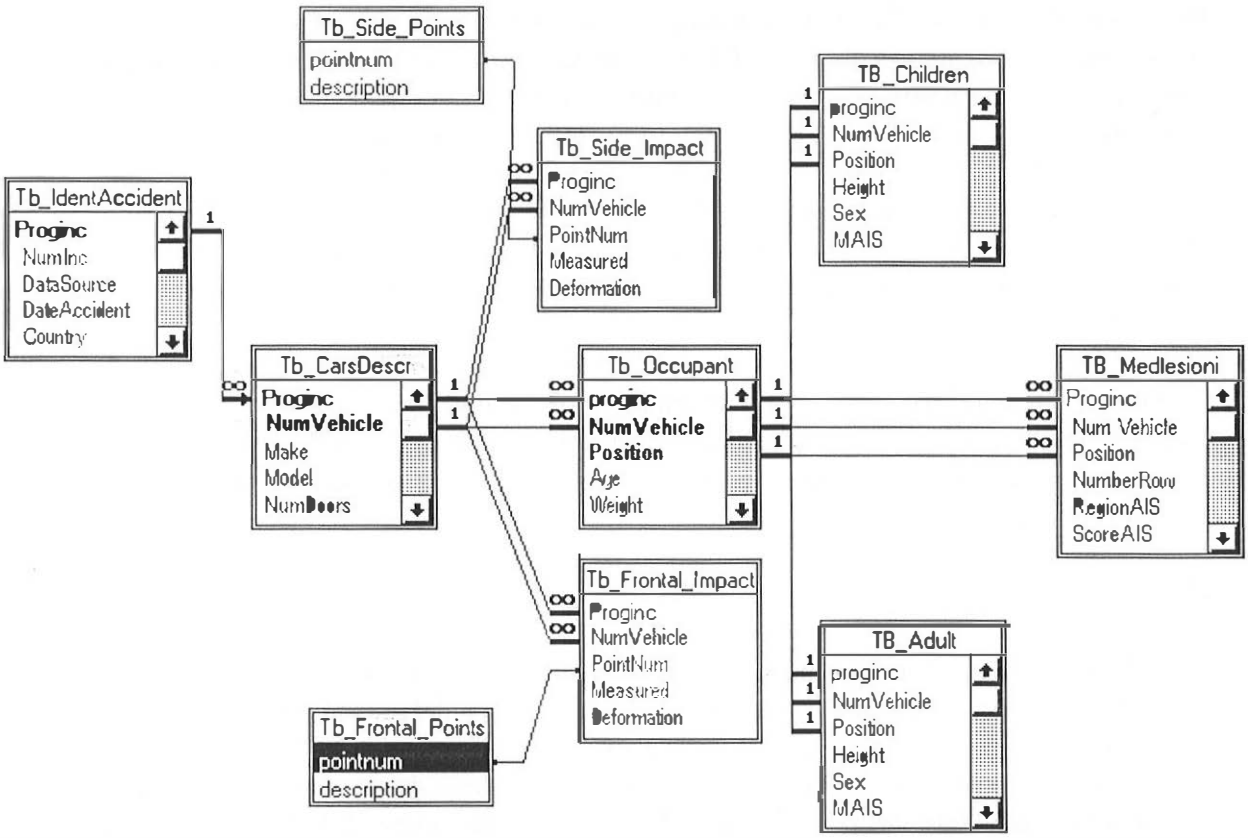
Form 4 Tb_Adult : there is one record for each occupant older than 12.
This form contains 9 variables relating to the person: height, gender, MAIS, ISS, etc.

Form 5 Tb_Children : there is one record for each occupant younger than 13. This form contains 24 variables regarding height, gender. MAIS, ISS, other information about the CRS and 1 photograph of the CRS.

Form 6 Tb_Medlesioni : there is one record for each injury sustained by the occupant. This form contains 5 variables relating to the injury: description of the injury, AIS region and score, impact area (that is the injury correlation between the occupant and the vehicle or CRS), etc.

Additional forms have been added for frontal and lateral impacts and the measurements that are taken for each.

Figure 1 - The accident case database architecture



ACCIDENT CASES continue to be investigated and in June 1998 the database contained records of 222 cases. The 222 cases include frontal and lateral impacts and other cases such as accidents involving 2 case vehicles. The cases held in the database are not all complete, as data are still outstanding from the more recent cases.

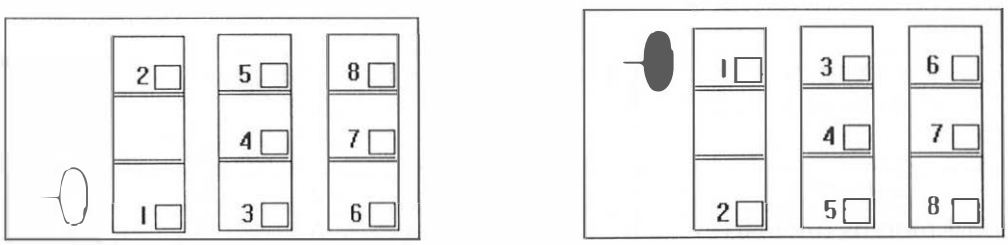
The data in this paper are intended only to demonstrate the content of the database. These data have not yet been analysed in any detail, and it is anticipated that as the database increases in size, the scope for analysis will be substantial. The number of cases considered in this paper is 196 with a total of 289 children being considered. This follows the removal of second and third case vehicles, any children in case vehicles who were not restrained and the incomplete cases.

The numbers of uninjured and injured children restrained in frontal and lateral impacts, by position within the vehicle, are presented in Table 3. Note that the MAIS is not known for 6 of the children. The positions within the vehicle are presented in Figure 2.

Table 3 - The numbers of uninjured and injured children involved in the frontal and lateral impacts by position in the vehicle.

Posi-tion	Frontal impact				Lateral impact				Total	
	MAIS 0 - 1		MAIS 2+		MAIS 0 - 1		MAIS 2+			
	n	(~%)	n	(~%)	n	(~%)	n	(~%)	n	(~%)
2	11	(4)	16	(5.5)	4	(1)	1	(0.5)	32	(11)
3	46	(16)	34	(12)	12	(4)	10	(3.5)	102	(35)
4	5	(2)	10	(3)	3	(1)	2	(0.5)	20	(7)
5	57	(20)	38	(13)	12	(4)	14	(5)	121	(42)
6	3	(1)	1	(0.5)	-	-	-	-	4	(1.5)
7	-		1	(0.5)					1	(0.5)
8	2	(0.5)	1	(0.5)	-	-	-	-	3	(1)
Total	124	(43.5)	101	(35)	31	(10)	27	(9.5)	N/K =6	(2)
	225 (78) N/K=3 (1)				58 (20) N/K=3 (1)				289	(100)

Figure 2 - Identification of the position in the vehicle.



LEFT HAND DRIVE CAR ***RIGHT HAND DRIVE CAR***

The different methods of restraint and the number of children using each in frontal and lateral impacts are presented in Table 4.

Table 4 - The number of children using each method of restraint in frontal and lateral impacts.

Type of restraint	Frontal impact		Lateral impact		Total	
	n	(~%)	n	(~%)	n	(~%)
Rearward facing infant carrier	18	8	2	3	20	7
Carricot with safety net	-	-	-	-	-	-
Carricot with torso restraint	-	-	-	-	-	-
Forward facing seat with harness	64	28	19	31	83	29
Forward facing seat with shield	6	3	2	3	8	3
Shield	3	1	-	-	3	1
Booster cushion and back rest with adult belt	16	7	9	15	25	9
Booster cushion and adult belt	41	18	12	20	53	18
Adult belt only	73	32	15	25	88	30
CRS (type not known)	-	-	-	-	-	-
Other	7	3	2	3	9	3
Total	228	100	61	100	289	100

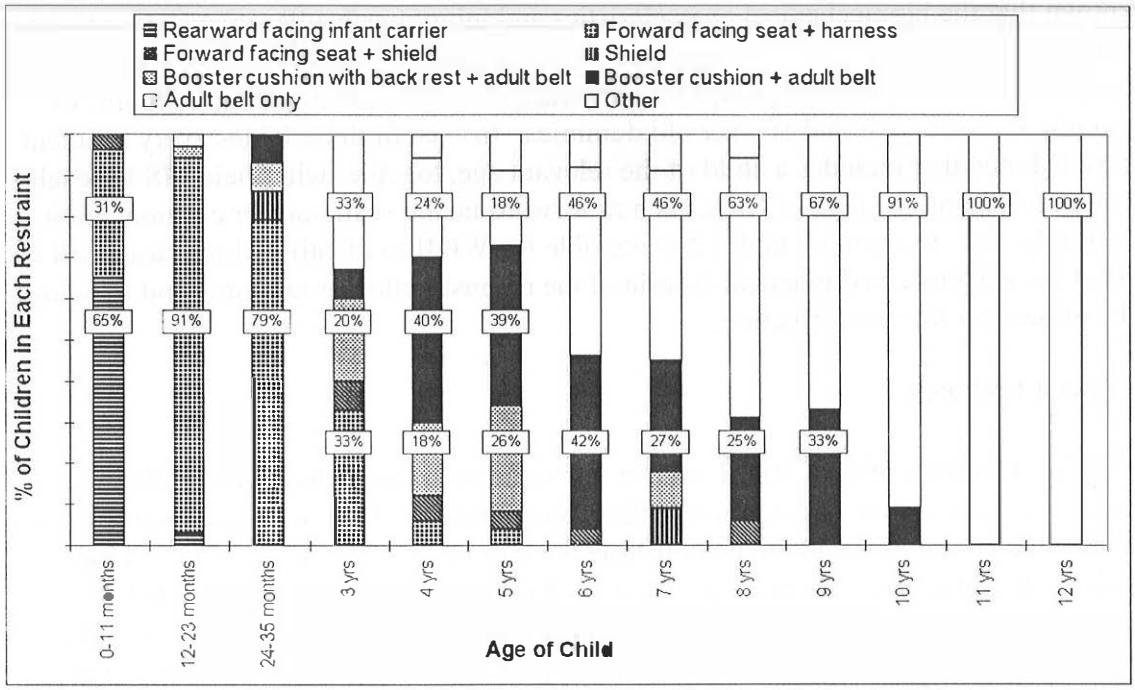
Children's ages are recorded in months up to and including 36 months, and then in years from 3 to 11. In certain circumstances cases have been included in the database which also include children who were 12 years of age. The number of children involved in frontal and lateral impacts by age is given in Table 5.

Table 5 - The number of children by age in frontal and lateral impacts.

Age in years (unless otherwise stated)	Frontal impact		Lateral impact		Total	
	n	(~%)	n	(~%)	n	(~%)
<12 months	26	11	5	8	31	11
12 - 23 months (inclusive)	30	13	6	10	36	12
24 - 35 months (inclusive)	28	12	10	16.5	38	13
36 months/3 years	15	7	4	6.5	19	7
4	17	7	12	20	29	10
5	23	10	4	6.5	27	9
6	24	11	6	10	30	10
7	11	5	3	5	14	5
8	16	7	2	3	18	6
9	12	5	4	6.5	16	6
10	11	5	-	-	11	4
11	9	4	3	5	12	4
12	6	3	2	3	8	3
Total	228	100	61	100	289	100

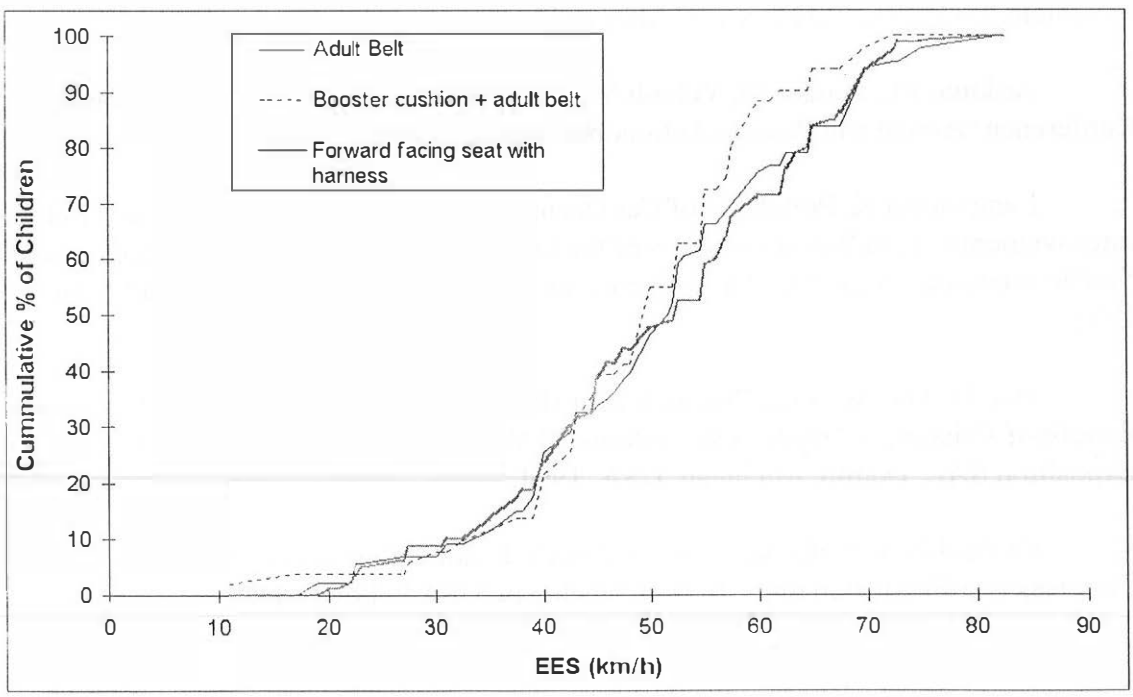
Looking at the frontal impacts the percentages of children using each method of restraint by age in years is shown in Figure 3.

Figure 3 - The percentages of children using each type of restraint by age in years.



As can be seen in Table 4, the three child restraint methods most commonly used in the frontal accident cases in the CREST data are the adult seat belt, forward facing seat with harness and booster seat with adult belt. Figure 4 shows the involvement of the children, whether uninjured or injured, in these three restraints plotted against EES and demonstrates that the distribution is similar for each of the restraint types.

Figure 4 - The distribution of EES for three most commonly used methods of restraint.



The output of the database is presented to WP II undertaking the reconstructions and WP III developing the improved child dummies in order to support their work. It is known that the biomechanical characteristics and injury mechanisms vary according to a child's age. The accident case information is therefore presented in 6 tables of injury frequency data, for the age groups relating most closely to the 6 month, 9 month, 18 month, 3 year, 6 year and 10 year old dummies. In each of these tables every accident case is listed that includes a child of the relevant age, together with their AIS for each body region and the type of CRS, such as forward facing seat, booster cushion, adult belt only, etc. From these tables it is possible for WP II to identify which cases will best meet the scientific and practical criteria of the reconstruction programme and to record the allocation for reconstruction.

CONCLUSIONS

The objectives of the CREST project are to improve the protection of children in the case of a car accident by determining the effectiveness of child restraint systems using instrumented dummies and to demonstrate the feasibility for industry to meet more stringent requirements for child protection. Workpackage I is providing detailed information from some 400 real world crash investigations which, together with the information from the other Workpackages, will form the basis on which these objectives can be met. At June 1998 WP I has investigated and allocated to the database 222 accident cases. The cases contained in the database meet specific criteria that are relevant to the CREST programme. The database is not, therefore, representative of the real-world accident scene and the presentation of these data in this paper serves only as a description of the CREST cases.

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ANNEX

CASE EXAMPLES

Two cases, a frontal and a lateral impact, are described briefly in order to illustrate the investigation of cases.

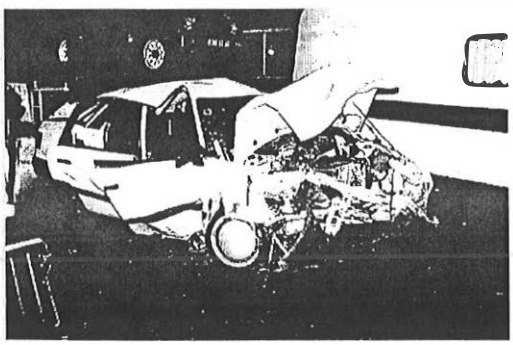
The first case, CCN 006 (see Figure 5), is a frontal crash investigated in January 1996 by the LAB which was reconstructed in June 1997 by the BASt. The case involved two passenger cars, a 1988 Audi 80 and a 1993 Citroën AX. The Citroën was overtaking another car on a single carriageway road and struck the oncoming Audi. The closing speed was estimated between 135 km/h and 145 km/h and the overlap was 75% on the right side.

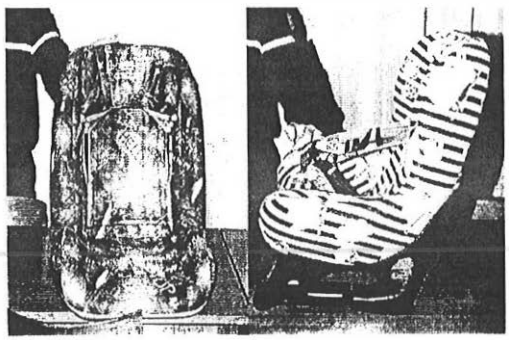
The Citroën had an EES of 75 km/h with a ΔV of 80 km/h. Its driver, a 43 year old female, sustained a head injury (AIS 5). A 7 year old male, who was sitting in the right rear place (position 5), was unrestrained.

The Audi (case car) had an EES of 60 km/h with a ΔV of 55 km/h. The maximum intrusion on the right side of the passenger compartment was 300 mm at the dashboard level and 340 mm at the right footwell. Two children were involved: in the right rear (position 5) a 5 year old female was restrained by a Britax Cruiser seat with the adult seat belt. She suffered a pelvis contusion (AIS 1) due to belt loading and an open fracture to the nose (AIS 2) resulting from a head impact against the front seat headrest. In the left rear (position 3) an 8 month old female was restrained with a 4 point harness in a Trottine forward facing seat, secured in the car by means of the adult seat belt. She suffered an odontoid fracture (AIS 3) without head contact.

The reconstruction was performed using P6 modified and $P^3/_4$, dummies. The results of the reconstruction carried out by the BASt form part of the output and deliverables of WP II.

Figure 5 - The case vehicle and CRS of CCN 006





The second case, CCN 073, is a side impact case which occurred in December 1996 and was investigated by RICE (see Figure 6). This case has been pre-selected for reconstruction but has not yet been allocated to a partner in WP II. It involved a 1987 Ford Fiesta XR2 (case vehicle) and a 1989 Austin Metro Clubman. Both vehicles were examined, medical information was obtained from the hospital and the occupants of the case vehicle were visited. The Fiesta, whilst negotiating a left hand bend, lost control and collided with the oncoming Metro. The Fiesta sustained a side impact with a collision angle of 90° and maximum intrusion of 330 mm.

The occupants were a 30 year old female driver and a 4 years and 4 months old male rear seat passenger. The boy was sitting on the struck side (position 5) in a K L Jeenay Kombi booster seat with a back rest, secured using the adult lap and diagonal belt. He sustained a bruise (AIS 1) and laceration (AIS 1) to the right side back of his head and fractures to his left femur, fibula and tibia (each AIS 2). The left side wing of the backrest and both wings of the booster were broken. The driver sustained neck strain (AIS 1) and bruising across the lower abdomen (AIS 1).

The opposing vehicle had an estimated ΔV of 30 km/h and EES of 34 km/h. It was being driven by a 39 year old male who sustained neck pain (AIS 1).

Figure 6 - The case vehicle and CRS of CCN 073.