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Child safety in cars
– Literature review

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Swedish National Road and Transport Research Institute

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Abstract (background, aims, methods, results) max 200 words:

In order to study child safety in cars, international literature was reviewed with respect to road vehicle transportation for children, with the focus being on the age up to 12 years. The review included literature in English and Swedish. Furthermore, the review was limited to focus on results from Australia, the U.K., the USA and Sweden.

To ensure that all children are protected as passengers in cars, several aspects needed to be considered. Within this study, the focus was, hence, on legal aspects and recommendations, traffic fatalities and serious injuries, the safety consequences for children due to the car development (airbags (SRS) and installation systems), use and misuse of child restraint systems (CRS) regarding medical, technical and user aspects, measurements for improvements, e.g. campaigns and, finally, children with disabilities. The review focused mainly on literature from 1990 until today.

The main conclusions were that:

* Available statistics show that rearward facing CRS is a good preventive measure to take for enhancement of traffic safety.
* Impacts from the in-safety development of cars on choosing and mounting safety devices for children were found to be a crucial issue.
* Children exposed to an airbag deployment can be fatally injured, despite being seated in an approved child restraint system.
* In Sweden and the U.K. the level of child restraint usage among infants and small children was found to be at least 95% in the front seat and approximately at the same level in the rear seat. Even though the levels of usage in several countries were high, the level of misuse was alarmingly high (90%).
* The road transportation of children with disabilities was found to be complex and insufficiently described in the literature.

The literature review was funded by the Swedish National Road Administration.

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Föreliggande litteraturstudie har genomförts med syfte att sammanfatta kunskapsläget avseende barns säkerhet i bil. Litteraturen har delats in i områdena; lagar/rekommendationer, olyckor med dödlig/svår personskada, säkerhetskonsekvensen för barn i bil avseende bilutvecklingen (speciellt avseende installationssystem och krockkuddar), användning/felanvändning sett ur ett medicinskt, tekniskt och handhavande perspektiv, åtgärder/kampanjer samt situationen för barn med funktionshinder.

Litteraturstudien omfattar i huvudsak litteratur om barn i åldern 0–12, vidare har fokus varit på litteratur skriven från 1990 och fram till idag. Endast litteratur skriven på engelska och svenska har ingått och ett fokus har varit på studier från Australien, England, USA och Sverige.

Litteraturen visar att det säkraste sättet att färdas i bil om man är barn är att åka bakåtvänt. Det kräver dock att skyddsutrustningen som används är rätt monterad, att bältet som håller fast barnet är korrekt placerat och barnet inte är placerad på en plats där det finns krockkudde.

I Sverige och i England är användningen av skyddsutrustning för spädbarn som åker bil, cirka 95 procent. Detta innebär inte att alla dessa barn åker säkert. Litteraturstudien visar att felanvändningen är stor. Vidare konstateras att ju äldre barnen är desto sämre skyddas de. För barn med funktionshinder är det långt ifrån en självklarhet att färdas säkert. Litteraturstudien har finansierats av Vägverket.

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Preface

This VTI report is a literature review within the field child safety in cars. This study has been financed by the Swedish National Road Administration (SNRA). The responsible person at SNRA has been Anders Lie.

The literature was reviewed in collaboration between researchers at Swedish National Road and Transport Research Institute (VTI). Contributors to the report have been Anna Anund, Torbjörn Falkmer, Åsa Forsman, Susanne Gustafsson, Ylva Matstoms, Gunilla Sörensen, Thomas Turbell and Jan Wenäll.

The contributors have been responsible for different topics within the field children in cars. The responsibility has been as follows;

Anna Anund	Legal aspects
Torbjörn Falkmer	Children with disabilities and the introduction section
Åsa Forsman	Car development – the implications of airbags
Susanne Gustafsson	Measures for improvements - campaigns
Ylva Matstoms	Traffic fatalities and serious injuries
Gunilla Sörensen	Use and misuse of restraints
Thomas Turbell	Car development – installation systems
Jan Wenäll	Data from accidents and crash tests

I also wish to thank Gunilla Sjöberg and Anita Carlsson at VTI, and Catharina Arvidsson and Claes Eriksson at BIC, VTI, for additional work on the references, constructive comments on specific areas and for layout work and for finalising the report.

Torbjörn Falkmer and I have edited the report. I have been coordinating the project.

I would like to thank all authors for their qualified and irreplaceable work.

Linköping, May 2003.

Anna Anund

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Child safety in cars – Literature review

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Summary

Available statistics show that rearward facing CRS (Child Restraint Systems) is a good preventive measure to take for enhancement of traffic safety.

Impacts from the in-safety development of cars on choosing and mounting safety devices for children were found to be a crucial issue. Children exposed to an airbag deployment can be fatally injured, despite being seated in an approved child restraint system.

In Sweden and the U.K. the level of child restraint usage among infants and small children was found to be at least 95 % in the front seat and approximately at the same level in the rear seat. Even though the levels of usage in several countries were high, the level of misuse was alarmingly high (90 %).

The road transportation of children with disabilities was found to be complex and insufficiently described in the literature.

This literature review has been divided into different topics within the area ***child safety in cars***. The review has been focused on legal aspects, traffic fatalities and serious injuries, the impact of the developments of cars for choosing safety demands for children, the advantage of rearward facing child safety seats as opposed to forward facing ones, the consequence of incorrect use, misconception, measures for improvements and children with disabilities. The review focused mainly on literature from 1990 until today.

A comparison of laws and recommendations in Sweden, the USA, the U.K. and Australia revealed large differences with respect to e.g. the children's age, height and weight related to CRS, if the CRS had to be rearward faced or not, and the age that the responsibility of the driver, concerning the child's safety in the car, was abolished.

Data concerning accidents for 2002 was compiled. However, data with one-year age groups was rarely published, which was unfortunate since the usage of CRS types and exposure rates were likely to vary between children of different ages.

The available statistics showed that rearward facing CRS was a good preventive measure to take for enhancement of traffic safety. In the few accident investigations found, the main concern was that most injured or killed children were not restrained at all. Head injuries were the main fatality cause. The second common misconception seemed to be putting too small children into forward facing seats. Using the CRS incorrectly was also reported but to a lesser degree. Improperly restrained children, in particular infants and small children, in age-appropriate restraint systems sustained a greater proportion of severe or moderate injuries than properly restrained children who were in the wrong restraints for their size.

In the reviewed literature, the physiological differences between children and adults were mentioned and shown in various ways, leading to the conclusion that children always need specific or additional protection in the car.

A good way of determining that a CRS was constructed for proper protection for a child was approval according the ECE R 44/03 tests. A field of crash safety protection that needs further investigation was the strength of the rear seat back.

Impacts from the in-safety development of cars on choosing and mounting safety devices for children were found to be a crucial issue. Children exposed to an airbag deployment can be fatally injured, despite being seated in an approved child restraint system. The conflict between children and airbags initiated a questionnaire based survey. The results from 23 general agencies showed that recommendations from most agents were to place children in the back seat; although the centre rear seat position was only recommended if equipped with a lap/shoulder belt, a recommendation not undisputed and, hence, it was considered important to address the question of how to deactivate the airbag.

In Sweden and the U.K., the level of child restraint usage among infants and small children (toddlers) was found to be at least 95 % in the front seat and approximately at the same level in the rear seat. In these countries, however, the level of restraint use among older children was significantly lower than for younger children.

Even though the levels of usage in several countries were high, the level of misuse was alarmingly high (90 %). Examples of serious misuse given were: dangerous buckle crunching and rearward-facing seats in front of an airbag. Common misuses were for example loose seat belts and harness straps, restraint devices not adequately secured to the seat or incompatible with the car, etc. The rates of misuse were, not surprisingly, often reported to be higher with systems where both the seat and the child need to be secured, such as infant seats and convertible restraints. An important finding in several studies was that parents and other caregivers think that their child is correctly restrained, while observations prove the opposite. Several studies showed that parents who were seeking or receiving information about car child safety had a lower level of misuse.

In many studies a relation was found between level of restraint use and different socio-economic factors. Examples of factors found to be related to high restraint usage were: high income and high level of education. Situations or groups in which restraint usage was found to be low were for example in the group of children from minority groups, such as immigrants.

The different campaigns described in the literature aimed to decrease the number of child fatalities in cars by emphasizing the importance of seat belt and CRS usage. The results from the campaigns were analyzed or reported in different ways. Some of the campaigns measured the awareness of the activities in the campaign; others measured the fatalities and the usage of the restraints prior to and following the campaign.

The road transportation of children with disabilities was found to be complex and insufficiently described in the literature. Some regulations and standards were identified. Two Swedish studies, one with the focus on children with locomotor disabilities and the other with the focus on children with autism spectrum disorders showed that the vast majority of journeys were made in the family vehicle. Traveling with school transportation or the Special Transport Systems (STS), both of them being performed partly in cars, was found to be a hazardous means of transportation. Parents of children with disabilities were mostly worried

about the driver’s lack of knowledge concerning the disability and the needs of the child. It was concluded that the problem of poor compatibility between the need for safe road transportation and the use of technical aids and special seating devices for children with disabilities needs be subjected to future research. In addition, comprehensive information, focused on the special needs of children with disabilities in their transportation, would probably reduce the parents’ worries significantly.

Barns säkerhet i bilar – Litteraturöversikt

av Anna Anund, Torbjörn Falkmer, Åsa Forsman, Susanne Gustafsson,
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Sammanfattning

Det säkraste sätt att färdas i bil om man är barn det är att åka bakåtvänt. Det kräver dock att skyddsutrustningen som används är rätt monterad, att bältet som håller fast barnet är korrekt placerat och barnet inte är placerat på en plats där det finns krockkudde.

I Sverige och i Storbritannien är användningen av skyddsutrustning för spädbarn som åker bil, cirka 95 procent. Det innebär dock inte att alla dessa barn åker säkert – felanvändningen är stor. Vetenskaplig litteratur visar att ju äldre barnen är desto sämre skyddas de. För barn med funktionshinder är det långt ifrån en självklarhet att färdas säkert.

Föreliggande litteraturstudie har genomförts med syfte att sammanfatta kunskapsläget avseende barns säkerhet i bil. Litteraturen har delats in i områdena; lagar/rekommendationer, olyckor med dödlig/svår personskada, säkerhets-konsekvensen för barn i bil avseende bilutvecklingen speciellt med avseende på krock kuddar, installationssystem, användning/felanvändning sett ur ett medicinsk, tekniskt och handhavande perspektiv, åtgärder/kampanjer samt transportsituationen för barn med funktionshinder.

Litteraturstudien omfattar i huvudsak litteratur om barn i åldern 0–12, vidare har fokus varit på litteratur skriven från 1990 och fram till idag. Litteratur skriven på engelska och svenska har ingått och studien begränsar sig till att omfatta material från Australien, England, USA och Sverige.

I samtliga dessa länder finns det lagar och rekommendationer för hur barn som åker bil ska skyddas. Kraven relaterar vanligtvis till barnens ålder, vikt eller längd. Skillnaden i vad som rekommenderas och vad lagen kräver är stor i de flesta studerade länder. Det finns även stora skillnader i vad som krävs i de olika länderna. Skillnaderna består t.ex. i kraven på att använda skyddsutrusning för barn i bil, hur länge en individ betraktas som barn, var i bilen barnen får sitta, etc.

Vid litteraturgenomgången visar det sig att studier baserade på data om inträffade olyckor med skadade/omkomna barn, uppdelade på ettårsklasser är mindre vanliga. Detta är en stor brist och viktigt att arbeta vidare med. Kunskap om omfattningen av antal skadade/omkomna barn som rest i bil är av stor betydelse, dels för att få en bild av problemets omfattning och orsaken till det, dels för att veta vilka åtgärder som behöver vidtas och för att kunna avgöra om vidtagna åtgärder har haft effekt.

Tillgängliga olycksdata visar på en god effekt av t.ex. bakåtvänt åkande. Djupstudier av olycksdrabbade visar att ett av de största problemen vid inträffade olyckor var att barnen inte använde bälte. Litteraturen visar att huvudskador var den vanligaste dödsorsaken för barn i trafikolyckor.

Den näst vanligaste felanvändningen var att små barn vändes till framåtvänt åkande alltför tidigt. Konsekvensen vid felanvändning i en olycka visade sig vara störst för spädbarn och de yngsta barnen.

En förklaring till detta är barnets fysiologiska förutsättningar. Den vikt som ett barns huvud utgör av barnets totala vikt är avsevärt större jämfört med för en vuxen. Detta innebär att mindre barn alltid behöver särskild skyddsanordning när de reser i bil.

De skyddsanordningar som finns för barn i bil ska i samtliga länder i Europa vara godkända enligt ECE R 44/03. Detta testförfarande finns anledning att utveckla ytterligare t.ex. avseende baksätets styrka och påfrestningar i nacke för barnen.

Litteraturen visar att utvecklingen av fordonen inte alltid är till fördel för barnens säkerhet. Flera studier visar t.ex. faran av att placera barn på platser där det finns krockkuddar. Att placera barn i bakåtvända skydd på passagerarplatsen fram i fordon utrustade med krockkudde är direkt livshotande i händelse av en olycka. Dock finns det inte någon studie som påvisar konsekvensen för barn som sitter på dessa platser i framåtvända skydd. Studier visar att den plats som fordonstillverkare rekommenderar att placera barnen på är i baksätet. Andra studier visar dock att det inte är på dessa platser som föräldrarna placerar eller vill placera barnen. De flesta barn under tre år placeras istället i framsätet.

I Sverige och England färdas nästan 95 procent av spädbarnen och de yngsta barnen i någon form av skyddsutrustning. Studier visar dock att felanvändningen var stor, nära 90 procent. Användning en av skyddsutrusning för de något äldre barnen var avsevärt lägre. Felanvändningen visade sig vara störst i de fall både skyddsutrustningen och barnen skulle säkras t.ex. som för babyskydden.

I flera studier framkom att föräldrarna trodde att de hade gjort rätt, men att det visade sig att så inte var fallet. Flera studier visade att föräldrar som själva sökte efter information hade en lägre felanvändning jämfört med dem som inte sökte efter information. Studier visade också ett samband mellan felanvändning och socioekonomiska faktorer. Exempelvis så var hög användning av skydds-utrustning vanligare förekommande för barn i familjer med hög inkomst och hög utbildningsnivå. Låg användning var vanligare förekommande för barn som kom från minoritets grupper t.ex. invandrar grupper.

I litteraturen återfinns beskrivningar av åtgärder som vidtagits; dessa är vanligtvis i form av kampanjer. Det förekom stora variationer avseende om och hur dessa var utvärderade, varför det är svårt att uttala sig om några resultat från insatserna.

Uppenbart från studierna av litteraturen är att situationen för barn med funktionshinder är särskilt bekymmersam. Denna grupp av barn är den mest sårbara och den grupp som kräver det bästa skyddet. Studierna visar dock att det förhåller sig precis tvärtom i verkligheten. Barn med funktionshinder skyddas sämre än andra barn. Detta gäller såväl barn med motoriska funktionshinder som barn med t.ex. autismspektrumstörningar. Föräldrarna kände en stor oro, framförallt beroende på att förarna inte upplevdes ha tillräckligt god kunskap om barnens funktionsnedsättning och vilka behov barnen hade. Det konstateras att ett sätt att öka säkerheten för barnen kan vara att ha en ökad kompatibilitet mellan barnens tekniska hjälpmedel t.ex. rullstolar och hur dessa ska kunna nyttjas på ett säkert sätt i samband med resor i bil/buss. I litteraturen återfinns även andra förslag på åtgärder t.ex. att öka föräldrarnas och förarnas kunskaper om barn med

funktionshinder och de behov de har. Detta förutsägs även minska föräldrarnas oro.

Terminology and abbreviations

The following terms and abbreviations are used in the present review. For further information on terms and abbreviations in the field, but not in this particular review check also on the NHTSA “Dictionary” web page
http://www.nhtsa.dot.gov/people/injury/childps/csr2001/csrhtml/glossary.html

Δ-v: Delta-v, the change of speed during impact.

Accident / Crash: these two terms are used as synonyms throughout the review, and mainly used the same way as the original authors have used them.

Air Bag: A passive (idle) restraint system that automatically deploys during a crash to act as a cushion for the occupant. It creates a broad surface on which to spread the forces of the crash, to reduce head and chest injury. It is considered “supplementary” to the lap/shoulder belts because it enhances the protection the belt system offers in frontal crashes. Also known as SRS – supplemental restraint system; SIR – supplemental inflatable restraint; SIPS – side impact protection system; IC – inflatable curtain; SIAB – side impact air bag.

AIS: Abbreviated Injury Scale, rating injuries from 1–6 (where 6 is almost always a fatal injury. For more info see Association for the Advancement of Automotive Medicine, (1998).

Asperger's syndrome: High functioning autism not in combination with mental retardation.

ATD: Anthropomorphic test device. Articulated analogue of the body of a human being, used to simulate a motor vehicle occupant during a crash test, also called *"Dummy"*. ATDs are not a perfect replica of a human being, but a standardised measurement equipment making comparable crash tests possible.

Autism: Congenital disability, mainly characterised by qualitative impairment in reciprocal social interaction, communication and imaginative activity, as well as by a restricted repertoire of activities and interests, often combined with mental retardation.

Booster Seats: Are intended to be used as a transition to lap and shoulder belts by older children who have outgrown convertible seats (over 40 pounds). They are available in high backs, for use in vehicles with low seat backs or no head restraints, and no-back; booster bases only. In this review, booster seats are used as a synonym to booster cushions.

Buckle: The locking mechanism of the vehicle belt and child safety seat buckle/latchplate system. Buckles are typically mounted/attached to fabric webbing and/or by metal or plastic stalks.

Car Seat: Common term for a specially designed device that secures a child in a motor vehicle, meets federal safety standards, and increases child safety in a crash.

Child Safety Seat/Child Restraint: A crash tested device that is specially designed to provide infant/child crash protection, abbreviated CRS in this review. CRS is used as a general term for all sorts of devices including those that are vests or car beds rather than seats.

Children with Disabilities in this review mainly refers to children with special transportation needs. This particular group comprise children whose physical,

medical, or behavioural condition makes the use of particular, often specially-designed, restraints necessary.

Crash / Accident: these two terms are used as synonyms throughout the review, and mainly used the same way as the original authors have used them.

CRS: A crash tested device that is specially designed to provide infant/child crash protection.

EuroNCAP: EuroNCAP (European New Car Assessment Program); A 40 % offset crash at 64 km/h against a non-solid barrier. The ATD, i.e. the crash test dummy, is exposed to 40–60 G**.** The EuroNCAP standard for child safety seats prescribes front facing positioning of the child.

FMVSS 213: Federal Motor Vehicle Safety Standard that pertains to all restraint systems intended for use as crash protection in vehicles for children up to 50 pounds.

Forward – Facing Child Restraint: A restraint that is intended for use only in the forward-facing position for a child at least age one and at least 20 pounds up to 40 pounds.

Frontal Air Bag: A frontal air bag is one installed in the dashboard.

ISS: Injury Severity Score.

Lap Belt: A safety belt anchored at two points, for use across the occupant's thighs/hips.

Lap/Shoulder Belt: A safety belt that is anchored at three points and restrains the occupant at the hips and across the shoulder; also called a “combination belt”.

LATCH: Lower **A**nchors and **T**ethers for **CH**ildren (new acronym for standardized vehicle anchorage system).

MAIS: Maximum Abbreviated Injury Scale, the highest obtained AIS value of a multiple injury trauma. For more info see Association for the Advancement of Automotive Medicine, (1998).

National Highway Traffic Safety Administration (NHTSA): The federal agency that sets performance requirements for motor vehicles and items of motor vehicle equipment such as child restraints in the USA.

NHTSA: see: National Highway Traffic Safety Administration.

OTC: Optimisation of Travel Capacity.

Passenger– Air Bag: An air bag that is in the right front part of the passenger compartment. It is larger than the driver bag and would restrain either centre or right-front occupants. Air bags are a supplement to the use of seat belts and designed to protect adult occupants in frontal crashes.

Postural support/seat belt: In this review seat belt is used as a synonym for safety belt, i.e. an assembly of belt and buckles to form an approved occupant restraint in a car. However, in some publications seat belts are equivalent to postural supports, i.e. seat components or lengths of webbing used to support a person in the desired position in a seating system (i.e. to prevent the person from falling out during normal conditions). A postural support is usually not designed or intended to provide occupant restraint in a vehicle impact. In this review, a postural support is denoted as such, not as seat belt.

Rearward – Facing Infant Seat: Type of child restraint system that is specifically meant for use by children from birth up to approximately 20 pounds used in the rearward-facing mode only.

RSC: Rating system for Serious Consequences.

Safety Belt: The webbing, anchor and buckle system that restrains the occupant and/or child safety seat in the vehicle. In this review seat belt is used as a synonym to seat belt.

SBS: Seat Belt Syndrome.

Seat belt/postural support: In this review seat belt is used as a synonym for safety belt, i.e. an assembly of belt and buckles to form an approved occupant restraint in a car. However, in some publications seat belts are equivalent to postural supports, i.e. seat components or lengths of webbing used to support a person in the desired position in a seating system (i.e. to prevent the person from falling out during normal conditions). A postural support is usually not designed or intended to provide occupant restraint in a vehicle impact. In this review, a postural support is denoted as such, not as seat belt.

Seat Belt: The webbing, anchor and buckle system that restrains the occupant and/or child safety seat in the vehicle. In this review seat belt is used as a synonym to safety belt.

Side Impact Air Bags: Provide additional chest protection to adults in many side crashes. Children who are seated in close proximity to a side air bag may be at risk of serious or fatal injury if the air bag deploys. Check with the vehicle dealer or vehicle owner's manual for information about danger to children.

STS: Special Transport Service.

SUV: Sport Utility Vehicle.

Tether Anchor: Attachment point in vehicle for child safety seat tether strap. Refer to vehicle owner's manual regarding anchor location.

Tether Strap: An additional belt that anchors the child safety seat top to the vehicle frame; keeps the restraint from tipping forward on impact; can provide an extra margin of protection. Can be optional or factory installed. A tether strap is typically available on most child safety seats manufactured after September 1, 1999.

Tiedown: A tiedown can be described as a strap or mechanism that secures a child safety seat, or a wheelchair in place in a motor vehicle.

Tray Shield: Part of a restraint system in a child safety seat; a wide, padded surface that swings down in front of the child's body, attached to shoulder straps and crotch buckle. Looks like a padded armrest, but is an integral part of the harness system.

T-Shield: Part of a restraint system in a child safety seat; a roughly triangular or “T” shaped pad that is attached to the shoulder harness straps, fits over the child's abdomen and hips and buckles between the legs.

Vest: A child restraint system that has shoulder straps, hip straps (and sometimes) a crotch strap. A vest can be specially made to order according to a child's chest measurement, etc. Vests must be used along with the vehicle belt system.

1 Introduction

A great many people, among them children, are killed or seriously injured in road traffic every year, which constitutes a major public health problem (Evans, 1991). For example, during the years 1994–2000, 186 children below that age of 18 were fatally injured as car, bus or lorry passengers/drivers in Sweden, based on compiled statistics from the Swedish National Road Administration (SNRA) for these years (Sörensen et al., 2003). Considering the rapid progress being made in developing different road safety measures, new knowledge must be spread more quickly and be put into application, first and foremost by system designers, but also by others in positions of responsibility within the road safety sector. One fast and cost-effective means of finding out where research stands today is to systematically review, analyse and make a compilation of the scientific literature published in the field. The present literature review was made for this reason.

1.1 Children in traffic and the “Vision Zero”

Automobile travel is a part of everyday life that begins in early infancy. Journeys to and from kindergarten, school and leisure activities become more frequent the older the child gets. Hence, children are frequent users of the road transport system and are thus exposed to the inherent risks associated with motor vehicle transportation.

During 1995, a goal – the “Vision Zero” - was set up in Sweden (SNRA, 1996). Similar goals of different target levels exist in many countries. The "Vision Zero" is based on attaining a level of zero fatalities and no serious health losses in the traffic system. A basic assumption in the "Vision Zero" is that the transport system should be designed to suit the least tolerant person using the system. Such a person should be taken as the design person for the system. The design of the road transport system, based on human tolerance, demands the most detailed knowledge of injury mechanisms and tolerance ability. Thus, one of the challenges is to identify such a design person for this system. Taking the “Vision Zero” seriously means that a person with low tolerance to mechanical forces (e.g. a child) should be the design criterion for the road transport system.

1.2 Child anatomy

Children in general are exposed to increased risks of fatalities and serious health losses in the traffic system owing to several factors (Evans, 1991), one of these being their anatomy. As shown in Figure 1, children differ from adults not only in size but also in body segment proportions and anatomy (Tingvall, 1987).

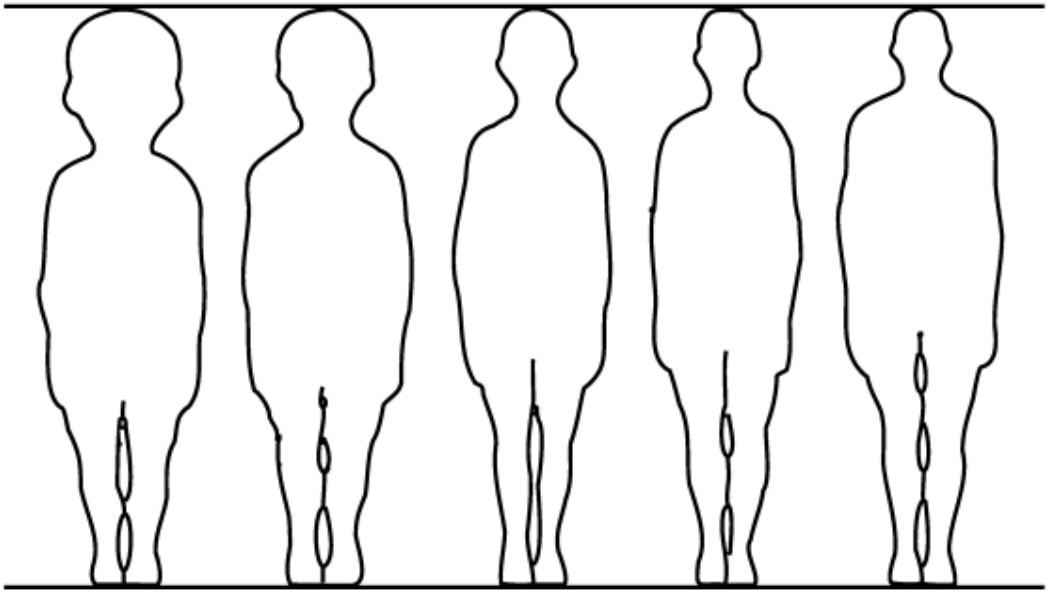

Figure 2 *Proportion of the human body in relation to different ages. From left to right: newborn infant, 2-year old child, 6 year old child, 12 year old child and 25 year old adult (Hove, Christensen and Poulsen, 1982).*

Hence, ribs will bend rather than break, resulting in collision energy being transferred to the heart and lungs. The spine's bony links are less well developed, which allows additional movement that can place undue stresses on the ligaments supporting the spine and, thus, lead to spinal damage. The abdomen is also different, in the sense that a smaller part is covered by the pelvis and rib cage in a child than in an adult. There is also a difference between the child and adult pelvis, in that the anterior superior iliac spine, shown in figure 3, which is important for the use of a lap belt, is absent up to the age of 10 (Tingvall, 1987).

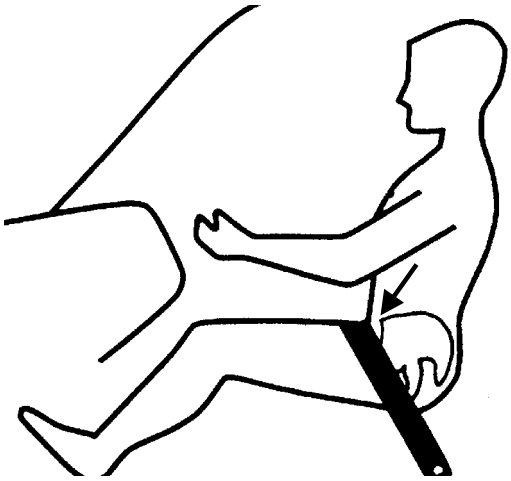

Figure 3 *Arrow indicates anterior superior iliac spine in an adult person and its relation to a correctly applied lap belt. The illustration is from Wevers (1983).*

The differences in body segment proportions are also reflected by a higher centre of gravity in the child, which may affect the body kinematics in the event of an accident. The tolerance of a child's body to high forces also differs from that of adults. The injury pattern among children is quite different from the injury pattern in adults. In the former, injuries to the head are common and those in other parts of the body are relatively rare, whereas in adults the reverse pattern is found.

Safety data for children demonstrate that a child is exposed to extremely high forces in a vehicle collision (Shaw, 1987). These forces can throw the child against the often sharp edges in the vehicle's interior and possibly eject the child through a window, open door, or windshield. Only properly designed and carefully used restraints can distribute collision forces in a non-injurious manner. Thus, safety restraints must be capable of withstanding these extreme forces and distributing them over the child's body to prevent injury (Shaw, 1987). Because a child’s physical structure is different from that of an adult, safety restraints must be designed differently for children. The shoulders and pelvis are the main points bearing the safety belt loading and these points are less well developed in the child, thus they are offering less protection. Nevertheless, Gammon (1995) argued that the effect of having a proper restraint for children was to reduce the number of serious injuries by 40–70 % and the number of fatalities by 50–100 %. These figures indicate that it is essential for a child’s safety to use safety restraints and, in adequate cases, in combination with child safety seats during road vehicle transportation.

2 The aim of the study and its limitations

In order to study child safety in cars, international literature was reviewed with respect to road vehicle transportation for the target group (0–12 years). The review only includes literature in English and Swedish. Furthermore, the review was limited to focus on results from Australia, the U.K., the USA and Sweden.

In Sweden, children are legally defined as persons younger than 18 (Socialdepartementet, 1981). Despite this fact, the focus is on children in age 0–12 years old, mainly due to the fact that from a safety perspective most children older than 12 have more similarities with adults than with smaller children with respect to anatomy. However, in case reviewed studies also included results about children older than 12, we have chosen to include these results, as well.

Children are different and we need to account for these differences. The most vulnerable sub group of children is probably children with disabilities (Falkmer, 2001). Thus we have included the transport safety situation in road vehicles and its consequences for children with disabilities in the review. For this particular group of children, the review focuses on children up to the age of 18, due to the fact that the variance in anatomy is larger than for other children (Falkmer, 2001).

To make sure that all children are protected as passenger in car, several aspects need to be considered. Within this study we have chosen to focus on legal aspects and recommendations, traffic fatalities and serious injuries, the safety consequences for children due to the car development, installation systems, use and misuse regarding medical, technical and user aspects, and, finally, measurements for improvement, e.g. campaigns.

3 Method

The search has been made by VTI Library and Information Centre (BIC). BIC collects, organises, stores and disseminates information in the field of transport and communication research. The review focused on road vehicle transportation and was based on international literature indexed in the Mobility (SAE), MIRA, Compendex MedLine, ITRD, TRAX, TRIS and Internet.

The following topics were covered: Regulations and standards, children in traffic and the "Vision Zero", child anatomy, rearward facing, forward facing, child restraint systems, children with disabilities and transportation safety equipment, travel habits, transport providers, transport procedures, and perceived risks and safety problems according to parents and drivers, improvements, counter measures campaigns, children and airbags, children and accidents, children and legislation, children and misconceptions, injuries and child safety devices.

The review concerned literature mostly from 1990 to the present. Exceptionally, we have also included some relevant documents of major importance older than this. However, no literature dated earlier than 1980 was reviewed with respect to children with disabilities. The reason for choosing this cut-off point was that the development of child safety seats and vehicle safety during the last twenty years has been so rapid that literature from 1979 or earlier was found to be less relevant.

In the literature review, we have also included searches on the World Wide Web (www). Assumptions regarding e.g. laws and recommendations consist of facts that change over time. The most updated version probably will be found on the web.

There are no general definitions of use and misuse of restraints. In some literature the concepts are used to describe use and misuse of seatbelts, in others it describes the use and misuse of Child Restraint System (CRS), and in others both seatbelts and child restraints are included. Moreover, the concept of misuse is ambiguous. The term misuse can include one, or a combination of several, of the following aspects:

- Length-inappropriate CRS according to the law
- Age-inappropriate CRS according to the law
- Weight-inappropriate CRS according to the law
- Length-inappropriate CRS according to the recommendations
- Age-inappropriate CRS according to the recommendations
- Weight-inappropriate CRS according to the recommendations
- Appropriate CRS not correct mounted
- Appropriate CRS not correct used, e.g. incorrect belt positioning

Furthermore, the difference between non-use and misuse is vague.

When we discuss about the above presented aspects we have used following structure:

- The parents/adults firstly need to decide on whether or not to utilise any type of safety belt and CRS.
- Secondly, if they chosen to use safety belts and CRS they have to chose a CRS according to the child's length, weight and age.
- Thirdly they need to mount the CRS.
- Fourthly, they have to seat the child in the CRS.

- Finally, they need to fit the safety belts and internal safety devices of the CRS.

In each of the above steps there is a question of doing it or not, and if doing it, doing it correctly or incorrectly. We have in this review chosen to refer to use or not, and misuse or not.

- Depending on the child's different ages, the need for CRS and safety belt varies. This means that at a certain age the need for CRS plus safety belt disappears and the child is both legally and safely as well protected as possible with the safety belt only. This means that when we refer to use and misuse it is relative to the age adequate CRS. However, this becomes somewhat altered with respect to children with disabilities, as many of them travel seated in the technical aids. For this reason, the transport mobility situation for children with disabilities is presented separately.

Since the authors of the reviewed literature seldom define what is meant by the used terms such as "misuse", it is difficult, if not impossible, to be sure how to correctly interpret the literature.

4 Results

4.1 Legal aspects

When trying to understand questions about e.g. misconceptions, misuse, campaigns concerning child safety in vehicles, it is important to keep in mind that there are different laws and recommendation in each country. This chapter mainly deals with what the law demands.

In all of the referred countries there are regulations about the technical construction of the CRS. Every child safety seat on the European market has to be approved and/or labelled according to ECE R. 44/03. In the USA it is called FMVSS and in Australia it is called Australia Standard 1754.

In most of the countries it is against the law for two passengers, even two children, to use the same seat belt.

There are a lot of websites with available information. One of the most comprehensive is the website from Royal Society for the Prevention of Accidents (Child Car Seats: types of child seats, 2002).

Table 1 presents an example of information from this website (March 2003) concerning existing laws in some countries.

Table 1 *Existing laws and regulations in different countries.*

Australia	Children under 1 year old must be restrained in a suitable approved child restraint. Children aged 1 to 15 years must be restrained in a suitable approved child restraint, or occupy a seating position fitted with a suitable seatbelt if one is available. If the vehicle has 2 or more rows of seats, the child must not be in the front row of seats unless restrained in a suitable approved child restraint or occupying a seating position fitted with a seatbelt. Australian child restraints must be fitted with a top tether which is attached to a suitable mounting point on the vehicle. The use of European child restraints without a top tether is, therefore, illegal.
Sweden	Children are permitted to travel in the front seat, although use of an approved child restraint is mandatory overall until the age of 6 years. It is forbidden to use a rear facing child safety seat in the front seat in a car that has a passenger front/side airbag.
U.K.	Children travelling in cars have to use a CRS or seat belt, if they are available. Children cannot be carried in the front seat unless they are either in a child restraint or are using the seat belt. It is the driver's responsibility to ensure that children under the age of 14 years are either using an appropriate child restraint or a seat belt if available.
USA:New York	Children aged 3 years and younger must be in a child restraint. 4 to 15 year olds must be restrained but can use the seat belt if no child restraint available.

USA: Florida	Children aged 3 years and younger must be in a child restraint. The seat belt can be used (if restraint unavailable) for 4 & 5 year olds who also must be restrained.
USA: California	Children must be secured in an appropriate child passenger restraint until they are at least 6 years old or weigh at least 60 lbs. Children weighing more than 40 lbs may be belted without a booster seat if they are seated in the rear seat of a vehicle not equipped with lap/shoulder belts. Children aged 6 to 15 years or children weighing 60 lbs or more must be restrained but the seat belt can be used.
USA: Michigan	Children aged 3 years and younger must be in a child restraint.

The law described on this web site is a summary and written in an easy language. We have looked more in detail for a selection of countries, i.e. Australia, the U.K., the USA and Sweden

4.1.1 Australia

All six States have regulations requiring children up to 1 year of age to be restrained in an infant restraint or child seat, if the vehicle is fitted with child restraint anchorages. Children older than 12 months up to the age of 14 years are required to use a child restraint system or a regular seat belt, if one is available. If a restraint is not available, the child must not ride in the seating compartment.

All child restraints are required to conform to Australia Standard 1754 and must be used in accordance with the manufacturer's specifications. Booster cushions are allowed in any seating position fitted with 3 point seat belt. All other child restraint systems must be used in a rearward seating position.

Also for Australia there are several websites providing information about legislation for children as passengers. Child and Youth Health (2003) have summarised the legislation and some recommendations for parents. Child and Youth Health is an independent State Government health unit, funded primarily by the Department of Human Services.

The driver is responsible for children under 16 years wearing their seat belt, or being strapped into a restraint. It is against the law for two passengers, even two children, to use the same seat belt. The law does not say that children cannot ride in the front seat of a car, provided they are using proper restraints; however the front passenger seat is the least safe seat in the car and provides less protection for the passenger than any other seat.

Also in Australia there are differences between what the law requires and the recommendations. The recommendation for infants is that they should travel rearward facing when weighing less than 9 kg. Booster seats are recommended to be used after a child grows out of the car seat (at approx. 18 kg or 4 years of age) but may be used from 14 kilograms.

4.1.2 U.K.

The law requires children in Great Britain travelling in cars to use an appropriate child restraint or a seat belt, if such restraints are available. Children are not

allowed to be carried in the front seat unless they are either in a CRS, or using the seat belt. It is the driver's responsibility to ensure that children under the age of 14 are either using an appropriate CRS or a seat belt, if available. If carried in the front seat, an appropriate CRS must be used for children younger than three (the seat belt is not sufficient). If carried in the rear seat, an appropriate CRS must be used, if available. If an appropriate restraint is fitted in the front seat of the car, but not the rear, children younger than 3 years old must sit in the front and use that restraint.

Children aged 3 to 11 years and shorter than 1.5 metres must, if carried in the front seat, wear an appropriate child restraint, if available. If not, a seat belt must be used. If carried in the rear seat, an appropriate child restraint must be used if available. If not, a seat belt must be used if available. If an appropriate restraint or seat belt is fitted in the front seat of the car, but not in the rear seat, children between 3 and 11 years old and shorter than 1.5 metres must use that restraint or seat belt.

New child restraints must conform to ECE R.44/03, but child restraints that conform to a British Standard or to an earlier version of ECE R.44 may be used.

4.1.3 USA

The National Highway Traffic Safety Administration (NHTSA, March 2003) has summarised the safety laws for children. All 50 states of the USA have child passenger safety laws ("car seat laws"). NHTSA has pointed out components that are essential for a strong child restraint law i.e. to:

- cover all occupants up to age 16 in all seating positions
- require child occupants to be properly restrained**.**
- include all vehicles equipped with safety belts.
- make the driver responsible for restraint use by all children younger than 16.
- allow passengers to ride only in seating areas equipped with safety belts.
- prohibit all passengers from riding in the cargo areas of pickup trucks.

More details can be found at the NHTSA website.

In May 1995, the National Highway Traffic Safety Administration (NHTSA) issued a final rule allowing manufacturers to install an on-off switch for the passenger air bag in vehicles that cannot accommodate a rearward-facing child seat anywhere except in the front seat, e.g., pickup trucks and cars with no rear seat or with small rear seats (Morgan, 2001).

In November 1997, NHTSA issued another final rule defining high-risk groups that should not be exposed to passenger air bags: infants, children 12 years old and younger, and adults with certain medical conditions. The rule enables owners of any car, pickup truck, van, or sport utility vehicle to obtain an on-off switch for their passenger air bag if they transport people in one of these high-risk groups.

In a study presented by the National Safety Council (2002) they argue that primary laws benefit children's safety compared with secondary laws. The reason is that if the adults use the seat belt they also will make sure that their children do. The primary laws allow the police to stop and ticket drivers for not using seat belts. States that actively enforce their laws have achieved increased seat belt usage, which in turn has an implication for increased child safety.

4.1.4 Sweden

The Swedish law (SFS 1998:1276 kap 4, §10) states that children up to and including the year they turn six, have to use an appropriate child restraint when travelling in a car. Apart from that, both adults and children travelling in a car are restricted to be positioned on a seat that is equipped with a seat belt if there is one available. Seat belt usage is mandatory for those seats equipped with them. According to the law it is the driver's responsibility to make sure that all passengers younger than 15 are restrained during the ride. Furthermore, rearward-facing child restraints are not allowed in the front seat if an airbag is fitted. New child restraints must conform to ECE R.44/03, but child restraints that conform to a T-godkännande or to an earlier version of ECE R.44 may be used.

To further improve the safety of children, the National Society for Road Safety (NTF, March 2003) and other traffic safety organisations provide recommendations regarding child occupant safety. Swedish parents are recommended to let the children travel rearward-facing as long as possible, at least until the child is four years' old. Rearward-facing infant seats are recommended for children younger than a year and shorter than 70 cm/weighing below 10 kilograms. Rearward-facing child seats are recommended for children from the age of 6–12 months up to 4–5 years. When they have outgrown the rearward-facing child restraints available on the market, children are recommended to use booster seats or booster cushions. Children shorter than 140 cm are recommended not to sit in the front seat if an airbag is fitted.

4.2 Traffic fatalities and serious injuries on the international scene

It could be useful to make statistical comparisons between different countries. For children, however, the availability of data is less than could be desired. This is definitely the case when we look at exposure data. To make good comparisons between data from different countries we need to know not only the number of accidents and the size of the population, but we also need to know traffic exposure data. The travel patterns are likely to vary between different countries. Children are often treated as one group, even though there are societal preconditions that affect the travel patterns. A few examples that affect the travel patterns between different countries are:

- Length of maternity leave
- Proportion of children in day care/kindergarten
- Age at school start and average distance to school

The availability of statistics varies between different countries in more than one aspect. In Appendix 2 some available sources are attached. One-year groups are readily available for fatalities and seriously injured only in Great Britain. Although not published as one year groups, the same statistics are available upon request in Sweden. Australia has published data as one-year groups for fatalities only. This study covers only published data and in some cases it is possible that one-year data is available upon request. In the USA all accident reports are available with the exact ages of victims. The population data is, however, not published as one year groups.

For most countries there are too limited amount of data to draw any definite conclusions from one single year. For example, during the year 2000, 63 children

in Australia were killed as passengers in cars. The corresponding number in the U.K. was 37, in the USA 1,126 and in Sweden 8 children. Due to this the conclusions drawn from Figure 4 should not generalised but it could give an idea of the extent of the problem.

As an example, traffic fatalities in cars from the year 2000 are used, see Figure 4. For each observation the number of fatalities is divided by the total number of children per country of that particular age. No exposure data is used.

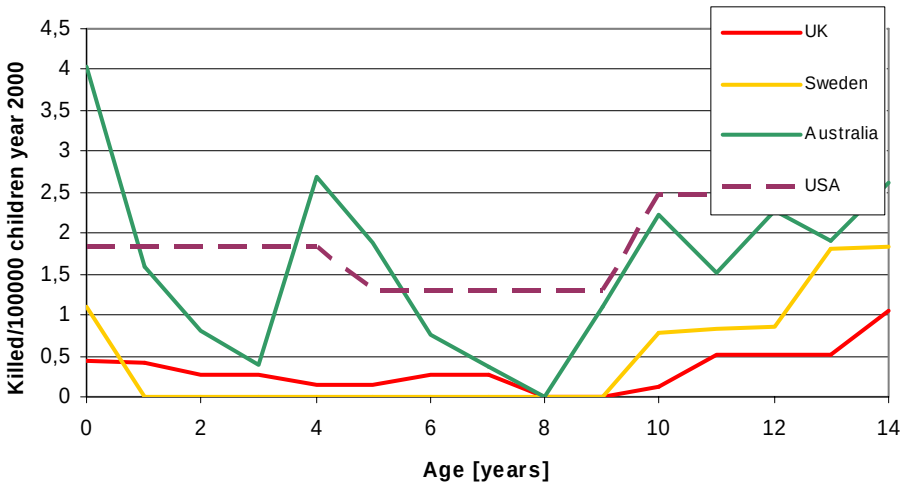

Figure 4 *A comparison of fatalities for car passengers (aged 0–12) between The U.K., Sweden, Australia and the USA., data from year 2000.*

From Figure 3 we can notice that there are great differences between the countries as well as between the age groups.

Instead of a comparison of fatalities it could be of interest to compare the serious injuries, see Figure 5. The exact definition of injury is not known for all countries. For Sweden and UK all reported injuries are included. The number of injured children of a certain age has been divided by the total number of children of the same age.

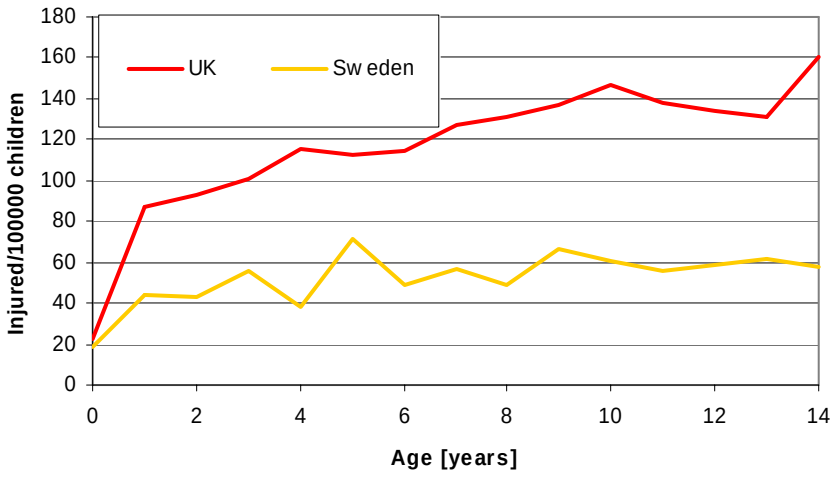

Figure 5 *Comparison of injured car passenger (aged 0–14) between the U.K. and Sweden, data from year 2000.*

Even from this small example it is obvious that correct evaluation of these statistics requires in-depth knowledge of both child restraint systems and the way they are used in other countries, and of course, to what extent they are used. During the review we have not found any literature focusing on one-year group's statistics for fatalities and seriously injured children in car.

4.3 Car development, installation systems and its implications for child safety

4.3.1 Car development

The introduction of passenger side airbags in vehicles has direct implications for child safety and the question of where to place the child. Airbags are installed in order to protect adults in case of a crash. However, children who are exposed to airbag deployment may be seriously injured or killed (Turbell, Lowne, Lundell & Tingvall, 1993; Weber, Dalmotas & Hendrick, 1993; Weber, 2000; Ziernicki, Finocchiaro, Hamernik & Fenton, 1997). Children in rearward facing child restraint are in particular danger since they are very close to the airbag housing. If a deploying airbag hits the child restraint while still inflating, the force will be considerable and the child could be fatally injured (Weber, 2000). Even children in forward-facing restraints could be at risk and the recommendation from the Swedish National Road Administration (SNRA) is to never let a person shorter than 140 cm ride in a seat equipped with an airbag (Vägverket, 2003). In the USA, a total of 135 cases of children killed by deploying airbags have been reported up to the year 2002 (NHTSA, 2003). Most of these children, 101, where not properly restrained or were not restrained at all, while 22 of them were placed in rearward facing child restraints. As of May 2001, no such deaths have been reported in Sweden (Socialstyrelsen, 2001).

The described conflict between children and airbags initiated a survey of how this conflict is treated by manufacturers and importers of cars in Sweden (Forsman, Hellsten & Falkmer, 2003). A questionnaire was sent to Swedish general agents and included questions of availability and placement of airbags in different vehicles, recommendations on where to place different types of child restraints and if and how the passenger side airbag could be deactivated. A total of 62 models from 23 different car manufacturers were included in the survey and they were all among the 71 most sold cars in Sweden during January to September 2002. The results showed that passenger side airbags were available in all but one model, either as standard (53 models) or as supplementary equipment (8 models). The recommendation from most of the general agents was to place children in the seat; although the centre rear seat position was only recommended if equipped with a 3-point belt. This recommendation is not undisputed; the SNRA are of the opinion that it can be advantageous to place small children in the front passenger seat if the driver and the child are alone in the car. In addition, the Swedish insurance company Folksam states that the front passenger seat is the best place for the type of rearward-facing child restraints that rests against the dashboard. This statement is based on results from their research division which shows that the dashboard provides a relatively gentle braking of the child restraint (Folksam, 2003).

If a child is placed in the front passenger seat, the airbag must somehow be deactivated. At present, there are no statutes in Sweden that regulate deactivation

of passenger side airbags, and results from the study by Forsman et al. (2003) show that different car manufacturers offer different solutions. Some vehicle models have an on-off switch that makes it possible to temporarily deactivate the airbag when a child is using the seat. For other models it is possible to permanently deactivate the airbag at a repair shop or to order the vehicle without a passenger airbag. However, there are models for which it is not possible to deactivate the passenger airbag. The National Road and Transport Research Institute (VTI), Folksam and the National Society for Road Safety (NTF) have a joint policy which states that the responsibility for deactivating the airbag should not be placed on the driver, parent or other non-authorised person by allowing installation of an on-off switch (VTI, Folksam Forskning & NTF, 2003). The SNRA also recommends permanent deactivation of the passenger airbag if children are to be transported on the seat in question. In the U.S., driver and passenger side airbags are mandatory since September 1, 1997 (U.S. Department of Transportation & NHTSA, 1993) and deactivation is strictly regulated (U.S. Department of Transportation & NHTSA, 1997). Permanent deactivation is never allowed and on-off switches can be installed only in exceptional cases. Such a case can be if children under the age of 13 for some reason must be transported in the front passenger seat. The U.S. standpoint is based on the opinion that adult passengers should always be protected by an airbag when seated in the front. A study of possible misuse of on-off switches has recently been conducted in four states, California, Georgia, Michigan, and Texas (Morgan, 2001). The study included late model pickup trucks equipped with a passenger side airbag and an on-off switch. A total of 1,637 vehicles were investigated, 1,117 of them had an adult as passenger and 520 had a child on the passenger seat (23 infants). In vehicles with an adult passenger 18 per cent incorrectly rode in front of a deactivated airbag and in vehicles with a child passenger 46 per cent rode in front of an activated airbag. However, of the 23 infants only 2 did sit in front of an activated airbag.

According to the Department of Transport and Regional Services the conflict between children and airbags does not exist in Australia (DOTARS, 2003). The child restraints used in Australia include a top tether strap which is attached to an anchorage point in the vehicle. Such anchorage points can only be mounted in the rear seat of the vehicle and accordingly, all children using child restraints are transported in the rear seat. Moreover, the Australian airbags inflate with less force and have larger vents than U.S. airbags. This makes them “softer” which decrease the injury risk for small adults and children who no longer use child restraints.

The European consumer organization, ANEC, has awarded a contract to one of the leading suppliers of automotive engineering and testing services to look at rear seat back strength. For many years, consumer groups have been arguing for improved strength of the rear seat back in cars. Accidents show that luggage in the rear seat can load the rear seat back in case of a frontal collision and cause the seat back to deform heavily or fail altogether, exposing the rear seat occupants to additional loading. Such additional loading can cause restrained rear occupants, both adults and children, needless injury. Split folding rear seats, because of their current design, are especially liable to provide poor luggage restraint. The situation has increased importance now, when many manufacturers are relying on the rear seat to carry loads from the top tethers of a new generation of child restraints. Such loads add to the existing loads imposed by luggage and the seat’s

own inertia in a frontal impact. On the basis of the test results of the ANEC research project, the organisation will make recommendations for improving the international regulations on testing rear seat back strength. The results of the ANEC study can also be used to contribute to discussions regarding luggage retention requirements in the new car assessment programme, EuroNCAP.

4.3.2 Installation systems

In the late 1980s, a working group of ISO (the International Standardisation Organisation) was formed, with the mission to achieve international harmonisation and standardisation of child safety in cars (Lundell, Claesson & Turbell, 1993). One of the aims was to reduce misuse and non-usage of different types of CRS, by simplified and standardized methods for usage. In the early 1990's, the initial development of a number of standardized anchorage devices to be mounted in cars for the CRS began; i.e. the so called ISOFIX standard. The CRS is supposed to be easily attached to these anchorage devices. A couple of the first prototypes are described in Turbell, Lowne, Lundell & Tingvall (1993). The ISOFIX standard system work was completed in 1999 (Weber, 2000) and ISOFIX systems are now mounted in more than 15 million cars world wide. However, CRS designated for the ISOFIX systems have, so far, only been subjected to official approvals when mounted in a certain vehicle and, hence, an approval has been given only together with a certain car model, according to the European directive ECE R. 44/03. There is a suggestion for a change in the directive so that CRS could be approved on a general level utilising the ISOFIX systems, but at present the timing for such a change is not settled.

In the USA, a system called LATCH (Lower Anchors and Tethers for Children) has been developed. It is based on the ISOFIX system but with certain modifications. The ISOFIX system has two lower anchor points between the horizontal part of the seat and the backrest. The LATCH system also includes a high mounted anchor point for forward facing CRS. The LATCH system is mandatory in all cars manufactured and sold after September 1st 2002 in the USA (FMVSS 213, 2003)

EuroNCAP, (2003) the European car crash test programme, has tried to introduce a new protocol to look at how the car manufacturer protects a 6 month old and a 3 year old child. The introduction of child protection in the scheme's star rating is so far not implemented.

4.4 Data from accidents and crash tests regarding child safety seats.

Back in 1974 the VTI did a series of tests where frontal impact performance of CRS was studied (Turbell, 1974). This study, although it might look old, seems to be a kind of milestone in the Swedish tradition about rearward facing child restraints. It is of historical interest and the results are also still valid. It is also the main source for the Swedish tradition of so eagerly supporting the rearward facing CRS and also a very important factor as to why there are no modern supporting crash tests. Rearward-facing systems, integral forward-facing systems, booster seats, booster cushions, shields, harness and lap belts were tested. Rearward-facing systems in the back seat had nearly as favourable values, but due to a somewhat softer frontal support than in the front seat, there was a slight slack inducing some G_z-components in the range of twice those of rearward-facing seats

in the front seat of the car. Forward-facing CRS and belts with upper torso straps show a completely different deceleration pulse, with mainly late and high G_z-components, induced by the head being decelerated by tension forces in the neck. The tension and the G_z, are at least three times those of the rearward-facing systems and the additional angular acceleration is also high. The study showed a significant advantage for rearward-facing CRS in relation to forward-facing CRS of all types. There was also a significant advantage of rearward-facing CRS in the front seat in comparison with rearward-facing CRS in the back seat. Harnesses and shields showed potential for both submarining and late but strong rebound deceleration.

One of the most frequently referred studies is by Tingvall (1987). Injuries to children (0–14 years of age), during 1976–1983, were compared to injuries to adult car occupants. The conclusion was that fatal injuries to children were mainly located to the head, whereas this is not the case for adults. About 72 % of fatally injured children had head injuries and for the adults the same figure was 56 %, whereas adult chest injuries were higher than for children. The same pattern was observed for non-fatal injuries, where adults showed a higher exposure to upper and lower extremities soft tissue injuries and fractures, as well as to thorax fractures. The author also described a strong correlation between the risk of injury and the type of restraint that was used. Out of a selection of about 80,000 cases reported to an insurance company, 2,763 children where involved in car accidents, and among those about 295 were reported with injury in various degrees. Injuries were coded according to the AIS (Abbreviated Injury Scale), the ISS (Injury Severity Score) and the RSC (Rating system for Serious Consequences). The effectiveness of different restraints was estimated. Among the injured children 1.2 % had used a rearward-facing CRS and 6.9 % had used a forward-facing CRS. Among children wearing only a seatbelt 8.9 % were injured. Unrestrained children represented 15.6 % of the children with injuries. The study also found that the injuries of restrained children were less severe than those of unrestrained children. Various data concerning protection effectiveness is derived from this study. One of the most used is that rearward-facing CRS has an effectiveness of 90.4 % (±11.2 %, 5 % level). One of the conclusions is also that CRS are effective in all collision directions.

A study by Carlsson, Norin & Ysander (1991) was based on about 13,000 Volvo car accidents that occurred between 1976 and 1988. In those crashes, approximately 22,000 persons were involved in various degrees, not all of them injured. We have to keep in mind that during this period the rear seat seatbelt became mandatory in 1986. Furthermore, that mandatory seatbelt use and requirements for approved CRS did not apply to children until 1988. About 1,500 of these crashes involved at least one child 0-14 years old. Among those children, 142 were restrained in rearward facing CRS, 130 in forward facing CRS, and an additional 228 children were unrestrained. (the "unrestrained children" group comprises all other modes of travel, e.g. unrestrained in normal seating positions, sitting on an adult's lap, lying or standing in the car.) The level of misuse/incorrect installation among those children was determined by interview studies and classed as partial misuse when the child was not properly restrained or had the wrong size. The wording "Gross misuse" is defined in the report as meaning incorrect mounting or no mounting of the child seat, or the child not being restrained in the seat. Of the 142 rearward facing child seats, 9 (6 %) were used incorrectly. The most common misuse was that the seat was not fitted

according to the instructions. In two cases the child seat was fitted facing forwards instead of properly rearward facing. Studying Maximum Abbreviated Injury Scale (MAIS) 2–6 values gives a 92 % injury reducing effect on rearward-facing CRS and 60 % injury reducing effect on forward-facing CRS/booster cushion/seat.

When investigating the fatality risk among children younger than 12 years' old, Braver, Whitfield & Ferguson (1997) compared front- and rear seated passengers involved in fatal crashes. For forward-facing children in the back seat, either in booster seats/cushion or using the seat belt, a 35–50 % reduction of fatality risk was found compared with children placed in a rearward-facing seat in the front seat. Although interesting, data is explicit noted as statistically not significant and also technically mainly due to the extended risk with passenger side airbags. A 10–20 % lower risk of fatality was noticed on the rear centre seat compared with rear outboard positions.

Arbogast, Cornejo, Kallan, Winston & Durbin (2002) have investigated specific injuries to children in forward-facing CRS. Out of 25,774 accidents, a sample selection was subjected to further survey investigation. Completed survey data was obtained for 1,722 children in the age group 12–47 months. The selected children were seated in forward-facing CRS. Most children (98.5 %) were seated in a rear seat. About 48.3 % were involved in a frontal collision, and 43 of the children (0.17 %) placed in forward facing child restraint were recorded as seriously injured. About 19 % of the children sustained head injuries, both as a result of contact induced injuries and internal injuries. Head and neck injuries were identified as the main cause of impairment and/or death. The author’s conclusions were that the occurrence of head and neck injuries for these children provides supporting data to suggest that an extension of the current recommendation to keep children rearward facing beyond 1 year of age may be appropriate. In this configuration, the CRS shell itself provides restraint and protection for the neck, as the forces are transferred to the entire torso of the child. This result is supported by data from Sweden (Isaksson-Hellman, Jakobsson, Gustafsson & Norin, 1997), which shows that keeping children rearward facing up to age three or four years reduces all types of serious injuries, not just those to the head and neck. The authors also stated that the CRS is part of a system, the car, the belt system and the CRS itself. The effectiveness of the CRS is often reduced by large intrusion into the passenger compartment in the event of a crash.

In a report from NTSB (National Transportation Safety Board, 1996) accidents with inappropriate restraint systems were investigated. Overall, the data showed small differences in injury severity for children in inappropriate restraints (n = 133) compared with those in the appropriate restraints (n = 51). In total, 32 of the 51 children in appropriate restraints sustained no or minor injury compared with 92 of the 133 children in inappropriate restraints. Five children who were in appropriate restraints and ten children who were not in appropriate restraints were fatally injured. However, when the data were examined by accident severity, differences appeared. The children in low to moderate severity accidents who were in appropriate restraints sustained less serious injuries than children in inappropriate restraints; six children in low to moderate severity accidents and who were not in the appropriate restraint system were fatally injured. Even when child restraint systems were used improperly, they still provided some level of protection to the child. Of the 26 children in improperly used child restraint systems, 14 sustained either no or minor injury. In this American study mainly forward-facing systems were used and the typical incorrect use of the CRS was

mainly too loose fit of belt systems or belt systems adjusted too high over the hip or shoulder. A couple of shoulder straps behind the back were also recorded.

An in-depth study of car crashes in Australia in which child occupants were injured (Henderson, 1994) confirmed the effectiveness of child restraints and seat belts in protecting children. The vast majority of children in the study who were restrained in child restraints suffered only minor injury. Many survived very high-speed crashes without injury to the neck or other parts. A far higher proportion of those unrestrained were seriously injured.

Wenäll (2001) analysed 70 fatal accidents that occurred during 1992–1997. In these accidents 79 children were killed. Among those 79 children only nine children were seated in a rearward-facing CRS, all except one were subjected to impact by heavy vehicles. One accident was a side collision with another car at high speed. All of these nine accidents recorded large occupant compartment intrusion or complete structural collapse. Twenty children were not restrained at all, nine were incorrectly restrained. More than 80 % of fatal injuries were injuries to the head and neck region. The author's prediction was that 25 of the 79 children would have had a fair chance of survival if proper restraints had been used in the way intended.

Tingvall (1987) made a comparative study in which common CRS misconceptions, found in real life, were subjected to a controlled crash test. The most common actual erroneous installations were chosen and reconstructed in five different tests. The most frequent misconception for forward-facing systems was improper use of belt guides. For rearward-facing systems the two most common misconceptions were that the CRS was not correctly attached to the car anchor points, or that the CRS was actually installed forward-facing. The tests showed that poor protection was provided by the incorrectly installed CRS, the most frequent consequences were variations of submarining of the ATD (i.e. the “crash test dummy”).

In a study by Gotschall et al. (1997), 121 restrained children who where injured in 97 car crashes were studied. The typical crash was a frontal collision with a difference in speed caused by the retardation in the crash (Δ-v) of 36.3 km/h ($\pm$ 15.5 km/h). The head and face of the children were the most frequently injured body regions; more than 60 % of the injuries were to one of these body regions. Nearly all injuries to the head, spine, and chest were moderate (AIS 2) or severe (AIS 4). Restraint misuse was found for 84 % of the children. Incorrectly restrained children experienced a higher mean Injury Severity Score (ISS) than correctly restrained children (12.3 vs. 7.1) and incurred medical charges more than 2 times higher (US $36.839 vs. US $15.004).

A Canadian study (Howard, 2001) discussed the risk of child car occupant ejection in rollover crashes. In case studies it was noted that the risk of ejection seemed to be higher in forward-facing CRS with T-shields (Part of a restraint system in a child safety seat; a roughly triangular or “T” shaped pad that is attached to the shoulder harness straps, fits over the child's abdomen and hips and buckles between the legs) compared to forward-facing CRS with a system restraining the child’s pelvis, and that adjustment and correct fitting of shoulder straps were essential. It was stated that the shoulders of a young child are very deformable and yielding, thus increasing the risk of a child slipping through too loosely adjusted shoulder straps.

A study by Kelleher-Walsh, Walsh, States and Duffey (1993) deals with forward-facing CRS and the corresponding injuries. In total, 198 injured children under five years of age in forward-facing CRS were studied. About 55 % of the accidents were frontal collisions and 34 % were lateral accidents, while 10 % were impacts from rear and 1 % was rollover accidents. Of the CRS used, 54 % were harness types and 19 % were shield type CRS. When injuries were studied, the author found that 57 % of the injuries were facial and an additional 19 % were head injuries. Upper and lower extremities injuries each occurred in 7 % of the cases and all other injury types represented less than 3 %. Among the severe injuries the most frequent injuries were those to head and face in forward-facing CRS.

The Seat Belt Syndrome (SBS) in children (Lane, 1994) was found to be a problem with 2-point lap belts in forward-facing positions of children sitting in rear seats. Abdominal gastro-intestinal injuries and kidney injuries might be the consequence if two-point belts are used instead of three-point belts. The use of three point belts and CRS was thus recommended. The risk factor is about doubled for a child in a two point forward-facing belt compared with a three point forward-facing belt system. Adults in outboard rear seats were at greater risk of SBS by a factor 2.7 than passengers on the left front seat, i.e. the passenger seat in a right hand drive car.

Spinal cord injuries in accidents have been studied by Stalnaker (1993). He stated that children's spine develops until about five years of age and recommends rearward-facing systems as long as possible. Of seven investigated automobile accidents with related child spinal cord injury, all but one injury could have been prevented in appropriate protection systems, i.e. rearward-facing CRS. The studied children were 1.5 to 55 months old.

In a reconstruction of a real world forward-facing CRS accident (Weber, 1993) a dummy simulating a 6 month old child was subjected to an impact. Neck forces exceeded 1,200 Newton (N). The technical conclusion of the report was that a rearward-facing CRS would have been preferable.

The influence of harness type was studied in Pennsylvania and New Jersey 1997–1998 (Arbogast, Morris, Durbin & Winston, 2002). Convertible CRS (tray-shields, T-shields and 5-point harness types) were found to have high (87–93 %) misuse rates.

Cervical spine fractures sustained in forward-facing CRS were studied by Fuchs, Barthel, Flannery & Christoffel (1989). They found that forward-facing CRS for children younger than two years of age constituted a great risk. Five real cases were studied. With a reference to Sweden the final recommendation of the paper was that all children younger than two years and preferably younger than four years should travel rearward-facing.

The risk of premature graduation of children to seat belts is treated in the dual NHTSA internet documents (NHTSA, 2001c; NHTSA, 1998). It was found to be common that parents put their children in the car without proper CRS. Children, 3–5 years of age, restrained only by a seat belt have a 3.5 times higher risk of being injured than children in correct forward-facing CRS.

Injuries to children restrained in 2- and 3-point belts (Gotschall et al., 1998) have been investigated in 98 cases. Contrary to other studies, in this specific study very small or no differences in injury risk (AIS>2) were found between 2-point and 3-point belts, but it appeared that 3-point belts were somewhat protective for lumbar fractures.

In a study by Sweitzer, Rink, Corey and Goldsmith (2002), 499 children in motor vehicle crashes have been studied. It was found that 33% were unrestrained and 20 % were improperly restrained. Unrestrained children accounted for 70 % of the fatalities. The restraint type was found to be of greater importance than the seating position.

4.5 Use and misuse of restraints – observations and questionnaires

4.5.1 Australia

A study funded by the Australian Transport Safety Bureau gives a background to child car occupant safety in Australia (Browning, Ferguson, Swan & Robinson, 2000). A recent study in Western Australia, referred to by Browning et al., showed that approximately 11 % of metropolitan children did not wear CRS whilst 15 % of rural children did not wear CRS. Furthermore, inadequate access to child restraints was one reason for not using CRS. Browning et al. also reported that a survey undertaken by Kidsafe WA indicated that more than 60 % of the child car restraints were fitted incorrectly.

In the 1970s, Australia mandated child restraint use and adopted an attachment system that incorporates an upper tether strap (FORS, 1996). Australian child restraints attach to the car via the seat belt at the bottom and to dedicated anchorage points on the vehicle by the upper tether strap. The need for the upper strap precludes child restraints from being used in the front seat. In addition, some State laws prohibit children of certain ages from riding in the front passenger seat. Data for the years 1990/92/94 indicated that around 290 children under 16 years of age who were killed or injured in an accident were unrestrained. This was some 25 % of children killed during the period. Compared with children who were restrained, those unrestrained were more likely to be seriously injured (62 % of unrestrained children compared with 53 % of children who were restrained). This supports the case for making child restraint laws more stringent than is generally reflected in present requirements.

To avoid misuse the Kidsafe organisation provides advice to the public on the Internet (Kidsafe, 2003). This consists of common mistakes in using restraints and a summary of the most dangerous misuses.

4.5.2 U.K.

In 1992, observed seat belt use for child rear seat occupants declined with age, so that 88 % of children under the age of one were being restrained, compared with 60 % in the 10–13 age group (Transport Research Laboratory, 1992). New figures from the Transport Research Laboratory (2002) show restraint use by car occupants in April 2002. The use by car occupants of seat belts and other restraint systems was observed at 32 sites chosen to represent all types of roads. Rear seat belt use was examined in 28,000 cars on two extensive areas centred on Crowthorne and Nottingham. The figures showed that 95 % of children from 0 to 13 years used a restraint in the front passenger seat. Ninety eight per cent of children younger than one year and 97 % from one to four years were restrained when travelling in the rear. The percentage was reduced to 86 % for 5–13 year-olds.

In Fife, Scotland, a study of restraint use was performed in 1995 and reported by Campbell, Macdonald & Richardson (1997). The survey gathered data from

596 occupants in 180 cars: 327 adults and 269 children. Car occupant restraint was assessed in 180 drivers, 151 front seat passengers, and 265 rear seat passengers. Among all occupants, 61 % wore seat belts. Among children, 25 % were restrained by a seat belt and booster cushion, 23 % in toddler seats, 9 % in two way seats, and 7 % in rearward facing infant carriers. Overall, 97 % of drivers, 95 % of front seat passengers, and 77 % of rear seat passengers were restrained.

According to The Royal Society for the Prevention of Accidents, RoSPA (2002) surveys have shown that a high proportion of child restraints are incorrectly fitted, usually for one or more of the following reasons:

- Seat belt too loose
- Seat belt not routed through child seat correctly
- Buckle crunch (buckle resting against part of the child seat's frame, which means that in a crash it might break or snap open)
- Handle on baby seat not positioned properly
- Child seat not compatible with car
- Child seat old and in bad condition
- Child too large or too small for the seat they are using.

The objective of the Fife study (Campbell, Macdonald & Richardson, 1997) was to pilot data collection instruments and to make a preliminary estimate of the level of incorrect use of car seat belts and child restraints. The method used was a cross sectional survey of cars containing adults and children at a number of public sites across Fife to assess use of car occupant restraints. Trained road safety officers assessed whether seat restraints were appropriate for the age of the passengers and whether restraints were used correctly. These assessments were based on standards published by the Child Accident Prevention Trust. About 52 % of the vehicles observed had at least one passenger restrained by a device that was used incorrectly. Twenty eight per cent of the children were secured incorrectly. The most common errors were loose seat belts and restraint devices not adequately secured to the seat. Rates of incorrect use were highest in child seat restraints, reaching 60 % with two way seats and 44 % with rearward facing infant seats. The conclusions drawn by the authors were that the incorrect use of car occupant restraints is an under-recognised problem, both by health professionals and the general public. Moreover, incorrect use has been shown to reduce the effectiveness of restraints, can itself result in injury, and is likely to be an important factor in child passenger injuries. The correct use of car seat restraints merits, according to Campbell, Macdonald & Richardson, greater attention in strategies aiming to reduce road traffic casualties. Among areas of intervention that could be considered are mentioned raising public awareness of this problem, improving information and instruction given to those who purchase child restraints, and encouraging increased collaboration between manufacturers of cars and child restraints, in considering safety issues.

4.5.3 USA

In a national study in the USA, the change in use of restraints between 1993 and 1997 was investigated through telephone interviews (Bolen & Bland, 1999). The number of respondents was 34,000–40,000 with approximately 660–770 per state. The response rate was 71 % in 1993 and 62 % in 1997. The respondents were

18 years or older. The group investigated was the oldest child (younger than 15 years) of the respondent. The restraint use among children 0–4 years increased from 91.2 to 93.7 %. Among children aged 5–10 years the rate increased from 82.6 to 90.1 % and for the age group 11–14 years from 69.0 to 79.1 %.

A national study in the USA recently showed that among 9,332 children aged 14 and younger, 14 % travelled unrestrained (Cody, Mickalide, Paul & Colella, 2002). The study was based on observations of 6,297 motor vehicles between November 2001 and January 2002, captured at 174 sites in 48 states and the District of Columbia. Older children were more likely to be unrestrained than younger children. More than 20 % (558) of children aged 5 to 9 and nearly 24 % (284) of children aged 10 to 14 were unrestrained. Furthermore, minority children were more likely to travel unrestrained (23 %) than white children (10 %). Moreover, nearly 33 % were using the wrong restraints for their size and age. Older children were more likely to be in the wrong restraint than younger children. More than 63 % of those who should have used booster seats (typically ages 4 to 8) were inappropriately restrained, most often in safety belts. Drivers who did not wear safety belts were less likely to restrain the children in their vehicle. Nearly 40 % of children travelling with unbelted drivers were unrestrained, compared with 5 % of children travelling with belted drivers. Similar findings were reported by Decina & Knoebel (1997)

In a summary the National Highway Traffic Safety Administration, NHTSA (2000) wrote that the effectiveness of child safety seats to reduce fatal injuries in cars was 71 % for infants (younger than 1 year), and 54 % for toddlers (1–4 years old). NHTSA has tried to estimate the number of lives saved by restraint systems. During 1994-2000 an estimated total of 2,186 children younger than five were saved, thanks to the use of restraints (CRS or adult seatbelts). Furthermore, in 2000, an estimated 316 lives of children under five years of age were saved, 282 were associated with the use of CRS and 33 with the use of adult seatbelts. During the same year, a total of 529 children in the age below five years were fatally injured as passengers in vehicle crashes in the United States. Of those, 251 children had not used any restraint, 219 used a child seat and 59 used an adult seatbelt. At 100 percent child safety seat use among those children, an additional 143 lives could have been saved in 2000, according to the estimations.

Cody, Mickalide Paul & Colella (2002) state that efforts to increase child occupant safety must be expanded and sustained over the next decade, including the following measures:

- Closing gaps in existing child occupant protection laws.
- Upgrading safety belt laws to include primary enforcement provisions.
- Better education for caregivers about the increased risk of death or serious injury for unrestrained children.
- Better information to caregivers about the importance of using the appropriate restraints, with a focus on belt-positioning booster seats.
- Continued targeted outreach to at-risk populations, using culturally appropriate messages and materials.
- Supporting more child safety seat distribution programs in communities in need.

To promote correct use of child restraint systems Biagioli (2002) gives a check list, entitled “Common Misuses of Child Safety Seats”. The list contains the following advises:

- No rearward-facing seats in front of an airbag.
- Children should face the rear until they weigh 20 lb and are at least one year of age.
- The child's height and weight should be appropriate for the seat.
- Infant seats only in a rearward-facing position.
- Convertible safety seats are designed to face rearward or forward, but each direction has weight limits. The child seat manual or the seat's label lists its rearward-facing weight limit.
- A child seat should not be used in a side-facing seat
- Check that correct seat-belt path is being used.
- No more than 1 inch of side-to-side motion when the car seat is pulled forcefully at the seat-belt path.
- Tether straps only in newer cars that have tether anchor sites
- To maintain the infant's airway, the back of a rearward-facing child seat should be at a 45-degree angle from the ground.
- The carrier handle or sun shield of infant seats should be in the down position while travelling.
- Harness straps should be snug enough that you cannot pinch the harness strap (lengthwise, not crosswise).
- Harness straps should be flat and free of knots. Straps should not be ironed or placed in a dryer.
- The harness clip should be at the armpit level.
- In a child seat that is facing rearward, the harness straps should be at or below the level of the shoulder.
- In a child seat that faces forward, the harness straps should be in a reinforced harness slot position. If more than one reinforced position, the harness straps should be at or above the level of the shoulder when the child is forward facing.
- Bulky clothes should not be worn under the harness straps.
- Missing or broken parts should be obtained only through the manufacturer.
- Check the seat for recalls.
- Child seats that have been in a crash should always be discarded and replaced
- A seat that is more than 10 years old should not be used, and it is best practice not to use a seat that is more than six years old.

The 1998 Motor Vehicle Occupant Safety Survey (MVOSS), a national telephone survey was conducted during the end of 1998 and the beginning of 1999. Block (2000) presents the survey findings pertaining to child restraints and child occupant protection among children under the age of 6 and seating position of children aged 12 and younger. About half of the children age 12 and younger were said to be less likely at that time to ride in the front seat while 19 % were more likely to ride in the front compared to one year earlier. The most frequently given reasons why children were more likely to ride in the front seat were that the child preferred the front and that there was no other place for the child. The most frequently given reasons why children were less likely to ride in the front were

that it was safer in the back and the danger from air bags. The selected subgroup of “parents/caregivers” were asked detailed questions about child restraint use, misuse and non-use among children under the age of 6. The “parents/caregivers” either reported that the child used a car seat “all the time” (71 %) or never used a car seat (22 %). Nearly all infants (98–99 %) were reported to use car seats “all of the time” if they weighed below 20 pounds (approximately 10 kg) or were younger than 2 years of age. Discontinuation of car seat use by most children occurred when the child was 3 or 4 years old and exceeded 40 pounds (approximately 20 kg). The most frequent reasons mentioned for non-use of car seats among part time users were that the child did not like the seat (31 %), the seat was unavailable (30 %), or the child was only going to be in the car a short time (29 %). Among children who never used car seats, the reasons given were that the child was too big (84 %) and that the child was using a seat belt (94 %). The vast majority of children who never used car seats were reported to wear seat belts all (92 %) or most of the time (5 %) when riding in motor vehicles. Most parents/caregivers (76 %) said they were aware of booster seats, but 21 % had not heard of them. Among those who had heard of booster seats, 30 % had concerns about their safety and another 7 % were unsure, according to Block (2000). Of several information sources read by the interviewers, the parents and other caregivers who drove a child that used a car seat most often said that they had heard about the need to use car seats from TV or radio (65 %) or from books or articles on child care (61 %).

A study by Glassbrenner (2003) found that during 2002 almost all infants (99 %) under age one were restrained, this was compared with 95 % in 2000. Yet, although all infants should be in a rear-facing restraint only 32 % were. Among toddlers 8 % ought to be rear-facing, according to the author, while 4 % actually were. Overall, 94 % of toddlers were restrained (compared with 91 % the year 2000), while only 83 % of children 4–7 years of age were restrained in 2002. The restraint use estimates were based on the National Occupant Protection Use Survey (NOPUS), conducted periodically by NHTSA. The survey also reported that many young children still ride in the front seat; 15 % of infants, 10 % of toddlers aged 1–3 and 29 % of children aged 4–7. The latest survey was conducted in 2002, and its results were compared with the NOPUS made during 2000. Other findings were that the relation between restraint use of drivers and their child passengers was strong. In 2002, more than 90 % of belted drivers also restrained the children in their vehicles while only 72 % of unbelted drivers restrained their child passengers.

An observational study of 1,258 children in Michigan, USA, showed that almost 75 % of the children younger than 4 years used a child restraint when travelling in cars, vans, sport utility vehicles (SUVs) and trucks (Eby & Kostyniuk, 1999). The seat use was highest for children travelling in vehicles driven by belted drivers and females. Inspections were carried out at a subset of sites. In this pilot, seat misuse of some degree was found in 88 % of the inspections. The most common type of misuse was associated with snugness of fit, use of safety belt locking clip and the harness positioning clip. Drivers who had a high occurrence of misuse had lower educational level, removed the seat frequently from the vehicle, were not the parent of the child or had younger or smaller children.

A similar study was performed and reported by Eby, Kostyniuk & Vivoda (2001). The purpose of the study was to conduct a direct observation survey of

restraint use designed specifically for older child passengers (4–15 years of age). Furthermore, the factors that were related to belt use by older child passengers in Michigan were to be determined in order to enable the development of effective programs to promote use of restraint devices in this age group. The study found that older child restraint use was about 58 %, state wide. Restraint use was highest in regions where overall belt use was higher, when the driver was using a safety belt, in sport utility vehicles (SUVs) and vans/minivans, and in the front-right seating position. No difference in restraint use was found for the day of week, the sex of the child, or the type of site where data were collected.

A study in the state of Georgia among 1,858 child car occupants younger than 13 years showed that 42 % of the children were properly restrained (Staunton, Dellinger, Davidson & Powell, 2002). Among children 4–8 years, only 21 % were using a suitable child restraint, while 75 % used only the seat belt and 4 % were totally unrestrained. The change in restraint use among adults due to legislation and the effect it had on child restraint use was also studied. The restraint use among children aged 0–4 increased from 91.2 % to 93.7 %, among children aged 5–10 from 82.6 % to 90.1 % and among children aged 11–14 from 69.0 % to 79.1 %.

A study was conducted to determine the risk of significant injury associated with premature graduation of young children (2–5 years) from child restraint systems to seat belts (Winston, Durbin, Kallan & Moll, 2000). A representative sample was selected, of children aged 0 to 15 years in crashes reported to insurance companies in a sample of states. Driver reports of crash circumstances and parent reports of child occupant injury were collected via telephone interviews. Among children aged 2 to 5 years, 98 % were restrained, but nearly 40 % of these children were only restrained in seat belts. Compared with children in CRS, children in seat belts were more likely to suffer a significant injury, particularly head injuries, when compared with children in CRS. The conclusion drawn was that premature graduation of young children from CRS to seat belts puts the children at greatly increased risk of injury in crashes. A major benefit of CRS was found to be a reduction in head injuries, potentially attributable to a reduction in the amount of head excursion in a crash.

Misuse of booster seats among a sample of children attending 76 child safety seat clinics in Pennsylvania and southern New Jersey has been studied by Morris, Arbogast, Durbin & Winston (2000). Four different characteristics of booster seat use were assessed (type, appropriateness for the child's age and weight, the fit of the child in the booster seat, the fit of the booster seat in the vehicle). Sixty eight per cent of shield boosters and 20 % of belt positioning boosters were misused. Thirty two per cent of the children using a shield booster weighed more than 40 lb (18.1 kg); 68 % of children in shield boosters and 63 % in belt positioning boosters weighed less than 40 lb. The majority of children in this study were less than 40 lb. In this weight range, a convertible child restraint system provides better protection than a booster seat. Booster seat use should only be initiated once the child has completely outgrown their convertible child restraint system. Altogether, 227 booster seats were observed. Booster seat practices were assessed at 76 clinics by a child passenger safety team that evaluated the booster seat and identified modes of misuse. In a further review of the data it was concluded that the overall misuse rate of booster seats was misreported (Morris, 2001). Referring the author the correct overall misuse rate of booster seats was 32 %.

The primary objective of another study performed by the same authors (Arbogast, Morris, Durbin & Winston, 2002) was to quantify the relationship between harness types and the prevalence of specific modes of misuse. Data were collected at 21 child safety seat clinics in 1997 and 1998 in south-eastern Pennsylvania and southern New Jersey. Convertible CRS are available in three basic harness designs: five-point, T-shield, and tray-shield. Previous research has, according to the authors, quantified the prevalence of misuse of child safety seats and has identified specific misuse modes. Of the 438 convertible CRS evaluated, roughly 90 % demonstrated at least one form of misuse. This rate of misuse did not vary by harness type. Having marked/twisted harness straps was more common among five-point harnesses. T-shields were more commonly recalled due to defects with the shield buckle and harness retractor mechanism.

To determine if hands-on instruction in child safety seat (i.e. CRS) installation decreases the number of errors in installation, cross-sectional studies were set up at primary care offices, emergency departments and CRS checkpoints (Lane, Liu & Newlin, 2000). Participants were parents of children younger than 2 years old, receiving medical care or attending a CRS check. The results showed that only 6.4 % of parents had a correctly installed CRS. Hands-on instruction was associated with fewer errors in seat installation. Increased parent age, completion of college, and having private insurance were also associated with fewer errors in CRS placement. The majority of parents learned to install seats from reading the manual, from friends and relatives, and from figuring it out on their own. The conclusions drawn by Lane et al. were that errors in CRS installation were a significant problem. Hands-on instruction decreases the numbers of errors in CRS installation. However, few parents received hands-on instruction from experts in CRS installation. Hands-on education by trained professionals could result in increased correct CRS use.

In a study by Weinstein, et al. (1997) the effects of not using an age-appropriate restraint system was examined and the effect of not using a restraint system properly on injury severity. The authors found that improperly restrained children in an age-appropriate restraint system sustained a greater proportion of moderate or worse injuries (AIS 2–6) than properly restrained children who were in the wrong restraint for their size. This was true particularly for infants and small children who were likely to be in a child restraint system. The study underscores the importance of proper use of restraint systems and makes recommendations for improvements in restraint system designs for children as follows:

1. CRS should be redesigned to simplify the placement of a child in the restraint system
2. instructions should be simplified
3. integrated restraints should be offered
4. standards should provide for the secure and uniform installation of CRS
5. standards should be established for booster seats that can restrain children up to 80 pounds
6. lap/shoulder belts should be provided at all center rear seating positions
7. adjustable upper anchorage points should be provided at all outboard seating positions

The premature graduation of children from child restraints to vehicle safety belts has been studied (NHTSA, 2001). The parents who used booster seats for their

children knew more about child passenger safety issues and were more proactive in seeking child safety information. Focus groups conducted in New Jersey and Pennsylvania found that these parents perceived a higher risk of injury from a motor vehicle crash for their children. In contrast, parents who only used seat belts for their young children expressed confidence that they were protecting the child from injury in the event of a crash effectively, using this type of restraint. In the study, two groups of children are found to be prematurely graduated from child restraints to seat belts: children under 40 pounds who should still be in child safety seats; and children over 40 pounds who have outgrown their child safety seats and moved to seat belts, but should be restrained in booster seats. Parents frequently did not recognize the importance of keeping their child in a booster seat until the seat belt fitted the child properly. Child resistance was a significant barrier to extended use of booster seats. The parents of children still using booster seats encountered the same types of resistance, but did not let the children make the decision. Other barriers were the need to accommodate other children, motor vehicle design, and situations where the seat was not available. Some parents altered the method of restraint depending on the length of the trip, the weather, or their own mood. Parents reported difficulties in installing the booster seats, and also concerns about restraints that they thought offered insufficient protection. A number of misperceptions about when a child is ready to graduate into a seat belt were found. Parents want to do the right thing, but not all have accurate information about which restraint to use and how. Laws provide poor guidance. The parents suggested a number of strategies to encourage booster seat, for example: to educate parents on successful parenting strategies including consistency, setting boundaries, and communication; to provide free or low cost booster seats use.

In a study by Ramsey, Simpson & Rivara (2000), booster seat use and reasons for non-use were reported. The children were observed at day care centers and drivers of unrestrained children were interviewed. One of the findings was that the most common reason for lack of booster seat use was that parents thought the child was large enough to use the regular lap-shoulder belt system, or problems with attempting to use the seat in the vehicle. Overall, 28 % of children in the target age group used booster seats; only 10 % of children 6 to 8 years old were restrained with booster seats. Booster seat use decreased when there were 3 or more passengers in the vehicle. More than one half of parents who were not using booster seats at the time of the survey reported owning seats. The conclusions drawn were that the results indicate that parental misconceptions about size and safety of regular restraint equipment are the most common reason that children are not appropriately restrained in vehicles.

The objective of a study reported by Simpson et al. (2002) was to identify barriers to booster seat use and strategies to increase their use. The study demonstrated that, in particular, differences in risk perception, awareness/knowledge, and parenting style were noted when comparing parents of children in booster seats with those whose children were in seat belts only. Media campaigns, improved laws, parenting education, and extending the use of child restraints to older ages were among the strategies suggested by parents to increase booster seat use. The study provides insights from parents about their perceptions regarding booster seats, how parents make safety decisions for their children and the important role of children in this decision-making process. The method used was a qualitative study consisting of focus groups with follow-up in-depth

discussions among parents and/or children. The total number of participants was 111.

Biagioli (2002) advises physicians to provide parents with information about child occupant safety, such as advice, pamphlets, web-site addresses, information about check-up clinics and community's safety seat experts and to use a multidisciplinary approach in educating parents about the correct use of child restraints.

The objectives of a study conducted by Wegner & Girasek (2003) were to measure the required reading level of a sample of child safety seat (CRS) installation instructions and to compare readability levels among CRS if different prices. Another objective was to determine whether the lower cost seats (to which low-income parents have greater access) are addressed to readers with a lower level of education. In the study a CD-ROM containing CRS installation instructions was used, obtained from NHTSA. Paper copies of the instruction sets were generated, and their readability levels were determined. No significant associations were found to exist between readability and seat prices. The conclusions drawn were that CRS instruction manuals were written at a reading level that exceeds the reading skills of most American consumers. Consequently, instruction sets should be written at a lower reading level to encourage the proper installation of CRS.

In a US national survey (Boyle, 1995) it was found that 29 % of the parents transporting children in rearward facing CRS believed that the combination of rearward facing CRS and passenger side airbag was safe. An additional 15 % claimed they did not know whether it was safe or not, or said that they did not know how airbags work. Of those who mistakenly believed that there was not any danger from the airbag, approximately 3 % had a passenger-side airbag in their primary vehicle. In the survey, two additional problems were identified related to young children not being fastened into their car seat; about one out of five (22 %) parents/caregivers reported that it happened that their child entered the car seat while riding in the vehicle. This was most common among children who used booster seats. Among part-time car seat users, 22 % of children usually rode in another passenger's lap when they were not in their car seat.

4.5.4 Sweden

In Sweden, the changes in seat belt usage in cars have been studied through annual observations at a sample of roundabouts since 1983 (Cedersund, 2002). From a level of less than 20 % in 1983 the proportion of restrained children in the rear seat increased rapidly to over 60 % in 1986. Since the end of the 1990's the level of restraint usage among children has been almost 90 % in the rear seat. Seat belt usage became mandatory in the rear seat in 1986 for adults and in 1988 for children.

In a national survey, restraint use and misuse was investigated (Anund, Yahya & Sörensen, 1998) through questionnaires. The questionnaire had, however, some disadvantages and improvements were therefore introduced when a similar study was performed in the west of Sweden (Anund, Sörensen & Yahya, 1999). Overall, no large differences were found, when the results from the west of Sweden were compared with the study among randomly selected children in the whole country.

In the study covering the west of Sweden (Anund, Sörensen & Yahya, 1999) the questionnaire was answered by 2,358 parents with children in the age from

two month to nine years. Questions were asked about the travel habits of the child who had been selected randomly. Overall, the proportion of children who always used a seat belt was estimated to 83 %, while another 12 % claimed to use the seat belt during 99 out of 100 trips. The remaining 5 % used the seat belt less often.

In the same study (Anund, Sörensen & Yahya, 1999) it was found that almost 25 % of all the children travelled, in at least one out of twenty trips, in a car without using a child restraint. Among children younger than three, the corresponding proportion was 6 %. The recommendation at the time of the study, i.e. 1998, was that all children younger than ten years of age ought to use child restraints, while child restraint use was, and still is, mandatory for all children up to and including the year when they become six years old. Children younger than three years were recommended to travel facing backwards. Despite this, almost 25 % of children younger than three years did not follow this recommendation. Moreover, during their first journey ever, approximately 10 % of all children in the west of Sweden travelled unrestrained.

Restraint and child restraint use and misuse were studied in Östergötland, Sweden. Observations of 274 child car occupants arriving at supermarkets, child care centres and central city blocks showed a misuse percentage of almost 40 %, including non-users. Ten percent of the children were not using any kind of restraint at all. Among children younger than three, nearly 30 % travelled forward-facing. The main misuse factor was misplacement of seatbelt (Anund, 1998).

In a questionnaire based survey in the west of Sweden (Anund, Sörensen & Yahya,1999) 10 % of the children younger than three were reported using booster seats or booster cushions and another two percent used no child restraints at all. One quarter of the children younger than three travelled forward-facing. One of the main reasons for changing to a forward-facing position was that there was not enough space for the feet/legs of the child or that the child was unhappy with travelling rearward-facing. Among children aged 3–9 twelve per cent did not use any child restraint at all. There was a correlation between the age of the child and the use of child restraint. Among children aged 1–2 approximately 7 % travelled at least one out of 20 trips without child restraint. Among children aged 3–9 the corresponding percentage was 30 %.

There was a significant correlation between the percentage of front-facing children younger than 3 years and the educational level of the parents as well as the household income. Among children of age 1–2, there were 43 % forward-facing children with parents with lower education. However, only 16 % of the children with parents with higher education were forward-facing. There was, however, reason to believe that there was a strong correlation between level of education and household income. Immigrant parents had not received or looked for information about child occupant safety to the same extent as parents born in Sweden. Furthermore, there was also a correlation between immigrant parents and non-use of child restraints. Approximately ten per cent among children with one or two parents born outside Sweden did occasionally travel unrestrained. The corresponding percentage for children with parents born in Sweden was four per cent. The percentage of children in the age group 0–2 travelling forward-facing was also higher among those with parents from another country. In one part of the questionnaire the knowledge about rules and recommendations was investigated. Although less than 60 % of all the answers were correct overall, more than three

out of four parents were convinced that their child travelled according to recommendations and regulations.

Krafft (2000) argues that car producers do not take child car safety seriously enough. Frontal collisions are the most common type of collisions. From a crash safety point of view rearward facing child restraints in the front seat are the safest way of transporting four year old children in cars in case of a frontal collision, says Kraft. Few cars are, however, produced without a passenger front/side airbag, although this is the safest position for rearward facing child car seats in case of a frontal collision.). One main reason for premature graduation from rearward facing restraints is the lack of space in the rear seat. Due to this reason, already at the age of two, children are being moved into a front facing restraint. Instead, the front seat should be available for rearward facing restraints and equipped with specific attachments for the child restraint.

In a study by Wenäll (2003), the Swedish laws and recommendations for child restraints in passenger cars are discussed. Furthermore, advises to parents and other user groups are given, based mainly on the experiences from a great number of different approval tests, including many crash tests. The Wenäll study supports the statements above quoted from Krafft (2000)

Another questionnaire based study in part of Sweden (Forward, Kós-Dienes & Obrenovic, 2000) showed the attitude and behaviour among approximately 300 Swedes and 300 immigrants, 38 % arriving in Sweden in 1985–1990 and 62 % arriving in 1991–1997. The results showed that immigrants were less likely to use child seats for their children. The general opinion was that children are safe enough travelling in the rear seat or sitting on the lap of an adult holding them. Many immigrants were ignorant of the risk of unrestrained children hitting the windscreen in case of an accident. A reason why seatbelts were not worn was that families with many children said they had no possibility to use a seat belt in the rear seat. The immigrants considered the use of child seats in the rear seat less attractive, since fewer passengers then could be seated there. The study recommends traffic safety information campaigns targeted at immigrant groups.

Tingvall (1987) investigated child safety in cars from different aspects, including restraint use effectiveness, restraint use limitations and drawbacks, data quality and improper use of child restraints. Questionnaires were used for studies of restraint use effectiveness. Data on injuries reported by the police were used for studies of limitations and drawbacks of restraint use. Observational studies were conducted to detect improper use of child restraints and these were followed-up by dynamic barrier tests to assess possible consequences in frontal collisions. Misuse of child restraints was found to exist which may decrease restraint use effectiveness or induce injuries. On the basis of these studies it was recommended that child restraints should be incorporated into cars as an in-built system with the same basic design as restraints that are available as extra equipment. However, certain considerations should be paid to those injuries occurring among restrained children that entail a risk of medical disability.

Long-term effects of legislation and local promotion of child restraint use in motor vehicles in Sweden have been analysed by Ekman, Welander, Svanström & Schelp (2001). The study included children from two age groups, 0–6 years and 7–14 years. Data from observational studies of car seat belt usage was used. Outcome evaluation was based on hospital-discharge data 1978–1996 and mortality statistics 1970–1996. The level of restraint use for children in the front seat was found to be 97 % in both 1988 and 1995. Mortality data showed a

decrease of 76 % over the 27 years studied. Hospital discharge showed a significant change over time in two intervention areas, but not in the rest of Sweden. The local authorities that started early with preventive programmes, such as safety seat loan schemes and those which have organised safety-promotion programmes showed a better improvement than the rest of Sweden. The conclusion drawn was that there is a need for appropriate information for local action on childhood injury prevention to accompany national legislation.

A standard empirical test procedure, ISO 8317, was applied to the study of child restraint misuse (Bell, 1991). A pilot group of 20 parent-couples was presented with a booster seat, including the permanent instruction that was fitted to the product, and were observed while installing the seat. One objective of the study was to determine whether such a panel procedure could be applied by lay investigators. Another objective was to determine whether potential sources of misuse could be identified. Ten of the couples made no mistakes and eight couples made errors that were judged to be less serious. Although this booster seat was held by experts as easy to use, two couples made serious errors. One couple placed the diagonal part of the adult seatbelt under the arm of the child. The other couple made an error when positioning the booster seat into the car that might lead to submarining in case of a collision. The study concluded that lay investigators can evaluate a product for a manufacturer, using such misuse testing. The technique can illuminate specific product drawbacks. Potentially, such testing might be part of the product approval or certification process. At the same time, this policy calls for cautious application, as improving products for misuse prevention does not necessarily lead to better products for injury prevention.

Systems based on the principle that elements for child seat fastening are already mounted in the car seats or chassis when delivered have been investigated with respect to correct mounting among parents of small children (Berg & Gregersen, 1992; Berg 1998). The results show that the systems minimise incorrect mounting and that parents are willing to pay a fairly large amount of money for installation in their car. The ISOFIX system is ranked highest when it comes to simplicity of use and was also ranked highest regarding how stable or safe the seats seemed when fastened.

Incorrect use of car safety seats for children leading to an unexpected risk of strangulation has been pointed out by Björnstig, Eriksson & Holm (1997). Parents were advised to use child seats with crotch strap only, especially if used forward-facing. The problem does not seem to occur if the child restraint is fitted rearward-facing, because the risk of sliding out of the seat is prohibited by the car seat back rest. When a child restraint without a crotch strap is used, however, there is a potential risk of strangulation. The authors give an example of a case where a one-year-old boy fell asleep while sitting in his child seat and was found unconscious by his parents. The boy had slid down and was hanging by his throat. His father gave first aid, which most likely saved the boy's life. The boy, however, did not regain consciousness at the hospital until five hours later. Fortunately, after a month he did not seem to suffer from any long lasting injuries.

4.6 Socioeconomic aspects

In some studies a relation has been found between level of restraint use and different socio-economic factors (Gustafsson, Anund, Sörensen & Vogel, 2003). Examples of factors found to be positively related with restraint use are: income,

and level of education. Situations or groups in which restraint use has been found to be low are:

- children from minority groups (such as immigrants),
- where restraints are reported to be frequently removed from the car,
- children in cars not driven by females, parents or belted drivers,
- in cars with more than two passengers,
- in minibuses, and caravans
- in the middle rear seat.

Situations or groups where level of usage was found to be high were:

- in rural areas,
- in SUVs and vans (Michigan),
- in the front-right seating position,
- in states with primary child restraint laws.

Other factors for restraint usage mentioned were differences in risk perception, awareness/knowledge, parenting style, purpose of the journey, and doubting the effectiveness of the restraint system used.

One study indicates that parental misconceptions about size and safety of regular restraint equipment are the most common reason for children not being appropriately restrained. This particular study mentions that the most common reason for lack of booster seat use was that parents thought the child was large enough to use the regular lap-shoulder belt only, or had problems with attempting to use the seat in the vehicle.

The National Transportation Safety Board found that improperly restrained children, in particular infants and small children, in age-appropriate restraint systems sustained a greater proportion of severe or moderate injuries than properly restrained children who were in the wrong restraints for their size.

4.7 Measures for improvement – Campaigns

4.7.1 Australia

Roads and Traffic Authority (RTA) (Roads and Traffic Authority New South Wales, 1992) in New South Wales in Australia carried through an occupant restraint campaign during 1991 and 1992 focused on the use of occupant restraints by children aged 5 to 13 years. The RTA commissioned RAMIS Corporation to conduct a telephone survey of the awareness of the campaign activities amongst the general and target (parents with children aged 5-13 years) population. The survey was conducted to evaluate:

- awareness of RTA occupant restraint advertising, together with advertising content, messages and perceived target audiences
- awareness of public relations activities
- awareness of and attitudes towards occupant restraint use enforcement activities, and perceived probability of being caught by the police and legal responsibility for enforcement
- awareness and usage of safety restraint fitting stations
- perceived impact of campaign activities.

Claimed awareness of past three month television advertising about wearing seat belt or occupant restraint was 83 %. Unaided awareness of radio advertising about wearing seat belts or occupant restraints measured 23 %. Overall, 35 % of the respondents indicated awareness of safety restraint fitting station, but only four per cent of parents with children in the 5–13 year age group indicated they had actually made use of a fitting station. One in four respondents indicated awareness of occupant restraint campaign activities other than television advertisements and radio commercials, for example billboards/road signs, newspaper articles or police blitz. Knowledge of the legal responsibility for ensuring that children under 14 years of age are restrained was high, with 73 % nominating the driver. Seven in ten of parents with children aged 5–13 years, whose oldest child had been exposed to the advertisements, reported they already ensured their child was restrained. 15 % of these parents felt the advertising had encouraged seat belt use and 15 % affirmed that their own behaviour had altered with respect to how they treat their child's seat belt use as a result of the advertising. They were more aware of the importance of children being restrained.

In New South Wales in Australia a communication strategy was developed to specifically address the needs of occupants from a non-English speaking background (NESB) (Preece, 1994). The objective was to increase knowledge, awareness, and commitment of NESB parents/carers toward restraint use by rear seat child passengers. The communication strategy should:

1. Create a heightened level of awareness in NESB communities about the safety of children in vehicles, to the point where occupant restraint use by children becomes an issue of concern for all NESB parents.
2. Make parents from non-English speaking backgrounds aware that their children are not safe if they travel unrestrained in the rear seat.
3. Target parents of children between 1 and 13 years, concentrating on the 5–8 years age group.
4. Alert NESB parents to the fact that the driver is responsible for ensuring that child passengers are restrained, and failing to do so means a fine and points.

A pilot campaign was accomplished in November and December 1993 as an integrated marketing initiative. Three language groups were targeted – Arabic, Italian and Vietnamese. As an introduction to the campaign, Ethnic Communications (ETCOM) organised a media briefing, which was well attended by both radio and press from the target communities. A media kit was developed and distributed by ETCOM to each of the media outlets in the three language groups. ETCOM provided an abundance of professional and detailed resource information, which was effectively disseminated throughout the communities via education, health, social and welfare groups and organisations. In terms of actual awareness of the campaign, 64 % of parents reported seeing or hearing advertising or information in the past three months about restraint used by children. 44 % of parents, who were shown some of the printed materials which had been part of the campaign, stated that they had seen the materials. Observational surveys of rear seat restraint use by children from the three target communities were conducted prior to and following the campaign. The surveys found that none of the three communities recorded a statistically significant increase in child restraint usage.

A major restraint usage promotional campaign with the theme "There's No Excuse, So Belt Up" was conducted in Victoria in Australia between 7 June and

15 July 1989 and reported by Wise and Healy (1990). The key messages were directed to both front and rear seat occupants including parents who allowed their children to travel unrestrained. The campaign included two television commercials contrasting the excuse vehicle occupants often use with the tragic consequences of not wearing a restraint, six radio commercials covering the similar themes but also emphasising increased Police enforcement, and a press advertisement appearing in major metropolitan and regional papers depicting a Traffic Infringement Notice issued by the Police with the fine for not wearing a seatbelt highlighted. A "before" and "after" survey showed significant increase in restraint wearing rates between 1988 and 1989 for the total of occupants and for rear seat passengers overall. There were significant increases in the restraint wearing rates of front passengers aged 14 to 25 years and of rear passengers aged 8 to 17 years. Increases were greatest in rural towns and for rear seat occupants. Victoria Police figures showed an increase in enforcement accompanied the campaign.

Robyn Seymour from Royal Automobile Club of Victoria (RACV) reported at a conference in Australia from a campaign to promote awareness of child restraint issues (Seymour, 2000). The campaign was promoted to encourage parents/guardians to:

- have their child restraints professionally fitted
- ensure that the children are in the appropriate restraint for their size and weight
- ensure that the restraint is always done up.

Three radio advertisements were developed, focusing on this message, and ran throughout Victoria for six weeks, on commercial radio stations whose main audience were people with children under the age of six. A poster with the title "Will you child survive a crash?" were distributed to all Victorian maternity hospitals, community centres, maternal and child health centres and to child care centres. Two articles relating to the child restraint campaign appeared in the RACV RoyalAuto Magazine. A brochure, the "Buyers Guide to Child Restraints", that listed all the restraints that received a preferred buy rating, was distributed to relevant outlets, agencies and organisations. The author reported that the campaign was a success even though it was difficult to evaluate its effectiveness. However, a survey of the campaign showed that the awareness of the advertising was high and reached its target audience. The key messages that respondents recalled from the advertising accurately reflected the key messages of the campaign.

Browning et al., (2000) describes a regional intervention targeted at increasing appropriate child car restraint usage in 4–7 year old rural school children. Out of 598 families, classroom intervention was targeted at 289 children. The observational study, however, involved all children at the schools. In total 900 observations were made. During the one month observation the children were rewarded by their teachers if they had been buckled up when being driven to school. Stickers were also handled out to children being observed wearing a restraint on arriving at school. Brochures and information sheets on child car safety were handed out to parents. Overall, observations showed that child car restraint usage was significantly increased from 79 to 90 %. Use of age-appropriate child car restraints increased from 45–51 to 69 %. No significant

increase in seat belt usage was observed among the children. The main seating positions for children were either front side or rear/side of the vehicle. Among the children not wearing a child restraint, 38 % were seated in the front passenger seat. A questionnaire showed that the majority of the 139 parents that had answered believed that not everyone can tell if a child restraint is incorrectly worn or installed and 40 % considered the restraints to be too expensive. Nevertheless, no more than 3 % of the parents took the offered opportunity to have their child restraints checked. Overall, 17 % of the children were reported to climb out of child car restraints or do not like to be strapped in such a device.

4.7.2 U.K.

In March 2000, the U.K. government set targets to reduce deaths and serious injuries by 2010, a 40 % reduction overall and a 50 % reduction for children. Therefore the Government introduced a campaign called “THINK!” (Think!: driver requires all your attention, 2000), which is still going on. THINK! is a year round road safety campaign aiming to create a greater public awareness of all road safety issues through publicity on television, radio, press, posters and other media The campaign is supported at local level by police and local authority road safety officers as well as voluntary and private sector organisations. A child restraint campaign, called “THINK! Child car seats”, is part of THINK! The aim of the campaign was to advise parents and carers on how to fit child seats correctly. The campaign wanted to direct parents/carers to road safety officers for further advice on fitting and choosing car seats or for names of reputable manufacturers or retailers. Radio and press advertising were used and the campaign worked with many third parties to help promote the message. A 30 second radio advertisement was produced and was aired on national and commercial radio stations in one week in February 2001. An A5 leaflet and a handy peel-off card with advice and useful tips were produced to support the advertising. Other examples of activities in the campaign was an advertorial placed in the March 2001 edition of Mother & Baby magazine and Britax installation experts checking over 1,000 child car seats in 10 Safeway car parks across the UK. Quantitative research revealed that 54 % of people and 59 % of parents of children aged 0–4 were aware of publicity regarding child car seats during the week of advertising. The campaign continued with press advertisements in a variety of parenting press and women's magazines, distributions of a pocket guide providing a full checklist of tips on buying, fitting and seating children in car seats, press notices and TV-fillers.

4.7.3 USA

The Task Force on Community Preventive Services has conducted systematic reviews of interventions designed to increase use of child safety seats, increase use of safety belts and reduce alcohol-impaired driving (Zaza, et al., 2001; U.S. Department of Health and Human Services, 2001). The Task Force used the Community Guide’s methods for conducting systematic reviews and linking evidence to recommendations. The development team, a multidisciplinary team, focused on the goals of NHTSA and the Healthy People 2010 objectives related to motor-vehicle occupant injury.

The NHTSA goal concerning CRS is to reduce child (aged 0–4 years) occupant fatalities by 25 % by the year 2005 (from 653 fatalities in 1996). Healthy People 2010 objective is to increase use of child restraint devices for passengers aged

0–4 years from 92 % (1998 preliminary data age-adjusted to the year 2000 standard population) to 100 %.

The consultation team generated a comprehensive list of strategies and created a priority list of interventions for review. The interventions were either single-component (i.e., using only one activity to achieve desired outcomes) or multi-component. Studies were grouped on the basis of the similarity of the interventions being evaluated. Interventions and outcome measures were classified according to definitions developed as part of the review process. To be included in the reviews of effectiveness, studies had to:

- be primary investigations of interventions selected for evaluation
- be published in English during 1966–June 2000
- be conducted in established market economies
- compare outcomes among groups of persons exposed to the interventions with outcomes among groups of persons not exposed or less exposed to the intervention.

For each intervention reviewed, the team developed an analytic framework indicating possible causal links between the intervention under study and predefined outcomes of interest. To make recommendations, the Task Force required that studies showed increase in use of child safety seats or safety belts or decrease in motor-vehicle crashes or crash-related injuries. Each study that met the inclusion criteria was evaluated using a standardized abstraction form and assessed for suitability of the study design and threats to validity. Results on each outcome of interest were obtained from each study that met the minimum quality criteria. The strength of the body of evidence of effectiveness was characterized as strong, sufficient or insufficient on the basis of the number of available studies, the suitability of study designs for evaluating effectiveness, the quality of execution of the studies, the consistency of the results, and the effect size.

On the basis of the evidence of effectiveness, the Task Force either strongly recommended or recommended four interventions to increase use of child safety seats. These interventions were:

- Laws requiring use
- Community wide information and enhanced enforcement campaigns
- Distribution and education programs
- Incentive and education programs

The Task Force strongly recommended or recommended three interventions to increase safety belt use. These interventions were:

- Laws requiring use
- Primary enforcement laws
- Enhanced enforcement programs.

The Task Force found insufficient evidence on which to make recommendation regarding education-only programs to improve child safety use, because of inconsistencies in the curricula, target populations, and effects of reported interventions.

The Task Force recommendations can be used to support or expand child safety seat distribution programs, bolster the use of incentives, and employ enhanced enforcement campaigns, all in conjunction with community wide

education efforts. For example, the recommendation for child safety seat distribution and education programs could help a community decide to concentrate the distribution of low-cost or no-cost child safety seats in low-income neighbourhoods or to seek local sponsorship to defray the cost of seats distributed to needy families.

The Buckle Up America (BUA) was a national initiative announced in January 1997 directing the Department of Transportation (DOT) to prepare a plan to increase seat belt usage nationwide (Solomon, Leaf & Nissen, 2001; Buckle up America., 2001; NHTSA, 2001b). In response, NHTSA developed a plan to

1. increase seat belt use to 85 % by the year 2000 and to 90 % by 2005 (from 68 % in 1996);
2. decrease fatalities to children under the age of five by 15 % by 2000 and by 25 % by 2005 (using 653 fatalities in 1996 as a baseline).

There are four components to BUA:

1. building partnerships, to bring all aspects of the community to bear;
2. enacting new legislation, to make it clear that elected officials are behind BUA;
3. conducting strong enforcement, to make sure the public understands that non-use can have immediate costs; and
4. expanding public information and education, to continue educating and motivating the public to use seat belts and to provide specific how-to knowledge to those using child safety seats.

Child restraint use has improved markedly for children under age five and fatalities have decreased dramatically. In 1998 fatalities had decreased by 20.9 % for children under age one, and by 8.6 % for children aged one through four. The goal of reducing child occupant fatalities (0–4 years) by 15 % by the year 2000 was reached in 1999 – one year early. This decrease in the number of childhood traffic deaths is, in part, due to the dramatic increases in child restraint use since the Buckle Up America Campaign began. Restraint use among infants (1–12 months) was measured at 97.2 % in 1998, compared to 85.2 % in 1996 just before the Buckle Up America Campaign began. In 1996, only about 60 % of toddlers (1–4 years old) were restrained while riding in vehicles; in 1998, over 90 % of toddlers were restrained. The increase in restraint use is not as dramatic among children 5–15 years old, but it is nonetheless significant: an 11 percentage point increase in only four years, from 57.7 % in 1994 up to 68.7 % in 1998.

Seat belt use among adults has also increased after the inception of Buckle Up America. The District of Columbia and 38 States reported an increase in seat belt use rates in 1999. However, in 1999, only five states and the District of Columbia were at or above 80 % belt use; all are jurisdictions having standard seat belt laws.

During year 1999, 24 States proposed legislation that would upgrade their seat belt laws and six States amended their child passenger safety laws. In May 1997, the Air Bag & Seat Belt Safety Campaign, in cooperation with NHTSA, began a national effort known as “Operation ABC Mobilization: America Buckles Up Children”. The Mobilization was based on a highly effective law enforcement model that combined periodic waves of stepped-up enforcement with aggressive publicity highlighting the enforcement.

Overall public support for seat belt and child passenger safety laws has been strong. A 1998 survey by NHTSA showed that 86 % of those surveyed favoured

laws that require drivers and front-seat passengers to wear seat belts. A 1999 survey conducted by the Air Bag & Seat Belt Safety Campaign found that 78 % of those surveyed agreed with the statement, “People who fail to buckle up their child passengers should be considered guilty of child endangerment”.

The Transportation Equity Act for the 21st Century (TEA-21) has created two Federal incentive grant programs to encourage States to increase the use of seat belts and child safety seats: “Section 405 incentive grants” and “Section 157 incentive grants”. These grant programs are designed to encourage States to increase seat belt use rates and target specific occupant protection laws and programs. Section 405 created a new incentive grant program to increase the use of seat belts and child safety seats by encouraging States to adopt more effective laws, stronger penalties, and highly visible enforcement and education programs. Section 157 created a program to encourage States to increase their seat belt use rates in recognition that increased belt use decreases crash injuries and the financial burden these preventable injuries place on Federal programs. Funds were allocated to eligible States based on savings in medical costs to the Federal government due to improved seat belt use.

The Buckle Up America Campaign is said to be a success and that depends on hard work and dedication of literally hundreds of partners in both government and the private sector. There are federal initiatives in order to promote the use of seat belts among U.S. Department of Transportation employees and their customers and other federal agencies outside the DOT. Usage among Federal employees continues to be significantly higher than among the general population. Initiatives by the States are said to be absolutely essential in achieving the goals of the Buckle Up America Campaign. It is up to the States to upgrade their child passenger safety laws and to enact standard legislation. It is also up to the States and local communities to enforce these laws. NHTSA developed partnerships with literally hundreds of organisations to effectively and appropriately reach all Americans through the Buckle Up America Campaign. These partnerships ensure that the message goes to the farthest reaches of the nation and gives communities a sense of "ownership" in helping to save lives and reduce injuries within their own geographic area. Hundreds of private organisations have joined NHTSA in spreading the message of the Buckle Up America Campaign. Small businesses, large companies, physicians’ groups, and college fraternities and sororities are just a few organisations that have been on the front lines to encourage everyone to buckle up on every trip.

To effectively reach all Americans through the Buckle Up America Campaign, NHTSA has developed strategies especially targeted towards African Americans, Native Americans, Asian Americans, Hispanic Americans, and people living in rural communities. NHTSA has also had a special challenge to reach children and teens since traffic crashes are the leading cause of death from age one through age 24. Another critical population important to reach with activities designed to increase safety belt use is people in rural areas, particularly young men.

To ensure that the goals of the campaign are met by 2005, NHTSA will continue to build and maintain partnerships, support law enforcement officials, deliver effective public education, and devise new technologies to promote occupant protection. NHTSA will also maintain its commitment to support States in their efforts to enact strong legislation that helps to protect all Americans as they travel in motor vehicles. NHTSA will also focus its efforts on high-risk

groups, including children and teens, minorities, part-time seat belt users, and those living in rural areas.

DaimlerChrysler partnered with Fisher-Price (a leading manufacture of child safety seats) and the National Safety Council and established a program called "Fit for a Kid" including permanent "fitting stations" to address non-use and misuse of child safety seats (Solomon et al., 2001). Pilot projects began in four cities by September 1999 and the goal was to have trained and certified child safety seat inspectors in 1,500 dealerships by November 2000. Fisher-Price contributes expertise and material support to the program and the National Safety Council conducts the employee-training courses. The Fit for a Kid program will create the capacity to inspect and assure proper installation of 800,000 seats annually.

In March 1995, under an agreement with the U.S. Department of Transportation, General Motors Corporation (GM) agreed to provide funds over a five year period to support highway safety research and programs to prevent motor vehicle deaths and injuries (NHTSA, 1999). One of the programs supported was the National Child Safety Seat Distribution Program (National Child Safety Seat Distribution Program Evaluation Assesses, 1999). GM provided non-profit organizations with funding to provide convertible, infant, booster, and special needs seats to families who could not otherwise obtain a seat in all 50 states, the District of Columbia and Puerto Rico. An administrative evaluation on this national distribution program was conducted. Over half of the facilities were medically related, like hospitals or community health centres. Nearly all facilities assessed recipient need before giving out a seat, and most trained all of their recipients. Most of the seats were given to recipients for permanent ownership. Training included demonstrations of safe use, hands on training, use of videos and lectures, and installation of the seat into the recipient's vehicle. Programs at medical related facilities appeared to work best because they were more likely to have trained staff and related programs in place already and were also more likely to find qualified recipients in-house.

4.7.4 Sweden

Parents of new-born babies in Blekinge in the south of Sweden (Anund & Sörensen, 2001) were offered to be members of a campaign called "Säkereken" and receive up-to-date information on how to protect children in traffic. The most common source of information was the Child Health Centre. The authors evaluated the level of safety when the children who participated in the campaign were travelling by car. The results were compared with results from an earlier study of a random sample of families in Blekinge. The comparison indicated that children who were members of "Säkereken" travelled more safely. Their parents also seemed to know more about traffic safety. For example it was more common for those parents to answer correctly to the questions about where to position the safety belt. In spite of parents' knowledge, children still travelled with the safety belt under the arm instead of on the shoulder or in restraints facing forwards although the children were recommended to travel facing rearwards. Parents who were members of the campaign were expected to have received more information on how to protect children when travelling by car, but this proved not to be the case. The information had not been received or absorbed by all the parents. The authors found in the study that parents had gaps in their knowledge which they

were not aware of. According to the authors, the parents have to be aware of their gaps in knowledge to be motivated to take in information.

4.8 Children with disabilities

4.8.1 Children with disabilities and transportation safety equipment

Children do not form a homogeneous group. In Sweden, approximately 100,000 children are born annually, more than 1 %, probably 2–5 %, will eventually have a disability during childhood (Falkmer & Paulsson, 2003). The group of children with disabilities consists mainly of children with congenital diseases (Molin, 1987; Paulsson & Fasth, 1998).

Child safety seats are developed for children without disabilities. Children who are born with disabilities or do not develop normally, with respect to weight and length, do not usually fit into these child safety seats. If the child does not have the normal motor and sensory functions, or has anomalies such as absence of one limb or part of it, the common design of the child safety seat cannot provide safe transportation for these children. Thus, these children are restricted to transport in their wheelchairs, sulkies or in tailor-made seating devices. Hence, the development of child safety seats for the target group of this study does not correspond to the demands. Nevertheless, parents and professionals are expected to transport children with disabilities to schools and developmental facilities on a daily basis despite the limitations in the standards and the lack of information and equipment options (Stout-Everly et al., 1993).

To be transported in wheelchairs, sulkies or in tailor-made seating devices means that the disabled child has to enter the vehicle while remaining seated in some sort of technical aid. These technical aids are usually constructed to optimize seating and manual transportation, but little attention has been paid to reducing the collision impact in the event of a crash during in-vehicle transportation. Some wheelchairs and buggies have seat belts to improve postural support, and these may be designed for restraining a user's weight at normal walking speed. However, these belts are not designed to restrain collision forces of 40–60 G, as required in the Euro NCAP crash test standard. Manufacturers of child safety seats do not develop and test their products, with the target group for this study as users, in a test such as the Euro NCAP test.

There is a lack of knowledge concerning biomechanical aspects for the group of children with disabilities. Anthropomorphic Test Devices (ATD), i.e. crash test dummies, has not been developed in accordance with the demands of the target group. The problem of poor compatibility between the need for safe road transportation and the use of technical aids and special seating devices for children with disabilities needs be subjected to future research.

4.8.2 Regulations and standards

The current amendment 3 of ECE Regulation 44 (Economic Commission for Europe, 1998), ECE R. 44/03, does allow certain "Special needs restraints". ECE R 44/03 section 7.1.4.1.7 states that *"In the case of a "Special Needs Restraint", every dynamic test specified by this Regulation for each mass group shall be performed twice: first, using the primary means of restraint and second, with all restraining devices in use. In these tests, special attention shall be given to the requirements in paragraphs 6.2.3 and 6.2.4"*. Despite the amendment No. 3,

problems with issuing general approvals of individual adaptations have remained, both formally and technically. An adaptation can be describes as a modification to a product made on more than a temporary basis, hence it can be non-reversible.

In the UK, safety guidelines were introduced for transporting *children in special seats* (Medical Devices Directorate, 1992). In Australia, standards AS/NZ 54 370 for transporting children with disabilities in motor vehicles were introduced (Baker et al., 1998). When the AS/NZ 54 370-1996 was being prepared, the committee recognized the fact that no two individuals with physical disabilities were the same, so provision was made to try to safely accommodate the majority of the consumers' needs.

As illustrated in Table 2, certain countries have introduced standards for transportation of wheelchairs in vehicles, including ISO 10542 (International Organization for Standardization).

Table 2 *Standards for vehicular transportation of wheelchairs and wheelchair occupants in certain countries.*

Country	Standard	Tiedown	Wheelchair in vehicle	Comments
All	ISO	ISO 10542 (1–5)	ISO 7176–19	Only informative, i.e. not normative, until referred to in national regulations or by consumers.
Australia		A 52942-1994	A 52942-1994	
European Union	CEN	Refers to ISO	Refers to ISO	Normative in Europe. Important for Product reliability.
USA		SAE J2249	ANSI WC/19	Similar to ISO standards

For the transportation of *wheelchair occupants in vehicles*, several countries have regulations or standards, which are listed below. The listing is mainly included to illustrate the different types of regulations and standards, not to describe them in detail.

Sweden, formerly 1978 TSVFS, 1978:9 1985:24, now SNRA, VVFS 1994:5 (Petzäll & Olsson, 1996). The U.K. has a consultative standard on the safety of wheelchair users in buses. The USA (SAE-WTORS, 1997; ANSI/RESNA , 1997), and Australia (Baker et al., 1998) do also have regulations or standards for wheelchair occupants in vehicles. For most other countries this literature review found nothing of this nature. An explanation may be that authorities were waiting for the International ISO standards in these fields to be adopted. Those standards are: ISO 7176-19 for transportation related requirements for wheelchairs that are suitable for occupant seating during motor-vehicle transportation and ISO 10542 for the wheelchair tiedowns and occupant restraints systems, i.e. WTORS. A tiedown can be described as a strap or mechanism that secures a child safety seat, or a wheelchair in place in a motor vehicle.

For wheelchairs, the ISO 10542 part 1–5 standard (International Organization for Standardization, 2003).will provide a good description for the use of tiedowns and occupant restraints. Nevertheless, the final result will depend on the type of wheelchair (the wheelchair should have been tested according to ISO standard 7176-19) and the choice of tiedown and restraint system. Furthermore, the type of car and the quality of the mounting or anchor point are also crucial.

The ISO standard 10542 is designed for adults, but part 5 of the standard does specify the requirements for children weighing more than 22 kg. For children below that weight the standard suggests that they should be *"transferred from their wheelchairs to appropriate vehicle child safety seats"*. As stated previously, not all children with disabilities will fit in to the child safety seats approved and available on the market. Hence, this remains a problem to be solved.

4.8.3 Travel habits

Generally, the literature did not provide much information on the extent of transportation of children with disabilities. Furthermore, the material showed that it was impossible to obtain information on weekend travel, which can be assumed to differ from weekday travel. School attendance is compulsory in many countries and, hence, journeys to and from school for disabled children older than six years can be used to illustrate travel habits, which in turn provides information on the extent of travel. The school situation for children with disabilities who travel by car or bus while sitting in their special seats or wheelchairs has changed rapidly. Thus, the need for transportation of persons with disabilities is increasingly being accepted (Bluth & Rosenfeld, 1993), at the same time as the need for regulations and standards in this field has been highlighted.

In the UK, 15 % of the school population receives free school transportation (Thornthwaite & Pettitt, 1993). The main reason for free transportation was that they lived more than 3.2 km, i.e. two miles, from the school. In the county of Berkshire, 32 out of 11,500 pupils were transported in wheelchairs, i.e. 3 per thousand of all the pupils transported to and from school. In the UK, approximately 3 % of all schoolchildren have significant special needs (Hall, 1995). If these pupils alone are taken into account, the figure for pupils transported in wheelchairs rises from 3 per thousand to 1.3 %. In a study conducted in Victoria, Australia (Vale, 1995), 0.52 % of the whole population aged 0–18 required special car restraints due to neurological conditions. Unfortunately, this study did not provide data showing what type of seating devices these persons used.

Due to the limited amount of data concerning the travel habits of children with disabilities, two studies have been performed in Sweden. One concerned the travel habits of children with locomotor disabilities (Falkmer & Gregersen, 2001) and the other of children with autism spectrum disorders (Falkmer, Anund, Sörensen, Falkmer, & Gerland, 2001). Both studies concerned transportation in the family vehicles, i.e. normally cars, as well as school transportation and in the Special Transport Systems, i.e. STS. Both school transportation and STS can be performed by cars, predominantly taxis; or buses, predominantly small buses, i.e. so called M2 buses. Due to the fact that these surveys did not report separate data depending on whether or not it was a car or a bus the children travelled with, data concerning possible travels with M2 buses may be part of this section of the report. However, the vast majority of journeys for this particular group of children were performed by cars and, hence, the studies are included in this section to provide an overall picture of the children with disabilities in cars.

With respect to children with disabilities Falkmer and Gregersen (2001) found that:

- Children with functional disabilities most likely represent the group classified as "individuals with the least protection and highest susceptibility

to violence”. In accordance with the "Vision Zero", they should thus be taken as a determinative factor in designing the traffic system.

- Children with functional disabilities who are obliged to travel in a technical aid are transported in products designed for travel at walking pace. Special seats (including internal belts for postural support) constitute in all probability a safety risk in the event of a serious crash.
- A survey of the transport situation for children with functional disabilities showed that the majority of journeys were made in the family car.
- The destinations were primarily day nurseries, recreational centres or schools, paediatric clinic, leisure activities or medical care.
- School transportation was used to a greater extent than the family car only for journeys to and from school.
- In many cases, the family car was not adapted to the functional disability of the child.
- Children were almost always transported facing forwards or backwards in the vehicle rather than sideways.
- Very few children were seated without restraint in the family car. Less than 15 % of the children travelled seated in the family car using some form of technical aid. One in eight of the technical aids was not secured in the vehicle. Corresponding figures were 42 % sitting in some form of technical aid in school transportation, of which 1 in 20 was not secured in the vehicle, and 46 % seated in some form of technical aid in the special transport service (STS), of which 1 in 20 was not secured in the vehicle.
- In school transportation, approximately three out of five (59 %) were restrained with a safety belt. The corresponding figure for STS was approximately two out of three (63 %).
- Especially on journeys with STS and school transportation, many children with locomotor disabilities travel with an increased risk of personal injury in the event of an accident/incident, partly because adequate safety measures have not been taken and partly because they form a group that is highly vulnerable to violent impact.
- Approximately two out of five children travelled alone in school transportation and STS.
- Approximately one parent in two was able to choose alternative transport. Increased freedom of choice correlated only weakly with increased population density in the home area.

In the above summarised investigation (Falkmer & Gregersen, 2001), only 2 % of the children had autism spectrum disorders,

Children with autism spectrum disorders are expected to be transported by their parents or by school transportation and STS on a daily basis, in order to attend school and day care centres, play with friends and perform leisure activities. This implies that children with autism spectrum disorders are exposed to the inherent risks connected with road vehicle transportation and in their special case, an increased risk. The reason for this statement is that it can be anticipated that for many of those children, being restrained by a safety belt and riding with unknown drivers and passengers may cause ‘emotional behavioural problems’, if approached inadequately. This, in turn, may lead to refusal to accept normal safety precautions during the ride, due to qualitative impairment in reciprocal

social interaction, communication and imaginative activity, as well as to a restricted repertoire of activities and interests (American Psychiatric Association, 1994; Wing & Gould, 1979), *''…. behaviour found to be specific and universal to autism''* (Happé, 1996 p.18). Furthermore, children with autism spectrum disorders can be expected to have an increased need for transportation compared with non- disabled children, due to a lack of cognitive skills which hinders free mobility even on short journeys, combined with an increased need for additional health care treatment, i.e. more frequent travel compared with non-disabled children. Thus, it was considered essential to map their travel habits as well.

Falkmer et al. (2001) found that a majority of the children with autism spectrum disorders, i.e. 63 %, utilised school transportation. This was not the case for STS, utilised only by every fourth child. One of the reasons for this could be that the person administering STS grants has a problem in fully understanding the mobility limitations caused by autism-spectrum disorders.

The journeys in school transportation usually took at least 10 minutes. Every second journey took more than 20 minutes. During such trips it is natural that the children ought to utilise recommended safety equipment, which proved not to be the case. Infants up to the age of 3–4 are recommended to be transported facing rearwards. In the present study, however, only one out of ten children in this age group was transported this way. Moreover, safety belt usage in school transportation and STS was low. Every seventh child in school transportation and every eight child in STS travelled totally unrestrained.

Even in some cases where safety belts were used, the children faced an increased risk in case of an impact. Of the children using the three-point safety belt, i.e. a combined sash belt and lap belt, 7 % travelled with the sash belt part under the arm instead of on the shoulder, a misuse that can prove to be fatal in case of an impact. Furthermore, another 5 % were only restrained by a lap belt or not restrained at all, indicating that in total 12 % of the children with autism-spectrum disorders travelled under reduced safety in case of an impact.

The journeys in the family vehicle, which constituted the vast majority of the children's journeys, were, however, the safest mode of transport with regard to the above-mentioned aspects. Transport mobility, being a crucial part of attending school and day care centres, playing with friends and performing leisure activities, is of vital interest for all children, regardless of whether the child is disabled or not. The results from the study of children with autism spectrum disorders show that they suffer from reduced transport mobility. The reason for this was found to be that the transport system was not adapted to the special needs of children with autism-spectrum disorders. Such adaptations would require drivers and other professionals involved in the transport situation to implement an approach towards the child, based on the knowledge of the communication problems involved in autism-spectrum disorders. Children with autism-spectrum disorders encounter problems in communicating with unfamiliar drivers, as well as with unknown passengers. For this reason it was unsatisfactory to notice that as many as every third child in school transportation travels with an unknown driver, at least once a week. In STS every fourth child travelled with an unknown driver, at least once a week. In many cases Optimisation of Travel Capacity (OTC) was in use, which means that not only unfamiliar drivers could be expected but also unknown passengers. The less populated the residential area the more frequent was the OTC system. The parents stated that the children were affected negatively

by the OTC system. More than half of the parents expressed that their child with autism-spectrum disorder suffers from reduced transport mobility.

4.8.4 Transport providers

The literature review provided information on several executive producers of transportation for children with disabilities who were restricted to transport in their wheelchairs or special seating systems. Authorities responsible for transportation to and from school, kindergarten and day care centers were mentioned in several sources (Bull, Bruner-Stroup, & Doll, 1991; Hobson, 1996; Kahdikar & Will, 1980; Rutenberg, Rhodes, & Smith, 1998; Shaw, 1987).

Parents as the executive producers of transportation were also mentioned in several sources (e.g. Bull et al., 1991; Bull, 1989; Bull, 1991; Bull, 1996; Dejeammes, 1998), as were health care providers (e.g. Paley, Walker, Cromwell, & Enlow, 1993). However, the extent of their provision of transportation could not be determined from the literature.

In Sweden, it can be assumed that families are the dominating executive producers of transportation for children with disabilities. This is due to the vehicle grants available in Sweden (Loman, 1996; SOU, 1994), which encourages the use of a family vehicle for transportation. The systems are fairly similar in the three countries.

4.8.5 Transport procedures

Most literature concerning transport procedures related to wheelchair and safety restraint measures offered by professional transport providers. In a study in the UK (Thornthwaite & Pettitt, 1993), a survey of local authority practice in transporting children in wheelchairs was carried out in 1988/89. It was found that the method of securing the wheelchairs varied widely. The survey highlighted the problems of securing electric wheelchairs and their occupants. It was found that 28 % used only harnesses, i.e. a restraint system containing more than three anchor points and designed to pass over the occupant’s pelvis and shoulders, and 12 % only lap belts.. Other terms with similar meaning are 4, 5, or 6-point restraints or belts. Two of the authorities admitted that some wheelchairs were not restrained and one of the authorities said that although all the wheelchairs were secured to the vehicle, about 70 % of the children were not restrained at all in their wheelchairs. The survey also found that half (25) of the responding authorities had had accidents transporting children in wheelchairs during the previous five years. Whilst most of the injuries sustained were classified as minor, eleven of the 25 authorities reported that accidents had resulted in a change of policy. The survey also found that six of the authorities (12 %) could not even provide figures on the number of children transported in wheelchairs on a daily basis.

In an American study (Stout-Everly et al., 1993), covering 285 transport providers in the public school systems in Iowa and Indiana, reports on occupant restraints for transporting children in wheelchairs presented the results in Figure 6.

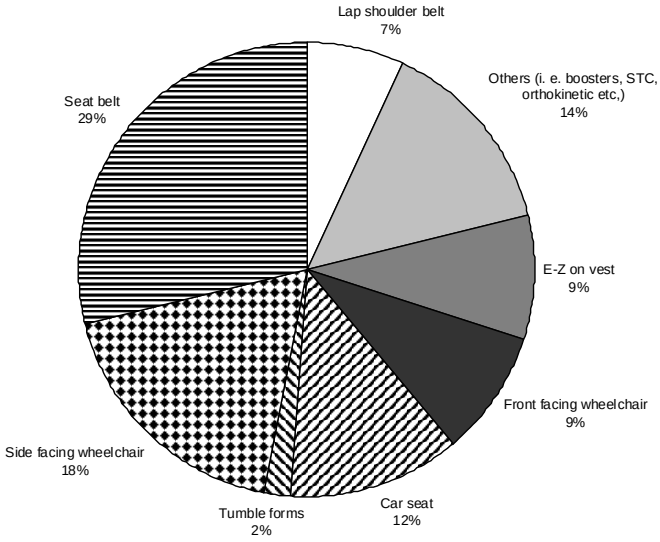

Figure 6 *Types of restraint used by 285 transportation providers of the public school system in Iowa and Indiana, USA, from Stout-Everly et al. (1993)*

At least 61 % were transported in an unsafe way. This includes side-facing wheelchairs, – occupied wheelchairs should never be transported sideways (Kahdikar & Will, 1980), – in ordinary car seats, i.e. without using safety belts, in seat belts, in "others" according to the classification used by the authors, i.e. probably supplementary postural supports (i.e. an unknown part of 14 %), and in tumble forms. Postural supports can be described as seat components or lengths of webbing used to support a person in a desired position in a seating system (i.e. to prevent the person from falling out during normal conditions). A postural support is usually not designed or intended to provide occupant restraint in a vehicle impact. Postural supports are not child safety seats and therefore cannot be considered safe.

Safe methods of transport in this study were found for 39 %, at most. This figure includes front-facing wheelchairs with the safety belt in use, E-Z-on vests, i.e. a type of harness, lap shoulder belts, and boosters for children less than 150 cm tall or weighing less than 35 kg, in the category of "others", i.e. an unknown part of 14 %.

In the American study (Stout-Everly et al., 1993) frequent problems were identified when schools, rehabilitation facilities and community agencies attempted transportation for their clients with disabilities aged from birth to 21 years. Children's size, disability differences and vehicle differences affected the safe transportation needs. For example, children weighing more than 22.7 kg, i.e. 50 lb., were no longer able to use a child safety seat, even though they could not ride unsupported on a bus seat. Survey respondents recognized this as a special need because there was no Federal Motor Vehicle Safety Standard (FMVSS) in the USA for equipment for children weighing more than 22.7 kg. Original equipment manufacturers therefore had no specific federal standards for

crash test durability and head and knee excursion limits for equipment for these larger children.

4.8.6 Perceived risks and safety problems according to parents and drivers

Several sources were found in the literature concerning perceived risks and safety problems according to parents and drivers. One study from Victoria, Australia (Vale, 1995) had used a questionnaire-based parental survey of transport problems for the target group of this study. Maintenance of head control was found to be a problem for all age ranges, as was not sitting straight and arching out of the seat.

The restraints were reported as being uncomfortable on both long trips and short trips. A need for special installation, i.e. the process of permanently fastening the wheelchair tie down and occupant restraint assembly to the vehicle, was reported more for the 8 years and older group. This reflects the greater use of special restraints and wheelchairs by this age range. A little less than half of those responding to these sections of the questionnaire reported no problems with the car restraints they used.

This result was in contrast with the findings in the American study (Stout-Everly et al., 1993). The problems the transport providers experienced were:

- Emotional behavioral problems (51 %)
- Children resist applying of restraint system (32 %)
- Additional personnel needed to assist (31 %)
- Cost of securing appropriate equipment (23 %)
- Children unable to use standard safety belt or child safety seat (21 %)
- No adequate restraint (19 %)
- Difficulty securing wheelchair (16 %)
- Lack of information about the equipment (16 %)
- Driver unable to assist (15 %)

Both these studies (Stout-Everly et al., 1993; Vale, 1995) asked the respondents to suggest improvements. The Australian parents suggested improvement of the trunk support (15 %), improvement of the harness for ease of application and comfort (15 %) and improvement of head support (14 %). The American transport providers suggested improvement of the head/neck support (24 %), regulations (FMVSS) for children weighing over 22.7 kg (17 %), and improvement of trunk support (10 %).

The demand for regulations in the USA was supported by Paley et al. (1993). By using a subjective safety score, from 0 (unsafe) to 10 (safe), they evaluated 63 children with disabilities in their family or agency vehicles. The mean safety score was 1.6, with no child achieving a score higher than 6. They found no significant differences in the scores of children transported by their families and those transported by agencies.

In the same study the seating devices were scrutinized. Of the 62 customized seating systems used in transportation at some point, 56 (90 %) were available for inspection. Only six were models that had been crash tested and earned FMVSS 213 approval. Furthermore, the transport situation was examined. Unsafe transportation was reported for 51 % of at-home transportation, for 60 % of transportation to school and for 48 % of transportation to hospital. Unsafe seating

was identified in 54 % of those taken to school – by school transport vehicles, with the most common unsafe practice being use of the side-facing position.

In another American study, an observation checklist was developed based on safety principles for wheelchair restraints (DiGaudio & Msall, 1991). Observations of the subjects were made as they were transported by their families or agencies to a residential summer camp, a pre-school program for children with developmental disabilities, and a school for children with cerebral palsy**,** (CP). A safety score system was developed based on laboratory studies conducted on wheelchair restraint systems. This observation tool described the position of the wheelchair in the vehicle, the occupant restraint system, and the wheelchair restraint system. These structured observations revealed inadequate safety measures, such as side facing wheelchair transport positions, and no or inadequate restraining of both the wheelchair and the passenger riding in it. Comparisons of safety scores of subjects transported by families with those transported by agencies were not found to contain statistically significant differences.

The parents' worries were studied in Sweden, both for children with locomotor disabilities (Falkmer & Gregersen, 2002) and for children with autism spectrum disorders (Falkmer et al. 2001) from a parental viewpoint, what subjective risks the parents perceive and what safety problems the children experience, in addition to the parents' knowledge about the existing regulations and standards concerning transportation.

Concerning children with locomotor disabilities, Falkmer and Gregersen (2002) found that:

- Parents were often worried when the child travelled alone with an unknown driver.
- Parents were worried about the child entering and exiting the vehicle and also about the journey itself.
- In many cases, the mother or father lifted and carried the child by hand, regardless of its age, which in turn caused worries.
- Worry about an accident/incident when entering/exiting the vehicle was greater the younger the child, regardless of whether the worry was due to the risk of the child or the parent being involved in an accident/incident.
- Some parents felt confused by different rules and authorities governing the provision of technical aids and transport for families.
- The attitude to optimisation of travel capacity (OTC) in school transportation and STS was more positive than expected, particularly in sparsely populated areas. In the cities, somewhat more than 50 % were negative to OTC.
- The rules governing transport in a family car and other transport means were considered diffuse. Approximately half the parents had no knowledge of the rules applying to transport (49 %) and STS (55 %). The corresponding figure for transport by family car was 27 %.

Concerning children with autism spectrum disorders Falkmer et al. (2001) found that the parents were mostly worried about drivers and other passengers being unaware of how to approach and communicate with the children. They were also worried that the drivers and other passengers were disturbed by the children, and vice versa, both conditions being negative for the child. Furthermore, the parents

were worried about their children manipulating the safety belt and thereby eliminating its function.

One conclusion was that the younger the child, the greater the worry among the parents. The transportation situation for children with Asperger's syndrome caused less worry than for children with other autism-spectrum disorders. Moreover, children who had "Medical problems" and "Communication problems", according to a sub classification of the children's additional disabilities, caused more worries among the parents than children with other types of additional disabilities.

Despite the worries experienced by the parents they thought that the children in general appreciated the journeys in the family vehicle, as well as in school transportation and STS. Also the postural positions of the children in the vehicles were regarded as acceptable.

5 Conclusions and discussion

5.1 Legal aspects

Within this study we have been looking in detail at the legal aspects concerning children travelling as passengers in a car. If we compare existing laws in Sweden, the USA, the U.K., and Australia it is obvious that there are quite big differences between the countries. The outcome of how the parents/drivers are protecting their children does not always depend on the law. There are also recommendations for how to protect the child passengers. These recommendations are more detailed and will often increase child safety a little more than the law demands. In all these countries there are both laws and recommendations concerning child safety. One way of improving child safety could be to have laws and recommendations that are more consistent e.g. rearward facing and the use of booster seat. This is not the situation today.

Age, length or weight

There are differences in the existing laws between the countries regarding the criteria concerning children. Sometimes the criteria are based on the age of the child (e.g. Sweden and Australia) and sometimes the criteria are based both on age, weight or length of the child (e.g. the U.K. and the USA). In these four countries it is mandatory to use safety belts both in the front and rear seat. Apart from this, the law in each country demands that CRS are used. When the child is at a certain age e.g. less than 7 years old in Sweden, and less than 4 years old in the USA, the child has to use a CRS according to the law.

Where to be seated

There are also differences between the countries regarding where in the vehicle the child is permitted to be carried. Different types of CRS are required depending on where the child is carried. For example, in the U.K. there are differences in what the law demands depending on whether the child is carried at the front seat or back seat. In Sweden the law does not prescribe front or rear seat position. The result from this review shows the importance of CRS for transportation safety, especially for the youngest children, no matter where in the car they are transported.

Rearward facing

As far as we can see, the law in the countries in this review does not prescribe in what position the child has to be transported, i.e. if the child is seated forward facing or rearward facing. In most of the countries there are also differences between the law and the official recommendations. In most countries infants are recommended to travel rearward-facing, but there are no rearward-facing seats available for toddlers. In Sweden, however, rearward-facing restraint systems are commonly used for both toddlers and infants, and are recommended to be used as long as possible. Even children who are 4–5 years old are recommended to use those seats.

The responsible person

According to the law, the driver is responsible for restraining children travelling in the car but there are differences between the definitions of a child, with respect to this legislation. In Sweden, the driver is responsible until the child turns 15. In

the U.K., the driver is responsible for children below the age of 14. In Australia, the corresponding age is 16. The question is why there are differences and what is the relevance of the different key ages? No comparison with respect to these questions has been made and, hence, these questions remain unsolved and a challenge for future research.

5.2 Traffic fatalities and serious injuries on the international scene

Data for 2002 were compiled. However, data with one-year age groups is often not published which is unfortunate since the usage of CRS types and exposure rates is likely to vary greatly between children of different ages. It is especially important to split the age group 0–5 years. Moreover, provision of exposure data for children is an international challenge. The situation now is that, in fact, we are comparing different countries without having the opportunity to take exposure data into account. Other factors that may influence the injury risk for children are the age and crash worthiness of the vehicle in which children travel and the proportions of heavy vehicles in the different countries. This implies that the results shown in this section of the review should be read with great care. No generalisations should be made. One important conclusion from this literature survey is therefore that more exposure data is needed so that correct conclusions may be drawn regarding accidents relating to exposure, i.e. the travel patterns of children of different age cohorts.

5.3 Car development, installation systems and its implication for child safety

Children should never be placed in front of an airbag that aims to protect adults. The recent introduction of passenger side airbags has therefore made the issue of transporting children more complicated, i.e. were can you safely place a child in the car equipped with side airbags, airbag curtains etc.? One way to avoid the problem is to always place children in the rear seat. However, this solution is not always possible and it is not necessarily the best option from a safety perspective. For example, one main reason for graduation from rearward facing restraints is that there is not enough space for the legs of the child. This problem usually occurs earlier for children seated in the rear (Krafft, 2002). It is thus important to address the question of how to deactivate the airbag. The best alternative would probably be a technical solution that automatically deactivates the airbag when a child restraint is installed on the seat. The results from a Swedish survey showed that two of the participating manufacturers offer such a solution (Forsman, Hellsten & Falkmer, 2003). However, the technical design differs between the manufacturers and the system only works with child restraints especially developed for that particular design. A general solution of the conflict between children and airbags requires a standardised system for all cars and child restraints. No such standardised system is being developed and, at present, the choice is between permanent deactivation and installation of an on-off switch. Both systems have advantages and disadvantages and there is no general agreement on the best system. For example, Swedish authorities recommend permanent deactivation while the U.S. regulation only permits on-off switches. The disadvantages of the two deactivation strategies are related to the potential

misuse. Two types of misuse can occur: (i) the airbag is deactivated when an adult is using the seat or (ii) the airbag is activated when a child is using the seat. Permanent deactivation prevents the second type of misuse but, on the other hand, adults will always be unprotected when using the seat. Both types of misuse can occur in a vehicle equipped with an on-off switch. Further investigations are needed in order to compare the two deactivation strategies. Both the effect of the misuse and the misuse rate must be elucidated. The effect of the misuse includes the risk of a child being injured from a deploying airbag and the increase in risk of an adult not being protected by an airbag.

It is indeed a drawback for child safety to find that the ISOFIX system has not come into everyday usage for CRS. The initial work in this area was ahead of its time, but the regulation of only approving ISOFIX mounted CRS in a particular car model has the result that in practice original manufacturers of CRS have not tested and got their products approved for ISOFIX. However, as noted previously a change is about to come, so that CRS mounted by ISOFIX will eventually be approved on a general basis. This will most certainly contribute to enhancement of child safety in cars. Already in 1992 Berg & Gregersen (1992) conducted an investigation showing that ISOFIX minimised incorrect mounting and parents were willing to pay a fairly large amount of money for having the system in their car.

From a technical aspect, the car occupant protection looks quite simple. The impact forces need to be distributed over a large area of the body, over as long a time as possible and distributed in such a way that body parts are exposed to equal retardation, minimising shearing forces and internal breakage. Finally, sharp edges must not come into contact with the car occupant. For children there is one major complication, the size of the head. Children are not miniatures of adults, and thus need specific restraint types. For the smallest children, the babies and toddlers, the head might be as much as 25 % of the body weight, compared to about 6–7 % for an average adult.

It is obvious that children are protected quite differently in the various countries studied. The most significant difference is the rationale behind rearward facing versus forward facing CRS. Countries with a generally high traffic safety standard tend to demand by legislation specific and approved CRS and/or otherwise mandatory seatbelt use. Most of these countries also demand or recommend rearward facing CRS, at least during the first year of life

One hypothesis could be that due to the long history of using CRS in Sweden this has been a promoter of child transportation safety; parents of today often have a history of being restrained in a CRS themselves in their childhood, which of course strengthens their belief in the necessity of using CRS (Wenäll, 2003).

While studying most of the articles in this material, it is obvious that the most common comment is some kind of a recommendation promoting rearward facing CRS, due to optimum crash protection, even though consideration is given to a lot of different practical limitations and disadvantages in the field of use. Reviewed statistics, although revealing and interesting, suffer somewhat from lack of data, due to the (lucky) fact that in some countries very few children die in car accidents. Thus the data are very sensitive to each and every accident. However, the statistics seem to show that rearward facing CRS provide the best protection and where children are turned forward facing at a certain age; this tends to be noticeable as an increased risk in the statistics.

The consequence of incorrect use of child restraints is not very well documented. Various observation studies show a large number of misuses. But the seriousness of misuse is graded very differently in the different studies. For example, a child weighing 1–2 kilogram too much for the CRS is actually exposed to the same risk as a child put facing forward in a CRS intended for rearward facing use. Grading of risk factors is rare in the reviewed literature. Furthermore, very few actual crash tests have been made. Some studies have investigated actual accidents, but the material is limited to a few accidents. Studies show that certain types of CRS are more exposed to misuse than others. Convertible CRS are pointed out to be a group of CRS with a lot of misuse problems. Some studies point out that the youngest children should travel rearward facing. Depending on the originating country, the recommendation on age where it is possible to turn the child around to forward facing varies from about 1 year of age up to about 4–5 years of age. As a summary, from a technical protection viewpoint most of the reviewed literature strongly favours rearward facing CRS. When the child is turned to be forward facing, the studies point out the importance of correct installation and proper placing of the seat belts over the child's body. Warnings are issued for the use of lap belt only and improper positioning of both the lap belt and the diagonal belt, which should both be over rigid skeleton parts of the body, the lap belt as low as possible over the pelvis and the diagonal belt well up over the rib cage.

What type of incorrect use is a real risk? The approval procedure ECE R.44/03 sets limits that sometimes are strictly formal, such as the weight limit, while in real life these limits probably do not represent sharp limits between success and failure. And the crash itself is not an event with plain go/no-go results. The effect of a properly used CRS might just not be fatal or non-fatal, but the difference between serious injuries and minor injuries. But it can be difficult for the victims to interpret a serious injury as a success, even though a crash without a CRS or with a misused CRS could easily have been a fatal accident instead. If a child is short but somewhat heavy, just over the weight limit of a CRS, this might formally be classified as a misuse, but the child will nevertheless probably gain a lot of protection from that CRS. On the other hand, a child that is too tall for a protective device is obviously at risk even though the weight is within the formal weight limitations.

The reviewed literature is somewhat scattered. Most of them report very good results for rearward facing CRS and issue warnings for different misuses. On the other hand, very few actual tests with comparable data have been found. The consequences are serious in a lot of accidents, even though CRS are used in a proper way. Serious incorrect uses were found to be;

- Placing a small child forward facing, even though it is in a CRS that formally can contain elderly children forward facing.
- Using a CRS, intended for rearward facing installation, forward facing. This often results in severe force loading on the specific child at belt locations on the body which are not suitable for loading. It is also a combination often found with younger, i.e. smaller, children.
- Using a booster seat or a forward facing CRS (ECE R. 44/03 group 1 universal forward facing, with integral belts) as a rearward facing CRS. These forward facing group 1 CRS seats do exist quite commonly on the European market and are sold to parents who might believe that these are

tested and approved for rearward facing installation. This has been a problem in Sweden several times during the past 4-5 years.

- Putting the seat belts incorrectly. Examples can be putting the diagonal belt under the arm of forward facing children on booster seats, booster cushions or just with the seat belt, often due to the fact that the child or the parents are concerned about comfort or do believe that the diagonal belt placed close to the throat might pose a risk. No such injuries were found in the literature. Putting the diagonal belt behind the upper part of the body, resulting in the child being only restrained by the lap part of the belt, is another common misuse, equally dangerous. There is a high risk of submarining, or sustaining other internal abdominal injuries.
- The most frightening misuse, even though such accidents have so far never happened in Sweden, is the combination of rearward facing CRS and an activated airbag. Both actual crash tests and real life have shown that this is a fatal combination.
- A Canadian study reported an increased risk of ejection from the vehicle in rollover crashes when a child is seated in forward facing CRS with shields.

Exceeding the actual CRS weight limit by half a kilo or so, under the circumstances that all other demands are fulfilled, is probably not the most dangerous thing to do. On the other hand, exceeding the height limit of a CRS is not recommended. When the height is outgrown, the head protection capability of any CRS rapidly decreases.

The three main consequences of incorrectly used CRS are found to be increased risk of head and neck injury, increased risk of spinal cord trauma and increased risk of internal injuries to the abdomen, mainly due to the risk of pelvis/abdomen submarining or upper body jack-knife effect if the car seat belts are not positioned correctly in a forward facing CRS.

Although it can be said that it is extremely important to use a CRS and to use it as intended, the conclusion is that the largest risk is determined for those who are not restrained by any means at all. Any protective CRS is better than none, but the very best protection is obviously gained from an approved and correctly installed CRS, preferably a rearward facing CRS, where the child is well within all limitations of that CRS. But no CRS can guarantee a 100 % success in case of an accident.

5.4 Data from accidents and crash test regarding child safety seats

Only a handful of studies have been found which report actual accidents and the corresponding outcome due to misuse. The one and only major misuse is no use at all of CRS. Unrestrained children are the biggest problem worldwide. Most studies are dealing with small numbers of children, from just five accidents up to around 500. The studies are rather sensitive to the stochastic variation of accidents. In the only large study, by Zweitzer, Rink, Corey & Goldsmith (2002), 33 % of the children were unrestrained and an additional 20 % were incorrectly restrained. These data are coherent with the data from the Wenäll report (Wenäll, 2001), in which 33 % of fatally injured children in Sweden 1992–1997 were unrestrained. Both studies thus support the conclusions that three point belts are better than two point lap belts, that forward facing CRS are better than just the

seat belt and that the rearward facing CRS is, by far, the most effective protective device in case of a frontal impact, at least for younger children.

5.5 Use and misuse of restraints

Laws and recommendations together form a platform for the child occupant safety. The level of restraint usage measures are in some way the level of safety for the children.

A comparison between child restraint use in Australia, The U.K., the USA and Sweden shows that although the level of usage differs between these countries, the percentage of usage generally decreases with age. Self reported studies, as well as observational studies, show similar results. With respect to child restraint systems, the reported level of use also decreases with age and the differences between age groups become even higher.

In Sweden and The U.K. the level of child restraint use among infants and small children (toddlers) was at least 95 % in the front seat and approximately at the same level in the rear. In the USA the usage is still increasing and the latest report shows approximately the same level of use as Sweden and UK. In all these countries, however, the level of restraint use among older children was significantly lower than among younger children.

The level of misuse was, nevertheless, alarmingly high. Some of the studies even reported a misuse level of 90 %. Serious examples of misuse were: dangerous buckle crunching, where part of the buckle comes in direct contact with the frame of the seat and may snap open in case of a crash; and rearward-facing seats in front of an airbag.

Common misuses were, loose seat belts and harness straps, restraint devices not adequately secured to the seat or incompatible with the car, wrong type of child restraint system with respect to age, weight or height. Infants and toddlers travelling forward-facing, shoulder belt behind the back or under the arm, harness strap slot position below the level of the shoulder, bulky clothes, use of restraints that have been recalled by the manufacturer, use of seats that have been involved in a crash, use of too old seats, misuse of safety belt locking clip and harness positioning clip, children climbing out of the restraints.

When studying rates of misuse, one should remember that systems where both the seat and the child need to be secured, such as infant seats, convertible restraints and rearward facing CRS for toddlers are more difficult to use. Only in Sweden is the rearward facing child seat for toddlers is commonly used.

Even though many children use child restraint systems, the premature graduation of children from child restraints to seat belt is a problem in more than one country. Lack of knowledge among parents is one reason found.

An important finding in several studies is that parents and other caregivers think that their child is correctly restrained, while observations actually show that they are not. Several studies showed that children with parents who were seeking or receiving information about car child safety had a lower level of misuse.

Several studies mention the need to increase the collaboration between manufacturers of child restraints and cars. The readability of instructions is also mentioned as one reason for misuse, while the reading level of the text in one study exceeds the reading skills of most American consumers.

5.6 Measures for improvement – Campaigns

Received literature contained studies or descriptions of campaigns carried through in Sweden, the USA and Australia. Searching on British internet pages resulted in a campaign carried out in the U.K.

The aims of all campaigns were to decrease fatalities to children by increasing seat belt use and use of child safety restraints. Not every campaign has measured the fatalities and the usage of restraints prior to and following the campaign. Instead there are measurements of the awareness of the activities in the campaign. No campaign has been evaluated regarding long term effects. The result of the campaign depends on the usage of the safety belt when the campaign started. Of course the result was better when the usage of seat belt was low before the campaign started than when the usage of safety belt was high.

Important interventions to increase use of restraints are primary enforcement laws requiring use and enhanced enforcement programmes. Programmes including distribution of child safety seats and education programmes including hands-on training are also effective.

A campaign in Australia towards parents from three non-English speaking communities showed no significant increase in child restraint usage. On the other hand, the nation-wide “Buckle Up America” campaign, still going on, presents a good result maybe because of its wide extension and great variety of activities.

5.7 Children with disabilities

The transport situation for children with disabilities was found to be complex and insufficiently described in the international literature. The present review found studies on lack of safety measures for the target group. These studies had different focus, nationalities and methodologies, which makes generalization of the results difficult. However, safety problems were identified in all of them. The outstanding finding of the literature review was, however, the insufficient data concerning travel habits, as well as parents’ opinions, of children with disabilities. For these reasons the studies on the Swedish transport situation for children with locomotor disabilities, as well as with autism spectrum disorders provided essential data.

For the vast majority of Swedish journeys, the family vehicle was used both for children with locomotor disabilities, and for children with autism spectrum disorders. Most of the journeys occupied a substantial length of time. This implies not only higher exposure to accident risks, but also a demand for comfortable seating solutions. Furthermore, the demand for personal assistance is greater on longer trips.

Although the vast majority of journeys were made in the family vehicle, less than a third of all family vehicles were adapted for transporting children with locomotor disabilities. The number of safety belt users in the family vehicle was high. The corresponding figures for school transportation and Special Transport Systems STS were, however, substantially lower.

Although the children were restrained in the family vehicle, some of the technical aids and/or the seating devices were not. Almost one in eight of the journeys in the family vehicle were made with the disabled child seated in some form of technical aid. Among these technical aids, one in eight was not restrained at all.

In school transportation, more than four out of ten travelled seated in their technical aids. Almost one in ten of these technical aids were not tied down. Less than six out of ten used safety belts. These figures show that school transportation in Sweden can be a very hazardous means of transport for children with disabilities. One explanation for these extreme figures may be that some school transportation vehicles are in fact ordinary buses registered for more than eight passengers and thus not subjected to mandatory use of safety belts by the passengers.

Although this argument does not apply to STS, the results of this study showed that less than two out of three used safety belts when transported in STS. Almost half of the journeys in STS were made with the child seated in a technical aid. Almost one in ten of these technical aids was not tied down at all. These facts also show that STS travel in Sweden can be another very hazardous means of transport.

The anchoring procedures must be subjected to more thorough rules and regulations. From a safety point of view, it is unsatisfactory that so many children travel in their technical aids with no tie-down system in use. The school transportation system must be compelled to use safety belts for children with disabilities, preferably all children, since children seated in technical aids face an even greater risk in the event of an impact than other children. Furthermore, the results show that several of these technical aids were adapted in order to increase postural support, which may have devastating consequences in a collision.

Many of the parents were worried about their children when they were transported alone in school transportation or STS. Lack of information and knowledge of the driver seemed to be one underlying reason for the parents' worries. Comprehensive information, focused on the special needs of children with disabilities in their transportation, would probably reduce the parents' worries significantly. The target group for this information should be professional drivers and the content should also address the safety aspects of tie down procedures, as well as basic medical and psychological knowledge. In addition, parents' need of information regarding safety procedures for their children should be fulfilled.

Children with autism spectrum disorders travel under reduced safety conditions, a situation which is considered risky by their parents and, hence, creates worry on their part among the parents. Transport adaptations to children with autism spectrum disorders should not be limited to physical/mechanical adaptations. Approximately two out of three children utilised school transportation, while only one out of four was permitted to use STS. The safety belt usage in school transportation and STS was low. Every seventh child in school transportation and every eighth child in STS travelled totally unrestrained. This suggests that transportation of children with autism spectrum disorders, in school transportation and STS, is in fact a hazardous means of transportation.

Parents were mostly worried about drivers and other passengers being unaware of how to approach and communicate with the children. They were also worried that the drivers and other passengers were disturbed by the children, and vice versa, both conditions being negative for the child. Furthermore, the parents were worried about their children manipulating the safety belt and thereby eliminating its function; the younger the child, the greater the worry among the parents. The parents' worries were justified by the fact that many of the children were not transported according to general safety recommendations.

To summarize: for children with disabilities there is clearly a need to create new regulations and standards or sharpen up and apply the present ones. Human factors should be taken into account during the design of any such regulation or standard, oriented towards children with disabilities (Joly, 1991). The reason is that a standard or a regulation must be fine-tuned to the needs and practices of the target group. On the one hand, if the standards or the regulations are too rigid, then the mobility of children with disabilities may be reduced. On the other hand, if the standards or the regulations are too lenient, then safety will be jeopardized. In finding an acceptable balance between these conflicting viewpoints, the importance of parents' information and opinions cannot be overemphasized.

6 Suggestions for future research and development

The present literature review has pointed out certain areas and topics, in which future research is needed in order to promote development of in-vehicle child safety. In the following, a selection of these areas and topics is listed:

- Discrepancies in laws and recommendations were found within as well as between the investigated countries. It is important to establish a consistency and consensus, especially concerning rearward facing seats and the usage of booster seat. When reference is made to studies within this area it is obvious that children seated facing forward are exposed to much more devastating forces in case of a crash than children facing rearwards. Historically, parents in Sweden have been recommended to place their children facing rearwards at least until the children reach the age of three. The result of this is a reduced number of fatalities in the age cohorts of 0–2 years compared with countries not recommending this, despite the fact that survey studies have shown that almost one out of four Swedish children in the age younger than 3 year were travelling facing forward. If also these children would travel facing rearwards, a further reduction in the number of fatal or severely injured children is possible. Hence, a potential for increased injury preventive measures could be defined and tested. In view of the fact that legally children are allowed to travel facing forwards regardless of age, but recommended to travel facing rearwards up to the age of four or five, it is suggested that legislation consistent with the recommendation should be implemented, and evaluated by a before/after study focusing on the number of killed and injured children and the types of injuries (i.e. the injury patterns).

- Reliable accident databases based on one year cohorts, CRS usage and misuse/misconception and exposure measurements, in combination with more specific analyses are necessary, in order to describe and compare the traffic safety situation for children in different countries, utilising different CRS during different ages. Furthermore, such databases are important for evaluation of campaigns etc. For this reason, a first natural step would be to start with the Swedish accident database.

- Compared with other countries included in the review, the usage of CRS in Sweden is high. It is not realistic to expect that the result from a nation-wide campaign should be as positive as in countries where usage of CRS is not so common. Instead, we suggest campaigns directed towards special groups of interest. More information will thus be needed about potential problems regarding misuse within special groups. The campaigns should be combined with qualified practical help from e.g. the retailers.

- A true challenge is to investigate and promote possibilities for the use of rearward facing CRS for the age group 4–6 years, which would include a feasibility study on how to adapt car interiors for this purpose.

- A major revision of the ECE Regulation 44 is expected within a few years. A new generation of test dummies, new measurements and new acceptance criteria are being developed. Side impact tests are discussed as well as different rating systems for consumer information. Research about the feasibility of these changes and their implication on the CRS market is necessary. There is an obvious risk that the Swedish interest in continuing with rearward facing CRS for toddlers will not be covered if Swedish researchers are not actively involved in these developments.

- Multi-children CRS, CRS for buses, and ambulance usage is a field of research and development yet to be covered. A natural first step would be to identify the scope of the problem and in a second step to address it by developing products according to the needs. The final step would be to evaluate the products with respect to crash testing and field research.

- Some years ago it was possible to rent or borrow CRS for Swedish infants. The CRS was normally provided by the public health care system. This improved the use of infant seats. Unfortunately this is not very common today. As far as we know there are no explanations for the disappearance of this opportunity. We suggest further investigation to find out if this still is a potential improvement for child safety in cars.

One group of children that needs special considerations is children with disabilities. The following objectives could facilitate equal rights to safe and secure transport mobility for children with disabilities:

- An increase in the government subsidies for vehicle adaptations, with respect to parents with disabled children, in terms both of the number of grants and their size

- School transportation systems and STS must be compelled to use safety belts for children and adolescents with disabilities, preferably for all passengers. Furthermore, tie-down systems must be made compulsory for all road vehicle transportation where technical aids or special seating devices are used for seating in the vehicles.

- An implementation of ISO standard 7176-19 for transportation related requirements for wheelchairs that are suitable for occupant seating during motor-vehicle transportation and ISO standard 10542 for wheelchair tiedowns and occupant restraint systems into the daily work of transport providers and technical aids centres. For wheelchairs, the ISO 10542 standard, part 1-5, will provide a good description for the use of tiedowns and occupant restraints. Nevertheless, the final result will depend on the type of wheelchair (the wheelchair should have been tested according to ISO standard 7176-19) and the choice of tiedown and restraint system. Furthermore, the type of car and the quality of the mounting or anchor point are also crucial. The ISO standard 10542 is designed for adults, but part 5 of the standard specifies the requirements for children weighing more than 22 kg. For children below that weight the standard suggests that they should be "*transferred from their*

wheelchairs to appropriate vehicle child safety seats". As stated previously, not all children with disabilities will fit in to the child safety seats approved and available on the market. Hence, safe transportation for disabled children, weighing less than 22 kg, remains a problem.

- A handbook, describing basic medical and psychological knowledge, regulations and standards and safety aspects of transportation, which is currently in production and will be a useful tool for professional drivers, would probably reduce parents' worries significantly. The implementation of the handbook is an important issue, especially to particular groups of children with different socio-economical backgrounds

A natural scientific approach to the above objectives is to evaluate the impact of the suggested objectives, once they are achieved.

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Available statistics and sources

Australia
Available data:

Accidents:	One year groups 0–16 years, -98–01
Severity level:	Fatalities only
Population:	One year groups, -98–00
Exposure:	Not available.

Source: http://www.atsb.gov.au/ Australian Transport Safety Bureau (accidents)
http://www.abs.gov.au/ The Australian Bureau of Statistics (population)

The U.K.
Available data:

Accidents:	One-year groups Killed/Killed or seriously injured/All
Severity level:	Killed/Killed or seriously injured/All
Population:	Estimates for groups >1, 1–4, 5–14
Exposure:	Distance travelled per year. Trips per person per year 1998-2000 as one group. Under 17 as one group Trips per person per year and age (one-year-groups) available 1992–2000.

Source: http://www.statistics.gov.uk/ National Statistics Online (population)
http://www.transtat.dft.gov.uk/roadsafe/index.htm Department for Transport (accidents)
http://www.transtat.dft.gov.uk/personal/index.htm (exposure)

The USA
Available data:

Accidents:	Available for age groups 5–9, 10–15 and up. -98–01.
Severity level:	Fatalities only
Population:	for age groups 5–9, 10–14 and up. -98–00.
Exposure:	Not available. All reports from fatal accidents are available with exact age of victims.

Source: http://www-fars.nhtsa.dot.gov/ Fatality Analysis Reporting System (FARS) Web-Based Encyclopedia (accidents)
http://www.bts.gov/ The Bureau of Transportation Statistics (BTS)
http://www.transtats.bts.gov/Tables.asp?DB_ID=150&DB_Name=Census%20Population%20Estimates BTS TranStats (population).

Sweden

Available data:

Accidents:	One-year groups available upon request
Severity level:	Killed, severely injured and slightly injured
Population:	One-year groups available
Exposure:	Age 0–5 not available Average number of journeys/year and Average travelled distance/day Age 6–17 as one single group 2001 available (SIKA:s årsbok 2003) Age 6–17 as one-year groups available upon request 1998, 1999, 2000, 2001 from VTI etc (RES data). This data was, however, not intended to be used as one-year groups which gives very large uncertainties.

Source: www.sika-institute.se Swedish Institute for Transport and Communications Analysis (accidents)
www.scb.se Statistics Sweden (population)