TECHNICAL SPECIFICATION

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Road vehicles — Sled test method to enable the evaluation of side impact protection of child restraint systems — Essential parameters

Véhicules routiers — Méthode d'essai sur chariot pour permettre l'évaluation de la protection en choc latéral des dispositifs de retenue pour enfants — Paramètres essentiels

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22 *Road vehicles*, Subcommittee SC 36, *Safety and impact testing*.

This document cancels and replaces ISO/PAS 13396:2009, which has been technically revised.

The main changes compared to ISO/PAS 13396 are as follows:

— accident statistics data have been further reviewed;

— input parameter data related to intrusion have been reviewed and supplemented with new data;

— based on the new and supplementary data presented, a judgement is made whether the ISO/PAS 13396 parameter recommendations are still valid.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

In 2008, the United Nations (UN) GRSP Informal Working Group on Child Restraint Systems (CRS) sent a request to ISO asking ISO's CRS working group to support their work on defining a side impact test procedure for CRS type approval based on state-of-the-art research and experience. It was specifically requested to define the **essential parameters** of a simplified test method, to ensure that a CRS has a sufficient capacity to contain the child and to absorb energy in the case of side impact exposure.

In response, a Publicly Available Specification was developed, published as ISO/PAS 13396:2009[1)]. This comprised a series of essential parameters that a side impact test procedure should seek to replicate. Much of the technical content was derived from a previous Technical Report, ISO/TR 14646:2007, with updated information where available.

In conjunction with a systematic review of ISO/PAS 13396:2009, it was decided to verify its applicability in relation to more recent accident data and the vehicle technology development.

This document reflects the review of ISO/PAS 13396:2009 considering the relevant accident data updates available and the in-depth vehicle data.

Since this document is a check of the applicability of the ISO/PAS 13396 data (on which the CRS side impact method in UN Regulation No. 129 is based), the ISO/PAS 13396 parameter recommendations are included together with the supplementary information, to judge whether an update of the parameter recommendations should be made.

1) Cancelled and replaced by this document (ISO/TS 13396:2021).

Road vehicles — Sled test method to enable the evaluation of side impact protection of child restraint systems — Essential parameters

1 Scope

This document comprises a set of essential input parameters that can be used to develop or evaluate side impact test procedures for child restraint systems.

Although children are undoubtedly involved in side impact collisions of differing configurations and severities, these input parameters are, in general, associated with the impact test scenario in UN Regulation No. 95 (lateral collision protection of vehicles). This vehicle type-approval regulation comprises a full-scale crash test in which the stationary test vehicle is struck at right angles by a mobile deformable barrier travelling at 50 km/h. This test scenario is the basis for most of ISO's previous work on side impact testing for child restraint systems.

NOTE Countries and regions that do not recognise UN regulations can evaluate vehicles under different conditions and can apply input parameters that reflect the vehicle crash tests in their own regulatory jurisdictions.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

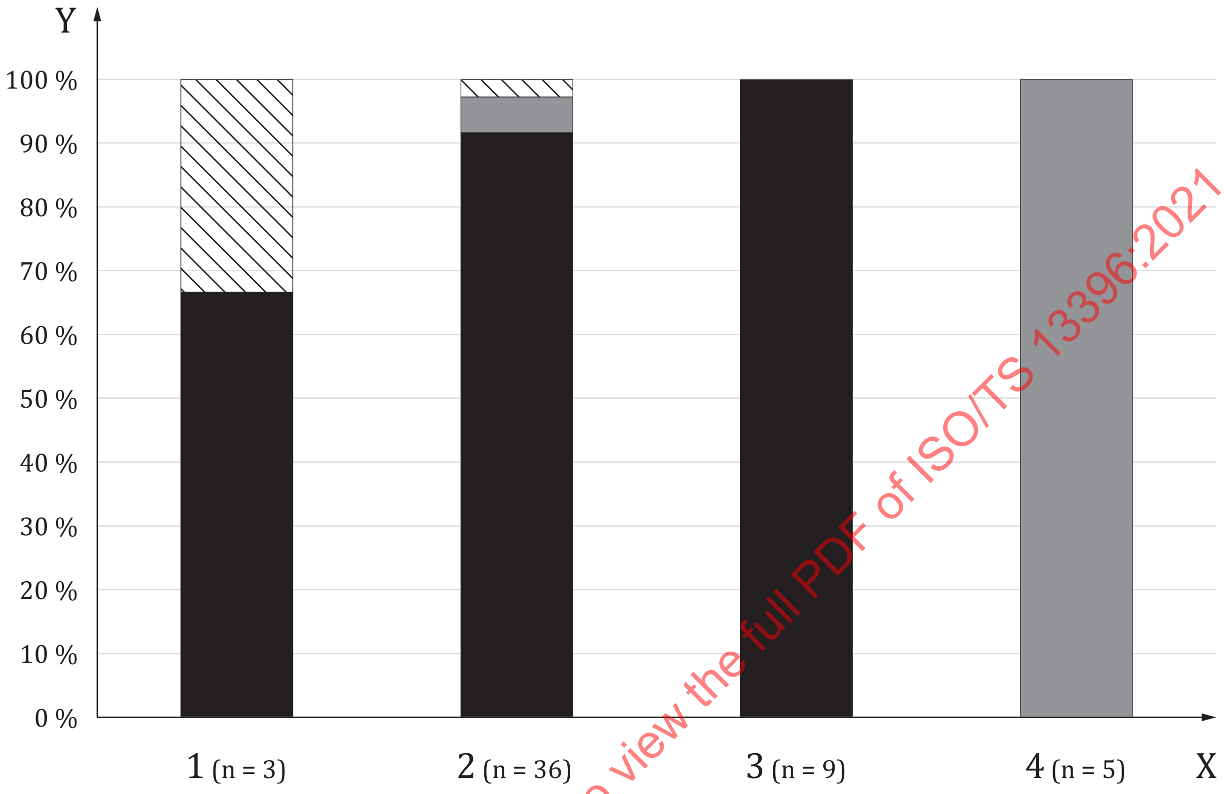
4 Accident statistics review

ISO has been studying injuries to children in side impact collisions since the mid 1990's. Early in that period, the risk of serious injury in a side impact was greater compared with other impact directions[3]. Furthermore, the risk was greater on the struck side of the car[4]. The European Enhanced Vehicle safety Committee (EEVC) recommended that increasing protection of the head should be the priority, following a wide-ranging review of European collision databases (EEVC, 2006). EEVC also reported that intrusion was an important parameter and influence on the injury severity level. These findings, along with other studies from the time, informed ISO's work on a side impact test procedure for child restraints.

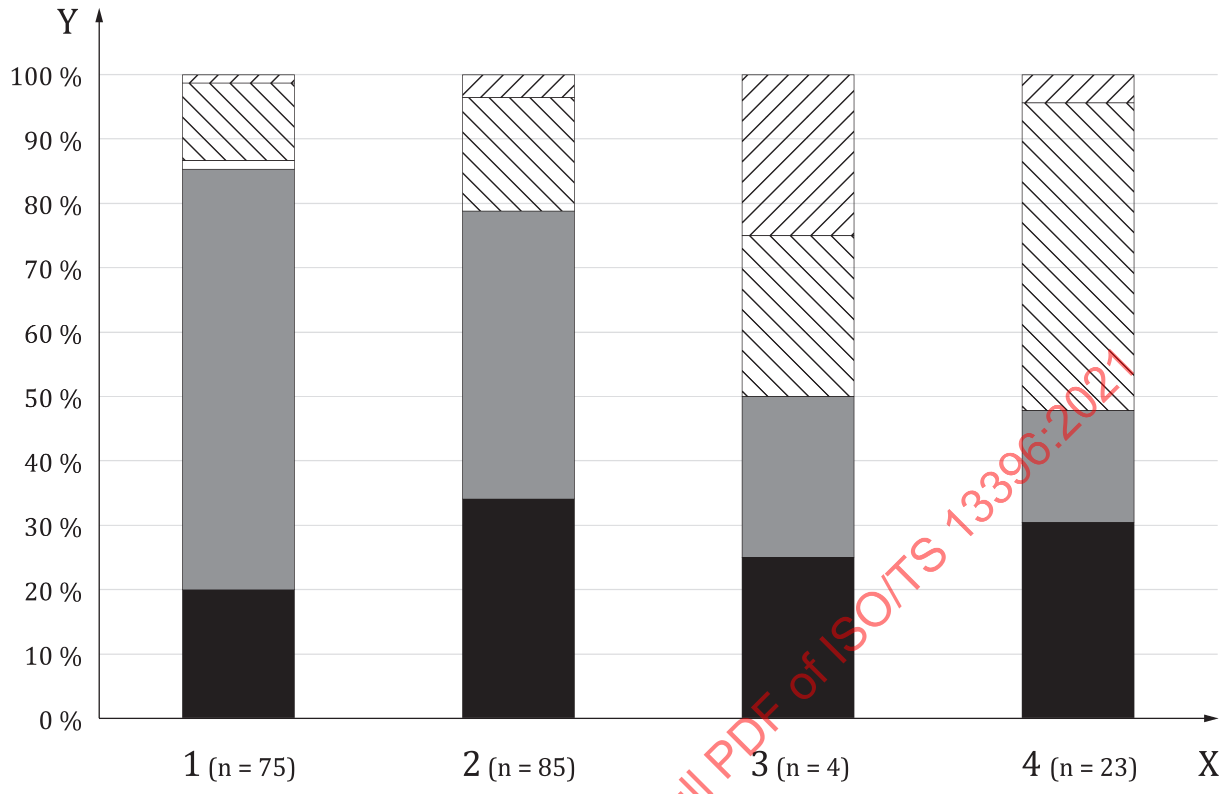
Since that time, the vehicle fleet has undergone significant changes, primarily in response to new regulatory and consumer test procedures. The side stiffness of cars has increased and although they are now also being struck by cars with increased frontal stiffness, it is possible that the boundary conditions for child restraint systems and injury outcomes for children in side impact collisions have changed.

Unfortunately, the literature on child restraint system performance in side impact is sparse and is limited to countries with on-going, in-depth collision studies. In the United Kingdom, data from the

Cooperative Crash Injury Study (CCIS) (1998-2010) and the Road Accident In-depth Study (RAIDS) (2012-2017) show a high proportion of children in child restraints with no or minor (MAIS1) injury in side impact; 79 %and 98 %respectively (see Figure 1). The newer, RAIDS data, appear to have fewer injuries, but both samples are relatively small. Therefore, any differences are unlikely to be statistically significant and neither sample may be nationally representative of the study period.



a) RAIDS data (2012-2017)



b) CCIS data (1998-2010)

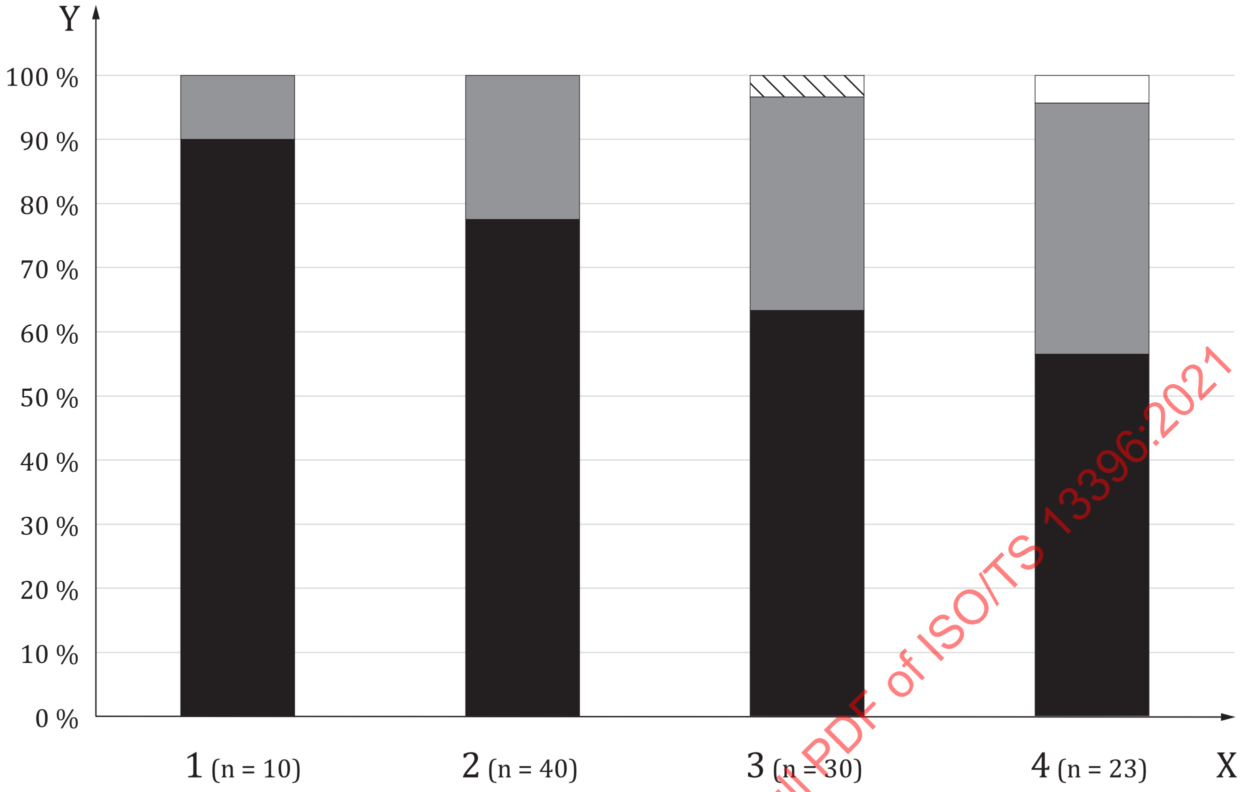
Key

X restraint type
Y proportion of child occupants
1 adult seat belt
2 CRS
3 restrained, not specified
4 unrestrained

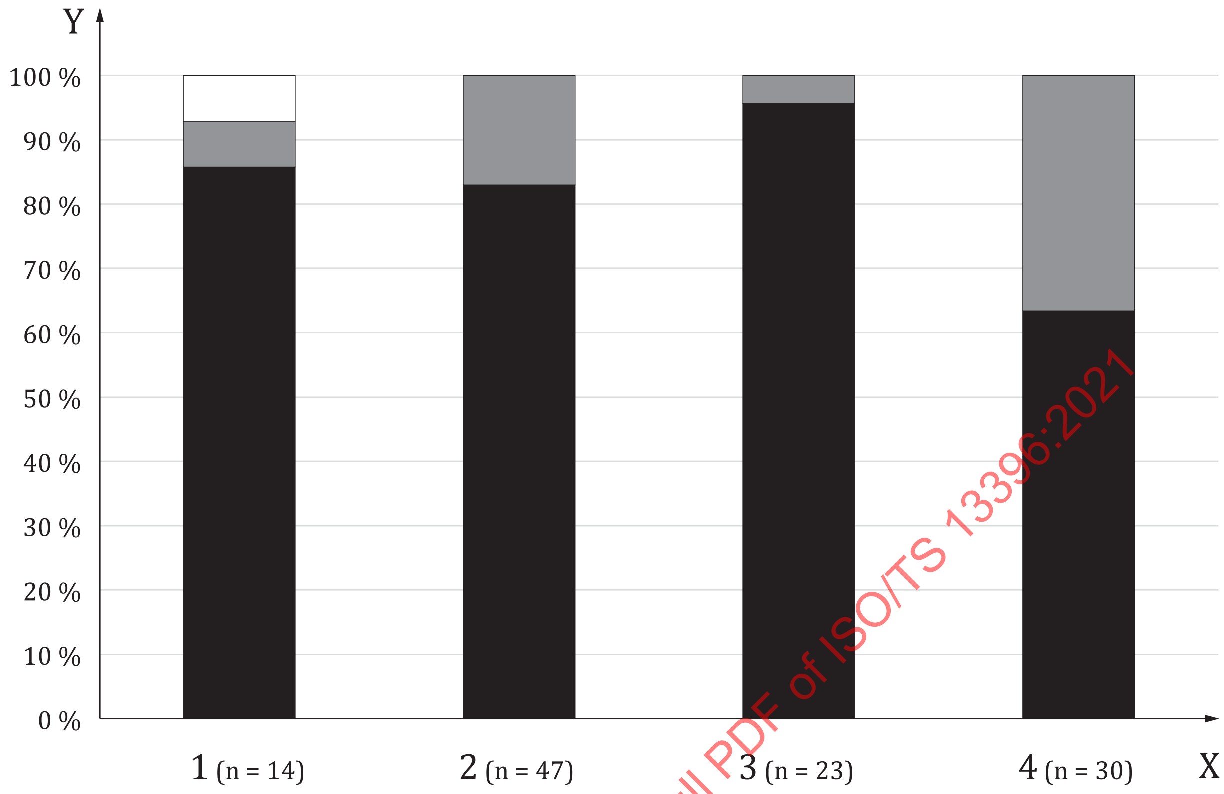
■ no injury
■ MAIS1
□ MAIS2
▧ MAIS3+ (survived)
▨ fatal

Figure 1 — Distribution of injury severity by restraint type (Reference [6])

The German In-depth Accident Study (GIDAS) also shows a high proportion of children in child restraints receiving no or minor injury in side impact (see Figure 2). In this instance, the sample size is larger than the UK RAIDS and CCIS samples but covers a single period of 20 years (1999-2019). Although, it was possible for the authors to break down the data by child restraint type and proximity to the striking vehicle, this also resulted in relatively small numbers. Struck side impacts had the lowest proportion of children with no injury for each child restraint type; however, the majority of injuries were minor (MAIS1).



a) Struck side



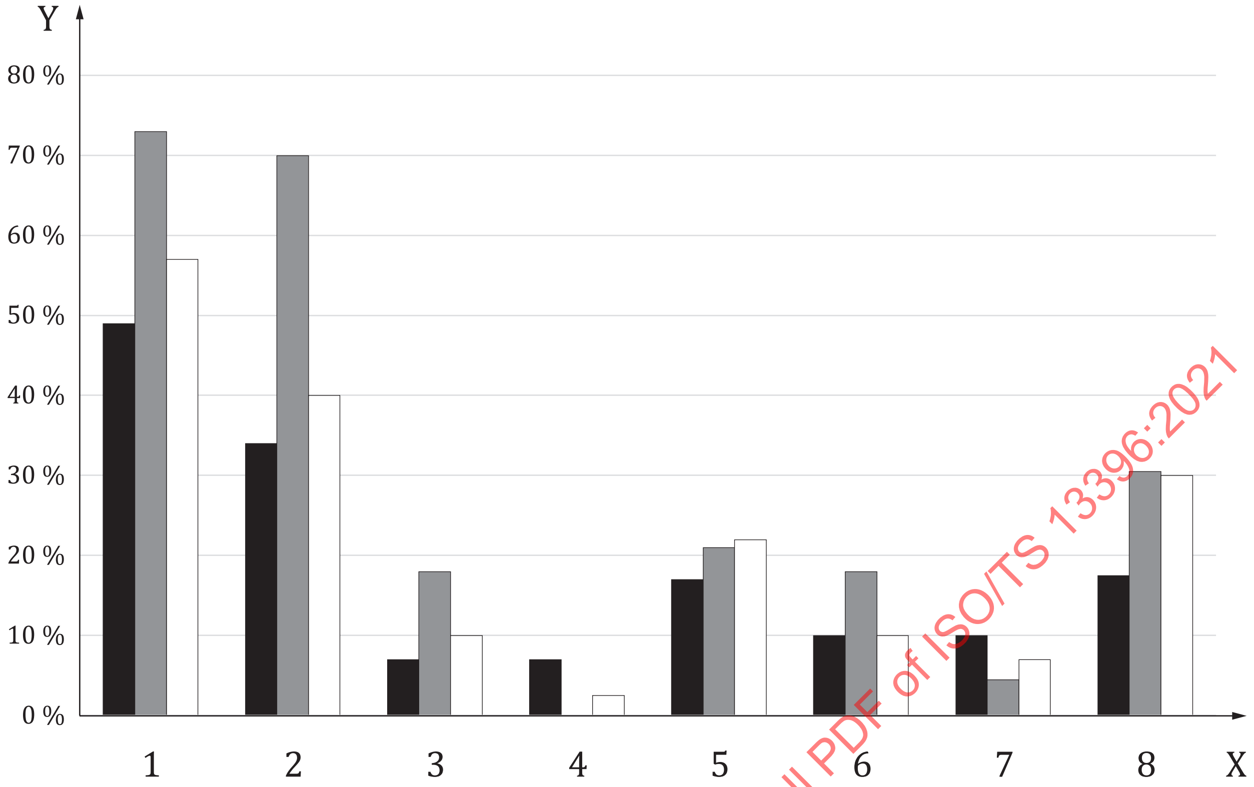
b) Non-struck side

Key

X CRS type
Y proportion of child occupants
1 baby shell
2 forward-facing with harness
3 booster seat (with backrest)
4 booster cushion (no backrest)
■ no injury
▒ MAIS1
□ MAIS2
▨ MAIS3+

Figure 2 — Distribution of injury severity by child restraint type – GIDAS data (Reference [7])

The head was the most frequently injured body region in the GIDAS sample reported by Reference [7]. However, the majority of these head injuries (94 %) were minor (AIS1). A non-representative sample of severe collisions was collected during the EU CASPER project (2009-2012). This included cases with moderate injury and above (MAIS ≥ 2) in side impact (see Figure 3). Although the sampling strategy and low numbers mean that comparisons cannot be drawn reliably between body regions and child restraint types, the data show the greatest proportion of injuries at this level were in the head and face. The data period for Figure 3 was not reported, but included cases from the previous project EU CHILD, which ran from 2002 to 2006.

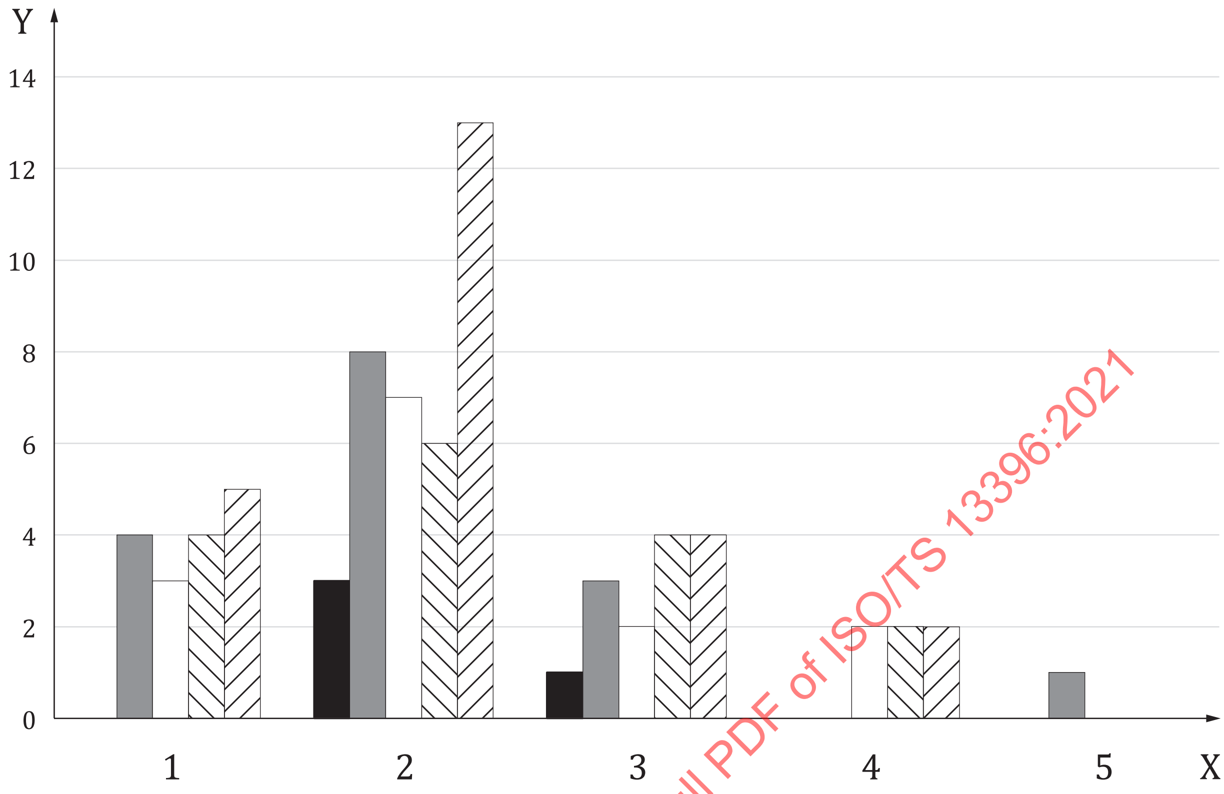


Key

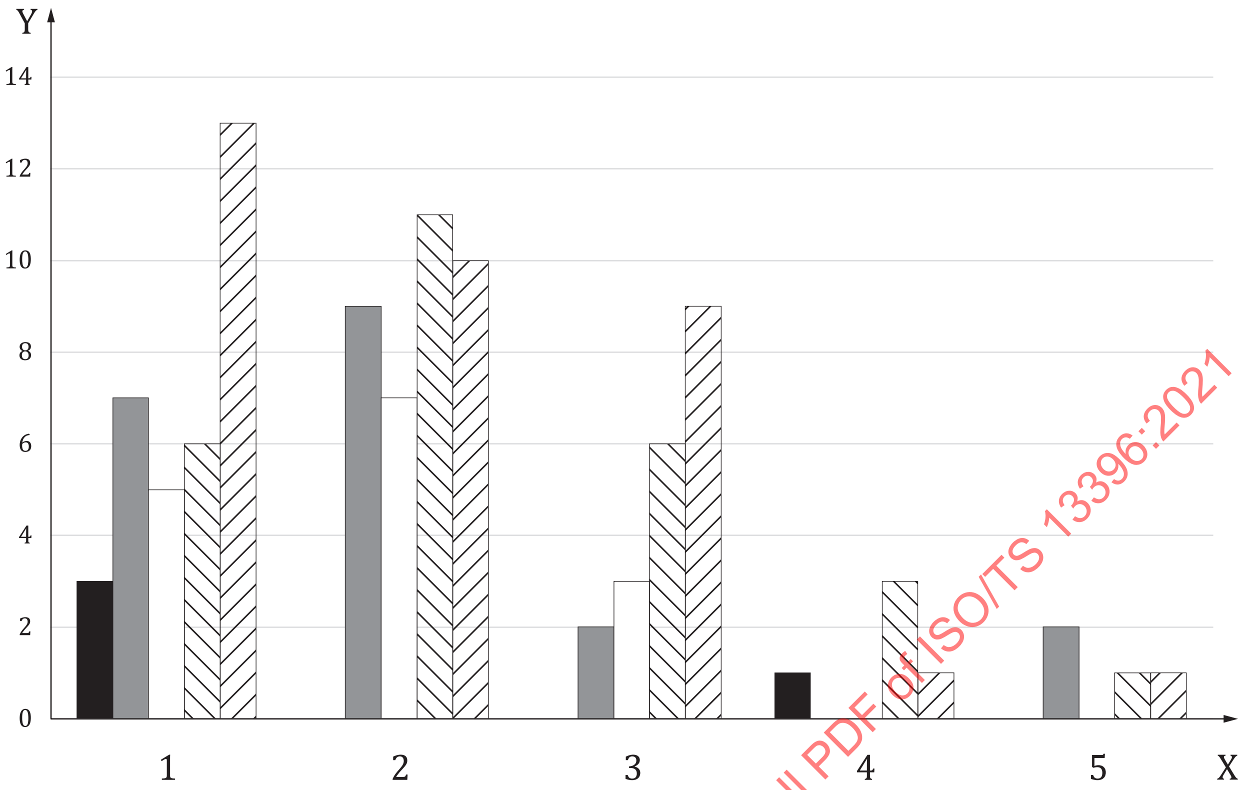
X	body region	4	neck		shell system
Y	MAIS ≥ 2 rate	5	thorax		booster seat/cushion
1	whole body	6	abdomen		adult seat belt
2	head	7	upper extremities		
3	face	8	lower extremities including pelvis		

Figure 3 — Body region distribution by child restraint type – CASPER data (Reference [8])

The limited information about child restraint system performance in real-world collisions means it is also difficult to determine the nature of side impacts involving children, particularly those that lead to injury. However, one attempt to analyse collision severity from GIDAS revealed that around 90 % of collisions involving children seated on the struck side occurred with a velocity change below 30 km/h, with most falling in the 11 km/h to 20 km/h band (see Figure 4). Similar findings were observed for children seated on the non-struck side. These included all injury severities.



a) Struck side



b) Non-struck side

Key

X velocity change interval

Y number of children

1 0-10 km/h

2 11-20 km/h

3 21-30 km/h

4 31-40 km/h

5 41-50 km/h

■ rearward-facing

forward-facing integral

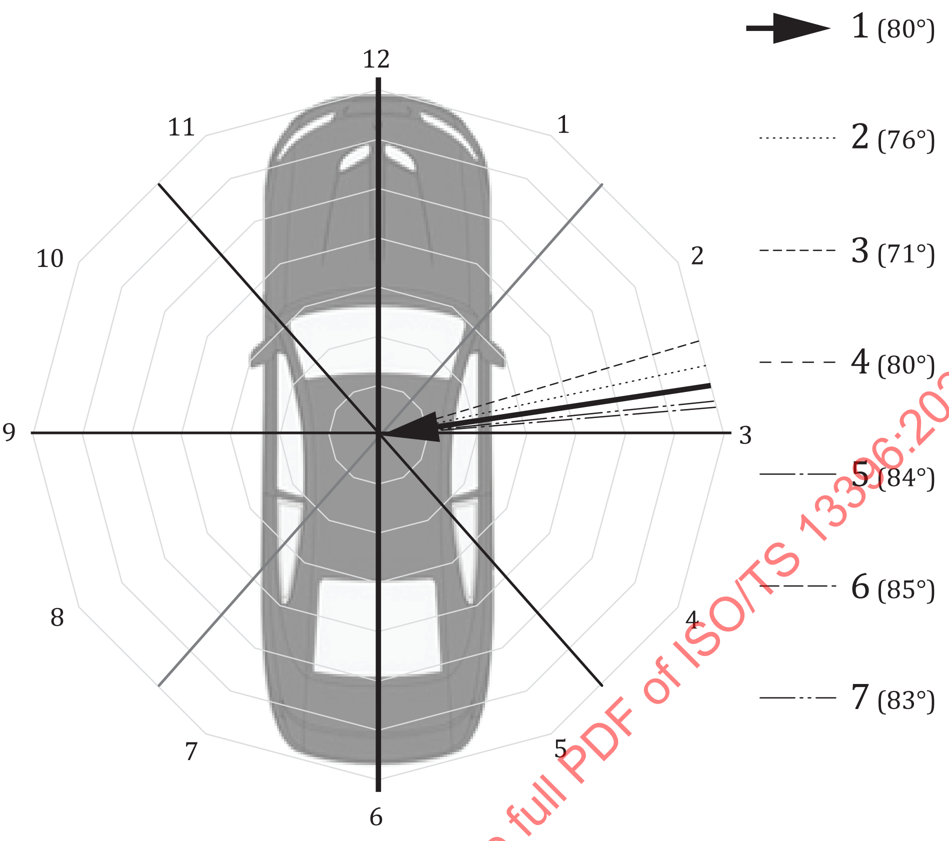
booster seat (with backrest)

booster cushion (no backrest)

unknown CRS architecture

Figure 4 — Struck vehicle velocity change distribution by child restraint type – GIDAS data (Reference [9])

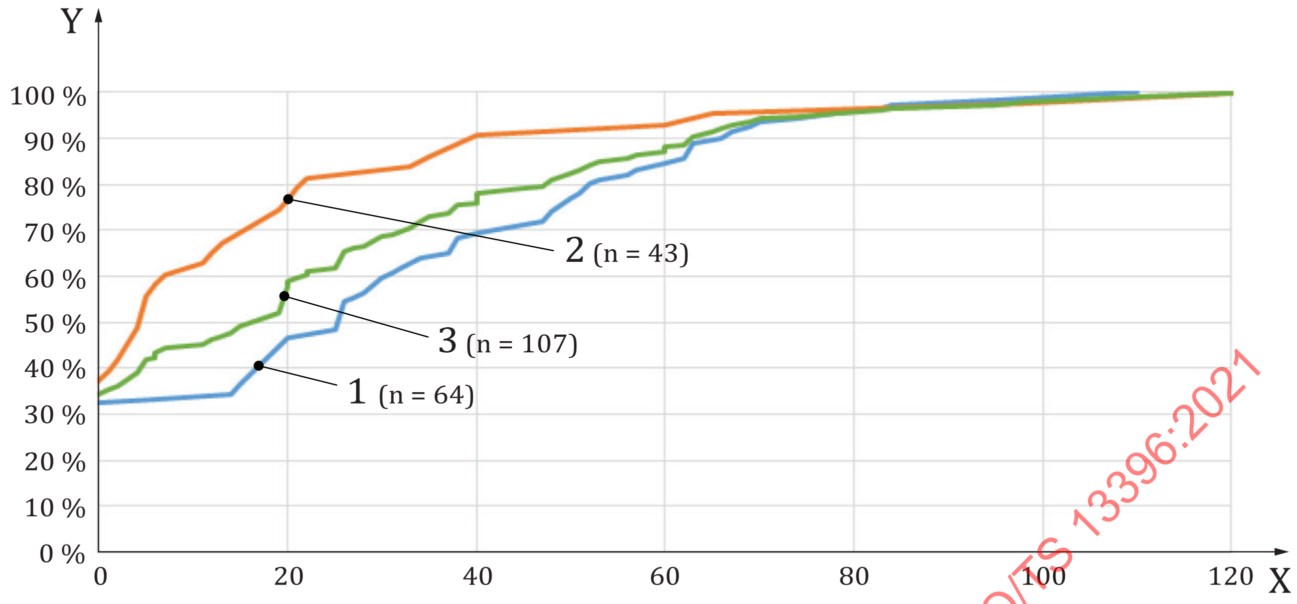
Given the limited data for children, more general information about the characteristics of side impact collisions can be a useful reference for this document (assuming children are involved in similar types of side impact collisions). Recent data for adults are also somewhat sparse, particularly since the European Enhanced Vehicle-safety Committee (EEVC) produced their overview of side impacts (EEVC Working Group 21, 2008). However, the Euro NCAP Side Impact Working Group undertook an analysis in 2016 as part of their work to develop a far-side impact test and assessment procedure for cars. Their data showed that the mean impact angles ranged from 71° to 85° and that intrusion levels showed a median level of 190 mm (see Figures 5 and 6). However, these findings should be treated with caution as they are focussed only on drivers and front seat passengers above the age of 10 years that received at least MAIS ≥ 2 injuries.



Key

1 average impact angle (80°)
2 GIDAS
3 Volvo
4 LAB
5 RAIDS
6 ADAC
7 APROSYS

Figure 5 — Impact angle data for drivers and front seat passengers (>10 years of age) receiving MAIS ≥ 2 injuries (Reference [11])



Key

X vehicle intrusion (cm)

Y cumulative frequency

1 LAB

2 GIDAS

3 LAB + GIDAS

Figure 6 — Vehicle intrusion data for drivers and front seat passengers (>10 years of age) receiving MAIS ≥ 2 injuries (Reference [11])

5 Input parameters for side impact test procedure

5.1 General

Relevant input parameters for defining a side impact test procedure for CRS based on experience from accident data analysis, full-scale tests and sled tests as described in ISO/TR 14646 are presented. These input parameters are divided into the sections: body regions to be protected, occupant kinematics, test severity, validation and field of application.

5.2 Body regions to be protected

Although the accident data were sparse, protection of the head remains the priority for side impact protection in child restraint systems. This requires control of the kinematics to contain the head within the child restraint as well as energy management to mitigate the loading.

5.3 Occupant kinematics

As head containment and head loadings are crucial issues with respect to the assessment of the performance of a CRS in side impact, it is necessary to utilise a test procedure capable of simulating real-world occupant kinematics and realistic loading conditions.

Containing the head within the CRS is more a challenge for the larger dummies, representing the upper limit of the respective CRS usage range than with smaller ones based on experience with different side impact test procedures within the development of ISO/TR 14646 and ISO/TS 29062.

The application of side impact test procedures shall be defined carefully considering the protection capabilities of today's cars.

5.4 Test characteristics

5.4.1 General

A side impact sled test method should ideally replicate the characteristics of a full-scale side impact test, but in a simplified and generic way. The following parameters describe essential side impact characteristics that can support the development and/or assessment of different side impact test methods for child restraint systems. The parameters were derived from full-scale, physical crash tests performed in the 1990s and early 2000s by members of the ISO CRS working group. These legacy crash tests typically followed the UN Regulation No. 95 procedure, namely a 50 km/h, 950 kg trolley impact on the driver's side of the car with the MDB-R95 (EEVC WG13) deformable barrier.

Although the principal UN Regulation No. 95 test conditions have not changed since these legacy tests were carried out, consumer information tests (e.g. Euro NCAP, JNCAP) have assessed cars under a higher severity than the regulation and have incentivised improved side impact performance. In preparing this document, new side impact data were sought to supplement the legacy data and assess whether the parameters remain relevant for modern cars. These new data comprised physical and simulated crash tests according to consumer side impact test procedures, primarily due to the limited availability of UN Regulation No. 95 data. Differences in severity from the legacy data are highlighted below and were taken into account when assessing the parameters.

5.4.2 Intrusion velocity

Figure 7 shows the front door intrusion velocity, relative to the chassis, from the legacy crash tests. Data for the rear door can be found in ISO/TR 14646. In these tests, the intrusion characteristics were derived from string potentiometers or cross-tubes attached to the inner door skin. The specific location of these sensors on the door has not been recorded and may have varied between tests. However, it seems likely they were positioned towards the centre of the door to avoid interaction with adult or child dummies in each seat.

The corridor lines shown in Figure 7 are meant as borders for defining a suitable intrusion velocity corridor. However, the allowed tolerance is too large to define a proper test procedure. It is crucial to define the intrusion velocity carefully, as it is an input parameter with considerable influence on the dummy measurements.

Figures 8 b) to 8 e) show the front and rear door intrusion velocity from new crash tests provided by current members of the ISO CRS working group. These tests followed two different procedures, as labelled in Figure 8:

— Euro NCAP: 60 km/h, 1 400 kg trolley with AE-MDB (two simulated tests – C and D segment cars);

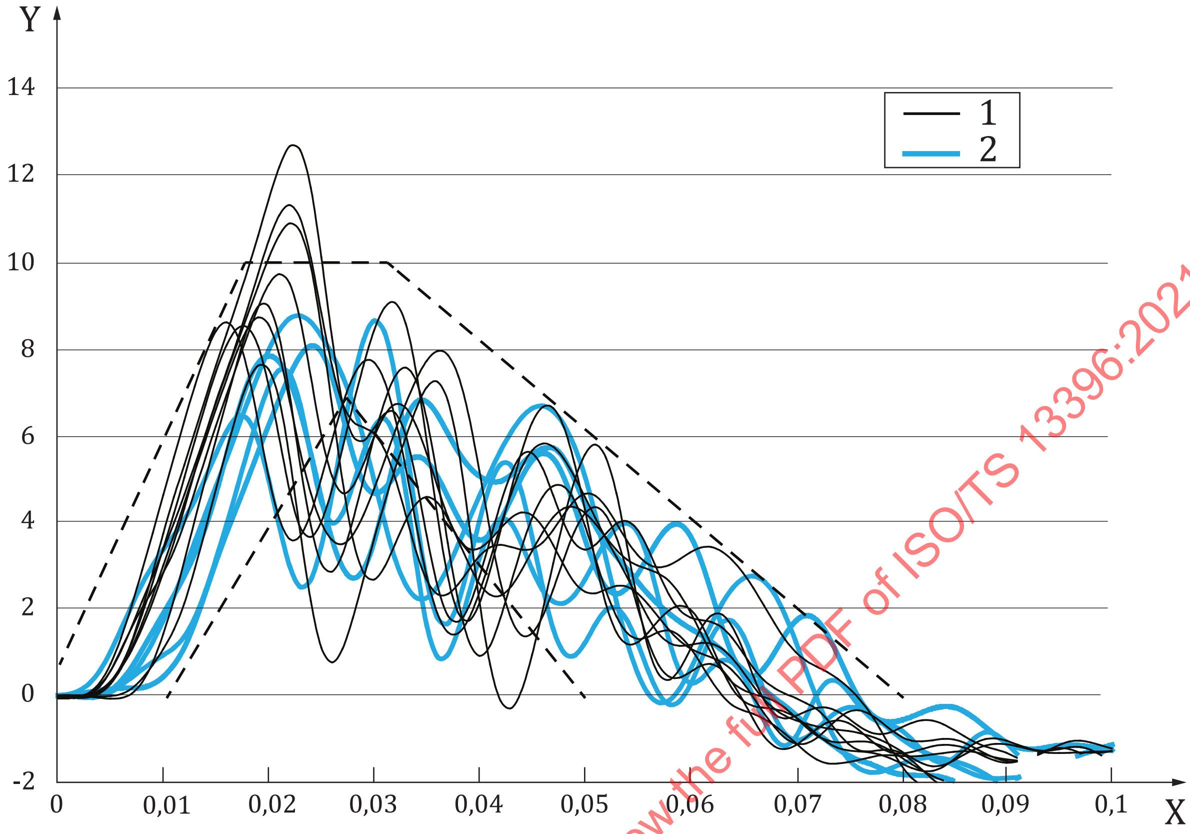
— JNCAP: 55 km/h, 1 300 kg trolley with AE-MDB (three simulated and one physical test – A, C and D segment cars).

The intrusion velocity was determined at five locations on the struck-side doors. These comprised the centre of the door plus four further locations, each related to the Cr point by pre-defined coordinates. Figure 8 a) shows the locations that tended to record the highest intrusion velocity.

The intrusion velocity in the new crash tests was broadly consistent with the legacy data and intrusion velocity corridor, albeit at a slightly lower level in most cases. However, the tests were carried out with a higher impact speed and trolley mass and a more aggressive barrier than UN Regulation 95. It seems likely, therefore, that the intrusion velocity in these cars would be even less in the regulatory test scenario. That said, in the absence of directly comparable tests, it seems premature to make any changes to the corridor at the present time.

As a conclusion, the original statement of ISO/PAS 13396 remains:

A maximum intrusion velocity between 7 m/s and 10 m/s at approximately 30 ms close to the dummy's head is required to represent realistic loading conditions.



Key

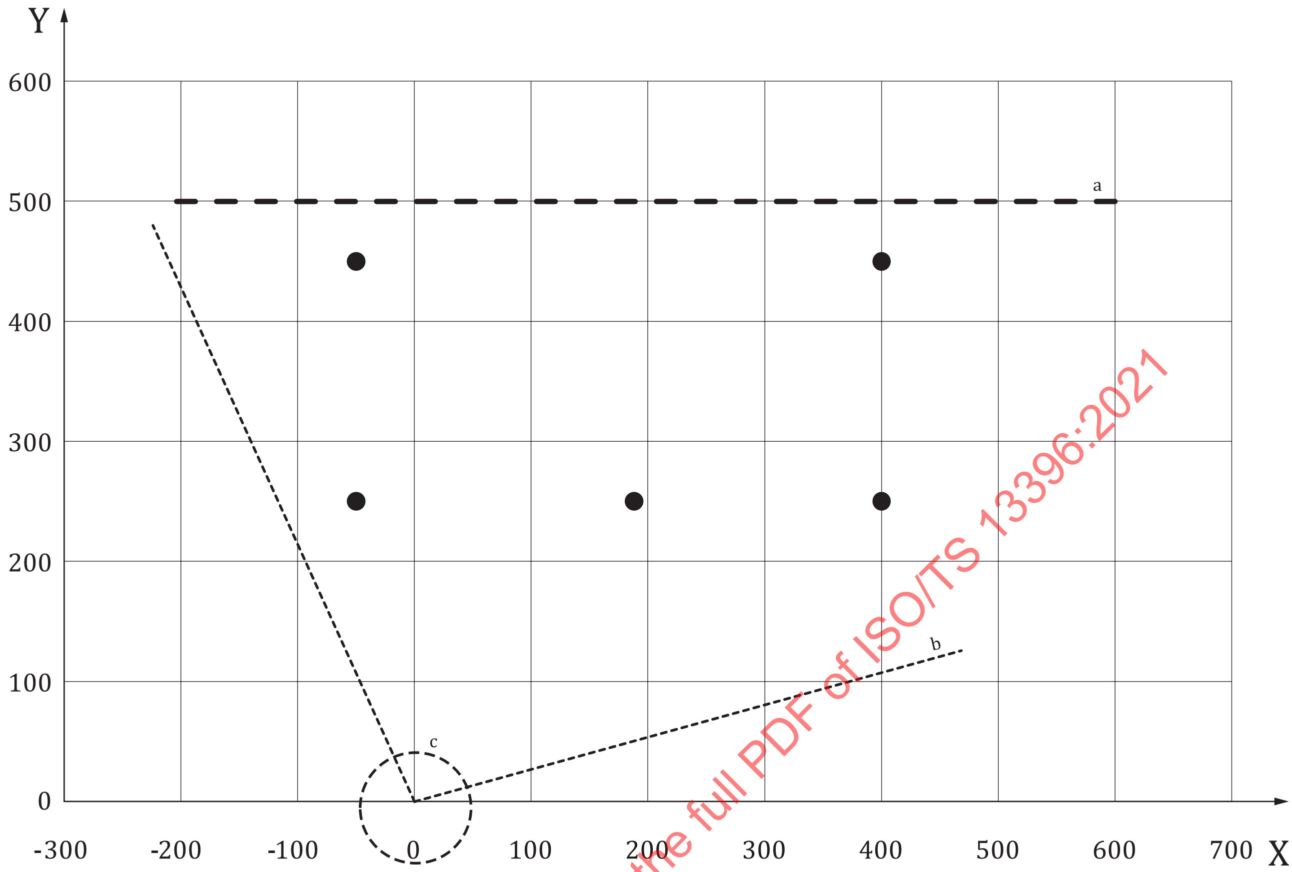
X time (s)

Y intrusion velocity (m/s)

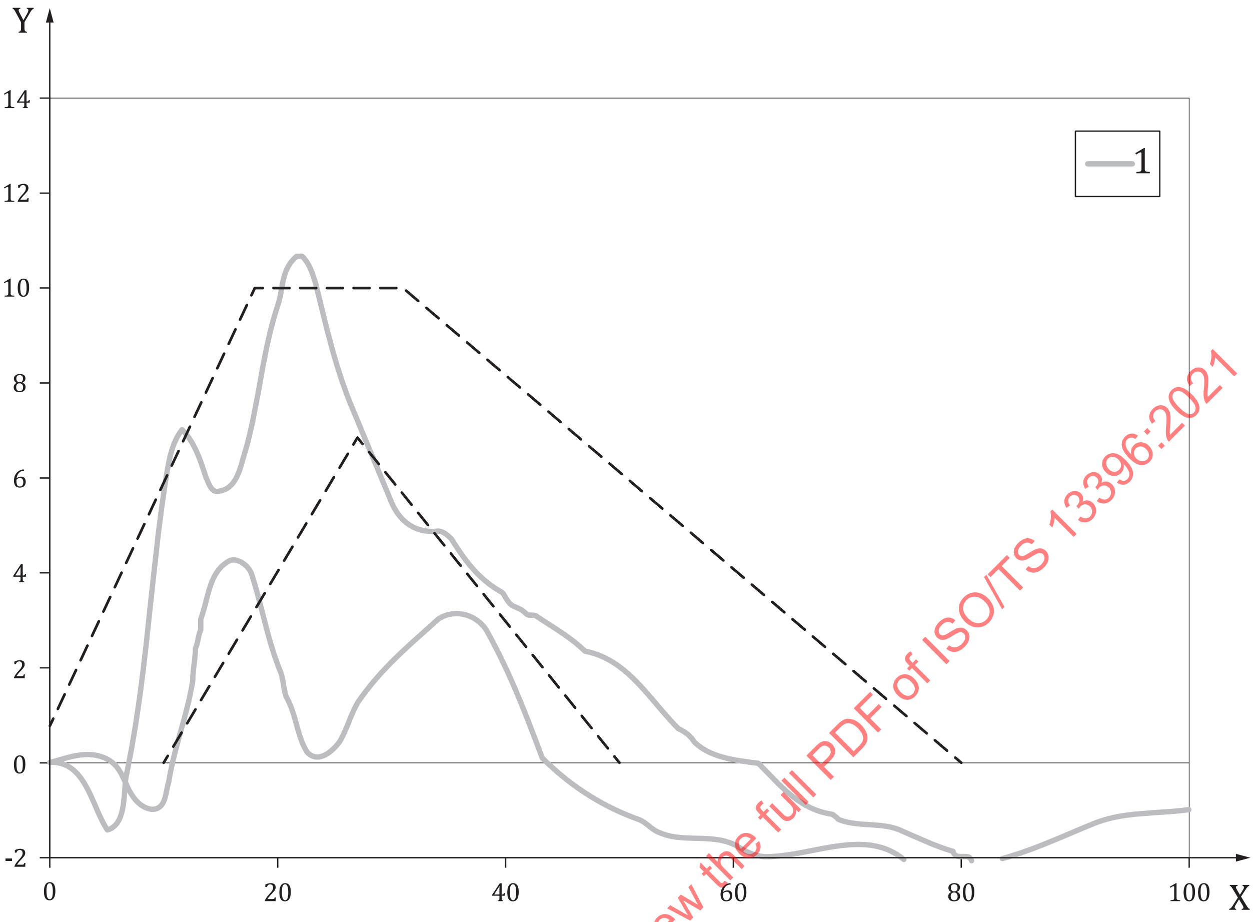
1 cars before model year 1995

2 cars between model year 1995 and 2005

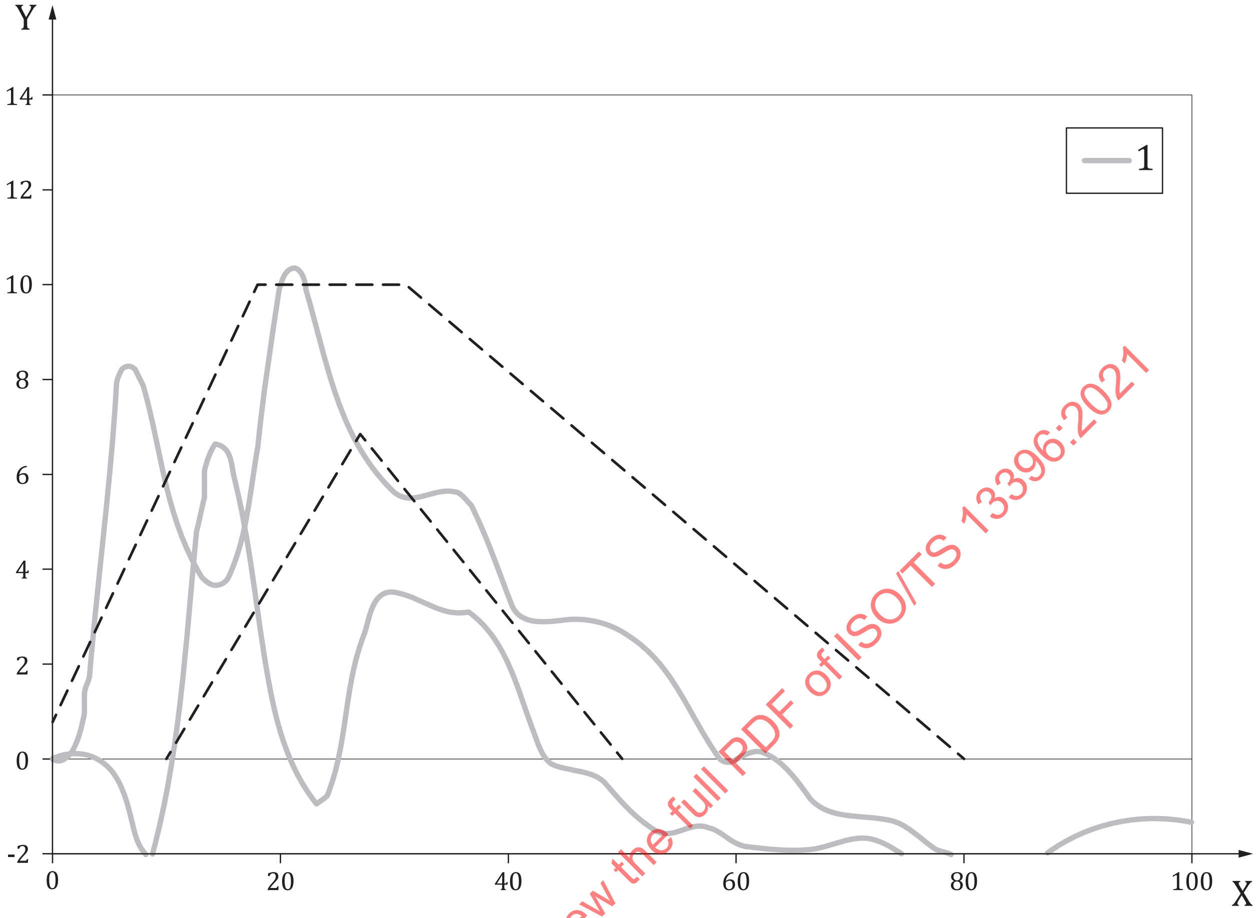
Figure 7 — General requirements for intrusion specification (ISO/PAS 13396 data)



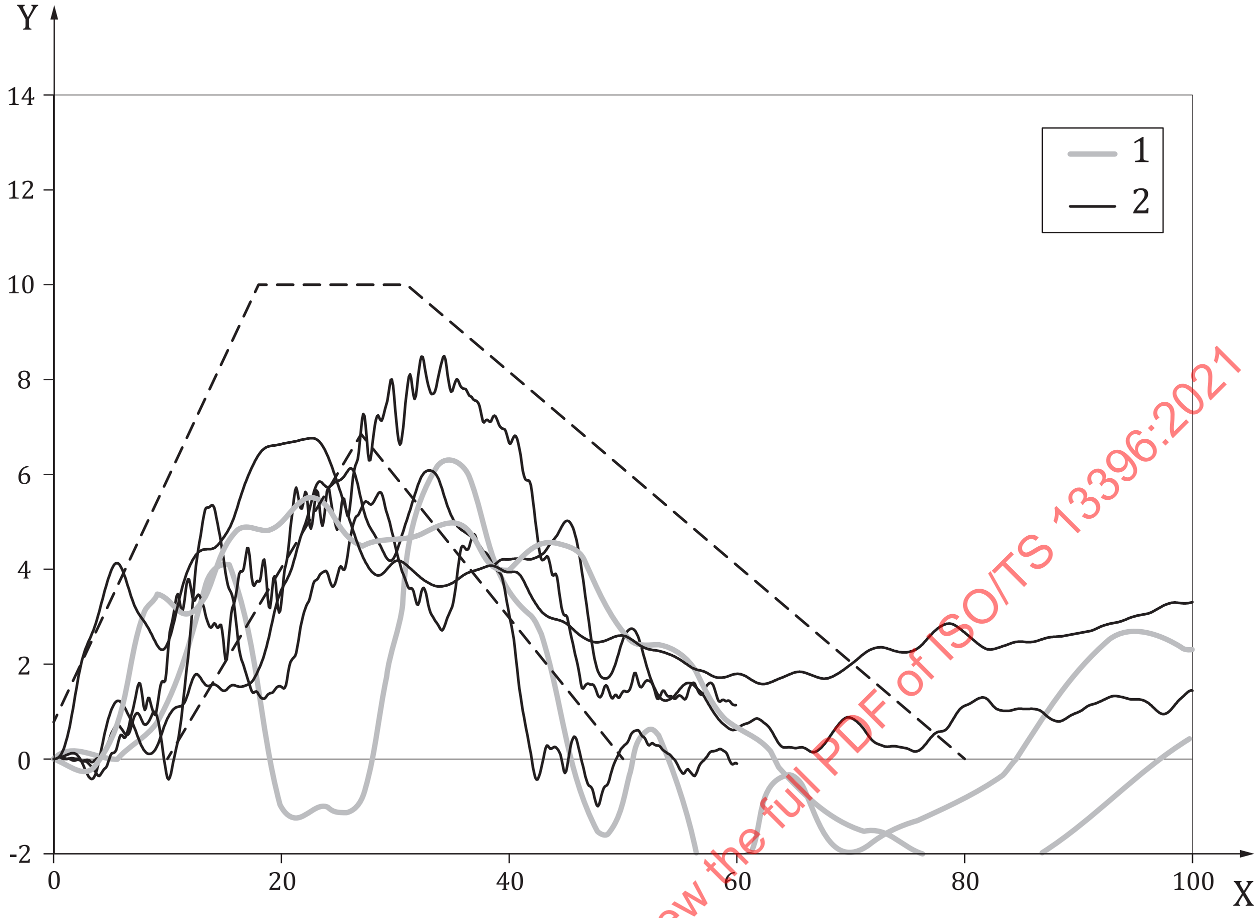
a) Locations on the struck-side door



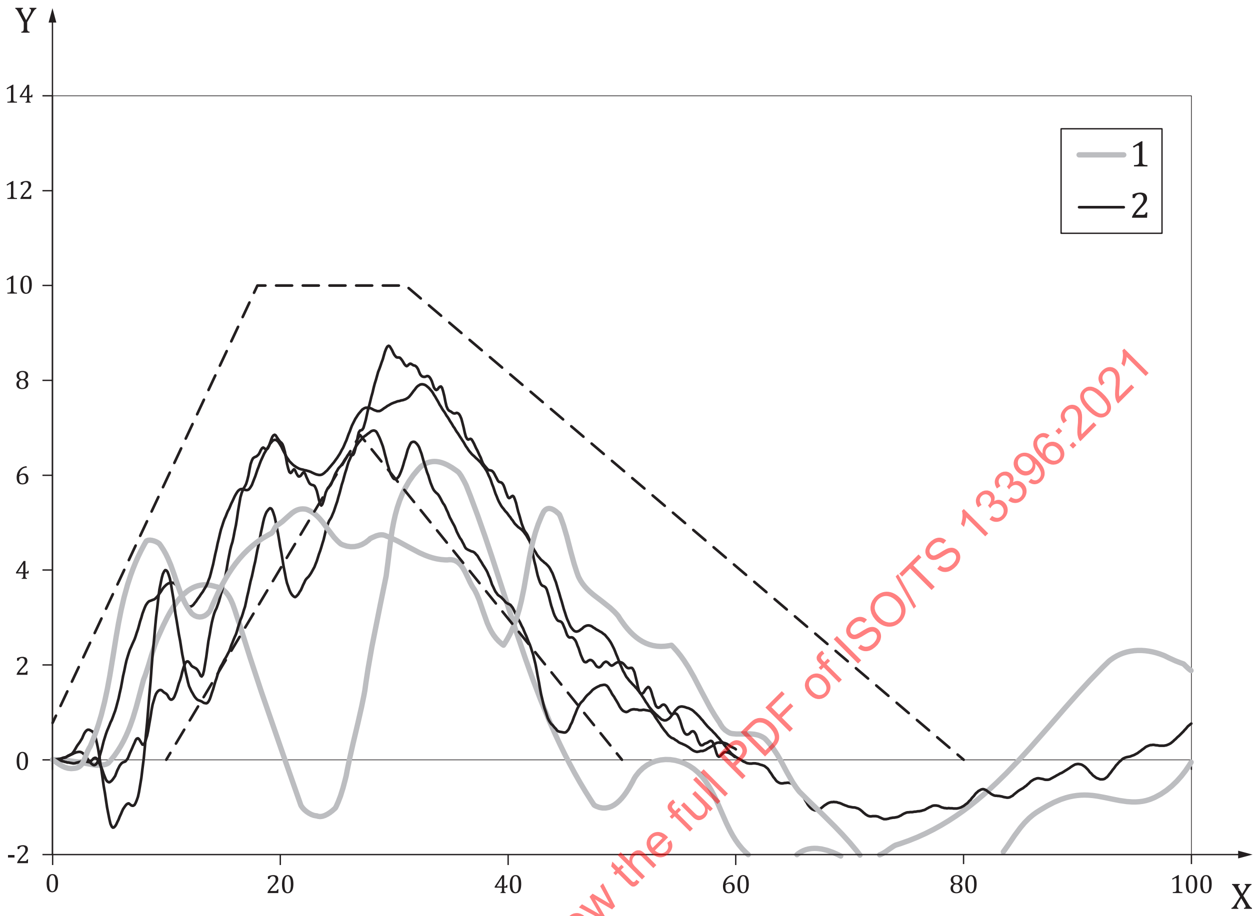
b) Front seat – door centre



c) Front seat – 400 mm, 250 mm from Cr



d) Rear seat – door centre



e) Rear seat – 400 mm, 250 mm from Cr

Key

X time (ms)

Y velocity (m/s)

1 Euro NCAP 60 km/h, AE-MDB (1 400 kg)

2 JNCAP 55 km/h, AE-MDB (1 300 kg)

a Top of UN R129 intrusion panel.

b UN R129 test bench surfaces.

c Cr point of vehicle seat.

Figure 8 — General requirements for intrusion specification (new data)

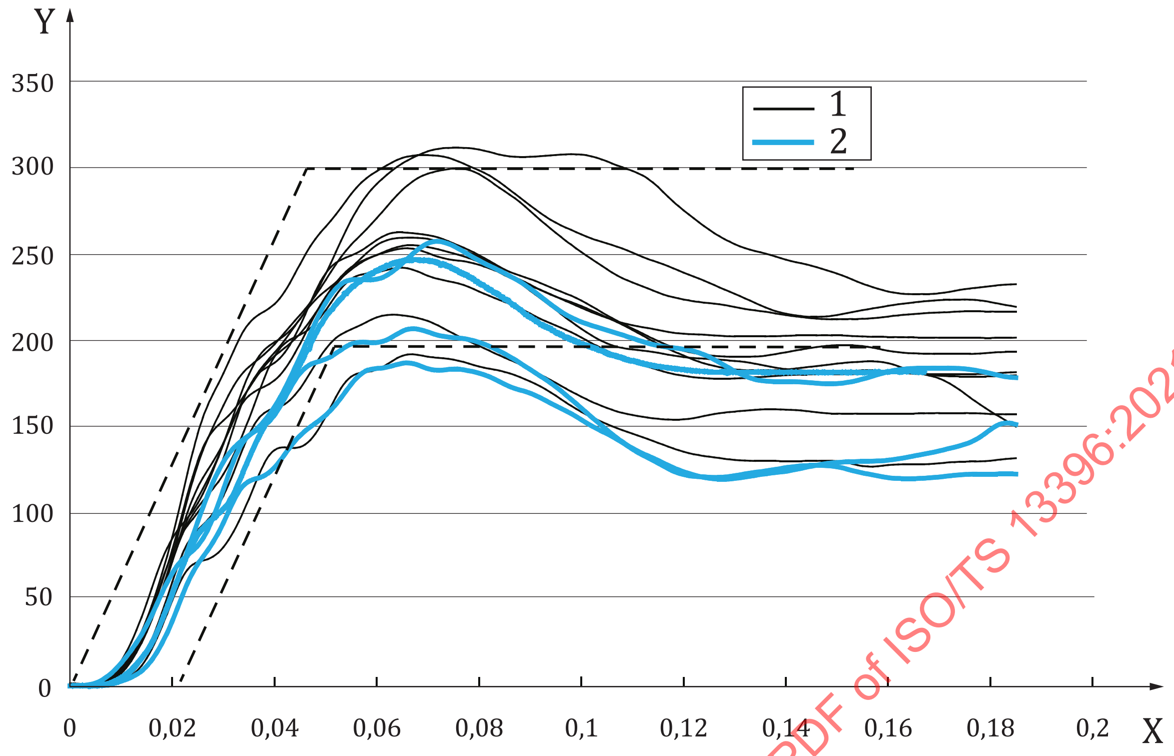
For defining a test procedure, it is important to take into account the combination of intrusion velocity and struck car velocity, defining the intrusion velocity relative to the ground.

5.4.3 Intrusion depth

Figure 9 shows the intrusion depth characteristics measured in a number of cars representing different sizes and different manufacturing dates in UN Regulation No. 95 tests. In these tests the lateral intrusion was measured close to the dummies head using either string potentiometers or cross tubes. The position of the measurement device was defined by the position of the Q3 dummy head in a forward-facing CRS in the front seat. As parts of the available data represents quite old cars, the cars older than 1995 can easily be identified. The review of ISO/PAS 13396 did not include an analysis of recent intrusion depth data.

The original statement in ISO/PAS 13396 regarding intrusion depth was:

The dynamic intrusion depths should be between 200 and 300 mm to represent realistic loading conditions.



Key

X time (s)

Y intrusion depth (mm)

1 cars before model year 1995

2 cars between model year 1995 and 2005

Figure 9 — General requirements for intrusion depth (ISO/PAS 13396 data)

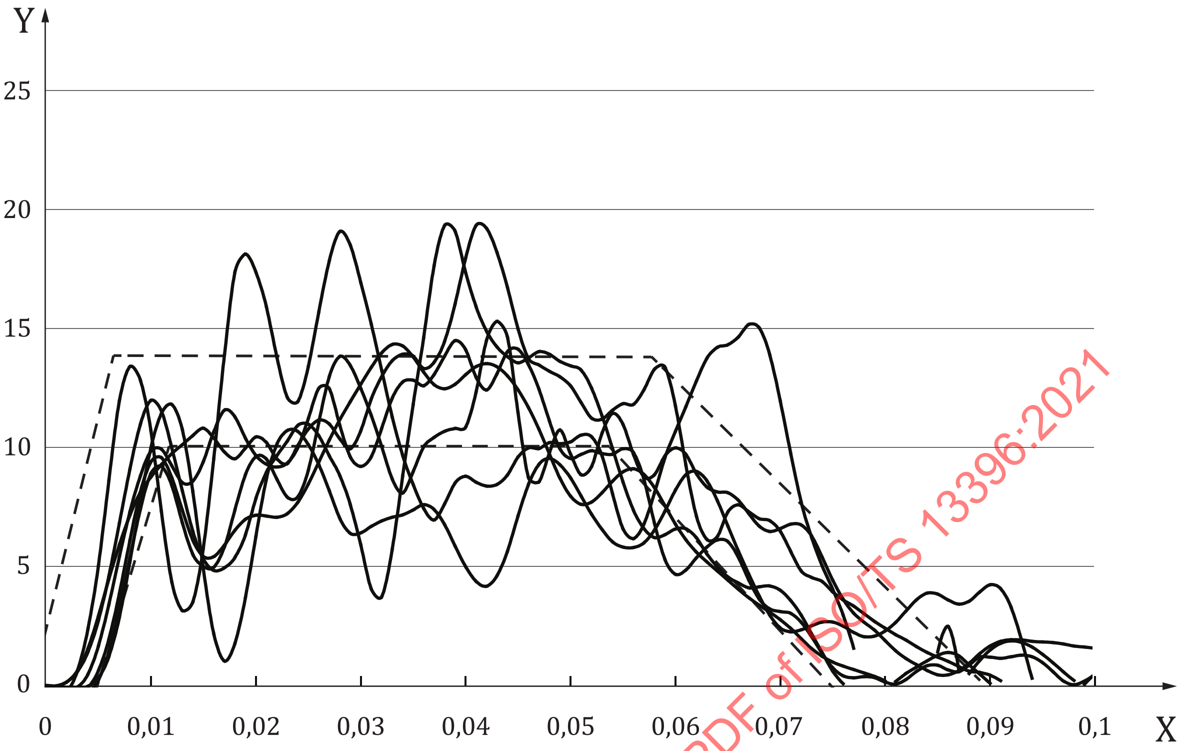
5.4.4 Struck car acceleration range and struck car delta-v

Figure 10 shows the struck car acceleration from the legacy crash tests. This was measured at the base of the non-struck side B-pillar of cars of various sizes and manufacturing dates.

Figure 11 shows the struck car acceleration from crash tests carried out by Euro NCAP according to the pre-2020 protocol (50 km/h, 1 300 kg trolley with AE-MDB). The struck car acceleration in the new crash tests was higher than the corridor for the smaller car segments. Although newer cars are likely to be stiffer in side impact than those in the legacy sample, the Euro NCAP tests were also carried out with a higher trolley mass and more aggressive barrier. In the absence of directly comparable tests, it seems premature to make any changes to the corridor at the present time.

As a conclusion, the original statement of the ISO/PAS 13396 remains:

The sled acceleration should be between 10 *g* and 14 *g* to represent realistic loading conditions.



Key

X time (s)

Y far side acceleration (g)

Figure 10 — General requirements for sled acceleration (ISO/PAS 13396 data)