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Feasibility of Center LATCH

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16. Abstract

This paper explores the geometric feasibility of installing dedicated lower anchors in the center rear seating positions of vehicles. Analysis was based on a previous research study in which the lateral spacing of seat belt and LATCH lower anchorages were measured in 85 model year 2010-2011 vehicles.

The goal of this study was to determine how many vehicles would have the physical space to incorporate a third set of dedicated lower anchors in the center seating position for child restraint installation. Usability of all of the lower anchors, as well as the seat belts, was also considered. To begin, nine vehicles that currently have dedicated lower anchors in the center position were reviewed. The distances between all seat belt anchors and lower anchors across the vehicle sample were also analyzed to identify spacings that are currently feasible in production. The arrangement of seat belt and lower anchor hardware across the rear seat was also reviewed with respect to usability.

Based on these analyses, a lateral distance between the outboard webbing and outboard lower anchor of 75 to 100 mm is common. The suggested minimum distance between lower anchors and seat belt hardware is 25 mm. Based on these dimensions, vehicles with 710 mm or more between the outboard lower anchor centerlines (OBLACL) should have sufficient space to provide three sets of usable, dedicated lower anchors in the right, center, and left seating positions. Providing the highest level of usability with regard to use of seat belt or LATCH hardware in adjacent seating positions would be achieved by placing each pair of lower anchors between the webbing and buckle hardware for the seating position. If the OBLACL is less than 710 mm, an improvised center LATCH position (permitting use of the inboard lower anchors from the outboard seating positions to secure a child restraint in the center seating position) may be feasible. The maximum spacing of this improvised center LATCH position would be 480 mm. If a vehicle allowed an improvised center LATCH position, placing the inboard lower anchor between the outboard buckle and nearest center seat belt hardware would maximize usability of the seat belt in the outboard seating position and lower anchors in the center seating position.

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We would like to acknowledge the Insurance Institute for Highway Safety for sponsoring the study on LATCH usability, in which the data analyzed in the current study on seat belt and lower anchor spacing were collected.

INTRODUCTION

Overview

FMVSS 225 requires that each vehicle provide two seating positions with LATCH and at least one additional seating position (if present) with a tether anchor. To meet this requirement, most vehicle manufacturers equip a second row of seating with LATCH anchors in the two outboard positions plus a top tether anchor in the center seating position.

This most common configuration meets the regulatory requirements. However, it poses a conflict for caregivers who want to use LATCH to install their child restraints, but also want to follow best practice recommendations to install a child restraint in the center seating position when possible (NHTSA 2014). Some vehicle manufacturers allow use of an improvised center LATCH position, where the inboard lower anchors from the two outboard seating positions can be used to secure a child restraint equipped with flexible lower attachment hardware. (In this report, we use the term "LATCH belt" to refer to the child restraint hardware consisting of webbing attached to lower connectors that is usually routed through the child restraint belt path to attach the child restraint to the vehicle lower anchors.) Since the spacing of the improvised center lower anchor hardware does not usually meet the regulated distance between anchors of 280 mm, using an improvised center LATCH position is only suggested if both the vehicle and child restraint manufacturers allow the practice.

Objectives and Approach

This paper explores the geometric feasibility of installing dedicated lower anchors in the center rear seating positions of vehicles. The analysis includes review of the vehicle seat belt and LATCH hardware geometry measured in a prior survey of vehicle rear seats (Klinich, Flannagan, Manary, & Moore, 2012), with a particular emphasis on the few vehicles that already have dedicated LATCH hardware in the center seating position.

In addition to considering the lateral spacing of the vehicle seat belt and lower anchor hardware across a seating row, the analysis considers the usability of such hardware as a function of its proximity to other hardware. The paper also includes discussion of the barriers to implementing center LATCH hardware gathered from informal discussions with vehicle manufacturers. Finally, the paper includes vehicle seating dimensions that appear to be sufficient for either providing dedicated center LATCH hardware or allowing an improvised center LATCH position. All measurements and presentation of data are from the viewpoint of someone installing the CRS in the second row, such that the 2L seating position behind the driver would be to the observer's right.

Usability considerations

The original intent of the LATCH system was to reduce installation errors by making child restraints easier to install. While the LATCH hardware does make installations easier in many vehicles, in some vehicles the LATCH hardware is difficult to use and some child restraints cannot be installed using LATCH. A common complaint with current vehicles is that seat belt hardware can interfere with use of lower anchors, either by making the lower anchors hard to find or by blocking access to the lower

anchors. If two additional lower anchors would be added to a row of seating, the potential for seat belt interference could possibly increase.

To improve usability at all seating positions, spacing between the vehicle seat belt and lower anchor hardware should be considered. In addition, the benefits of providing center LATCH might be offset by making all LATCH positions harder to use. Since seat belt webbing is approximately 50 mm wide, spacing the centerline of a seat belt at least 50 mm from the centerline of a lower anchor would be sufficient to prevent the width of the seat belt from overlapping with the lower anchor. However, a spacing of 25-49 mm might be considered acceptable because at least half of the lower anchor would not be blocked by the seat belt. For seat belt components, spacing between them is not as critical for typical occupant use because unlike the lower anchor, the user is not attaching anything near the seat belt anchorage. Some vehicles "share" anchorage locations for the outboard buckle and center seat belt hardware components. An example is shown in Figure 1, where there is at least 50 mm between the lower anchors and the nearest seat belt hardware, but the center and outboard seat belt anchorage locations are less than 25 mm from each other. Although many vehicles have the center and outboard seat belt hardware placed close together, wider spacing between seat belt anchorages might improve the ability to install child restraints in adjacent seating positions using the seat belt. For this reason, keeping seat belt anchorages at least 25 or 50 mm apart was also evaluated when considering lateral seat belt anchorage locations.

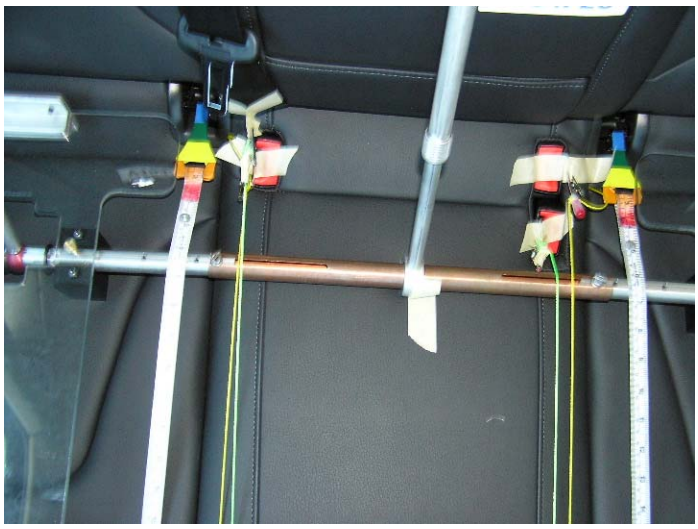


Figure 1. Example with at least 50 mm lateral spacing between lower anchors (attached to measuring tape) and nearby seat belt hardware (yellow and white strings), but less than 25 mm between seat belt hardware anchors for the outboard and center positions.

Another point to consider is the usability of seat belts in adjacent seating positions when lower anchors are used. The following arrangement of hardware would likely minimize interference between seat belts and lower anchors in adjacent seating positions: webbing, lower anchors, buckle; buckle, lower anchors, webbing; buckle, lower anchors, webbing. (However, the buckle and webbing positions could be switched for the center seating position.) This would potentially allow use of the lower anchors or seat belt in each seating position without interference with the adjacent seating position. For the current study, this arrangement is called "preferred."

Figure 2. Example of "preferred" anchorage arrangement with lower anchors for the outboard positions placed in between the seat belt anchors for those positions.

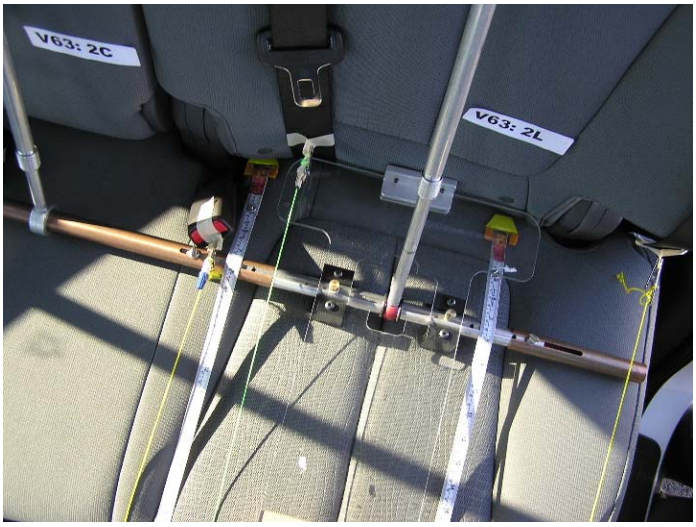


Figure 3. Example of anchor arrangement where LATCH belt and center seat belt webbing would have to cross if child restraints are installed in adjacent positions.

The arrangement of lower anchors and seat belt anchors is particularly important relative to booster use. There is a trend for some boosters to be attached to lower anchors even though the child is restrained by the vehicle seat belt. Some arrangements of lower anchors and seat belt anchors would make this installation difficult or impossible because the buckle stalk and LATCH belt would need to cross each other.

Barriers to center LATCH

The information in this section was gathered from informal conversations with representatives of vehicle manufacturers. It provided insight and motivated some of the analyses described in the methods and included in the results. Some statements are opinions of the representatives and are not necessarily shared by the authors.

In many second row seats, it appears that there might be sufficient space to provide center LATCH hardware if the hardware for the outboard positions could be shifted further outboard. However, the seat contours, seat belt hardware locations, and lower anchors are often designed to shift the outboard occupants towards the vehicle center for several reasons. First, the presence of door- or roof-mounted airbags makes it desirable to leave some space between the occupant and the door to prevent severe loading to occupants very close to the airbag. Second, rooflines over the rear occupant compartment have evolved to have lower contours. In these cases, designing the rear seat to shift the outboard occupants towards the center provides more headroom.

Vehicle manufacturers report a high demand for rear seats that fold down and/or stow, even in sedans. The hardware for the hinges is located near the zone where the lower anchors need to be positioned.

Sometimes hinges are present within the seat and not visible. The prevalence of fold-down seats has led to many vehicles with seats split 50-50 or 60-40. In some of these vehicles, the left and right lower anchors for a center seating position could be on different seat components. Sometimes the fore-aft position of these seats can be shifted independently, which would cause the pair of lower anchors to be offset from each other.

The center seating position is often designed to be narrower than the outboard seating positions. Even if dedicated center LATCH hardware was provided, it may be physically impossible for a child restraint to fit in that location. Sometimes the contour of the center seating position may also prevent child restraint installation.

Finally, comfort and style are important factors that manufacturers consider when deciding if lower anchors can be added to the center seating position. Some vehicle manufacturers also prioritize centering seat belt anchor locations about the centerline of the vehicle seat position. Some vehicle manufacturers indicated that the strength requirements to test three LATCH positions simultaneously could be challenging. Allowing greater displacements or not requiring all positions to be tested simultaneously in FMVSS No. 225 might make it easier to meet requirements.

METHODS

Data Measurement

The data on lateral spacing of seat belt and lower anchors were collected as part of a previous study; details of the measurement procedure have been published elsewhere (Klinich, Flannagan, Manary, & Moore, 2012). However, relevant measures analyzed in the current study are summarized here.

A survey was conducted of 98 model-year 2010 and 2011 vehicles that were identified as top selling vehicles likely to be used by families. The vehicles include models representing approximately two-thirds of the vehicle sales of 2009. Of those 98 vehicles, 85 included center seating positions in the second rows and are included in the current analysis.

To document implementations of LATCH vehicle hardware in the sample of vehicles, a reference fixture was developed that provides a common origin near the average H-point of rear seating positions measured in 56 vehicles for measurements in the XZ plane. The fixture design was modeled after a fixture developed by Huang and Reed (2006) to measure cushion angle and length in a survey of vehicle rear seat geometry. As shown in Figure 4, the average distance between the H-point and the undeflected seat contour was 50 mm (standard deviation 16 mm), and the average distance from the H-point rearward to the seat back was 135 mm.

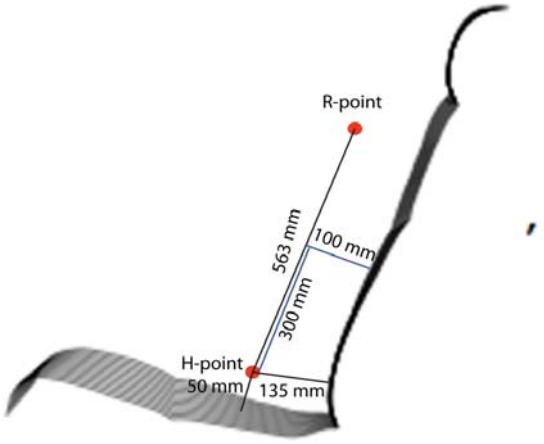


Figure 4. Illustration of average location of H-point.

The reference fixture is shown installed in a vehicle in Figure 5. It is designed so the top centerline of the bar that extends across the seating row approximates the location of the H-point. The bar adjusts so the T-shaped plates can be placed at the centerlines of the outboard seating positions. The shape of the clear T-shaped plate matches the contour of the H-point manikin at the level of the H-point where it would contact the seat back. The fore-aft distance between the back of the T-plates and the H-point origin is set to be 135 mm, while the vertical standoffs are set to be 50 mm tall.

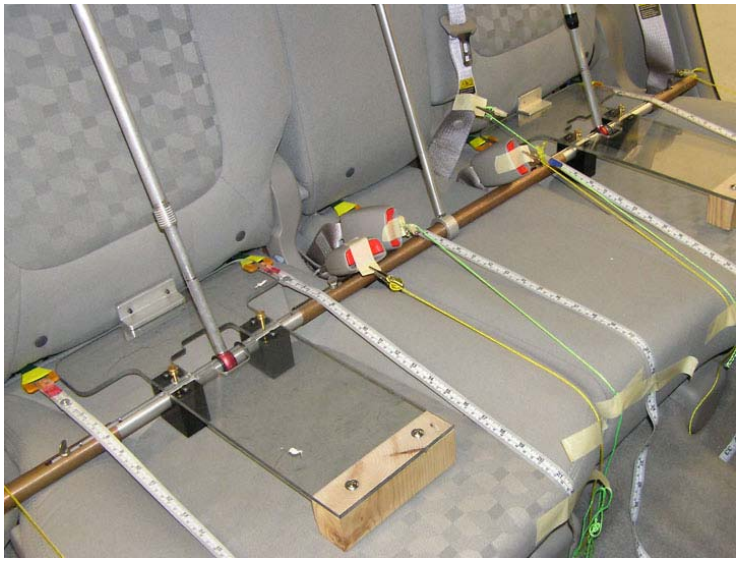


Figure 5. Reference measurement fixture.

The current study analyzes the lateral measurements between lower anchors and seat belt anchors. The tape measures attached to the multi-colored hooks are attached to the lower anchors. The yellow strings are attached to the approximate centerline of each seat belt buckle anchor or webbing anchor for the outboard seating positions, while green or white strings are used for the center seating position. The lateral locations are measured along the origin bar using the vehicle centerline as the origin. For each seating position, a vertical rod is placed at the seat centerline based on the location of the head restraint center or other indications from the upholstery.

Analysis

For the current study, the lateral distances between anchor locations were calculated. Analysis of measures across vehicles included calculating quartiles, minimum, maximum, mean, and standard deviations. The distances analyzed include:

- Distance between seat belt anchors at each seating position;
- Distance between outboard lower anchor and outboard webbing;
- Distance between inboard lower anchor and inboard buckle;
- Distance between inboard lower anchor and nearest center seat belt hardware;
- Distance between left and right buckle anchors; and
- Distance between center position lower anchors and nearest lower anchor for outboard seating position (where present).

In addition, a measure of seat width was developed for this study termed the outboard lower anchor centerlines (OBLACL). The centerline between each pair of lower anchors for the outboard seating location was calculated by averaging the distance to the vehicle centerline from each lower anchor. The OBLACL distance was calculated by subtracting the right lower anchor centerline from the left lower anchor centerline. The OBLACL distance is used to represent the width of the rear seat and the general distance between the outboard seating positions. This dimension is used because while head restraint centerlines or upholstery contours can be used to approximate centerlines of outboard seating positions, consistent definition across vehicle manufacturers is difficult to achieve.

RESULTS

Current vehicles with dedicated center LATCH hardware

Nine vehicles with dedicated center LATCH hardware were measured. Figure 6 shows the lateral locations of the seat belt hardware and lower anchors for each vehicle, while top views of each seating position are shown in Figure 7. The Acura MDX has the preferred anchorage arrangement for the right seating position but not for the center/left positions. Use of a seat belt in the left seating position would make use of center lower anchors more challenging. The arrangement of anchors is similar in the Honda Ridgeline and the Honda Pilot, although the center/left anchors are even more closely spaced together and the left buckle is positioned in between the two lower anchors, which would make use of the center lower anchors somewhat easier compared to the Acura MDX when using the left seat belt. All three of these vehicles have a 60/40 split bench seat with the division located between the center and right seating positions. The Honda Odyssey has the preferred arrangement for each seating position, and each seat is hinged for stowing. In the Odyssey, although the lower anchors are relatively close to the seat belt anchors laterally, they are offset fore and aft in the outboard positions and vertically in the center position, which makes them somewhat easier to use.

The Chevrolet Malibu has the lower anchors shifted relative to the seat belt anchors so one of the seat belt anchors for a given seating position lies between the lower anchors for a given seating position. In addition, the arrangement of the lower anchors would make it possible to install child restraints with LATCH in the right and center positions at the same time, but not the center and left positions. The left seating position may not be usable if a child restraint is installed with LATCH in the center, as the child restraint may take up too much of the left seating position and the left buckle may be inaccessible. Although no hinges are visible, the seat back appears to have a seam that allows it to be folded down, with the seam located just to the right of the vehicle centerline.

The Chevrolet Tahoe included dedicated pairs of lower anchors in the center and right seating positions, but not the left. However, there is sufficient space to allow lower anchors in the left seating position as well. The Tahoe arrangement of anchors meets the preferred sequence of lower anchors between the seat belt anchors for a given position. There is a hinge between the center and right positions that allows the seat back to fold down in a 60/40 split.

The Chevrolet Impala has the anchorages arranged in the preferred configuration for all three seating positions. The Chrysler 300 and the Dodge Charger also have each pair of lower anchors placed between vehicle seat belt anchors.

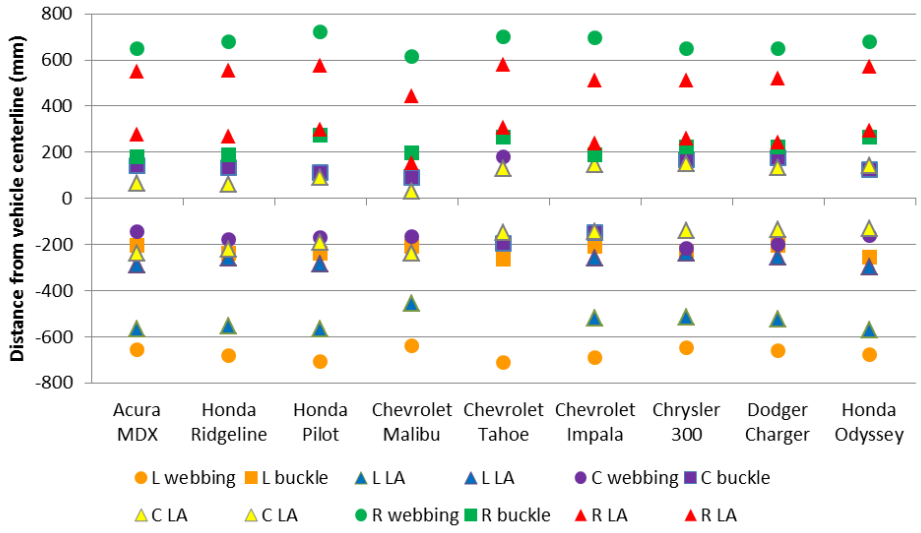
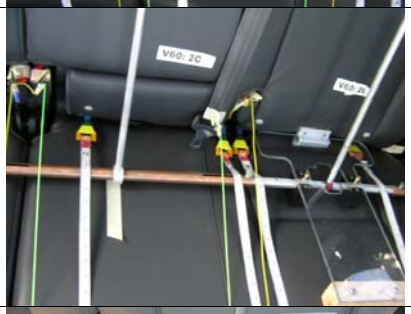
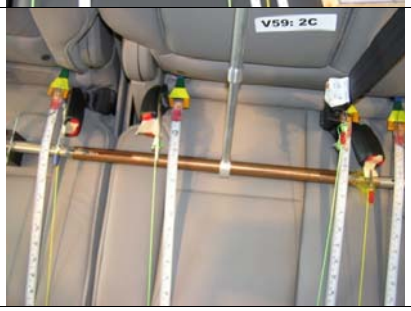
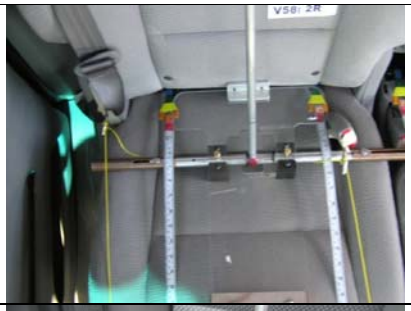
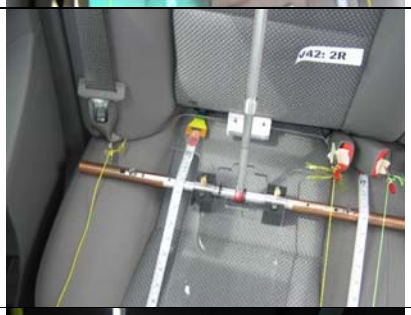
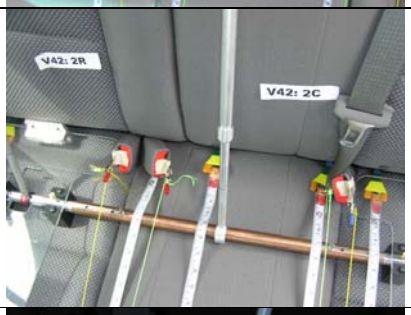
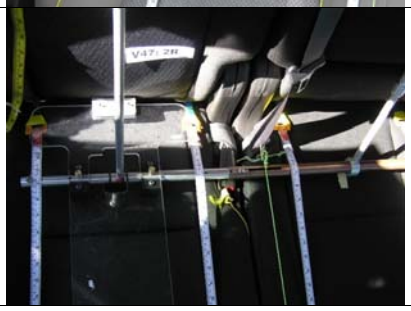
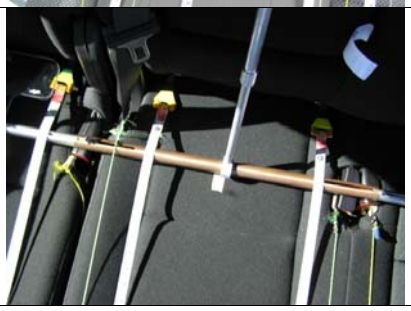


Figure 6. Lateral spacing of seat belt and lower anchors in vehicles that currently have a dedicated center LATCH position.

Figure 7. (next page) Top views of right, center, and left second-row seating positions in vehicles with dedicated center LATCH. Colored hooks with measuring tape indicate lower anchor locations, while yellow strings are attached to outboard seat belt hardware and white strings are attached to center seat belt hardware.

	2R	2C	2L
Acura MDX			
Honda Ridgeline			
Honda Pilot			

Honda Odyssey			
Chevrolet Malibu			
Chevrolet Tahoe			

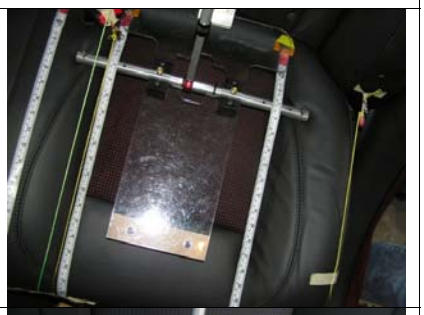
Chevrolet Impala			
Chrysler 300			
Dodge Charger			

Table 1 lists the spacing between seat belt and lower anchors in the nine vehicles with dedicated center LATCH. The first column lists the distance between the buckle stalk anchors for the left and right seating positions. In these vehicles, the values range from 385 to 528 mm, so if 280 mm of space is used for the center lower anchors, between 105 mm and 248 mm are available to position the center seat belt hardware. Almost all of these vehicles have over 100 mm between the outboard lower anchor and the outboard webbing, with the largest having 183 mm.

The next six columns report the distance between the inboard lower anchor for the left and right positions and the nearest seat belt hardware, and the left and right center lower anchors and the nearest seat belt hardware. Values are color-coded as red for less than 25 mm, orange for 25-49 mm, and green for greater than 50 mm. The relatively few values that are green illustrates the challenge in implementing dedicated center lower anchors that are usable, as it is difficult to position all of the lower anchors at least 50 mm from seat belt hardware to improve usability. The last two columns of the table list the distance between the left and right inboard lower anchor and the nearest center lower anchor. In most vehicles, the lower anchors are at least 90 mm apart, but they are much closer in the Honda Ridgeline and the left side of the Acura MDX.

Table 1. Lateral spacing between seat belt and lower anchors in vehicles that currently have center LATCH.

Vehicle	Distance between IB belt anchors	OB webbing to OB LA		Distance between IB LA and nearest belt anchor		Distance between center LA and nearest belt anchor		Distance between inboard and center LA	
		Left	Right	Left	Right	Left	Right	Left	Right
Acura MDX	385	89	102	85	98	35	76	50	214
Honda Ridgeline	430	125	125	80	20	19	71	39	9
Honda Pilot	513	140	145	46	28	35	20	93	211
Chevrolet Malibu	408	183	170	30	43	15	58	90	123
Chevrolet Tahoe	528	NA	122	NA	42	45	53	NA	179
Chevrolet Impala	398	170	181	52	50	5	39	115	95
Chrysler 300	458	135	137	5	36	66	40	119	109
Dodge Charger	427	136	129	49	23	76	40	119	110
Honda Odyssey	510	108	108	41	40	30	16	164	155

Current improvised center LATCH with standard spacing

The Ford Taurus is the only vehicle that designed the inboard lower anchors to meet the 280 mm standard LATCH spacing. While their efforts to create a "standard" improvised center seating position are commendable, the lower anchors are difficult to use. As seen in Figure 8, the left inboard lower anchor is located directly behind the center and left buckles, which cannot be stowed. The right inboard lower anchor is also close to the buckle and center webbing anchor. If the improvised center LATCH position is used, both outboard buckles are accessible. If the left LATCH is used, the center seat belt is accessible, but if the right LATCH is used, accessing center webbing might be hampered by the lower connector hardware. In addition, because the lower anchors are offset towards the center of the vehicle relative to the contours of the outboard seating positions (as well as the tether anchor), installation in the outboard positions with LATCH requires the CRS to perch on part of the center seat contour.

Figure 8. Arrangement of anchors in Ford Taurus, where the distance between the inboard lower anchors for the outboard positions is 280 mm.

Arrangement of seat belt anchorages and lower anchors across vehicle second rows

Among the 85 vehicle second-rows, there are 28 different arrangements and orders of webbing, buckles, and lower anchors. To describe the sequences, W stands for webbing, B stands for buckle and A stands for lower anchorage; upper case letters indicate outboard positions and lower case letters designate hardware for the center seating position. Appendix A contains photos of the top view of the center seating position for the vehicles in this study.

For the vehicles without dedicated center anchors, an example of the most common arrangements is shown in Figure 9. These vehicles place the pairs of lower anchors between the outboard seat belt buckle and seat belt webbing anchors, and place the center webbing and buckle between the outboard buckles. Using this arrangement, 24 vehicles place the center webbing to the right (WAABbwBAAW), while 14 vehicles place the center webbing to the left (WAABwbBAAW). The next most frequent arrangement is found in 16 vehicles, with an example shown in Figure 10, and places the center webbing inboard of the right or left buckle (WAAwBbBAAW or WAABbBwAAW). Seven vehicles position the center webbing between one of the pairs of outboard lower anchors (WAABbBAwAW or WAwABbBAAW), as shown in Figure 11. The last 14 vehicles (without dedicated center lower anchors) have unique arrangements of anchorage hardware.

Figure 9. Most common arrangement of each pair of lower anchors between the outboard position seat belt anchors, and center seat belt anchors between the outboard buckle anchors.

Figure 10. 2011 Honda Civic has the center webbing outboard of the left buckle (WAABbBwAAW)

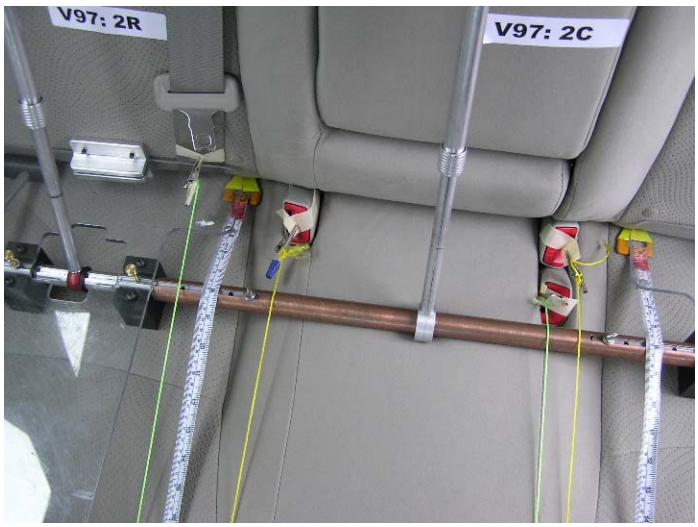


Figure 11. In the 2010 Toyota Prius, the center webbing is outboard of the right inboard lower anchor.

Several vehicles place the inboard lower anchors in between the buckles or buckle/webbing. An example is shown with the Dodge Caliber in Figure 12. This arrangement could facilitate an improvised center LATCH position, as the outboard buckles would still be accessible if the inboard lower anchors were used to secure a child restraint in the center using LATCH. The main disadvantage to this arrangement, with regard to child restraint use, is that it would be difficult to use a booster in the outboard seating positions if the child restraint manufacturer recommended securing it with the LATCH belt. The spacing in this vehicle provides at least 25 mm between each type of anchor.

Figure 12. Lower anchor placement between center and outboard seat belt hardware would be conducive to improvised center LATCH.

Current spacing of lower anchors and seat belt anchors

For the 85 vehicles in the study, an analysis was performed to calculate the current spacing between lower anchors and seat belt anchors. Appendix A also lists some of the key spacing dimensions for the vehicles considered in this study.

The distribution of distances between the webbing and buckle anchor for each seating position are shown in Figure 13. The minimum designated seating position is 330 mm wide (FMVSS 208), and the minimum lateral spacing between buckle and webbing is 165 mm (FMVSS 210). All but one of the outboard seating positions have spacing over 330 mm, while over half have outboard spacing of seat belt hardware greater than 400 mm. In contrast, over half of center seating positions have lateral seat belt spacing less than 350 mm, including two vehicles with close to the minimum allowed spacing. Table 2 lists the mean, standard deviation, minimum, quartile, and maximum values of seat belt hardware spacing for each seating position. The values for the left and right positions are similar, while the center position has lower values of each measure except for a larger standard deviation.

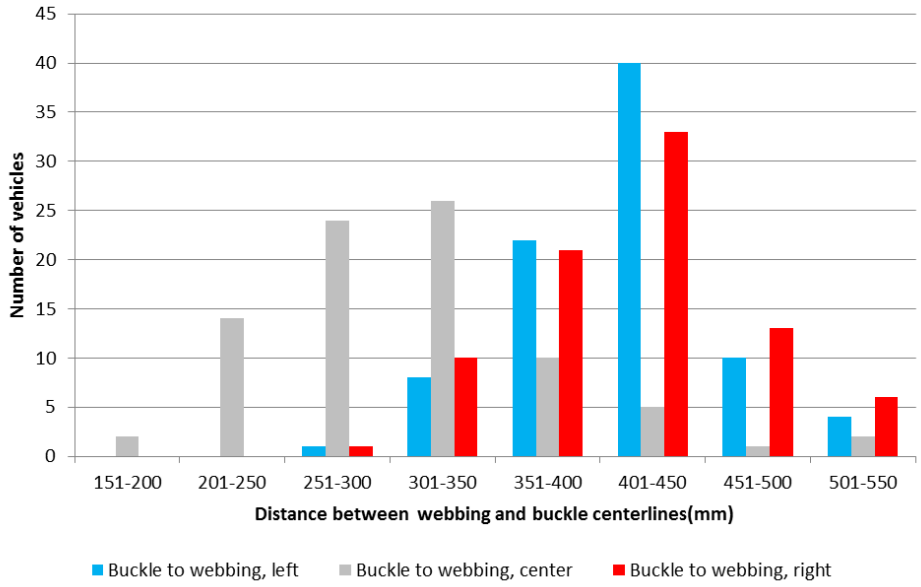


Figure 13. Distribution of vehicles by the lateral distance between seat belt buckle and seat belt webbing for each seating position.

Table 2. Measures of lateral distance between seat belt webbing and buckle for each seating position.

Seating position	Mean (mm)	Standard Deviation (mm)	Min	Q1	Q2	Q3	Max
Left	416	47	290	382	423	443	535
Center	307	68	179	263	303	341	522
Right	416	53	290	377	421	447	547

The distribution of vehicles according to the lateral spacing between an outboard buckle and the nearest center seat belt hardware is shown in Figure 14. Measures of these distances are summarized in Table 3. Overall, there is more space between the right buckle and center seat belt component than the left buckle and the center seat belt component; the mean distance is 52 mm for the left side and 70 mm for the right. In vehicles with a 60/40 split bench, the split is generally between the center and right position, so this may be the cause of the greater spacing on the right side. The most common spacing is 50 to 74 mm between the outboard buckle and center seat belt hardware. More vehicles have spacing lower than 50 mm compared to those with higher than 75 mm of distance. In a few vehicles, the

outboard buckle and the center seat belt component are less than 10 mm apart, indicating that the buckle and center seat belt hardware essentially "share" an anchor location.

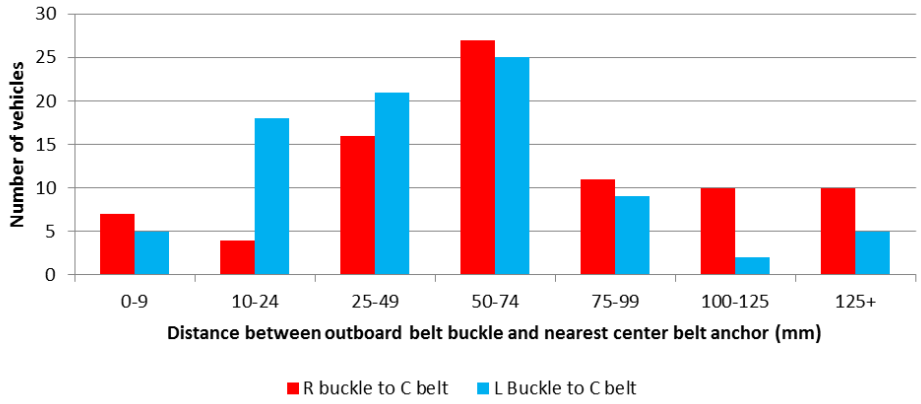


Figure 14. Distribution of vehicles according to the lateral distance between the outboard buckle and nearest center seat belt component (buckle or webbing).

Table 3. Measures of lateral distance between outboard seat belt buckle and nearest center seat belt component.

Belt hardware	Mean (mm)	Standard Deviation (mm)	Min	Q1	Q2	Q3	Max
Left to center	52	38	3	22	45	69	170
Right to center	70	45	3	41	61	91	235

Figure 15 shows the distance between the outboard seat belt webbing and the outboard lower anchors, while Table 4 shows the corresponding measures. In the Honda CR-V, the left LA was outboard of the left webbing, and in the Mazda 6, the right LA was outboard of the right webbing. In all other cases, the seat belt webbing is outboard of the lower anchors. All vehicles had at least 25 mm between the outboard LA and the webbing; several had over 175 mm. Values were similar for the left and right sides.

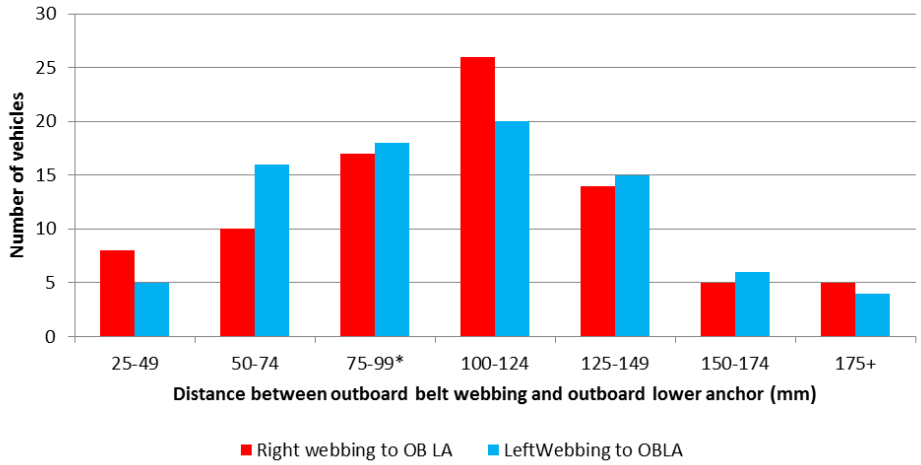


Figure 15. Spacing between outboard seat belt webbing and outboard lower anchor. * indicates one case each with LA outboard of webbing.

Table 4. Measures of lateral distance between outboard lower anchor and outboard seat belt webbing.

Anchor distance from	Mean (mm)	Standard Deviation (mm)	Min	Q1	Q2	Q3	Max
Left webbing to OB LA	104	44	-54	75	101	136	223
Right webbing to OB LA	104	46	-92	77	105	129	230

Figure 16 shows the distance between the inboard lower anchors for the left and right seating positions and the buckle for the seating position, as well as the nearest center seat belt hardware. There are only one or two vehicles where the buckle lies almost directly over the lower anchor. But there are 15 vehicles where the right buckle is less than 25 mm from the right inboard lower anchor, and 20 vehicles where the left buckle is less than 25 mm from the left inboard lower anchor. Interference with center seat belt and the lower anchor hardware is less common. In most vehicles, the inboard lower anchor lies 26 to 100 mm from the nearest outboard buckle stalk. Reviewing the data in the corresponding Table 5, results are similar for the left and right buckles except the maximum value, which is higher on the left. Regarding center seat belt hardware, the distances are usually closer to the left inboard anchor and the center seat belt hardware than the right inboard anchor and center seat belt hardware.

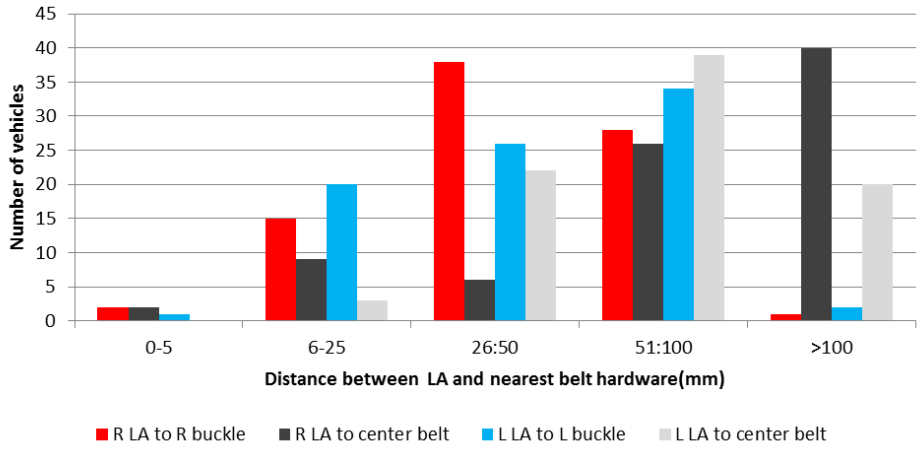


Figure 16. Distribution of vehicles by the lateral distance between inboard lower anchors of the outboard seating positions and the nearest seat belt hardware.

Table 5. Measures of lateral distance between seat belt webbing and buckle for each seating position.

Anchor location	Mean (mm)	Standard Deviation (mm)	Min	Q1	Q2	Q3	Max
Left LA to L buckle	48	33	5	27	49	60	264
Left LA to center belt	190	164	23	49	96	378	507
Right LA to R buckle	46	23	4	30	44	59	110
Right LA to center belt	215	133	19	105	158	326	525

Simulations of different anchor spacings

Some calculations were performed to determine the maximum width of a seating row required to allow three sets of usable lower anchors and seat belt anchors, without regard for seat folding hardware. For the spacing between the outboard webbing and the outboard LA, distances of 100 and 75 mm were considered to be feasible, as they correspond to values close to the mean of 104 mm and first quartile value near 76 mm. For the lateral spacing between the inboard lower anchors (as well as center) and the nearest seat belt hardware for the seating position, distances of 50 and 25 mm (close to the average and first quartile values across vehicles) were considered to be feasible. The different simulations are shown in Figure 17. The conditions for each scenario in the plot are as follows:

- Optimal: 100 mm between outboard webbing and outboard lower anchor, 50 mm between all other anchors. OBLACL distance of 860 mm.

- Possible: 75 mm between outboard webbing and outboard lower anchor, 25 mm between center position seat belt anchors and the left and right inboard seat belt anchors, 50 mm between other lower anchors and nearest seat belt webbing. OBLACL distance of 810 mm.
- Minimal: 75 mm between outboard webbing and outboard lower anchor, 25 mm between all other anchors. OBLACL distance of 710 mm.
- Shared 280 through Shared 430: 75 mm between outboard webbing and outboard lower anchor, 25 mm between all other anchors. Distances between inboard lower anchors of 280 through 430. OBLACL distances from 560 to 710 mm.

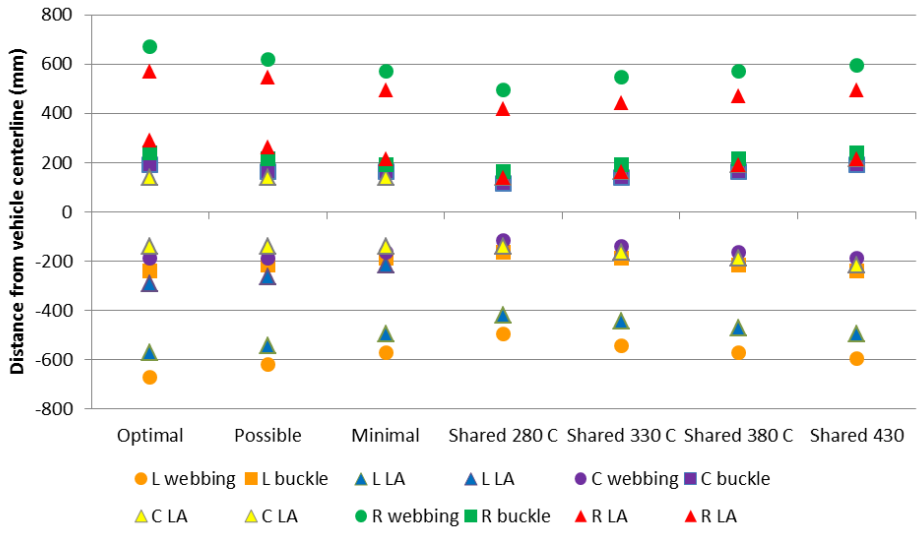


Figure 17. Simulations of possible seat belt and lower anchor configurations that would allow either dedicated center LATCH or improvised center LATCH.

For the minimal feasible center LATCH scenario, the distance between the OBLACL is 710 mm as illustrated in Figure 18. This would allow 280 mm of space for the center position lower anchors, and 75 mm of space to accommodate center and inboard seat belt hardware plus the inboard lower anchor for the outboard seating position. This also could allow placement of the center seat belt hardware at a lateral distance of 330 mm, which is the width of a designated seating position. (However, many vehicles have less than this distance between the center seat belt anchors as shown in Figure 13.) The arrangement of each pair of lower anchors between the seat belt anchors for a given seating position prevents interference of seat belt and LATCH belt hardware between adjacent seating positions. This also allows for attaching a booster seat to the lower anchors while keeping the seat belt hardware accessible in each seating position. If the spacing from the outboard LA and outboard webbing falls near the average of 104 mm rather than the minimum, the lateral distance between the outboard buckle and

webbing would be 409 mm (25+280+104), close to the mean lateral outboard seat belt distance of 416 mm.

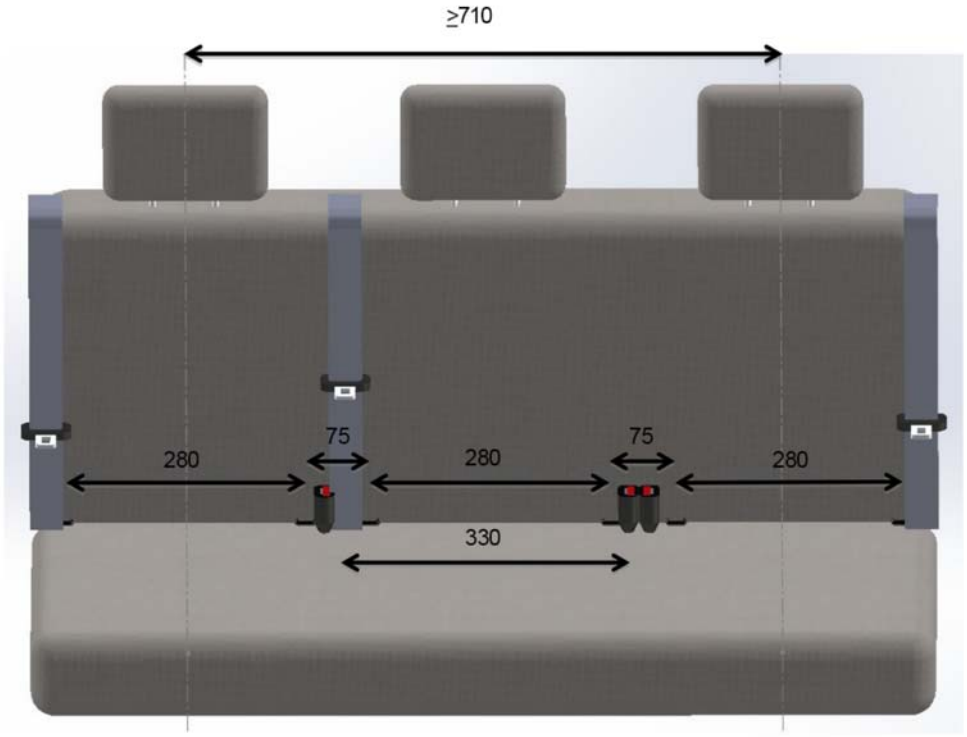


Figure 18. Suggested arrangement of seat belt anchors and lower anchors to allow provision of dedicated center LATCH hardware. Units are in mm.

For vehicles where the distance between the OBLACL is less than 710 mm, an improvised center LATCH position may be feasible. The maximum spacing between the inboard lower anchors would be 480 mm, which is within the range of non-standard lower anchor spacing shown in laboratory testing to produce acceptable kinematics (Manary, Whalen, Reed, Klinich, Ritchie, & Schneider, 2013). To facilitate use of the restraint hardware at all seating positions, placing the inboard lower anchor in between the seat belt hardware for the center and outboard seating positions would likely maximize usability. If improvised center LATCH was used to secure a child restraint, the outboard seat belts should not interfere. If the outboard LATCH hardware is used to secure a child restraint, the center seat belts are still accessible. This arrangement would need to have some flexibility in the buckle hardware so it could be stowed or moved to facilitate outboard child restraint installation with LATCH.

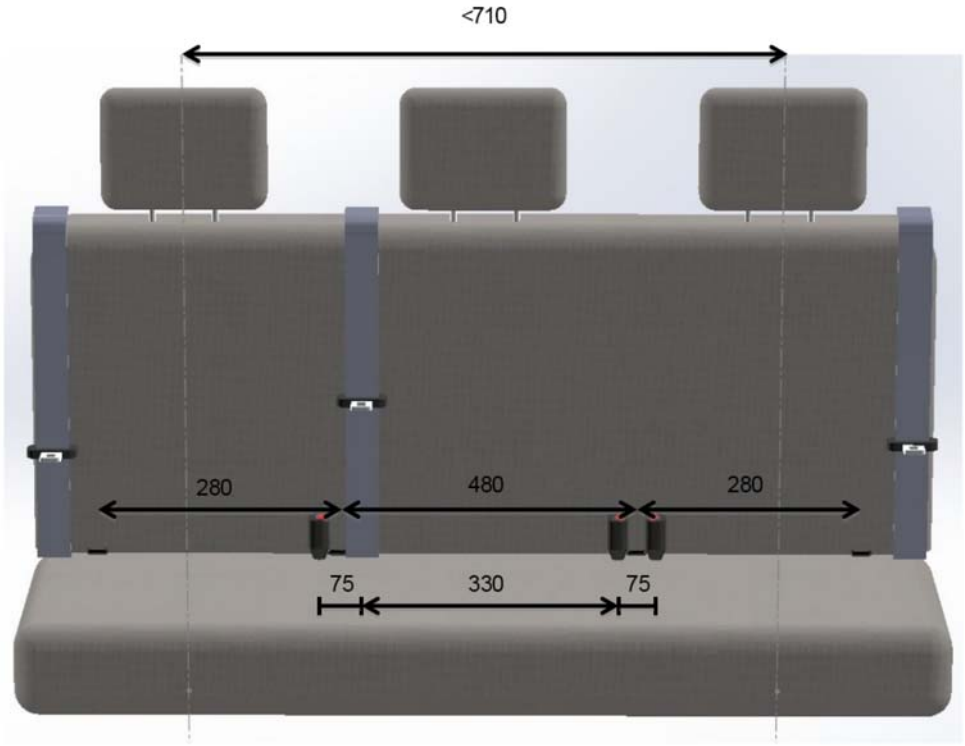


Figure 19. Suggested arrangement of seat belt anchors and lower anchors to maximize usability when using an improvised center LATCH seating position. Units are in mm.

Figure 20 shows number of vehicles according to the distance between the inboard lower anchors in the vehicles measured. For each bar, the vehicles currently with dedicated center LATCH are indicated by light blue, and vehicles with OBLACL distances above and below 710 are indicated with darker blue and red, respectively. Of the 85 vehicles, 13 would have an improvised center LATCH position with lateral spacing of 280-399 mm, while 24 would have an improvised center LATCH position with lateral spacing of 400-449. Only one of the vehicles with a dedicated center LATCH position, the Chevrolet Malibu, has a OBLACL distance less than 710 mm, but for this vehicle, the lower anchors for the center and left positions "overlap" and cannot be used simultaneously. For the remaining 8 vehicles that currently have dedicated center LATCH hardware, all have OBLACL distances greater than 710 mm. Half have between 450 mm and 550 mm of space between the inboard lower anchors of the outboard positions, while the other four have greater than 550 mm of space. This analysis suggests that instead of 11% of vehicles

with a dedicated center LATCH position, 56 percent of the vehicles measured could have a dedicated center LATCH position with a reasonable level of anchor usability.

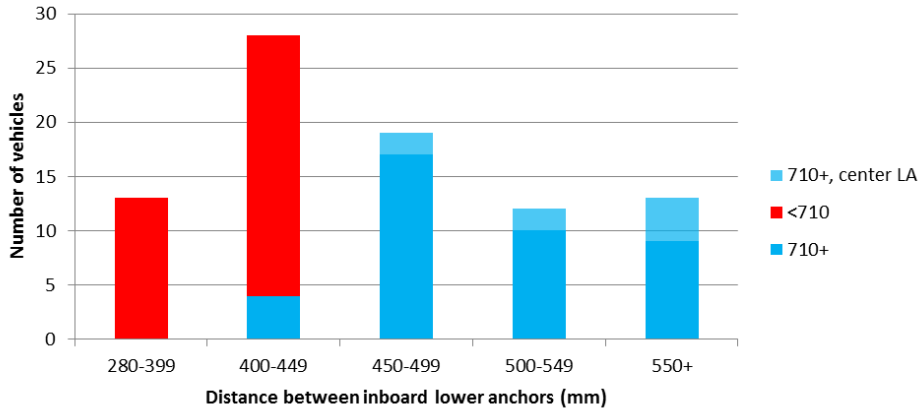


Figure 20. Distribution of vehicles by the outboard lower anchor centerline (OBLACL) and the distance between the current inboard lower anchors.

DISCUSSION

One of the limitations of this analysis is that it only used 85 vehicles. While these represent the highest selling models, they may not represent all vehicles. In addition, all of the vehicle model years are 2010 or 2011. Designs may have changed on more recent vehicles.

Another limitation of this study is that the suggested dimensions that might allow feasible center LATCH hardware do not account for spacing issues related to seat backs that fold down. Although the seat belt hardware spacing usually seems to be symmetric for the left and right outboard seating positions, the lower anchors in the right outboard seating position seem to be shifted more outboard relative to the seat belt anchors compared to the left outboard seating position. This may result from the 60/40 split seat found in many vehicles, where the right outboard seat is separate from the left and center seats.

This analysis does not consider changes to minimum lateral seat belt spacing that may facilitate child restraint installation with seat belts. In two vehicles shown in Figure 21, the spacing between the center webbing and buckle is less than 200 mm. This would make child restraint installation using the center seat belt challenging.

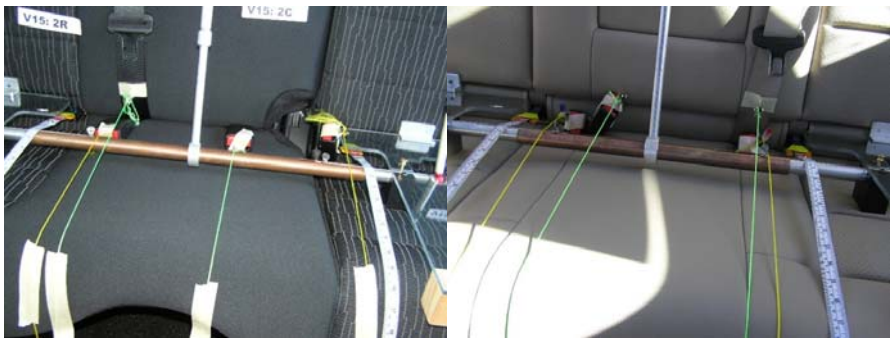


Figure 21. Vehicles in which lateral spacing between center seat belt anchors is less than 200 mm.

A number of vehicles already have vehicle seat designs that allow the seat belt buckles to be moved out of the way or stowed within recesses in the seat cushion. This feature facilitates child restraint installation using LATCH by minimizing interference between LATCH belts, lower anchors, and seat belt buckles. Seat belt buckles that are stowable would improve the feasibility of using an improvised center LATCH position.

The current analysis focused on the lateral spacing between anchors. In some vehicles, the lower anchors are offset fore/aft or vertically from the seat belt anchors, improving usability of the hardware. In addition, the usability of the lower anchors is also affected by the depth within the seat bight. These other dimensions between seat belt hardware were not considered in this study.

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Manary, M. A. , Whalen, J., Reed, M. P., Klinich, K. D., Ritchie, N., & Schneider, L. W. (2013). LATCH Anchor Loads and the Effect of Irregularly-Spaced Lower Attachments. (Report No. UMTRI-2013-24). Ann Arbor, MI: University of Michigan Transportation Research Institute.

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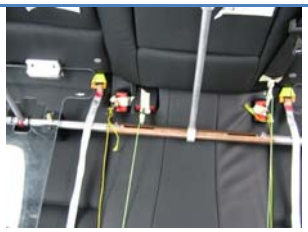
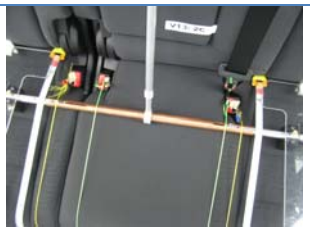
APPENDIX A: PHOTOS AND KEY DIMENSIONS OF VEHICLES

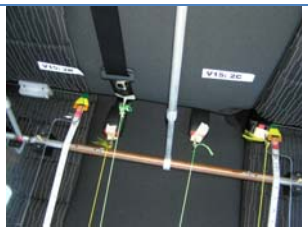
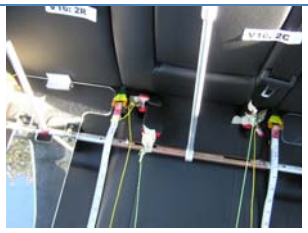
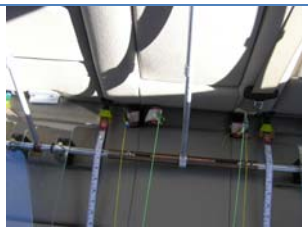
White strings: center belt hardware

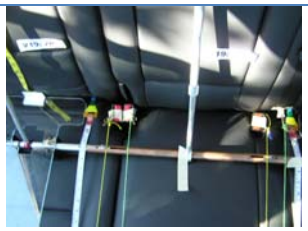
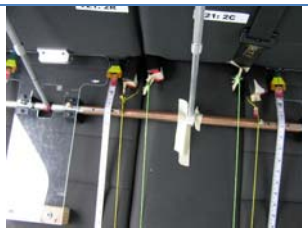
Yellow strings: outboard belt hardware

Use asterisk on preferred spacing column to indicate presence of dedicated center LATCH

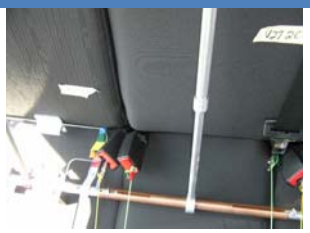
		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
BMW	328i		367	355	320		No
BMW	528i		265	432	335		No
Chrysler	300		384	499	458		Yes*
Dodge	Avenger		154	397	364		No

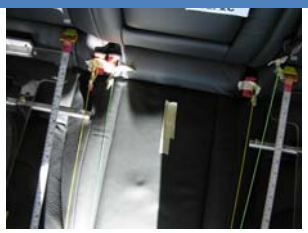
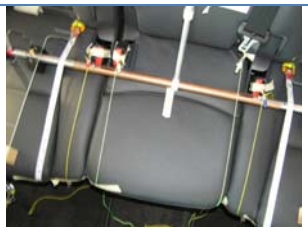
		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Dodge	Caliber		276	392	470		Yes
Dodge	Charger		376	499	427		Yes*
Dodge	Ram 1500		303	676	585		No
Jeep	Grand Cherokee		310	532	451		No

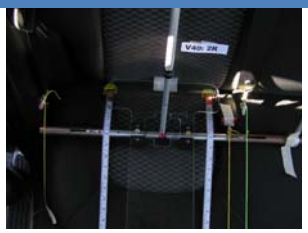
		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Jeep	Liberty		235	444	334		No
Jeep	Wrangler		179	505	370		No
Mercedes	C300		230	378	282		No
Mercedes	E350 4 MATIC		195	408	289		No

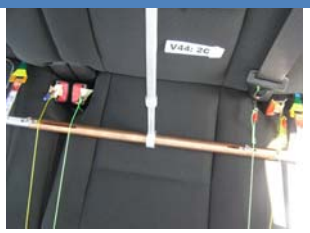
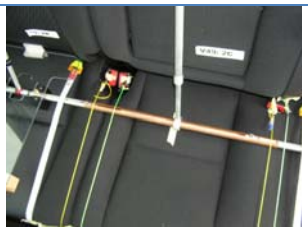
		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Mercedes	GL450		311	540	415		No
Mercedes	ML350		341	531	438		No
Ford	Edge		206	465	393		No
Ford	Escape		211	400	312		No

		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Ford	Explorer		333	524	349		No
Ford	F150		433	645	483		No
Ford	F150		402	640	450		No
Ford	Flex		330	517	410		No

		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Ford	Focus		260	423	375		No
Ford	Fusion		345	478	430		No
Ford	Taurus		355	280	416		Yes
Volvo	S40		306	434	332		No

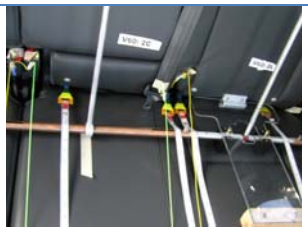
		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Volvo	S60 T6		302	489	375		No
Volvo	XC-90		286	562	425		No
Cadillac	CTS		325	468	407		No
Chevrolet	Equinox		322	414	295		Yes

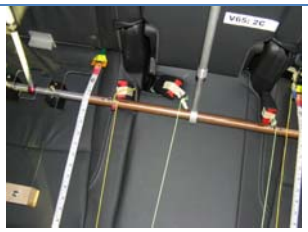
		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Chevrolet	HHR		275	431	416		No
Chevrolet	Impala		334	500	398		Yes*
Chevrolet	Malibu		255	395	408		No*
Chevrolet	Silverado 1500		237	624	485		No

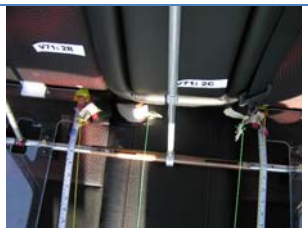
		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Chevrolet	Silverado		378	621	495		No
Chevrolet	Tahoe		375	306	528		Yes*
GMC	Sierra 1500		439	641	465		No
GMC	Sierra 1500		465	635	492		No

		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Acura	MDX Tech		285	568	385		No*
Honda	Accord		296	413	372		No
Honda	Accord		404	386	490		Yes
Honda	Civic		268	401	304		No

		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Honda	Civic		274	392	345		No
Honda	CR-V		230	459	414		No*
Honda	Fit		336	356	422		No*
Honda	Odyssey		286	591	255		Yes*

		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Honda	Pilot		281	587	513		No*
Honda	Ridgeline		310	530	430		No*
Hyundai	Azera		272	439	419		No
Hyundai	Santa Fe		336	440	368		No

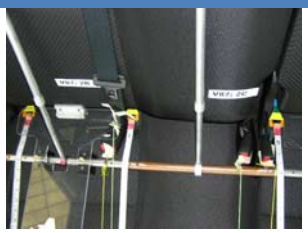
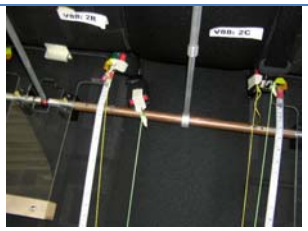
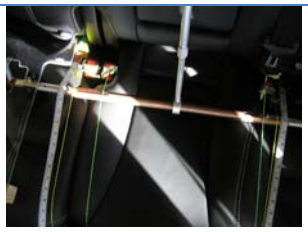
		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Hyundai	Sonata		300	435	315		No
Hyundai	Veracruz		235	512	404		No
Kia	Soul		260	412	397		No
Kia	Sportage		325	372	369		Yes

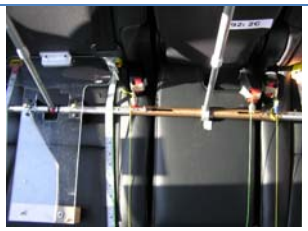
		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Mazda	CX-9		240	521	456		No
Mazda	3		210	416	390		No
Mazda	3 Sport		206	428	400		No
Mazda	6		304	461	404		No

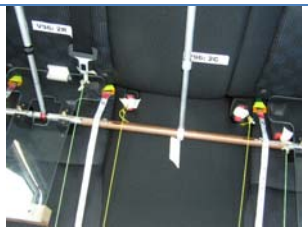
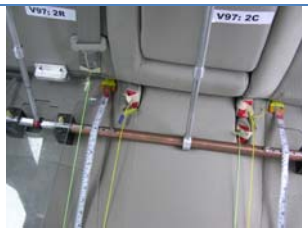
		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Mitsubishi	Lancer		260	406	377		No
Nissan	Altima		241	417	352		No
Nissan	Murano		380	481	483		No
Nissan	Rogue		221	424	387		No

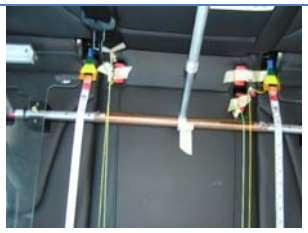
		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Nissan	Sentra		267	472	385		No
Nissan	Versa		360	343	343		Yes
Porsche	Cayenne		257	517	378		No
Subaru	Forester		249	416	354		No

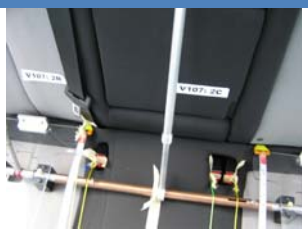
		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Subaru	Impreza		310	425	291		No
Subaru	Legacy		263	452	359		No
Subaru	Outback		265	454	358		No
Subaru	Tribeca		333	494	390		No

		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Suzuki	Grand Vitara		300	367	398		No
Suzuki	SX4		278	406	329		No
Jaguar	XF		328	460	431		No
Land Rover	Range Rover		364	501	457		No

		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Lexus	ES-350		370	480	335		No
Lexus	RX 350		316	468	341		No
Toyota	Camry		313	467	378		No
Toyota	Corolla		521	434	335		Yes

		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Toyota	Highlander		282	498	370		No
Toyota	Matrix		522	420	311		Yes
Toyota	Prius		341	412	278		No
Toyota	RAV4		349	390	300		No

		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Toyota	Tundra		420	621	690		
Toyota	Venza		311	470	371		No
Audi	A4		267	404	290		No
Volkswagen	Jetta		205	433	310		No

		OB CL	Center belt spacing	LATCH spacing	OB buckle spacing		Preferred spacing?
Chevrolet	Cruze		314	441	347		No

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