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Advanced methods for improved CHILD occupant safety in cars.

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Abstract:

The European project CHILD (2002 – 2005) aims to a more comprehensive understanding of the injury mechanisms experienced by children as car occupants of different ages in road accidents. Through innovative tools and methods, CHILD will contribute to revise or improve standards and more efficient design of child restraint systems. It is conducted in association with thirteen partners representing a balance between research, industry, regulation and testing institutes, from seven European countries. The basis is in-depth accident studies, experimental and virtual testing including development of new tools (dummies, models,…) for the evaluation of child protection.
CHILD will enable the investigation of injury mechanisms and tolerances for different ages of children and to reinforce injury criteria and risk curves previously proposed for frontal and lateral impacts, in the European project CREST (1996-2000). The methods used to achieve these goals are described in this article, illustrated with several examples. The stakes of this project are to significantly decrease the number of killed children (more than 700) or severely injured each year on European roads, which is an unacceptable high burden on Europe's society and economy.

INTRODUCTION

The main objective is therefore to increase our level of knowledge in these areas specifically regarding children, in order to make recommendations regarding the content and context of child seat standards, relating to testing issues and computer simulation methods. Enhanced standards and testing methods will be proposed, but equally methods will be developed and evaluated for future virtual child restraint standard (CRS) development and testing.
The short-term exploitation of these outputs will be an application of methodologies and processes for the development of improved CRS, providing a better protection of the children in cars. In the medium and long term, the number of children killed or injured in cars should be considerably reduced.

A large Consortium is involved to conduct this project. The representation includes the organisations that were previously involved in the CREST project and additional ones, which bring specialised expertise to the activities. Good geographical representation within Europe (with different CRS usage rates) and a balance between research, industry and those involved in regulation and testing make the strength of this project.

The objectives of CHILD are more efficiently addressed at the European level than at national or private level. The main reasons are the following:

- Road vehicle safety is a worldwide issue; such items are addressed in special international working groups such as ISO (International Standards Organisation) and IHRA (International Harmonised Research Activities) and EEVC (European Enhanced Vehicle-Safety Committee).
- Child safety legislation within the member states is established at the EU level. In addition, CHILD seeks to complement the activities of Euro NCAP with regard to child occupant protection assessment, in order to establish PRVs (Protection Reference Values) for the different body regions of the children.
- The participation of European car manufacturers, top research institutes and universities in passive safety established in seven countries, safeguards the technology uptake on a European scale.

CHILD's success relies on the skills of experts in passive safety. A specialised knowledge is required for in depth accident analysis, testing, modellisation, numerical simulations and injury mechanisms analysis. All these experts, test facilities, and sufficient number of real world accident cases which are interesting for reconstruction cannot be found in a single country nor in a private company and the international nature of the consortium is essential to its success.

CONTRIBUTION TO EUROPEAN STANDARDS AND REGULATIONS

An important benefit of CHILD is that it will contribute to the harmonisation of passive safety research on child safety worldwide. Harmonisation of such research is necessary to save children not only in Europe but also world-wide and particularly in the emerging economies where motorisation is growing at its fastest. This could also improve the cost effectiveness of regulations because the necessity for the car industry to comply with different regulations in various countries, as is the case often now, can be avoided. This task is complementary to the work performed in ISO/TC22/SC12/WG1, devoted to child protection in cars, which is still based on EEC44 regulation and which should evolve in order to afford a better protection to children with more efficient child restraint systems.

One of the outputs expected is a complete new work methodology. Standard procedures of testing (both physical and virtual) will emerge from this project and they could then be used to improve the actual procedures of certification of child restraint systems in Europe. This will promote better relationships and exchanges between car manufacturers and child restraint manufacturers.

Information is also needed in some specialised working groups such as ISO for instance, as regards the lateral test procedure of evaluation of CRS's. At this time only scaling factors have been used to derivate injury criteria from the adult, as no side impact injury risk curves are available. This further reinforces the need for biomechanical data from real children to be available and injury risk curves to be established from real children.

EEVC WG 18 has, among other tasks, to identify the lack of knowledge in the field of child safety, lack of methods and lack of tools. This group will benefit of all the information gathered in the CHILD project.

The research addressed in these projects is of significant importance and the continual improvement in occupant protection is to be commended. However, it is important not to overlook the implications for children of, for example, new safety devices such as side airbags and curtains, particularly is such implications are negative. Such devices should not result in a reduction in the protection of children, an exacerbation of injuries or at worst, the causing of injuries that would otherwise not have occurred. It is therefore, important to ensure that developing designs, whilst intended for adults, also perform well for children prior to them being widespread on Europe's roads. To this end, established testing and regulation programmes are vital, but need to be kept ahead of design innovation and development.

OBJECTIVES OF THE CHILD PROJECT

The main technical objectives of the project are to propose enhanced standards and testing methods, but equally , methods will be developed and evaluated for virtual CRS development and testing. This will be a great step for the development of CRS providing an optimum level of protection for children in cars.
The main scientific objectives of the project are the following:

- to create an international data base of accidents with restrained children involved in accidents,
- a better knowledge of the real situation concerning the use of CRS in different European countries in terms of rate of use and quality of use.
- a better understanding of the events in real world crashes and the associated injury outcomes experienced by child occupants through real world crash investigations (more than 300) and full-scale reconstructions (about 35),
- a better evaluation of the child kinematics in different types of impacts (specifically frontal and lateral), for different ages and for different types of child restraint systems, taking into account occupant interactions,
- an evaluation through real world observation, reconstruction and computer simulation of the effectiveness of child restraint anchorage systems, such as ISOFIX,
- take into consideration the consequences of interactions with new smart restraint systems which have been designed for the adult population but with which children may have injurious interactions such as pretensioners, frontal and lateral airbags,
- contribute additional data to the small pool of biomechanical data available for children,

- obtain through experimental reconstructions the data necessary to consolidate or establish child injury criteria and child injury risk curves, for different ages and different body segments,
- evaluate and assist some further sensor developments of the Q series,
- add to early development of child human body models for the neck – (it was first planned to develop human models for the head and the chest, but due to reduction of the global budget, partners have to revised their participation).
- validate the dummy and human models through virtual crash reconstruction,
- make recommendations regarding the content and context of child seat standards, relating to testing issues and computer simulation methods,
- feed this child research into other EC projects,
- to make recommendations to consumers, manufacturers, ISO, EEVC, IHRA….
- give the tools to the child restraint manufacturers and particularly SME's to design CRS's offering an optimised level of protection to children in cars.

The main exploitable outputs of the project are :

- An accident data base with a report on 300 cases of restrained children, which will add to the 405 cases already analysed in CREST
- a report on the the misuse situation in different countries,
- a report on the main mechanisms of injury for the children,
- a new-born child dummy to complete the European child dummy family,
- improved dummies, both as regards behaviour and instrumentation,
- injury criteria for use in regulation and consumer testing programmes, e.g. Euro NCAP,
- definition of completely improved test procedures including characteristics of recent cars,
- simulation methods & tools for virtual product design, development and testing including virtual dummy models and virtual hybrid human models,
- a data base of reconstructions of 35 cases, 50 sled tests and numerical simulations, which will extend the CREST database.

CONSORTIUM OVERVIEW

Seven European countries are involved in the CHILD Consortium. All partners have a substantial interest in child protection and, more generally speaking, a long experience in the field of passive safety. Moreover the partners have complementary profiles: car manufacturers, other industries, research and development organisations, and universities.

All the partners were chosen for their high level of competence and knowledge in the field of child safety as regards the different matters, such as crash investigations, test performance, computer simulations, experience on dummies and instrumentation, injury biomechanics and computer modelling.

A large Consortium is involved and representation includes the organisations, which were involved in the CREST project, but also other organisations, which bring complementary expertise to the activities. There is also a good geographical representation within Europe (with different CRS usage rates and different designs) and a balance between research, industry, and those involved in regulation and testing.

With such a big Consortium, all the fields of child safety are addressed and the research can be effectively conducted to meet the objectives of the project.

There are no child restraint manufacturers in this Consortium as the aim is to be completely free of possible influence of design and commercial bias to influence the objectives, but as was the case in the CREST project, an ongoing co-operation with CRS manufacturers is possible.

Organisation name		Activity	Role in project
RENAULT SA (F)		car and commercial vehicle manufacturer	project co-ordinator co-ordinator of WP 4
PSA PEUGEOT CITROEN (F)		car and commercial vehicle manufacturer	co-ordinator of WP 3
FIAT AUTO (I)		car and commercial vehicle manufacturer	Member
TECHNICAL UNIVERSITY of BERLIN (D)		Vehicle safety and injury biomechanics	co-ordinator of WP 2
VSRC - UNIVERSITY LOUGHBOROUGH (UK)		Vehicle safety research	co-ordinator of WP 1
INRETS (F)		Transport safety research	Member
TNO (NL)		Vehicle safety research and crash tests	Member
IDIADA (E)		Vehicle testing and Homologation	Member
Chalmers University (S)		Vehicle safety and biomechanical research	Member
TRL (UK)		Vehicle safety and injury biomechanics	member
UNIVERSITE Louis Pasteur – STRASBOURG (F)		Biomechanical research and testing	Member
BAST (D)		Vehicle safety research and biomechanics	Member
ARU Medical University of HANNOVER (D)		Biomechanical research	Member

PROJECT ORGANISATION :

The most scientific way of determining the child tolerance is to observe how restrained children are injured or killed in the real life when they are car passengers and properly determine in which conditions. Then the child kinematics has to be reproduced using child dummies in the same environment, with the same conditions as in the accident. This leads to a set of data composed of initial conditions, pictures, films and curves which have to be

analysed in order to determine the injury mechanisms observed on the child and their correct reproduction in a considered test.
To ensure a good progress of these different steps, the project has been organized in four work packages (WP). The first one is based on crash data collection and observation of children in cars on open roads. The second one consists of experimentation and modelling. The results of the experimentations will be analysed and consolidated in the third work package, who has the task to establish injury criteria, risk curves and improved standards for CRS improvement. The fourth one is dedicated to the co-ordination of the project, management, exploitation and dissemination, including the creation of a WEB site.

Organisational structure

Work packages		
	Content	**Leader**
WPI	**ACCIDENTOLOGY**	**VSRC - Loughborough**
Task 1.1	crash data collection	VSRC
Task 1.2	CRS use	TRL
Task 1.3	Database management	PSA
Task 1.4	Analysis	VSRC
WP2	**EXPERIMENTATION AND MODELLING**	**T.U.Berlin**
Task 2.1	dummy and sensor development	TUB
Task 2.2	virtual dummy and human modelling	ULP
Task 2.3	experimental accident reconstruction	TUB
Task 2.4	virtual accident reconstructions	ULP
WP3	**CONSOLIDATION AND SYNTHESIS**	**PSA Peugeot Citroën**
Task 3.1	selection of accidents and synthesis	PSA
Task 3.2	development of database analytical tools	FIAT
Task 3.3	development of injury criteria and standards	RENAULT
WP4	**CO-ORDINATION**	**RENAULT S.A.**
Task 4.1	management,	RENAULT
Task 4.2	WEB site	VSRC
Task 4.3	exploitation and dissemination	RENAULT

The management of the project is made by RENAULT who has participated in more than 100 European RTD projects over the years and has a strong experience of projects.
The manager has been involved in the ITFCRS (International Task Force on Child Restraint Systems) from 1990, which was a co-operation between automotive industry, Universities and different public or private Institutes from Europe, Australia, Canada and USA. He was also involved in the European project CREST, from the 4th Framework Programme. He is responsible for the management of the project in order to reach the objectives within the financial, organisational, quality and time schedule as described in the work programme.
The duration of the project is initially of 36 months.

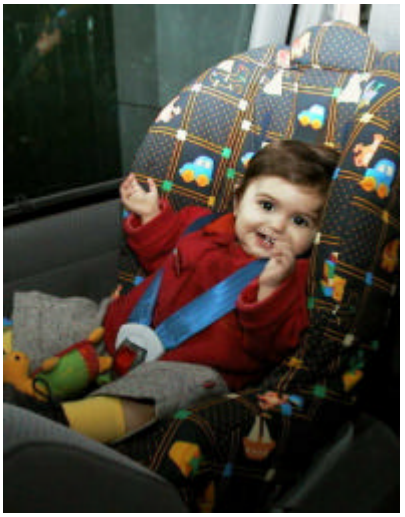
WORKPACKAGE 1 – accidentology - consists in two main tasks and two associated tasks :

T1.1 Real world crash investigation

The first one is the analysis of real car crashes in which **restrained children** are involved : it is linked with task 1.3 which is the collection of all these data in a database and the management of it. This database will include more than 700 accident cases (when cumulated with the 405 cases recorded in the CREST programme). This part of the WP1, which corresponds to task 1.4, aims to analyse the data recorded, in order to give an objective overview of the accidents in which children are killed or severely injured.
The organisations are all experienced in real world accident investigation. They will each investigate crashes in which at least one child is restrained and which meet specific selection criteria appropriate to the scientific needs of the CHILD programme. Due to these criteria of severity, **this database will not be representative of the real world situation** but only of the part of crashes with killed or severely injured occupants or over a certain level of violence safe occupants using efficient and adapted restraint systems.
The cases will contain as much information as possible about the crash scene (impact positions, resting positions, etc), the vehicle containing the child (case vehicle) and other vehicles and obstacles (vehicle information and damage measurements, etc), the occupants (descriptions, injury data coded to AIS90, etc) and restraint information (method of restraint, type and model of CRS, damage, etc).
These case data will, wherever possible, be sufficient to enable either real or virtual reconstruction by another working group of the project. The cases will be documented in a common format. Each case will be presented at a case review involving the Task members, and either selected or rejected for inclusion in the CHILD database.
The total duration of the activity will be 3 years, which takes into account an initial start up phase and the follow up time for gathering accident data and completing the case files.

T1.2 CRS use

The second part of this WP corresponds to the analysis of use of child restraint systems on the road, in order to understand the causes of such injuries for children ; is it misuse or bad design of the CRS? It is one of the most important issues to address solutions to save children. To achieve this objective, it is necessary to collect and collate existing information and data from across Europe relating to the use of child restraint systems.
The involved organisations are conducting a national review of literature and information about child restraint use and misuse. The issues to be addressed, wherever possible, include levels of use of the different types of restraint type, levels of inappropriate use (wrong CRS for size of child) and levels of misuse and issues associated with the second hand market for CRS. This information will be obtained from government figures, safety organisations, local government offices, parent groups, and police forces. Partners from France and Spain will gather, as part of this Task, data relating to CRS use. For that, a data collection form has been set up. Each study will lead to a specific report and the results will be included with the one of the literature review.



The Task Leader will compile a State of the Art report from all of the information gathered. This will be in complement of the real accident studies which are most of the time retrospective, which is not good for the determination of misuse of CRS, as describe in the CREST accident data base analysis.

T1.3: Effective and efficient management of the CHILD accident database.

Following the decision to include a case in the real world database, each participant will be responsible for providing the case documentation in an agreed format in order to include it in an electronic database. This database will be developed on an improved basis of the CREST database. The Task leader will be responsible for the management of the database of real world cases, which include the level and quality of information for each accident, the management of the different tables of the database, and the dissemination of the database to the different partners of the project.

T1.4 Accident Data base analysis

This task has been set up in order to conduct analysis of the WPI database and disseminate such analysis through publications.
Such a specialised and valuable data set needs to be used to its maximum potential. Analysis of the database to address issues of interest to the work packages in charge of accident reconstructions, dummy improvements, injury criteria definition and procedure development will be necessary, but in addition dissemination of information contained within the database to other bodies interested in child occupant safety will be invaluable.
Such analysis will be considered at regular intervals during the project, taking account of the availability of the data, the activities of other groups and opportunities for publication.

Deliverables
Some 300 real world accident cases involving restrained child occupants.
A document reviewing the issues associated with child restraint use across Europe as represented by those countries participating in the project.
A database containing the real world cases and allows the manipulation of the data to address research questions.
Analytical output from the database in the form of (a minimum of) one technical report and one published paper.

Interrelation with other work-packages
The cases included in the WPI real world database form the basis of the activities of both the work packages in charge of accident reconstructions, dummy improvements, injury criteria definition and procedure development. The first one will select cases for either real or virtual reconstruction. The others will use the analysis of both real world and experimental crash data to investigate injury mechanisms and establish injury criteria for the different body segments and age groups of children.

WORKPACKAGE 2 is the experimentation and modelling part of the project.

Objectives

The objective of WP2 is the high-quality reconstruction of real-world accidents as regards a realistic car dynamic behaviour, a reasonable kinematics of the dummies, confident measurement values and appropriated sensor signals according to child injury locations and mechanisms.

It is covering several aspects that are the following:

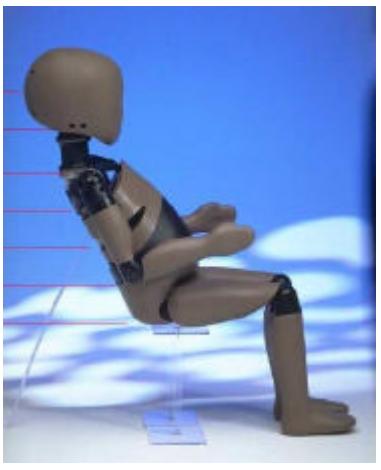
- Improve the "effectiveness" of the tools which are used in the experimentation, that means dummies and their instrumentation, in order to interpret the injuries sustained by the children in real crashes in terms of physical measurements,
- Improve the mathematical models of Q dummies which were developed in the CREST programme and implement them with real child behaviour, at least for the body segments the most severely injured,
- Simulate virtual collisions with the environment of the car, the CRS and those virtual dummies,
- Validate these tools and provide them to the cars and CRS manufacturers.

Task 2.1 : dummy and sensor development

This task is divided in two main actions: the analysis of existing child dummy family concerning their belt interaction behaviour, and the development of a new child dummy.

The first one has the aim of optimising the existing child dummy parts, so that the interaction with the adult seatbelt is more biofidelic especially on the chest and abdominal areas. It is also planned to develop new dummy sensor devices for the load detection on the abdominal region. It was first planned to work on sensors able to predict injuries on the lower limbs and local head sections but due to budget reduction, it was decided that abdominal area was by far more important in terms of frequency and severity.

The development of a Q0 child dummy that correlates to newborn children, with sufficient instrumentation was decided at the beginning of the project. This is an important item because up to now, the new born dummy had no instrumentation, which means that there is no biomechanical limit possible for the first group of CRS on their lower limit (Group 0 and Group 0+). This tool will be useful to improve safety given and rearward facing CRS that became very common for young children in most of the European countries. This dummy has been designed to be omni-directional.



Task 2.2 : virtual dummy and human modelling

The first prototypes of the Q-family dummies have been developed within the CREST program; the Q3, corresponding approximately to a three years old child and two others, the Q6 (6 years old) and the Q1 (1 year old). All of them have been designed to be omni-directional dummies, and some reconstructions were conducted in frontal and side impacts. A model of the Q3 has been developed by the same time. The aim of this task is first to improve the existing models of the Q family dummies, to develop a Q0 virtual child dummy model, and to develop and implement a human-like virtual neck model for an age corresponding to a three-year-old child.

Task 2.3 : experimental accident reconstruction

The quality of the work conducted in this task is essential for the definition of the injury mechanisms and the corresponding measurements on dummies necessary for the construction of injury risk curves that will be used in the proposal of procedures for the evaluation of the performance of child restraint systems. In such tests the reproduction of the correct kinematics is essential which is only possible to verify on on board views of high-speed films.

35 full-scale experimental tests will be performed and in addition, 50 experimental component tests in which the variation of some parameters is studied should be performed. All the results, films and measurements of these tests will be stored in an electronic database that is an improved version of the one of the CREST program.

Task 2.4 : Conduction of virtual crash tests.

In a first step, it is planned to use simulation techniques to run parametric studies and to simulate sled tests. These techniques will also be used for virtual component tests to validate the new neck model.

Deliverables

Optimised child dummy family as regards belt interactions and measurement abilities.
Completion of new European child dummy family
Provision of validated virtual dummy family.
Provision of hybrid virtual dummy models, including virtual neck and chest properties;
Provision of experimental test reports including all items of the tests preparation, conduction and results (measurements graphs, pictures and high-speed films).

Interrelation with other work-packages

With WP1: Appropriated accident cases will be the basis for crash reconstructions even if the selection of the accident cases is done within WP3. In addition, all the results of crash reconstructions will be compared and analysed with the real world accidents and observations in WP3. The tests performed in WP2 are the basis of the injury risks curves and procedure proposals that will be done in WP3. With the WP4, the relation will be limited to the provision of regular reports to the project manager, and the update on the web site of the activities WP2 by its leader.

WORKPACKAGE 3 – Consolidation and synthesis- selects the material on which validated test procedures will be proposed

Objectives

This work package has two main objectives: to be the link between WP1 and WP2 during the life of the project, and propose validated procedures – including criteria- for the child protection evaluation.

This WP has been organised in three main tasks in which the partners have volunteered to participate according to their experience and to their expertise on the different subjects. To be part of that WP, partners have to be involved in at least one of the other work package, of the project.

Task 3.1 : selection of accidents and synthesis

The partners involved in this task are experts of accidentology, of crash configurations, or have a good knowledge of crash testing, child dummies and injury mechanisms. They have to select, in the accident database, the cases that appear to be the most interesting for full-scale reconstructions, according to the injuries of involved children and the possibility to reproduce the crash configuration on a crash test facilities of organisations that have volunteered to perform tests in this project. Each time it is possible, and in addition to expert's advices, the crash configuration will be verified using specific software. After each test performed, partners of that task have to evaluate its quality according to the crash severity in comparison with the accident, the kinematics of the child dummy and the reproduction of the probable injury mechanism, in order to make a correlation between dummy measurements and child injuries. This group can then decide if the results of the tests can be used by the task in charge of developing injury criteria, and procedures or if component tests are necessary.

The quality of the information exchanged between the teams studying in depth accident and the teams performing full-scale reconstructions is essential to ensure good quality results.

Task 3.2 : development of database analytical tools

This task was created to develop all the tools necessary in each work-package to store and analyse data and to link those tools in order to use them for the synthesis work described in tasks 3.1 and 3.3.

These databases and tools must allow integrating the data of the CREST Program but making sufficient distinction between the "new" material and the "old" one when performing the analysis. They have to be convivial for data entering, and data visualisation.

This includes that a viewer is available for software simulation (for accident configuration), pictures of accidents and corresponding of crash tests, films of reconstructions, curves obtained on vehicles and child dummies.

Task 3.3 : development of injury criteria and standards

This task has been divided in two subtasks due to the amount of work necessary to reach its objectives.

-The first one is the development of injury criteria for the different body segments of children in frontal and lateral impacts. It is planned to have a reinforcement of the existing injury curves for the head, and a focus should be done on neck injuries for children below 3 years of age, and abdominal injury risk for children older than 3 year old for frontal impacts. For side impact only few data are available on the Q dummies and it is necessary to have additional data for all body segments.

-The second one is to enhance the procedure used for child system approval, based on CREST results and consolidated with CHILD project for frontal impacts. This includes some modification of the test bench, a deceleration pulse based on accident reconstructions, chosen because of the high risk of being injured for children. The injury criteria will be of course implemented in the proposal and a new validation of that procedure is necessary.

For side impacts, the results obtained in the full-scale tests will be the basis of the work. Decisions on the procedure itself will be taken according to the material available both in accidentology and in full-scale reconstructions. Effectively, it seems more difficult to reproduce properly the right kinematics, impact location, have the right intrusion at the right location for side impact than for frontal. In addition, it has to be considered that these lateral impacts sometimes occur at crossroads with speed for both vehicles. This gives to the child an oblique kinematics that is very difficult to be reproduced in laboratories, because it means that both vehicles have to move and the impact point becomes then a difficult target to reach.

Deliverables

Accident database, reconstruction database, separates but able to be linked in order to enable the analysis of tests. Their contents will be published in technical reports and the empty databases and user manuals, will be available for teams investigating accident investigations or performing accident reconstructions.

Technical reports and publications on the analysis of accidents and their associated tests in order to validate the relation between dummy measurements and child injuries.

Injury risk curves and proposed criteria for children protection based on biomechanical data will lead to a technical report and publications.

Validated procedures for the evaluation of the protection of children both in front and side impacts will be proposed and will lead to technical reports and publications.

Interrelation with other work-packages

Due to its objectives, this work-package is closely linked to WP 1 and WP 2, with a lot of collaborations of technical experts of both work-packages in order to lead to a cross-validation of the results obtained in the different tasks. In addition, this work package is in relation with WP 4 for a part of management and for the part of web site where information on WP 3 will be available.

WP4 - management and co-ordination of the project

Objectives
To ensure the management and the co-ordination of the project as well as the dissemination of the results.
To offer to CHILD members and to the public and researchers a contact through a website.

Task 4.1 : management,
To ensure the management and the co-ordination of the project, the respect by the partners of their engagements in terms of work and deadlines.
To be the link between project partners and the Commission and to validate the publications done with the results of the work done in the project.

Task 4.2 : WEB site
A CHILD web site has been created, which contains general information about the different partners of the project, the description of the goals of the project. Regularly, the status of the different tasks conducted in the project are be updated by the different work-package leaders and organisations involved in CHILD, a kind of electronic newsletter
Web site address: **www.childincarsafety.com**

Task 4.3 : exploitation and dissemination
To disseminate the methodologies used in the different tasks of the project and the results through publications and a specific workshop at the end of the project.

Deliverables
Progress reports and technical reports. Publications to conferences, web site to make public the knowledge of the project and a dissemination workshop organized at the end of the project.

Interrelation with other work packages
The partners involved in this work-package are the leaders of the other work-packages and the co-ordinator of the project, so the interrelation is very strong with the other work-packages essentially in terms of management and dissemination of the results.