

Evaluation of Proposed Protocols for Assessing Vehicle LATCH System Usability

Kathleen D. Klinich, Miriam Manary, Carol Flannagan and Jamie Moore
Univ. of Mich. Trans. Res. Inst.

Jessica Jermakian
Insurance Institute for Highway Safety

ABSTRACT

This project assessed current or proposed protocols for improving the usability of LATCH (Lower Anchors and Tethers for Children). LATCH hardware in the left second-row position of 98 2011 or 2010 model-year vehicles was evaluated using ISO and SAE LATCH usability rating guidelines. Child restraint/vehicle interaction was assessed using ISO and NHTSA proposed procedures.

ISO ratings of vehicle LATCH usability ranged from 41% to 78%, while vehicles assessed using the SAE draft recommended practice met between 2 and all 10 of the recommendations that apply to all vehicles. There was a weak relationship between vehicle ISO usability ratings and the number of SAE recommended practices met by a vehicle. Twenty vehicles with a range of vehicle features were assessed using the ISO vehicle-child restraint form and 7 child restraints; ISO vehicle-child restraint interaction scores ranged from 14% to 86%. Twelve vehicles and 7 child restraints were evaluated using the proposed NHTSA fit criteria in the left second-row position. Most styles of child restraints met the criteria in most vehicles, with the exception that rear-facing convertible restraints did not meet the proposed criteria in most vehicles.

Testing with volunteers using 12 vehicles and three child restraints indicated that the overall ISO vehicle rating, ISO vehicle-child restraint interaction rating, or the number of SAE recommended practices that were met were not associated with the rate of correct child restraint installations performed by volunteers. Vehicle-child restraint pairings meeting the proposed NHTSA fit criteria had error-free installations four times as often as those that did not, but still few were error-free (16% vs. 4%).

CITATION: Klinich, K., Manary, M., Flannagan, C., Moore, J. et al., "Evaluation of Proposed Protocols for Assessing Vehicle LATCH System Usability," *SAE Int. J. Trans. Safety* 1(1):2013, doi:10.4271/2013-01-1155.

INTRODUCTION

The LATCH (Lower Anchors and Tethers for Children) system was mandated by FMVSS 225 in an effort to standardize the attachment of child restraints to vehicles and thereby make it easier to install child restraints. LATCH consists of two lower attachments on child restraints that connect to lower anchors located near the vehicle seat bight, and top tethers on forward-facing restraints that attach to anchors located on the rear shelf, seat back, floor or ceiling, or in the cargo area. The LATCH strap and lower connectors take the place of the vehicle seat belt as the primary means of securing the child restraint to the vehicle. The top tether provides a key additional attachment point that improves the performance of the child restraint by reducing head excursion; it should be used when the child restraint is

installed with either the lower attachment webbing or vehicle seat belt.

Many vehicles do allow easier child restraint installation with LATCH compared to seatbelts. However, in other vehicles the LATCH hardware makes child restraint installation difficult, and outright incompatibilities between child restraints and particular vehicles have been documented [9]. Many people do not use LATCH hardware, particularly the tether, and some do not use it correctly [1,4].

A three-phase study was conducted to identify the characteristics of LATCH systems in vehicles that make them easier to use. The first phase was a survey of 98 top-selling 2010-11 model year vehicles to document the characteristics of the LATCH systems. The second phase involved volunteer testing to relate the quality of child restraint installations to

specific vehicle LATCH features [5]. The third phase, reported here, involved using and evaluating proposed International Standards Organization (ISO), Society of Automotive Engineers (SAE), and National Highway Traffic Safety Administration (NHTSA) protocols for assessing the ease-of-use of LATCH systems and vehicle-child restraint compatibility.

The SAE Child Restraint Systems (CRS) Subcommittee and ISO TC22/SC12/WG1/TF2 have drafted procedures and tools for assessing LATCH usability and the compatibility between vehicle and child restraints when using LATCH [2,8]. The SAE procedures generally specify tools and procedures for quantifying properties of hardware configurations, while the ISO procedures focus on instructions and labeling and more qualitative assessments of hardware usability. While some manufacturers and agencies may have used these procedures as design guidelines, no comprehensive assessment of LATCH usability based on these procedures and tools has been published. NHTSA has also recently proposed a consumer “child restraint fit” information program [6] whereby vehicle manufacturers would provide a list of child restraints that fit in each vehicle model beginning with 2012 model year vehicles. NHTSA has provided sample evaluation forms and procedures, but has not demonstrated that installation errors would be reduced when using recommended child restraints in each vehicle. NHTSA has requested comments on the proposed procedures, but has not yet issued response to comments as of December 2012.

This paper documents the usability of LATCH systems in 2010-2011 vehicles and assesses the interaction between particular pairings of child restraints and vehicle models using proposed rating systems. Whether vehicles that meet SAE recommended practices achieve good scores using the ISO rating system is explored. The ratings from each system also are compared to volunteer test results to identify whether good SAE, ISO, and proposed NHTSA ratings predict improved usability and lead to better child restraint installation by volunteer subjects.

METHODS

SAE Draft Recommended Practice

The SAE Child Restraint Standards Committee drafted “Guidelines for Implementation of the Child Restraint Anchor System or LATCH System in Motor Vehicles and Child Restraint Systems.” [7]. The intent of the guidelines is to help vehicle and child restraint manufacturers improve the compatibility of child restraints and vehicles using LATCH. The current project focuses on SAE's proposed recommended practices dealing with vehicle design, which includes evaluations of lower and tether anchors as well as the vehicle seat. The vehicle-focused parts of the recommended practice are summarized below, while details are reported elsewhere [5,8].

1. Can the child restraint fixture attach to the lower anchors?

2. Is the force to attach lower anchors less than 75 N (16.9 lbf)?
3. Is the clearance angle (i.e., the amount of tool rotation allowed when the fixture is attached to the lower LATCH anchor) as measured with the specified angle measurement tool greater than 75 degrees?
4. When resting unattached on the vehicle seat, is the lateral angle of the child restraint fixture less than 5 degrees?
5. When installed on the lower anchors, is the pitch angle of the child restraint between 5 and 20 degrees?
6. Does the collinearity tool attach to the lower anchors?
7. Does the angle measurement tool contact any rigid structure around the lower anchors?
8. When installed, is the distance from the Z-point on the child restraint fixture to the seat cushion less than 51 mm?
9. Are tether anchors marked with the ISOfix symbol?
10. Are lower anchors marked with the ISOfix symbol?
11. If a tether router is present, does it accommodate the tether hardware clearance tool?

All measurements pertaining to the SAE guidelines were completed using tools specified in the reference document, but a few modifications to the protocols were necessary. The procedure to measure attachment force could not be performed as written in the draft recommended practice. The SAE document directs the user to slide the force gauge along the seat cushion until it can be attached. The intent is to simulate how a child restraint with rigid anchors would need to be installed. However, it was not possible to attach the gauge from this angle in many vehicles, and the procedure was not repeatable among different testers. Instead, the approach angle requiring the least amount of force to attach the gauge to the lower anchors was identified, and three force measurements were taken at this angle and averaged for use as the measurement attachment force for that anchor.

The SAE Recommended Practice refers to a child restraint fixture used in FMVSS 225. There are two different child restraint fixtures included in FMVSS 225. The current study used the fixture shown in Figure 1 which is intended to represent a composite profile of forward-facing and rear-facing child restraints. The profile of this fixture would be more likely to have interference with head restraints, an outcome of interest for the current study.

The proposed SAE recommended practices do not result in a composite usability rating. For this study, an overall measure of usability, referred to as the SAE grade was derived for each vehicle. The number of criteria met was tabulated, and a percentage score out of a possible total of 10 or 11 (if a tether router is present) was calculated. Criteria that could not be evaluated were counted as not passing.

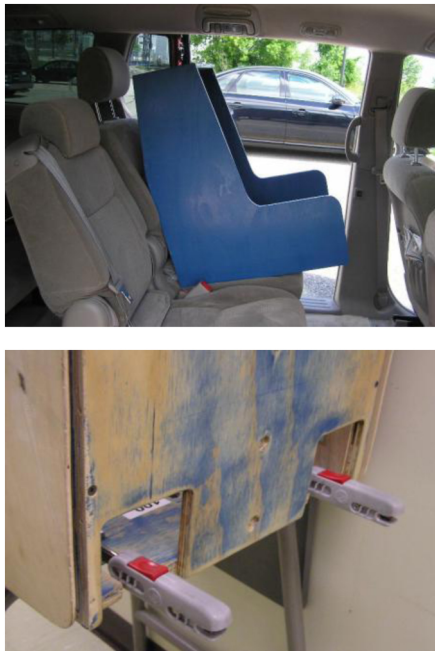


Figure 1. Child Restraint Fixture installed in vehicle and close-up of rigid connectors.

ISO Usability

In November 2010, the ISO TC 22/SC 12/WG1 published a final version of ISO 29061-1:2010 “Road vehicles - Methods and criteria for usability evaluation of child restraint systems and their interface with vehicle anchor systems - Part 1: Vehicles and child restraint systems equipped with ISOFIX anchors and attachments” [2]. The current paper refers to this document as the ISO LATCH Usability Rating System. A supplementary document [3] gives additional details and examples of how to score each item.

The ISO LATCH Usability rating system provides forms for assessing the child restraint, the vehicle, and the child restraint/vehicle interaction. Each assessed item receives scores of 0, 1, or 3, with a higher score indicating better usability, and each item has an assigned weighting factor of 1, 2, or 3 based on its safety impact. A percentage rating across all the items is calculated using the sum of the scores times the weight, divided by the total possible highest score. The highest possible scores vary based on the vehicle and child restraint combinations, so using a percentage allows comparison across different styles of child restraint. For example, with the vehicle-child restraint interaction ratings, the highest possible scores were 60 for a rear-facing convertible or 84 for a rear-facing infant seat with separate base. Scores are calculated separately for each child restraint, vehicle, and vehicle-child restraint interaction in a particular seating position. There is no method for combining the different scores, or for developing an overall vehicle rating based on multiple seating positions.

Vehicle assessment

The first section of the vehicle assessment evaluates whether the manual clearly indicates the locations of the lower and tether anchors, and whether the manual is clear regarding how the tether should be routed. The next section assesses whether the lower and tether anchors are visible and marked with the recommended ISO symbols. In addition, the vehicle is assessed to determine if the tether anchor hardware is unambiguous or whether there is potential for confusing it with other hardware.

The number of actions required to use the lower anchors and tether anchors is counted. A description of any covering for the lower and tether anchors is noted because the ISO form records whether there are any steps needed to prepare to use the anchors, and some may require opening a door, cover, or panel to access the anchors.

The ISO form evaluates the usability of the anchors according to the following descriptions:

- Good (score of 3): can attach on each anchor without additional actions; sufficient clear space around the anchors
- Average (score of 1): can attach on each anchor after single action, e.g. one-handed depression of seat cushion, or moving seat belt buckle or other feature such as head restraint out of the way
- Poor (score of 0): cannot attach or not accessible without tools, physically modifying seat, or extreme effort.

For the current evaluation, data collected from some of the SAE procedures were used to quantify whether the anchors were usable according to the qualitative descriptions of the ISO rating system. Tether anchor usability was given a score of good unless there was a tether routing device that did not accommodate the SAE tool for checking clearance, in which case it was scored poor. Lower anchor usability was given a score of poor if the measured attachment force was 13.6 N or greater, if the clearance angle was less than 40°, if the anchor depth within the bight was over 8 cm, or if the clearance angle tool could not be attached to the anchor. These outcomes were considered to be extreme effort. Lower anchor usability received an average score if the anchors were located 6-8 cm within the bight, because this depth would require depression of the seat cushion to access. Other lower anchor conditions receive a good score.

Finally, the potential for interference from seatbelt hardware with use of the lower anchors was assessed two ways. Vehicles received a poor rating if there was potential contact with a rigid vehicle structure. Lateral measurements were used to document the minimal distance between each lower anchor and the nearest belt webbing or hardware. Vehicles received a poor score if the minimal distance for the 2L seating position was 0-35 mm, average if the distance was 36-70 mm, or good if the minimum distance was at least 71 mm.

Table 1. Example ISO vehicle-child restraint interaction rating

	Evaluation Item	Weight	Possible Scores	Example: Frontier /Soul	Weighted score	Best possible score	ISO % Rating
3.1.1	Are ISOFIX anchors usable (on child restraint)?	3	3/1/0	1	3	9	
3.1.2	Are ISOFIX attachments accessible during process?	3	3/0	3	9	9	
3.1.3	Is there clear feedback on correct ISOFIX attachment?	3	3/1/0	1	3	9	
3.1.4	Can ISOFIX attachments be tightened?	3	3/1/0	1	3	9	
3.1.5	Hidden slack possible?	3	3/1/0	1	3	9	
3.1.6	Harness fully operable?	3	3/0	3	9	9	
3.2.1	Number of actions required to attach tether	2	3/1/0	3	6	6	
3.2.2	Can top tether be tightened properly?	3	3/1/0	1	3	9	
3.2.3	Is there clear feedback on tether attachment?	3	3/1/0	1	3	9	
3.3.1	Number of actions for primary ARD	2	3/1/0	NA			
3.3.2	Number of actions for secondary ARD	2	3/1/0	NA			
3.4.1	Are child restraint base and shell ready for install?	2	3/1/0	NA			
3.4.2	Number of actions to attach child restraint to base?	2	3/0	NA			
3.4.3	Is there clear feedback on correct locking to base?	3	3/1/0	NA			
3.4.4	Number of actions to detach child restraint base	1	3/1/0	NA			
3.5.1	Ease of releasing top tether tension	1	3/1/0	0	0	3	
3.5.2	Number of actions to detach and store top tether	1	3/1/0	3	3	3	
3.5.3	Ease of releasing tension of flexible child restraint	1	3/1/0	1	1	3	
3.5.4	Number of actions to remove and store primary ARD	1	3/1/0	NA			
3.5.5	Number of actions to remove and store secondary ARD	1	3/1/0	NA			
3.5.6	Number of actions to detach from lower anchors	1	3/1/0	3	3	3	
		Sums of weighted scores:			49	90	54%

Items listed in gray do not usually apply to US products. ARD=anti rotation device, such as support leg

Vehicle-child restraint interaction

For the vehicle-child restraint interaction assessment, the procedure first examines whether the lower anchors are usable with this particular child restraint, whether they remain accessible during installation, and what type of feedback is available (visible/tactile/audible) to determine if the lower connectors are appropriately attached. The form is used to assess whether the LATCH belt can be tightened, although this refers to the ability to adjust the LATCH belt, not whether it can be tightened sufficiently. It also evaluates whether the harness can be adjusted after installation and if there is potential for hidden slack in the LATCH belt. The ISO evaluation also assesses the actions to attach the tether, whether it can be tightened, and what type of feedback is available to ensure correct attachment. If the child restraint has a separate base, the form is used to record whether the shell and base are ready for installation, the actions required to attach the shell to the base, feedback available on connection, and the number of actions to remove the shell

from the base. Finally, the form is used to record the ease of releasing the tether and LATCH belt tension, the actions required to remove the LATCH belt, and the actions required to detach and store the tether. The form includes a few other assessments to address features relevant to design features found primarily on European child restraints, such as a support leg. [Table 1](#) shows an example of the ISO vehicle-child restraint interaction form using the Britax Frontier and the Kia Soul, which scored 54% out of a possible 90 points.

NHTSA Fit Program

In February 2011, NHTSA proposed a consumer information program for assessing the fit between a vehicle and child restraint [6]. While usability is not directly assessed in this program, the proposed procedures address vehicle-child restraint compatibility which is a factor in usability. For a child restraint to be listed by a vehicle manufacturer as fitting in a specific vehicle, the child restraint must be able to be installed in all rear seating positions, using any available installation method (seatbelt or LATCH). In addition,

participating in the program to list their vehicle-child restraint fit data on NHTSA's safercar.gov website, manufacturers must recommend at least three child restraints in three categories (rear-facing, forward-facing, booster) for use in the vehicle, and their recommendations must include products in each price range.

Different assessment forms are proposed for use with each mode of child restraint (rear-facing, forward-facing, booster). The forms review whether tethers can be appropriately attached and tightened. For LATCH installations, the forms document whether the lower anchors can be attached properly, and be tightened, and if the seatbelts in the adjacent seating position can be used. For seatbelt installations, possible problems with belt geometry, seatbelt length, buckle interference, or latch plate button interference are documented. (A latch plate button is the plastic button inserted through belt webbing to keep the latch plate easily accessible, but sometimes the button does not allow a seatbelt to be sufficiently tightened during child restraint installation.) For any type of installation, whether or not at least 80% of the bottom of the child restraint contacts the vehicle seat is assessed, as well as the tightness of the installation and the ability to operate the harness. For rear-facing installations, the ability to meet manufacturer's instructions regarding contact with the vehicle front seat is evaluated. The ability to be installed at the correct recline angle (without using a rolled towel or pool noodles) and the proper use of available anti-rotational devices, usually tethers, are also assessed. Finally, the form notes whether the child restraint can be installed while following the instructions of both the restraint manufacturer and the vehicle manufacturer. (An example of failing this criterion is that the child restraint can be installed, but not at the vehicle seatback angle specified by the manufacturer.) For forward-facing installations, potential interference with head restraints is evaluated. For booster seat evaluation, the form primarily assesses whether the booster can be placed in a stable manner with access to the seatbelts but belt fit provided by the booster is not assessed.

Vehicle and Child Restraint Selection

Ninety-eight top-selling vehicles were evaluated using the elements of the previous three usability/compatibility protocols. Vehicles with 2010 or 2011 model year availability were selected if they had high volume sales figures reported in the 2008 Ward's Automotive Yearbook, or if they were recommended as family vehicles by several automotive, consumer, or parenting magazines and websites. The list was expanded to include at least one vehicle from the most common product lines. A few more were added based on an informal survey of several child passenger safety technicians to identify vehicles with challenging LATCH systems. Since the vehicles have multiple seating positions with LATCH, the second-row left (2L) seating position was used for comparisons among vehicles.

As the ISO and NHTSA procedures evaluate interaction between specific child restraints and vehicles, various child restraint types and features were used in the evaluations. A rear-facing infant seat with base, a convertible child restraint (installed both forward-facing and rear-facing), and a combination seat (used as a forward-facing restraint with harness) represented each of the main types of child restraints, with the combination seat likely providing a taller volume (and increased potential for head restraint interaction) than the forward-facing convertible. In addition, these child restraints provide examples of the different types of lower connector hardware. Two infant child restraints, two convertible child restraints, and two forward-facing only child restraints were selected that met the following criteria:

- One of each pair had hook-on and the other push-on lower connectors
- Six different manufacturers
- A variety of widths, heights, contours, and tether attachment locations
- Some popular products included
- Range of prices

In addition, a Magna Clek Olli booster with rigid lower anchors was included because at the time of the study there were no harnessed restraints with rigid lower anchors sold in the U.S. [Table 2](#) shows the seven child restraints that were selected. The information below each illustration shows the approximate price range; the product height, width, and depth; and the weight range and location where the tether attaches to the child restraint relative to the floor.

Twenty vehicles were selected from the 98 measured vehicles for the ISO vehicle-child restraint interaction assessments. These vehicles were selected to have a wide variety of LATCH systems and vehicle seat characteristics that may affect child restraint installation. Vehicles were categorized based on three measurements, characterizing the lower anchor hardware, the tether, and the vehicle seat. For each vehicle, the values of clearance angle around the lower anchors, the tether wrap distance, and the angle from the H-point to the bight were used to classify each vehicle in the upper or lower range of values measured in seat position 2L. This divided the vehicle list into eight groupings ($2 \times 2 \times 2$ combinations of high and low of three measures) with 8 to 18 vehicles in each category. To select 20 vehicles for the vehicle-child restraint interaction assessments, two or three were chosen from each of the eight groupings while trying to obtain a variety of vehicle manufacturers and vehicle types. [Table 3](#) lists the vehicles selected for evaluation. The column marked "grouping" indicates whether each vehicle was in the high (H) or low (L) category of clearance angle, tether wrap distance, and angle from estimated H-point to bight.