Car crashes rank among the leading causes of death in the United States.

# Evaluating LATCH System Ease of Use and Key Features in New Vehicles

*November 2013*

AAA Foundation for Traffic Safety

607 14th Street, NW, Suite 201 | Washington, DC 20005 | AAAFoundation.org | 202-638-5944

## Title

Evaluating LATCH System Ease of Use and Key Features in New Vehicles
*(November 2013)*

## Authors

Bari Kotwal, Katie Womack, Alicia Nelson, and Irene Rodriguez
*Texas A&M Transportation Institute*

## About the Sponsor

AAA Foundation for Traffic Safety
607 14th Street, NW, Suite 201
Washington, DC 20005
202-638-5944
www.AAAFoundation.org

Founded in 1947, the AAA Foundation in Washington, D.C. is a not-for-profit, publicly supported charitable research and education organization dedicated to saving lives by preventing traffic crashes and reducing injuries when crashes occur. Funding for this report was provided by voluntary contributions from AAA/CAA and their affiliated motor clubs, from individual members, from AAA-affiliated insurance companies, as well as from other organizations or sources.

## Table of Contents


| | |
|---|---|
| Overview | 3 |
| Topic Investigation | 3 |
| Expert Workshop | 6 |
| Human Factors Systems Analyses | 7 |
| Components | 8 |
| Types of Child Safety Seats | 10 |
| Task Analysis | 11 |
| Safety Critical Task Analysis | 13 |
| Fault Tree Analysis | 28 |
| Conclusions and Recommendations | 31 |
| References | 34 |
| Appendix | 36 |

## Overview

The goal of this project was to examine the Lower Anchors and Tethers for CHildren (LATCH) system (e.g., anchors, lower attachments, and tethers) and vehicle design related to compatibility and ease of use, with an emphasis on issues that can inform National Highway Traffic Safety Administration (NHTSA) regulations for the LATCH system. The project included a topic investigation focused on the development and contextual background of LATCH to add perspective to current usability issues. A human factors analysis was conducted to define user performance demands and the ease of use of LATCH systems. The study also included an expert panel workshop consisting of child passenger safety (CPS) instructors, technicians, and human factors experts in which more detailed insight was elicited regarding proper use, misuse, and ease-of-use issues associated with the LATCH system. The results of these efforts were used to develop a white paper that summarizes the key issues related to LATCH system usability and lists recommendations for enhancements. This report details each of these research activities and conclusions.

## Topic Investigation

To understand the context of current LATCH issues, knowing the history of LATCH is helpful. The LATCH system was borne out of a need for a universal child safety seat (CSS) attachment system, as evidenced by high rates of incorrect CSS installations with associated injuries and fatalities. Usage studies conducted in the 1980s and 1990s began to document the commonality of misuse that included incorrect seat belt routing to secure the CSS, loose installations, and more specifically loose installations resulting from failure to lock the CSS into the vehicle with the non-locking safety belt systems that were common in vehicles at the time [1, 2].

In 1995, NHTSA established a Blue Ribbon Panel on Child Restraint and Vehicle Compatibility. The panel included representatives from vehicle manufacturers, CSS manufacturers, and CPS advocates. The panel's recommendations included a call for a universal anchorage system that does not rely on the vehicle's seat belt system, referred to as ISOFIX (International Standards Organisation FIX). The panel's recommendations also called for improved instructions on installation and more education on correct use of CSSs. These recommendations also led to the development and implementation of NHTSA's national training and certification program for Child Passenger Safety Technicians and Instructors (CPST/I) launched in 1997.

Over the next five years, 22,000 technicians and instructors were certified. The 32-hour certification curriculum emphasized the prevalence and ramifications of incorrectly and loosely installed CSSs and taught technicians how to remedy these problems. The importance of a tightly installed and locked-in-place car seat was heavily emphasized to parents and caregivers in child safety seat checkup events all over the country. Vehicle and child seat incompatibility was now much more likely to be discovered and documented, and the difficulties, along with the importance of tightly securing CSSs, became much more widely known throughout the United States.

Meanwhile, regulatory measures were being introduced to strengthen requirements for CSS and vehicle manufacturers. In 1999, federal standards were introduced in Federal

Motor Vehicle Safety Standard (FMVSS) 225 that relate to the vehicle and specifically how CSSs attach to the vehicle. FMVSS 213 required that CSSs be designed and tested with attachments to the vehicle using the vehicle's safety belt system, and the forward movement of the CSS was regulated. The tether, which is a safety belt-grade strap on the CSS designed to be secured to the vehicle by connecting to a vehicle tether anchor to further reduce CSS movement, had been available since the 1970s. However, even though numerous studies between 1985 and 1999 indicated that head excursions were significantly reduced with properly tethered CSSs, rates of tether use were very low, primarily due to unavailable vehicle anchorage systems [1, 2]. In early 1999, FMVSS 213 was amended to require CSSs to have tethers by September 1999 and lower attachments by September 2002. Seats were still required to be able to be secured by the vehicle's seat belt as well. FMVSS 225 required that upper tether anchors be phased in for all passenger vehicles by September 1, 2000, and lower anchorages phased in by September 1, 2002. The standards called for upper anchorages for all forward-facing seating positions in the back seats of cars and the third-row seat of minivans and vans, and lower anchorages at two of the seating positions. FMVSS 225 specifically "establishes requirements for CSS anchorage systems to ensure their proper location and strength for the effective securing of CSSs, to reduce the likelihood of the anchorage systems' failure, and to increase the likelihood that CSSs are properly secured and thus more fully achieve their potential effectiveness in motor vehicles" [3]. By 2003, with only a few exceptions, passenger vehicle models manufactured in the United States were required to have both upper and lower anchorages for CSSs.

Although universal anchorages were intended to address most vehicle/CSS interface problems, reports from real-world experiences soon emerged that significant usability and ease-of-use issues remained. Studies over the past 10 years revealed lack of use, misuse, and misunderstandings regarding the LATCH system.

NHTSA conducted national telephone surveys biennially on occupant protection issues during the 1900s and 2000s. Immediately following the implementation of LATCH, a new set of questions was included in the 2003 telephone survey to assess knowledge and use of LATCH [4]. Because its availability was so new, it was not surprising that awareness was low among respondents who used CSSs. Some were aware that a change had occurred with how seats could be attached but were unfamiliar with the term LATCH. Twenty-seven percent overall had heard of LATCH. Of those who had heard of LATCH, only 26 percent said they had used it. Slightly more than half (53 percent) of the respondents with forward-facing CSSs reported having a top tether and usually using it. Fifty percent of those who reported they did not use the top tether provided on their CSS said the reason was because their vehicle did not have the tether anchor. By 2007, 39 percent of the respondents had heard of LATCH, and 66 percent of those who had heard of LATCH had used it [5]. However, 30 percent of those who used LATCH reported they had difficulties attaching the seat to the vehicle. As in 2003, about half who did not use the top tether said the reason was because there was no place to attach it to the vehicle. Most of the difficulty reported in this survey regarding LATCH was in finding the anchors and understanding the instructions.

The Insurance Institute for Highway Safety (IIHS) examined LATCH in 2003 to see if the new system improved the ease of CSS installation. Researchers studied 10 2003 model vehicles representing a variety of anchorage access designs. The study concluded that LATCH-compliant systems generally made installations easier and less complicated than

routing seat belts through CSSs. The authors also pointed out that "still, LATCH doesn't always make it a simple click-in operation to install a restraint" [6]. A problematic issue raised in this study was recessed lower anchors that were not visible. In most cases installations were easier with visible anchors. However, in at least one case even with a visible anchor, installing two seats was difficult because of the interference of the safety belt buckles. Additionally, two of the vehicles were incompatible with rigid lower anchor attachments. The attachments on the seats simply would not line up with the vehicle anchors. The study also found that uninstalling the CSS was simpler with rigid attachments with a release button (see lower attachments in Figure 3). However, when the anchor was buried in the vehicle seat bight, the flexible hook was more difficult to operate because it requires depressing and rotating the hook [6]. The IIHS study also noted problems associated with top tethers, especially in popular family vehicles such as sport utility vehicles (SUVs) and minivans. The problems noted included anchors not being clearly marked, head restraints that had to be removed for tether strap use, and the location of anchors on the backs of vehicle seats, which had to be folded down for installation [6].

The first large-scale study that brought LATCH use issues into sharper focus was published in 2004. The objective of this study was to "obtain quantitative data and other information regarding whether young children were riding in CSSs equipped with top tether and lower anchor attachments, and if so, whether LATCH was being used, and being used properly to secure the CSSs to vehicles equipped with LATCH anchors" [7]. Approximately 1,000 children in seven states under five years of age were observed riding in the back seats of vehicles equipped with LATCH. This study found that when the vehicle had tether anchors and the CSS had tether straps, they were both used 51 percent of the time. When the vehicle had lower anchors and the CSS had lower attachments, they were both used 58 percent of the time. The most common misuses were identified as loose lower attachments (30 percent), loose tether straps (18 percent), and use of both the vehicle seat belt and LATCH to secure the seat (18 percent) [7].

Drivers' opinions regarding the ease of use of LATCH were also gathered in the study. For the majority of the 327 drivers who used the lower attachments to install their CSSs, the installation was considered "very easy" or "relatively easy" (74 percent) [7]. In contrast, 18 percent found use to be "somewhat difficult" or "very difficult." The 246 drivers who had installed their CSS themselves using LATCH were asked what they liked and did not like about LATCH. The purpose of LATCH had been achieved to a degree for some of the LATCH users who responded—64 percent responded that it was easy to use, and 30 percent responded that it resulted in a tight fit for the CSS. A subset of users (n=144) who did not like some aspect of LATCH most often cited the difficulty of releasing the seat from the anchor bars as something they did not like (mentioned 67 times). Other common dislikes included the difficulty of connecting the lower anchors to the "bars" (mentioned 29 times), not being able to get a tight fit (mentioned 20 times), not being able to see the "bars" (mentioned 14 times), and not being able to find the "bars" (mentioned 6 times). Recommendations from the study included educational programs directed toward how to use LATCH hardware in vehicles. The authors recommended that a LATCH Ease of Use Rating System be developed for vehicles according to the manufacturer, similar to NHTSA's Child Safety Seat Ease of Use Rating Program, to help parents with vehicle selection.

A more recent study (2005) was conducted by Decina et al. focusing on LATCH. This survey included data regarding the make and model of vehicles, type of restraint for each occupant, demographic information, and user knowledge and opinions [8]. Although some gains in use were observed, there was still lack of awareness and proper use of LATCH. Only 55 percent of observed CSSs located in a seating position equipped with a tether anchor were attached to them, and among the 87 percent who placed CSSs in a position equipped with lower anchors, only 60 percent used the attachments to secure their CSS. A majority of the nonusers said not knowing the attachments were available, where they were located, the importance of using them, or how to use them were the factors leading to their nonuse.

A follow-up survey by IIHS was reported on in the September 2010 IIHS *Status Report*. Despite years of increasing availability, the 2010 survey found top tether use had actually declined since 2003 [9]. The 2010 survey included 1,500 vehicles in the Washington, D.C., area. Top tether use was at 44 percent across all vehicles (compared to 47 percent in 2003) and substantially lower in pickups at 17 percent.

Safe Kids Worldwide conducted an analysis of the data forms from CSS checks completed at community checkup events throughout the United States during 2009 and 2010, where documentation of errors and corrections are detailed for each CSS checked. These data constitute the largest source of information on real-world use and misuse available for American families [10]. Over 79,000 data forms were studied. Safe Kids considered the findings regarding use of LATCH disappointing: "Tether use was abysmally low with only slightly more than 28 percent of forward-facing car seats making use of this added safety protection. Of those who did use the tether, 59 percent used it correctly."

The most current study that directly relates to LATCH usability was conducted jointly by the University of Michigan Transportation Research Institute (UMTRI) and IIHS in 2012 [11]. In this study, key factors for usability were identified and tested on 98 different family vehicle models with 36 subjects who were familiar with CSS installations. The study found that only 21 vehicles passed all ease-of-use criteria. Seven vehicles did not meet any of the criteria. This study brought the issues of vehicle LATCH and CSS design interfaces into sharper focus and highlighted the need for a more comprehensive human factors analysis.

## Expert Workshop

To lay a foundation for the human factors analysis, a group of CPS instructors and technicians and human factors engineers was convened for a workshop. The panel consisted of 13 CPS experts and two human factors engineers with expertise in law enforcement, education, medical, and transportation fields. The experts were best qualified to provide information on LATCH's key features and misuse because they either work with parents and child caregivers with CSS installations on a routine basis or have expertise specific to ease-of-use evaluation.

During the five-hour workshop the participants were asked to give their general impressions of LATCH based on their experience or human factors knowledge. Following this general discussion, they were asked to focus on key features for improving usability. The panel members then brainstormed to create a detailed list of LATCH installation issues. Next, the panel assigned a severity score to each error or LATCH system problem.

The severity ranking was defined by the three categories of negligible, marginal, or critical. The final task was to indicate the frequency—improbable, occasional, or frequent—with which these issues are likely to occur, again referring to their own experiences.

There was much agreement among the panel members regarding the benefits of LATCH, and a consensus was reached on the key issues or problem areas that needed to be addressed. The primary benefit of LATCH was said to be the likelihood of achieving a correct installation more often than when not using LATCH; notably, the primary benefit was not its ease of use. Key factors affecting usability included:

- The lack of design consistency;
- The need for visible and accessible anchors;
- The need for improved information provided in the vehicle owners' manuals; and
- The need for education, awareness, and/or clarification of issues relating to LATCH for users.

Ultimately, the panel members agreed that, at a minimum, LATCH should be provided in the center backseat position; that attachment/installation should be intuitive; that vehicle/LATCH information should be easier to access and in a condensed, more understandable form; that anchors and labeling should be visible and easy to access; and that as much standardization and consistency as possible regarding weight limits, specifications, and labeling should be required. These recommendations are supported by the human factors analysis. Installation errors and usability issues discovered during the expert panel workshop are discussed in greater detail as part of the human factors systems analysis results.

## Human Factors Systems Analyses

Usability as it relates to user performance demands and the ease of use of LATCH systems was examined using a human factors systems analysis approach. The evaluation focused on user error during installation of the CSS into the vehicle, including examination of both the vehicle and the CSS components of the system. The analysis included common problems associated with the location and orientation of the CSS within the vehicle as well as installation issues that may occur when securing the CSS within the vehicle using LATCH. The clarity, availability, and conspicuity of the instructions and labeling were considered, along with the human factors design of the CSS and vehicle LATCH user interfaces. Consideration was also given to the fact that not everyone installing a CSS has an awareness of LATCH or, if aware of the system, knows how to locate the LATCH components or install the CSS once the components are identified. Each of these factors must be considered during any usability analysis of LATCH.
For this analysis, the following factors were assumed:

- The vehicle is properly operating and has at least one LATCH system in place;
- Vehicle LATCH systems conform to FMVSS 225;
- CSSs conform to FMVSS 213; and
- Emergency braking or collisions occur at moderate to high speeds.

### *Components*

Major components of the vehicle/LATCH/CSS system are shown in Figures 1 through 5. LATCH components in the vehicle include the following:

- Two lower anchors.
- Tether anchors, including:
  - Tether anchor bracket and bolt.
  - Tether anchor cover (e.g., fabric panel, slits in carpeting, plastic covers, and plugs).
  - D-ring (for some rear-facing CSSs approved for tether use).

The CSS includes the following major LATCH components:

- Two lower attachments.
- A top tether strap, tether adjuster, and hook attachment.

*Note: tethering for rear-facing CSSs is not regulated, and most tethers are designed for forward-facing seats. Tethers should only be used on rear-facing CSSs if they are designed for use with a tether and tether use is explicitly permitted by the CSS manufacturer. Also, CSSs including car beds, boosters, and vests are exempt from LATCH requirements.*

**Figure 1.** Lower anchors [12, 13].

Tether anchor cover

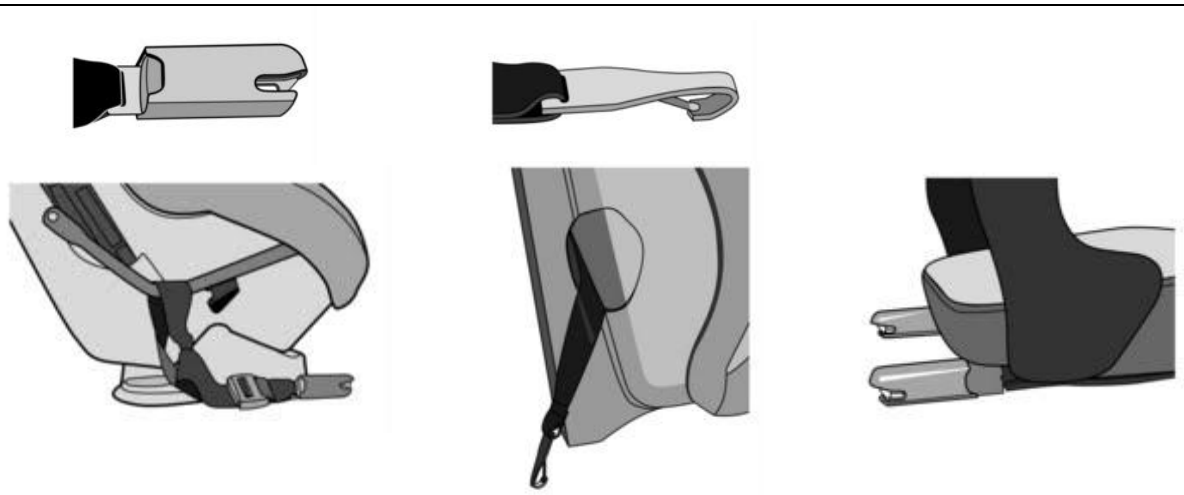
Tether anchor bracket and bolt

Tether strap, tether adjuster, and hook attachment

D-ring

Sample D-ring installation

**Figure 2.** Top tether anchor [12-14].

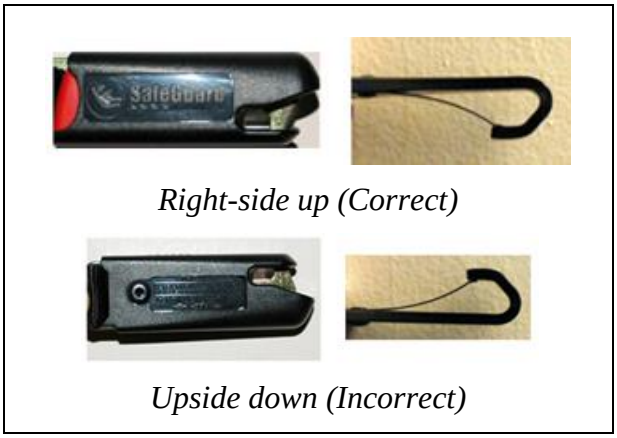


Flexible push-on attachment

Flexible hook-on attachment

Rigid attachment

**Figure 3.** Types of lower attachments [12].




*Right-side up (Correct)*

*Upside down (Incorrect)*

**Figure 4.** Correct versus incorrect orientation of flexible connectors [15].

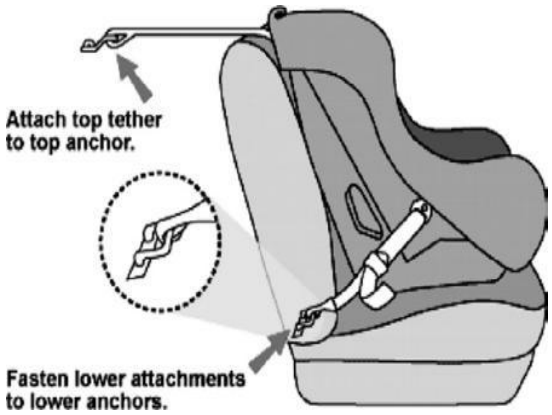



**Figure 5.** Vehicle and child safety seat LATCH system [16].

### *Types of Child Safety Seats*

A wide variety of CSSs are available on the market today. Although the designs may vary greatly, they all fall into four basic categories based on the child's size and weight (see Figure 6). (Note: belt-positioning boosters generally do not have a LATCH system used to anchor the seat into the vehicle and are not relevant to this study.)


**Figure 6.** Types of child safety seats [17].

### *Task Analysis*

Task analysis is a fundamental methodology often used to assess user error. As the name implies, a task analysis details the steps required for a user to complete a task, including both active and cognitive behaviors. This is often the first step in identifying areas where human error and/or safety issues may arise. The Texas A&M Transportation Institute performed a task analysis for the use of LATCH, incorporating both vehicle and CSS design features. *The LATCH Manual* [18] provided a strong basis of information and was referenced throughout the course of the analysis.

Connecting to the Lower Anchors: The following steps are required to use lower anchors and attachments correctly:

- Locate vehicle owner's manual and CSS instruction manual.
- Locate positions in the vehicle that do and do not have lower anchors. (Note: if lower anchors are not available in the desired seating position, a seat belt must be used to install the CSS.)
- Note the CSS weight limit and the child's weight.
    - Is the child's weight greater than the weight limit specified by the CSS?
        - Yes—Use a different CSS that is rated for the child's weight.
        - No—Determine the combined weight of the child and the CSS.
    - Is the combined weight of the child and the CSS greater than the maximum lower anchor weight limit specified by the vehicle manufacturer?
        - Yes—Use the seat belt rather than the lower anchors to install the CSS.
        - No—Install the CSS using lower anchors.
- Are the CSS lower attachments flexible or rigid?
    - Flexible:
        - Is the CSS convertible (i.e., can it be used rear-facing or forward-facing)?
            - Yes:
                - Confirm whether you will be using the CSS in the rear- or forward-facing position.
                - Confirm that the flexible attachment is routed properly through the appropriate belt path.
            - No—Continue to the next step.
        - Locate lower anchors in the seat bight.
        - Locate lower attachments on the CSS.
        - Depress connectors (if necessary) and attach to the lower anchors.
        - Can you see the lower anchors?
            - Yes—Confirm that both attachments are connected to both anchors.
            - No—Feel the attachments and the anchors with your fingers to make sure the attachments are properly connected to both anchors and not some other component behind the seat cushion.
        - For CSSs with flexible lower anchors, tighten the CSS into position.

- Rigid:
  - Move the rigid CSS attachments into the installation position.
  - Push the rigid attachments onto the lower anchors. Press one side at a time or both sides at the same time. Connectors should click into place.
  - Confirm that both attachments are connected securely by pulling forward on the CSS firmly.
  - Push the CSS toward the vehicle seat back until it is securely in place.

Connecting to the Tether Anchor: The following steps are required to use tether anchors and attachments correctly:

- Locate vehicle owner's manual and CSS instruction manual.
- Is the CSS in the rear-facing or forward-facing position?
  - Rear facing—Tethers are not required.
    *Note: tethers should only be used on rear-facing CSSs if they are designed for use with a tether and tether use is recommended by the CSS manufacturer.*
  - Forward facing—Continue with installation.
- Confirm top tether and tether anchor availability.
  - For CSSs:
    - For CSSs requiring a top tether, read the CSS instructions/label to determine:
      - Weight requirements of the child for using the tether.
      - For convertible CSSs, whether the tether can be used when the CSS is in the rear-facing position or only in the forward-facing position.
  - For vehicles:
    - Look for tether anchor labels with icons similar to that pictured in Figure 7.
    - Determine the seating positions in the vehicle that do and do not have tether anchors. For tether anchors that are not readily visible, look for the tether symbol (Figure 7). For seating positions without tether anchors, refer to the vehicle owner's manual to determine which tether anchors are authorized for use with each seating position and/or for multiple tether attachments at once.
    - Determine the maximum weight allowed for the tether anchor (child's weight plus CSS weight).
    - Consult the vehicle owner's manual to determine how to route the tether.
- Install the CSS by connecting the lower attachments to the lower anchors. (See previous section, "Connecting to the Lower Anchors.")
- Route the tether strap from the CSS to the tether anchor as instructed in the vehicle owner's manual.
- Attach the tether hook to the tether anchor. (Note: if the tether anchor is in a location that is difficult to reach, the user may need to connect the top tether to the tether anchor prior to connecting the CSS to the lower anchors.)

Source: *The LATCH Manual* [18]
**Figure 7.** Standard tether anchor icon in vehicles.

Securing the Child Safety Seat in the Vehicle: Is the CSS installed tightly in the vehicle? (Note: the CSS should not move more than 1 inch either forward/back or side to side.)

- No:
    - Tighten the flexible lower attachments and then tighten the tether attachment.
    - If the CSS is still not secure, use another seating position or secure the CSS using the seat belt instead of LATCH.
- Yes—The CSS is properly installed.

Notes:

- In some vehicles, such as pickup trucks with tether anchors behind the seat back, the tether may need to be attached before the lower attachments and lower anchors are connected. If so, attach the tether loosely and then install the CSS using the lower attachments and lower anchors; then tighten all straps.
- Only one tether should be attached to each tether anchor. However, some pickup trucks require the tether to be routed through a loop or bracket behind the CSS and then attached to a tether anchor in the adjacent seating position. In this case, two outboard CSS tethers may be connected to the center tether anchor.

### *Safety Critical Task Analysis of CSS Installation Using LATCH*

The basic task analysis can be further extended to include the impact of human factors on safety as the user interacts with the vehicle/LATCH/ CSS system, referred to as a use error analysis or a safety critical task analysis. The Energy Institute, London, [19] outlines the process involved in conducting a safety critical task analysis as the following:

- Determining which tasks are safety critical.
- Understanding which human action or inaction might make a failure more likely or more serious.
- Guiding the user in how to identify and install adequate layers of protection for these safety critical tasks in order to reduce the likelihood or consequences of human failure.

A safety critical task analysis was performed for the LATCH system and is provided in Table 3. Usability issues were discussed during the expert workshop, and researchers gained input from a group of 15 child safety technicians and instructors, as well as human factors and ergonomics specialists. Once the LATCH installation issues were identified, individual participants assigned each issue a severity rating (see Table 1).

**Table 1.** Severity ratings.

| RATING | DESCRIPTION |
|---|---|
| 1 | *Negligible:* Less than minor injury to the child. |
| 2 | *Marginal:* Minor injury to the child, including minor abrasions and contusions. |
| 3 | *Critical:* Severe injury, including broken bones, spinal damage, head injuries, internal organ damage, and/or loss of life. |

Because each severity rating was assigned on an individual basis, there may be multiple ratings assigned for the same issue if one rank was not clearly dominant among the members. Finally, as a group, the panel then assigned each installation issue a frequency of occurrence rating (see Table 2). Specific controls provided in Table 3 are suggestions by researchers based on findings and were not tested in the current study.

**Table 2.** Frequency of occurrence ratings.

| RATING | FREQUENCY |
|---|---|
| 1 | Improbable |
| 2 | Occasional |
| 3 | Frequent |

**Table 3.** Safety Critical Task Analysis

| OPERATING MODE | FAILURE MODE | HAZARD DESCRIPTION | FREQUENCY | SEVERITY | CONTROL |
|---|---|---|---|---|---|
| Determine weight limits for vehicle lower anchors | Cannot determine weight limits of lower anchors | Lower anchors and attachments may not adequately restrain the CSS and child during a collision | 3 | 2–3 | • Increase the amount of force specified in S9.4.1(a)(b) of FMVSS 225 [3] for lower anchors to accommodate the heaviest CSS available occupied by a child at the weight limit of the CSS, with an acceptable safety factor, such that no plausible combined weight of a child and CSS could pose a significant risk of lower anchor failure in a crash.* • Standardize weight limits of lower anchors among vehicles. • Vehicle owner's manual: specify weight limits. • Vehicle LATCH quick reference guide: specify weight limits. • Vehicle label: display weight limits. |
| | Weight of CSS is not readily available | Lower anchors and attachments may not adequately restrain the CSS and child during a collision | 3 | 2–3 | • Increase the amount of force specified in S9.4.1(a)(b) of FMVSS 225 [3] for lower anchors to accommodate the heaviest CSS available occupied by a child at the weight limit of the CSS, with an acceptable safety factor, such that no plausible combined weight of a child and CSS could pose a significant risk of lower anchor failure in a crash.* • CSS instruction manual: specify CSS weight. • CSS label: display CSS weight. |
| | Does not know weight of child | Lower anchors and attachments may not adequately restrain the CSS and child during a collision | 3 | 2–3 | • Increase the amount of force specified in S9.4.1(a)(b) of FMVSS 225 [3] for lower anchors to accommodate the heaviest CSS available occupied by a child at the weight limit of the CSS, with an acceptable safety factor, such that no plausible combined weight of a child and CSS could pose a significant risk of lower anchor failure in a crash.* • Public awareness campaigns/education: always know the child's approximate weight. |

∗ If this recommendation is implemented, many of the recommendations that follow would no longer be necessary. They are, however, included here as options.

| OPERATING MODE | FAILURE MODE | HAZARD DESCRIPTION | FREQUENCY | SEVERITY | CONTROL |
|---|---|---|---|---|---|
| Determine weight limits for vehicle lower anchors (continued) | Confusion/ misinterpretation of weight limit; not factoring in weight of both CSS and child | Lower anchors and attachments may not adequately restrain the CSS and child during a collision | 3 | 2–3 | • Increase the amount of force specified in S9.4.1(a)(b) of FMVSS 225 [3] for lower anchors to accommodate the heaviest CSS available occupied by a child at the weight limit of the CSS, with an acceptable safety factor, such that no plausible combined weight of a child and CSS could pose a significant risk of lower anchor failure in a crash.* • Vehicle owner's manual: explain weight limits, including weight of child and weight of CSS. • LATCH quick reference guide: explain weight limits, including combined weight of child and CSS. • Public awareness campaigns/education: explain weight limits, including combined weight of child and CSS. |
| | Child's weight plus CSS weight exceeds design weight limit of lower anchors | Lower anchors and attachments may not adequately restrain the CSS and child during a collision | 1 | 2–3 | • Increase the amount of force specified in S9.4.1(a)(b) of FMVSS 225 [3] for lower anchors to accommodate the heaviest CSS available occupied by a child at the weight limit of the CSS, with an acceptable safety factor, such that no plausible combined weight of a child and CSS could pose a significant risk of lower anchor failure in a crash.* • Use lower-weight CSS. • Use seat belt rather than lower anchors to secure CSS in vehicle. |

* If this recommendation is implemented, many of the recommendations that follow would no longer be necessary. They are, however, included here as options.

| OPERATING MODE | FAILURE MODE | HAZARD DESCRIPTION | FREQUENCY | SEVERITY | CONTROL |
|---|---|---|---|---|---|
| Determine weight limits of vehicle tether anchors | Cannot determine weight limits of tether anchors | Tether anchor and top tether may not adequately restrain the CSS and child during a collision | 3 | 2–3 | • Standardize weight limits of tether anchors among vehicles.<br>• Vehicle owner's manual: specify weight limits.<br>• Vehicle LATCH quick reference guide: specify weight limits.<br>• Vehicle label: display weight limits. |
| | Weight of CSS is not readily available | Tether anchor and top tether may not adequately restrain the CSS and child during a collision | 3 | 2–3 | • CSS instruction manual: specify weight of CSS.<br>• CSS label: display weight of CSS. |
| | Does not know weight of child | Tether anchor and top tether may not adequately restrain the CSS and child during a collision | 3 | 2–3 | • Public awareness campaigns/education: always know the child's approximate weight. |
| | Confusion/ misinterpretation of weight limit; not factoring in weight of both CSS and child | Tether anchor and top tether may not adequately restrain the CSS and child during a collision | 3 | 2–3 | • Vehicle owner's manual: explain weight limits, including weight of child and weight of CSS.<br>• Vehicle LATCH quick reference guide: explain weight limits, including combined weight of child and CSS.<br>• Public awareness campaigns/education: explain weight limits, including combined weight of child and CSS. |
| | Child's weight plus CSS weight exceeds design weight limit of tether anchor | Tether anchor and top tether may not adequately restrain the CSS and child during a collision | 1 | 2–3 | • Use lower-weight CSS. |

| OPERATING MODE | FAILURE MODE | HAZARD DESCRIPTION | FREQUENCY | SEVERITY | CONTROL |
|---|---|---|---|---|---|
| Locate lower attachments on CSS | Cannot locate or identify lower attachment straps/connectors; lack of awareness | N/A - Cannot use LATCH | 1 | N/A - LATCH not used | • Use standardized, intuitive design of lower attachment straps/connectors on CSSs to improve general recognition (e.g., color-coding components, consistent labeling/icons).<br>• CSS instruction manual: identify lower attachment straps/connectors.<br>• CSS label: conspicuously label lower attachment straps/connectors.<br>• Public awareness campaigns/education: help users identify LATCH and lower attachment straps/connectors. |
| Locate top tether on CSS (strap, adjuster, and connector/hook) | Cannot locate or identify top tether; lack of awareness | Nonuse of top tether may result in excessive head excursion in a collision | 1 | 2–3 | • Use standardized, intuitive design of top tethers on CSSs to improve general recognition (eg, color-coding components, consistent labeling/icons).<br>• CSS instruction manual: identify top tether.<br>• CSS label: conspicuously label top tether.<br>• Public awareness campaigns/education: help users identify LATCH and top tether. |

| OPERATING MODE | FAILURE MODE | HAZARD DESCRIPTION | FREQUENCY | SEVERITY | CONTROL |
|---|---|---|---|---|---|
| Locate vehicle lower anchors | Cannot locate lower anchors; lack of awareness of LATCH | N/A - Cannot use LATCH | 3 | N/A - LATCH not used | • Use standardized, intuitive design of lower anchors to improve general recognition.<br>• Public awareness campaigns/education: help users identify LATCH. |
| | Cannot locate lower anchors; not properly noted in vehicle owner's manual and/or not properly labeled | N/A - Cannot use LATCH | 2 | N/A - LATCH not used | • Vehicle owner's manual: identify specific locations where lower anchors are and are not available.<br>• Vehicle quick reference guide: identify specific locations where lower anchors are and are not available.<br>• Vehicle labels: identify specific locations of lower anchors where lower anchors are not visible.<br>• Use seat belt to secure CSS in vehicle. |
| | Cannot locate lower anchors; recessed too far behind surface of the seat back or bight of the seat | N/A - Cannot use LATCH | 2–3 | N/A - LATCH not used | • Enact regulations to reduce distance that lower anchors can be recessed.<br>• Provide funnel guides to assist with locating lower anchors and connecting lower attachments.<br>• Vehicle owner's manual: identify specific locations where lower anchors are and are not available.<br>• Vehicle quick reference guide: identify specific seat positions where lower anchors are and are not available.<br>• Vehicle labels: identify specific locations of lower anchors where lower anchors are not visible.<br>• Use seat belt to secure CSS in vehicle. |
| | Cannot locate lower anchors; covered or otherwise obstructed (e.g., cosmetic flaps) | N/A - Cannot use LATCH | 2 | N/A - LATCH not used | • Vehicle owner's manual: identify specific locations where lower anchors are and are not available, along with depiction or description of cover/obstruction.<br>• Vehicle quick reference guide: identify specific locations where lower anchors are and are not available, along with depiction or description of cover/obstruction.<br>• Vehicle labels: identify specific locations of lower anchors where lower anchors are not visible.<br>• Use seat belt to secure CSS in vehicle. |

| OPERATING MODE | FAILURE MODE | HAZARD DESCRIPTION | FREQUENCY | SEVERITY | CONTROL |
|---|---|---|---|---|---|
| Locate vehicle lower anchors (continued) | Mistakes other vehicle components for lower anchors | Non-lower anchor vehicle components are not designed to bear the forces required of lower anchors and may not adequately restrain the CSS and child during a collision | 1 | 3 | • Use standardized, intuitive design of lower anchors to reduce confusion.<br>• Vehicle owner's manual: identify specific locations where lower anchors are and are not available; provide illustrations of lower anchors.<br>• Vehicle quick reference guide: identify specific locations where lower anchors are and are not available; provide illustrations of lower anchors.<br>• Vehicle labels: identify specific locations of lower anchors where lower anchors are not visible.<br>• Public awareness campaigns/education: stress importance of connecting only to manufacturer-authorized lower anchors. |
| Locate vehicle tether anchors | Cannot locate tether anchors; lack of awareness of LATCH | Nonuse of the tether results in possible excessive head excursion in a collision | 3 | 2–3 | • Use standardized, intuitive design of tether anchors to improve recognition.<br>• Public awareness campaigns/education: help users identify LATCH. |
| | Cannot locate tether anchors; not properly noted in vehicle owner's manual and/or not properly labeled | Nonuse of the tether results in possible excessive head excursion in a collision | 2 | 2–3 | • Vehicle owner's manual: identify specific locations where tether anchors are and are not available.<br>• Vehicle quick reference guide: identify specific locations where tether anchors are and are not available.<br>• Vehicle labels: identify specific locations of tether anchors. |
| | Cannot locate tether anchors; covered or otherwise obstructed (e.g., upholstery flap, carpeting, or plastic cover) | Nonuse of the tether results in possible excessive head excursion in a collision | 1 | 2–3 | • Vehicle owner's manual: identify specific locations where tether anchors are and are not available, along with depiction or description of cover/obstruction.<br>• Vehicle quick reference guide: identify specific locations where tether anchors are and are not available, along with depiction or description of cover/obstruction.<br>• Vehicle labels: identify specific locations of tether anchors where tether anchors are not visible. |

| OPERATING MODE | FAILURE MODE | HAZARD DESCRIPTION | FREQUENCY | SEVERITY | CONTROL |
|---|---|---|---|---|---|
| Position CSS in vehicle—preferred seating position | LATCH is not available in the center back seat position | N/A - Cannot use LATCH | 3 | N/A - LATCH not used | • Require LATCH in more seating positions, especially center back seat for vehicles with center back seat positions.<br>• Vehicle owner's manual: identify which seating positions do and do not have LATCH.<br>• Vehicle quick reference guide: identify which seating positions do and do not have LATCH.<br>• Install CSS in another seating position.<br>• If using center back seat position, use seat belt to secure CSS in vehicle. |
| | Uses LATCH in center position of back seat by using inner bars of outboard lower anchors when not specified as an option by vehicle manufacturer (i.e., center LATCH) | Lower anchors and attachments may not adequately restrain the CSS and child during a collision | 3 | 2–3 | • Design inner bars of outboard lower anchors for use in center position.<br>• Vehicle owner's manual: stress importance of connecting only to manufacturer-authorized lower anchor positions.<br>• Public awareness campaigns/education: stress importance of connecting only to manufacturer-authorized lower anchor positions. |
| | LATCH is not available in all positions for all CSSs | N/A - Cannot use LATCH | 3 | N/A - LATCH not used | • Place CSSs only in positions where they can be securely installed with either LATCH or a seat belt.<br>• Use seat belts to secure CSSs that do not have LATCH available.<br>• Require LATCH in more seating positions, especially center back seat for vehicles with adequate space. |
| | Multiple CSSs cannot be placed in the preferred seating positions, even if LATCH is available (not enough space to accommodate CSSs) | N/A - Cannot use LATCH | 3 | N/A - LATCH not used | • Place CSSs only in seating positions that accommodate space requirements for proper installation of all CSSs present. |

| OPERATING MODE | FAILURE MODE | HAZARD DESCRIPTION | FREQUENCY | SEVERITY | CONTROL |
|---|---|---|---|---|---|
| Connect CSS lower attachments to lower anchors | Lower attachments are not securely connected to both lower anchors (i.e., did not hear click or feel snap into place) | Lower anchors and attachments may not adequately restrain the CSS and child during a collision | 2 | 3 | • Improve lower anchor design to enhance usability (e.g., user feels click or snap into place, or make design more forgiving in regard to need for alignment and connection of components).<br>• Use standardized, intuitive design of lower anchors and lower attachments.<br>• Vehicle owner's manual: give instructions and warning about the dangers of not having the lower attachments correctly secured.<br>• Vehicle LATCH quick reference guide: give instructions and warning about the dangers of not having the lower attachments correctly secured.<br>• Public awareness campaigns/education: warn about the dangers of not having the lower attachments correctly secured. |
| | Cannot securely connect lower attachments to lower anchors due to seat design (e.g., shape of seat or stiff materials) | Lower anchors and attachments may not adequately restrain the CSS and child during a collision | 2 | 3 | • Do not use LATCH.<br>• If using the same seating position, use seat belt to secure CSS in vehicle.<br>• Use a different seating position.<br>• Design seat shape, seat materials, and location of lower anchors so that lower anchors are readily accessible and easy to connect to lower attachments. |
| | Two CSSs connected to the same lower anchors | If the lower anchor is not rated for the weight of two CSSs and two children, the anchor may not sustain the additional forces during a collision; CSS may not adequately protect and/or restrain the child | 1 | 2–3 | • Vehicle owner's manual: warn about the dangers of connecting two CSSs to same lower anchor.<br>• Vehicle LATCH quick reference guide: warn about the dangers of connecting two CSSs to same lower anchor.<br>• Public awareness campaigns/education: warn about the dangers of connecting two CSSs to same lower anchor. |

| OPERATING MODE | FAILURE MODE | HAZARD DESCRIPTION | FREQUENCY | SEVERITY | CONTROL |
|---|---|---|---|---|---|
| Connect CSS lower attachments to lower anchors (continued) | Lower attachment is connected to vehicle hardware other than lower anchor (e.g., other vehicle seat component) | Non-lower anchor vehicle components are not designed to bear the forces required of lower anchors and may not adequately restrain the CSS and child during a collision | 1 | 3 | • Use standardized, intuitive design of lower anchors to reduce confusion.<br>• Vehicle owner's manual: identify specific locations where lower anchors are and are not available; provide illustrations of lower anchors.<br>• Vehicle quick reference guide: identify specific locations where lower anchors are and are not available; provide illustrations of lower anchors.<br>• Vehicle labels: identify specific locations of lower anchors where lower anchors are not visible.<br>• Public awareness campaigns/education: stress importance of connecting only to manufacturer-authorized lower anchors. |
| Connect CSS *flexible* lower attachment straps to lower anchors | Flexible lower attachment strap is loose | Lower anchors and attachments may not adequately restrain the CSS and child during a collision | 2 | 2–3 | • Improve adjuster designs that allow for intuitive, quick, secure tightening of lower attachment straps with minimal effort (e.g., SuperCinch design by Chicco).<br>• Vehicle owner's manual: warn about the importance of securely tightening lower attachment straps.<br>• Vehicle LATCH quick reference guide: warn about the importance of securely tightening lower attachment straps.<br>• Public awareness campaigns/education: warn about the importance of securely tightening lower attachment straps. |
| | Flexible lower attachment strap is twisted | N/A - Improper use but not necessarily harmful to child | 1 | 1–2 | • Improve strap designs to reduce likelihood of twisting (e.g., use stiffer strap materials, provide strap routing guides).<br>• Vehicle owner's manual: caution against twisting lower attachment straps when connecting to lower anchors.<br>• Vehicle LATCH quick reference guide: caution against twisting lower attachment straps when connecting to lower anchors.<br>• Public awareness campaigns/education: caution against twisting lower attachment straps when connecting to lower anchors. |

| OPERATING MODE | FAILURE MODE | HAZARD DESCRIPTION | FREQUENCY | SEVERITY | CONTROL |
|---|---|---|---|---|---|
| Connect *convertible CSS* lower attachment straps to lower anchors | For convertible CSSs, flexible lower attachment strap is not routed correctly for rear-facing versus forward-facing use | Lower anchors and lower attachment straps may not adequately restrain the CSS and child during a collision | 2 | 2 | • Use standardized, intuitive design of routing paths for lower attachment straps.<br>• CSS instruction manual: give instructions and warning about the importance of correctly routing lower attachment straps.<br>• CSS labels: put conspicuous labels on CSS indicating correct routing of lower attachment straps.<br>• Public awareness/education: warn about the importance of correctly routing lower attachment straps. |
| | For convertible CSSs, push-on connectors are not right-side up after being moved from one routing path to another (see Figure 4) | Lower anchors and lower attachment straps may not adequately restrain the CSS and child during a collision | 2 | 2–3 | • Use standardized, intuitive design of push-on connectors so they can only be connected when in the correct orientation.<br>• CSS instruction manual: give instructions and warning about the importance of correct orientation of push-on connectors.<br>• CSS labels: put conspicuous labels on CSS and/or on connectors indicating correct orientation of connectors. |
| | For convertible CSSs, push-on connectors that are "handed" (i.e., must be on a particular side of the CSS) are not switched accordingly when the CSS is rear facing versus forward-facing | Lower anchors and lower attachment straps may not adequately restrain the CSS and child during a collision | 2 | 2–3 | • Use standardized, intuitive design of push-on connectors to reduce/eliminate "handedness" or so they can only be connected when in the correct orientation.<br>• CSS instruction manual: give instructions and warning about the importance of correct orientation of push-on connectors.<br>• CSS labels: put conspicuous labels on CSS and/or on connectors indicating correct orientation of connectors. |

| OPERATING MODE | FAILURE MODE | HAZARD DESCRIPTION | FREQUENCY | SEVERITY | CONTROL |
|---|---|---|---|---|---|
| Connect CSS top tether to tether anchor | Difficult to access tether anchor to properly connect top tether (i.e., difficult to reach behind pickup truck seat) | Nonuse or misuse of the top tether results in possible excessive head excursion during a collision | 2 | 2–3 | • Place tether anchor in readily accessible location that is within comfortable reach and view of the average user.<br>• Vehicle owner's manual: instruct user to attach top tether to tether anchor prior to attaching lower attachments to lower anchors.<br>• Public awareness/education: instruct user to attach top tether to tether anchor prior to attaching lower attachments to lower anchors. |
| | Top tether is not securely connected to tether anchor (i.e., did not hear click or feel snap into place) | Not securing the top tether results in possible excessive head excursion during a collision | 1 | 2–3 | • Improve tether anchor design to enhance usability (e.g., user feels click or snap into place, or make design more forgiving in regard to need for alignment and connection of components).<br>• Use standardized, intuitive design of tether anchor and top tether hook/connector.<br>• Vehicle owner's manual: give instructions and warning about the dangers of not having the top tether correctly secured.<br>• Vehicle LATCH quick reference guide: give instructions and warning about the dangers of not having the top tether correctly secured.<br>• Public awareness campaigns/education: warn about the dangers of not having the top tether correctly secured. |
| | Tether strap is loose | Misuse of the top tether results in possible excessive head excursion during a collision | 1 | 2 | • Improve adjuster designs that allow for intuitive, quick, secure tightening of tether strap with minimal effort (e.g., SuperCinch design by Chicco).<br>• Vehicle owner's manual: warn about the importance of securely tightening tether strap.<br>• Vehicle LATCH quick reference guide: warn about the importance of securely tightening tether strap.<br>• Public awareness campaigns/education: warn about the importance of securely tightening tether strap. |

| OPERATING MODE | FAILURE MODE | HAZARD DESCRIPTION | FREQUENCY | SEVERITY | CONTROL |
|---|---|---|---|---|---|
| Connect CSS top tether to tether anchor (continued) | Tether strap is twisted | N/A - Improper use but not necessarily harmful to child | 1 | 1 | • Improve strap designs to reduce likelihood of twisting (e.g., stiffer materials).<br>• Vehicle owner's manual: caution against twisting tether strap when connecting to tether anchor.<br>• Vehicle LATCH quick reference guide: caution against twisting tether strap when connecting to tether anchor.<br>• Public awareness campaigns/education: caution against twisting tether strap when connecting to tether anchor. |
| | Top tether is not routed correctly from CSS to tether anchor (i.e., over or around head restraint) | Misuse of the tether results in possible excessive head excursion during a collision | 2 | 2 | • Keep routing requirements as simple and intuitive as possible (i.e., reduce number of steps required, ensure route is readily visible).<br>• Vehicle owner's manual: give instructions and warning about the importance of correctly routing top tether.<br>• Vehicle quick reference guide: give instructions and warning about the importance of correctly routing top tether.<br>• Vehicle labels: use conspicuous labels indicating correct route for top tether.<br>• Public awareness/education: warn about the importance of correctly routing top tether. |
| | Top tether is connected to vehicle hardware other than the tether anchor (e.g., tie-down hook) | Non-tether anchor vehicle components are not designed to bear the forces required of tether anchors and may not adequately restrain the CSS and child during a collision; misuse of the tether results in possible excessive head excursion during a collision | 1 | 3 | • Use standardized, intuitive design of tether anchors to reduce confusion (i.e., standard appearance, label/icon, location).<br>• Vehicle owner's manual: identify specific locations where tether anchors are and are not available; provide illustrations of tether anchors; stress importance of connecting only to manufacturer-authorized tether anchors.<br>• Vehicle quick reference guide: identify specific locations where tether anchors are and are not available; provide illustrations of tether anchors.<br>• Vehicle labels: identify specific locations of tether anchors. |

| OPERATING MODE | FAILURE MODE | HAZARD DESCRIPTION | FREQUENCY | SEVERITY | CONTROL |
|---|---|---|---|---|---|
| Connect CSS top tether to tether anchor (continued) | Two CSSs are connected to the same tether anchor (not authorized by manufacturer) | If the tether anchor is not rated for the weight of two CSSs and two children, the anchor may not sustain the additional forces during a collision; misuse of the tether results in possible excessive head excursion during a collision | 1 | 2–3 | • Vehicle owner's manual: warn about importance of not attaching more than one CSS to tether anchor unless authorized by the manufacturer.<br>• Vehicle quick reference guide: warn about importance of not attaching more than one CSS to tether anchor unless authorized by the manufacturer.<br>• Vehicle labels: warn about importance of not attaching more than one CSS to tether anchor unless authorized by the manufacturer.<br>• Public awareness campaigns/education: stress importance of not attaching more than one CSS to tether anchor unless authorized by the manufacturer. |
| Connect *convertible CSS* top tether to tether anchor | Convertible CSS top tether is being used for rear-facing position when it is not designed for this use | Improper use may potentially harm the child during a collision. | 1 | 1–2 | • CSS instruction manual: clearly indicate whether top tether use is authorized by the CSS manufacturer for the rear-facing position.<br>• CSS label: clearly indicate whether top tether use is authorized by the CSS manufacturer for the rear-facing position.<br>• Public awareness campaigns/education: show users how to determine if top tether use is authorized by the CSS manufacturer for the rear-facing position. |
| | Convertible CSS top tether is not secured/stowed when convertible seat is used in rear-facing position | Loose tether strap/hook may injure the child or other passengers (e.g., projectile hazard) | 3 | 3 | • CSS instruction manual: emphasize need for stowing top tether and indicate where top tether should be stowed.<br>• CSS label: indicate where top tether should be stowed.<br>• Public awareness campaigns/education: emphasize need for stowing top tether when not in use. |

FREQUENCY
1—Improbable
2—Occasional
3—Frequent

SEVERITY
1—Negligible
2—Marginal
3—Critical

### *Fault Tree Analysis*

A fault tree analysis (FTA) was conducted based on the previous safety critical task analysis as well as the findings of the expert workshop. An FTA is a deductive, top-down approach used to identify system failures, in this case the failure of LATCH to be used correctly by parents and child caregivers. The usability issues identified with the various tasks involved when installing CSSs into vehicles using LATCH are shown in the following pages (see Table 4). In addition to the table below, findings are also presented in a more traditional FTA flow chart format which can be found in the Appendix.

**Table 4.** LATCH usability issues.

| LATCH USABILITY ISSUES | |
|---|---|
| **LOWER ANCHORING** | |
| Difficulty connecting to lower anchors | • Recessed lower anchors are too far under seat bight to be seen or reached.<br>• Vehicle seat padding is too stiff to allow for easy access to lower anchors. |
| Incorrectly connecting to lower anchors | • Lower attachment connectors are not completely engaged/securely connected to both lower anchors.<br>• Lower attachment connectors are connected to vehicle hardware other than lower anchors.<br>• Two CSSs connected to the same lower anchor.<br>• Using both LATCH and seat belt to install a CSS when not authorized in vehicle and CSS manufacturer instructions.<br>• Specific to flexible lower attachment straps:<br>  o Attachment straps are too loose, allowing more than 1 inch of movement.<br>  o Attachment strap is twisted.<br>• Specific to convertible CSSs:<br>  o Flexible lower attachment strap is not routed through the correct belt path for rear-facing versus forward-facing use.<br>  o Push-on or hook connectors are not right-side up.<br>  o "Handed" connectors on flexible lower attachments are not moved accordingly when the CSS is rear facing versus forward facing (i.e., must be on a particular side of the CSS). |
| Cannot locate lower anchors | • Locations where lower anchors are and are not available are not easy to find in vehicle owner's manual.<br>• Lower anchor locations are not conspicuously labeled or marked in the vehicle.<br>• Lower anchors are covered or otherwise obstructed (e.g., for cosmetic purposes).<br>• Lower anchors are recessed too far under seat bight to be seen or easily reached.<br>• Mistaking non-lower anchor vehicle components for lower anchors. |
| Not securing unused components | • Lower attachment straps are not secured/stowed when top tether is used in conjunction with seat belt.<br>• Unused seat belt poses strangulation hazard. |

| **TOP TETHERING** | |
|---|---|
| Difficulty connecting to tether anchor | • Orientation/location makes top tether difficult to connect to and/or disconnect from tether anchor (especially in pickup trucks, vans, SUVs, etc.).<br>• Top tether strap is too short to reach tether anchor.<br>• Cannot determine how top tether should be routed (i.e., around head restraints especially in pickup trucks, SUVs, vans, etc.).<br>• Top tether adjustment mechanism will not fit through tether routing guide.<br>• No dedicated tether anchor for rear-facing CSSs is provided for top tether use. |
| Incorrectly connecting to tether anchor | • Top tether is not completely engaged/securely connected to tether anchor.<br>• Top tether strap is loose.<br>• Top tether strap is twisted.<br>• Top tether is connected to vehicle hardware other than tether anchor (e.g., cargo tie-down or vehicle seat component).<br>• Two CSSs connected to the same tether anchor.<br>• Top tether is not routed correctly from CSS to tether anchor (e.g., around or over head restraints). |
| Incorrect use of tether anchor | • Not using top tether when using lower anchors.<br>• Top tether is used for rear-facing CSS when it is not required according to manufacturer instructions. |
| Cannot locate tether anchor | • Designated tether anchor locations are not easy to find in vehicle owner's manual.<br>• Tether anchor locations are not conspicuous or conspicuously labeled in the vehicle.<br>• Tether anchor is covered or otherwise obstructed (e.g., material flap, carpeting, or plastic cover).<br>• Tether anchor location is variable among different vehicles (especially in SUVs, vans, pickup trucks, etc.).<br>• Mistaking other vehicle component for tether anchor (e.g., cargo tie-down or vehicle seat component). |
| Not securing unused components | • Top tether is not secured/stowed when convertible CSS is used in rear-facing position (e.g., strangulation or projectile hazard). |

| **VEHICLE FACTORS** | |
|---|---|
| CSS/child combined weight exceeds weight limits | • Lack of awareness of weight limits.<br>• Weight of child not factored in when using LATCH.<br>• Weight of CSS is not readily available on CSS or in CSS instruction manual.<br>• Confusion/misinterpretation of weight limit, not knowing that it includes the combined weight of child and CSS.<br>• Weight limits for lower anchors and tether anchors are not provided in vehicle owner's manual.<br>• Confusion due to weight limit differences for lower anchors and tether anchors within the same vehicle.<br>• Confusion due to different weight limits for lower anchors and tether anchors between vehicles. |
| Difficulties with center seating position | • Using inner bars of outboard lower anchors in the center position of the back seat when not specified as an option by vehicle manufacturer. |
| Lack of awareness of LATCH | • Vehicle owner's manual does not clearly indicate presence of LATCH.<br>• Lower anchors and/or tether anchors are not clearly labeled in the vehicle.<br>• Lack of public awareness campaigns/education regarding LATCH (i.e., new parents and their interactions with healthcare providers surrounding the birth of the child; NHTSA safety awareness brochures and pamphlets, etc.). |

## Conclusions and Recommendations

LATCH is a simple concept that is made more complex due to the wide variety of designs within vehicles and with CSSs. As with many systems, standardization is key to the ultimate success of LATCH as it relates to not only the design of the system components but also to the user interface and design for ease of use. Particularly important are the ability to easily locate and recognize LATCH components within the various seating positions in the vehicle, having unobstructed access to the components, and requiring LATCH in the center seating position of the back seat if space permits. In addition, consistency of design between vehicles will lead to more familiarity with the LATCH system, thus promoting more confidence and increasing the likelihood of proper use among parents and child caregivers. Also, beyond improvements in the physical design of the system, efforts must be placed on improving labeling and documentation in vehicle owners' manuals, continuing to raise overall awareness of LATCH by incorporating information into public awareness/media campaigns when appropriate, and through more strategic educational outreach programs such as during hospital discharges for newborns, which can be tailored especially for new parents and child caregivers on the proper use of LATCH. These conclusions lead to the following list of recommendations. The list is highly inclusive and provides a comprehensive itemization of the improvement options identified in the study.

*LATCH Availability*

- Provide LATCH in the center back seat position in all vehicles where space allows.
- Provide LATCH availability in all three seat locations in back seats where space allows.

*Standardization*

- Standardize weight limits for LATCH, both lower anchors and tether anchors, so they are the same in all new vehicles. Alternatively, increase the amount of force specified in S9.4.1(a)(b) of FMVSS 225 [3] for lower anchors to accommodate the heaviest CSS available occupied by a child at the weight limit of that CSS, with an acceptable safety factor, such that no plausible combined weight of a child and CSS could pose a significant risk of lower anchor failure in a crash.*
- Require minimum accessibility and ease-of-use standards. Researchers with IIHS/UMTRI recommend that lower anchors be at a depth of no more than ¾ inch in the seat bight, with a clearance angle of 54 degrees and requiring less than 40 pounds of force to connect to the anchor. (Note: the clearance angle refers to the angle of approach to the anchor. This area should be clear of obstructions.)
- Although not a vehicle issue per se, the lower attachments on CSSs (e.g., claw, snap-hook, or push-on) should be more consistent in their design from restraint to restraint. The variety of options available should be minimized, with a standard, intuitive design to reduce confusion.
- Set minimum guidelines for the size of routing guides so they adequately accommodate top tether adjustment mechanisms.

---

* If this recommendation is implemented, many of the recommendations that follow would no longer be necessary. They are, however, included here as options.

*Information Requirements*

- Clearly label locations of all lower anchors that are not readily visible.
- Require that all vehicle manufacturers include the following information in their vehicle owners' manuals:
    - Clearly indicate the 65-pound weight limit for LATCH and require this limit to be consistent among all vehicles.
    - Emphasize that the weight limit includes the combined weight of the child and the CSS.
- Require that all CSS manufacturers clearly indicate the weight of the CSS on the product label.

*Clarity and Consistency of Information Provided*

- Clearly label locations of all tether anchors, especially in non-sedan vehicles including SUVs, vans, pickup trucks, etc.
- For more complex routing, especially common in vans and pickups, provide labels near the tether anchor clearly diagramming the tether route (e.g., around head restraint).
- Provide consistent information in vehicle owners' manuals. The terminology and types of information presented should be consistent from vehicle to vehicle and include but not be limited to the following:
    - Seating positions where lower anchors are and are not available.
    - Depiction of labels/icons identifying LATCH components.
    - Weight limits, including an explanation that the weight limits include the combined weight of the child and the CSS.
    - Importance of tethering, with and without LATCH.
    - Warnings regarding incorrect installation including:
        - Lower anchors/connectors:
            - Using the lower attachments/anchors and the seat belt simultaneously to install a CSS in cases where not allowed.
            - Lower attachment connectors that are not completely engaged/securely connected to both lower anchors.
            - Lower attachment connectors that are connected to vehicle hardware other than the lower anchors (e.g., vehicle seat component).
            - Using inner bars of outboard lower anchors in the center position of the back seat when not specified as an option by the vehicle manufacturer.
            - When using the lower anchors, the unused seat belt may pose a strangulation hazard if not stowed out of reach of the child.
        - Tether anchors/connector:
            - Incorrect routing of the top tether to the tether anchor (e.g., around head restraint).
            - Not using the top tether; emphasizing that the top tether must be used when the lower anchors/attachments are used and that the tether should also be used when possible with seat belt installation.
            - Top tether that is not completely engaged/securely connected to the tether anchor.

- Top tether that is connected to vehicle hardware other than the tether anchor (e.g., cargo tie-down or vehicle seat component).
- Two CSSs connected to the same tether anchor when not specified as an option by the vehicle manufacturer.

*Public Awareness and Education*

- Develop and implement strategic educational outreach programs such as during hospital discharges for newborns, which can be tailored especially for new parents and child caregivers on the proper use of LATCH.
- Increase public awareness through public information and education efforts specific to LATCH (online and printed material). The following information should be included:
    - What is LATCH?
    - How is LATCH used?
    - What are the benefits to the safety of the child when a CSS is installed using LATCH?
    - What are the dangers to the child if the restraint is not installed correctly, with or without LATCH?
    - What are the most common mistakes made when installing a CSS using LATCH?
    - What is the tether and why is its use so critical (emphasizing importance of tether use with lower anchors or with seat belt use)?
    - What are the weight limits of the LATCH components, and how does the user determine the weight (i.e., child plus CSS)?
    - As the child grows, how is LATCH different when using rear- versus forward-facing CSSs?

Future studies building on current research, including focus groups and prototype design studies tailored specifically to the usability issues associated with LATCH, would provide insight into the specific features that will further enhance the design of the LATCH system, as well as identify design features to avoid.

## References


1. Bull, Marilyn J., Karen Bruner Stroup, and Susan Gerhart (1988) Misuse of Car Safety Seats, *Pediatrics* 1988; 81-98.

2. Decina, Lawrence E. and KathleenY. Knoebel, (1996). Patterns of Misuse of Child Safety Seats. DOT HS 808 440. U.S. Department of Transportation/National Highway Traffic Safety Administration, Washington, D.C.

3. Code of Federal Regulations, Title 49, Government Printing Office, Washington, D.C., 2002, Part 571.213 and 571.225.

4. Boyle, John M., and Patricia Vanderwolf (2005). *2003 Motor Vehicle Occupant Safety Survey, Volume 5, Child Safety Seat Report.* DOT HS 809 858. U.S. Department of Transportation/National Highway Traffic Safety Administration, Washington, D.C.

5. Boyle, John M., and Cheryl Lampkin (2009). *2007 Motor Vehicle Occupant Safety Survey, Volume 5, Child Safety Seat Report.* DOT HS 810 978. U.S. Department of Transportation/National Highway Traffic Safety Administration, Washington, D.C.

6. Insurance Institute for Highway Safety. *Status Report,* Vol. 38, No. 5, June 11, 2003.

7. Decina, Lawrence E., and Kathy H. Lococo (May 2003). *Misuse of Child Restraints.* DOT HS 809 671. National Highway Traffic Safety Administration, Washington, D.C.

8. Decina, Lawrence E., Kathy H. Lococo, and Charlene T. Doyle (December 2006). *Child Restraint Use Survey: LATCH Use and Misuse.* DOT HS 810 679. National Highway Traffic Safety Administration, Washington, D.C.

9. Insurance Institute for Highway Safety. "Tethers Get Used 43 Percent of the Time," *Status Report*, Vol. 45, No. 9, September 8, 2010.

10. Safe Kids USA (2011). A Look inside American Family Vehicles, http://www.safekids.org/research-report/look-inside-american-family-vehicles-national-study-79000-car-seats-2009-2010.

11. Insurance Institute for Highway Safety and University of Michigan Transportation Research Institute (April 2012). *Vehicle LATCH System Features Associated with Correct Child Restraint Installations*. Insurance Institute for Highway Safety, Arlington, Virginia.

12. University of Michigan Transportation Research Institute. Crash Protection for Child Passengers: Rationale for Best Practice, http://www.umtri.umich.edu/content/rr_43_1.pdf.

13. CarSeatsMadeSimple. LATCH (Lower Anchors and Tethers for Children): Rear-Facing, http://www.carseatsmadesimple.org/install.cfm?FSID=263.

14. Carseatblog.com. How to Use a Rear-Facing Tether, http://carseatblog.com/12749/how-to-use-a-rear-facing-tether/.

15. The Car Seat Lady. LATCH Tip: Right Way Up or Upside Down–Attaching the Lower Anchor Connector Right. http://thecarseatlady.wordpress.com/2011/02/09/latch-tip-right-way-up-or-upside-down-attaching-the-lower-anchor-connector-right /

16. HealthyChildren.org. On the Go, http://www.healthychildren.org/English/safety-prevention/on-the-go/Pages/Car-Safety-Seat-Checkup.aspx.

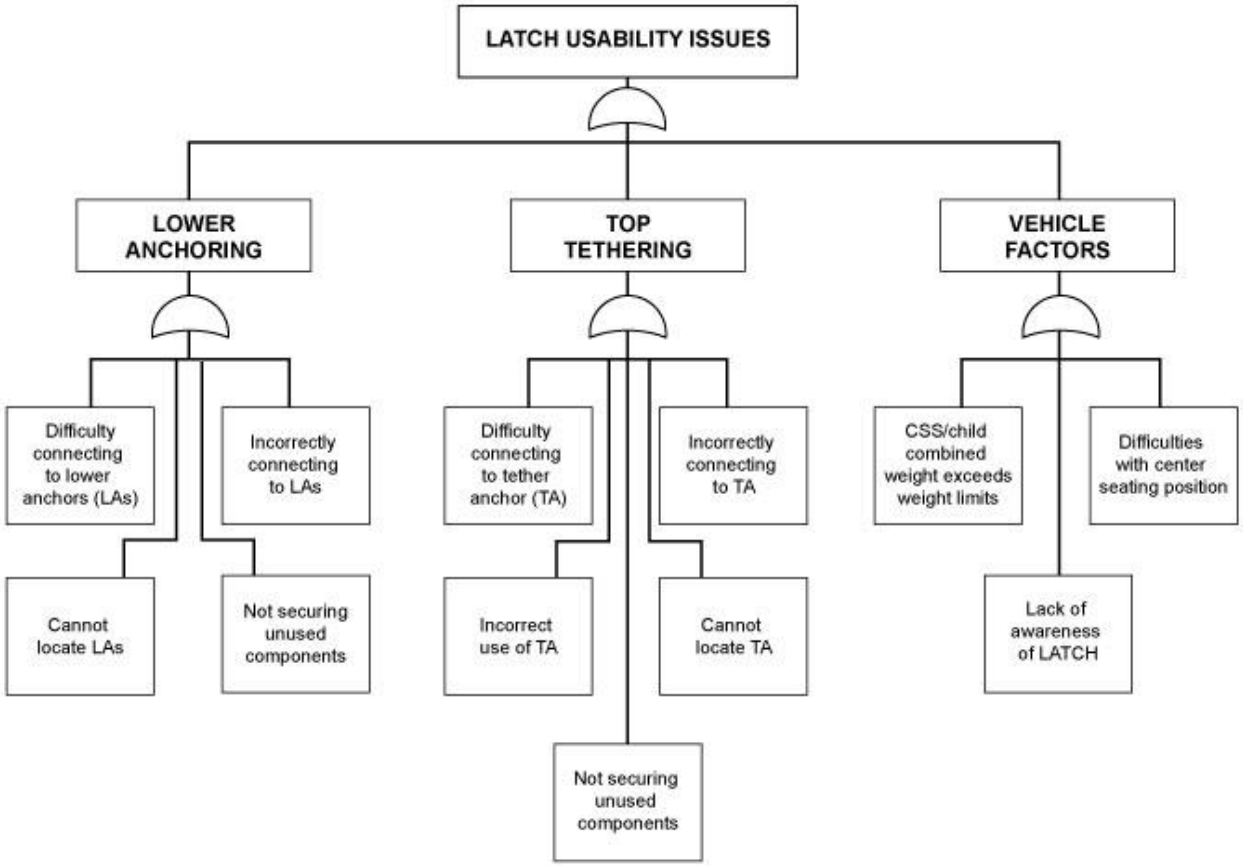
17. National Highway Traffic Safety Administration, http://www.nhtsa.gov/ChildSafety/step2

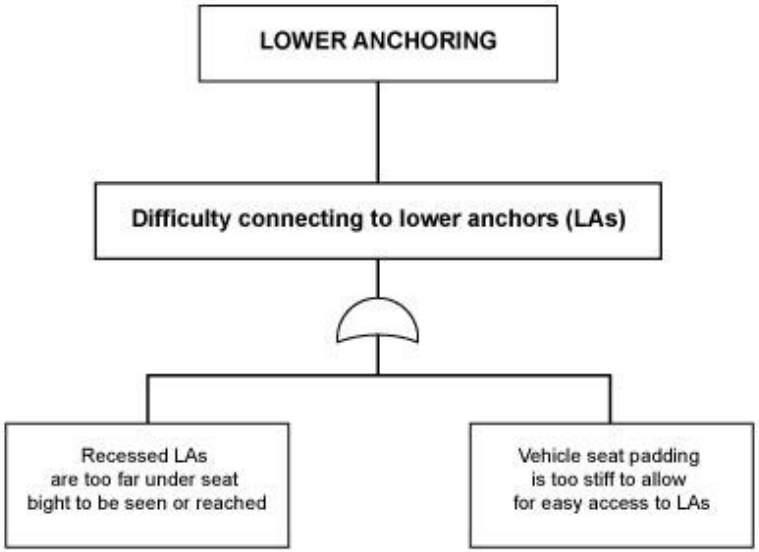
18. Stewart, Deborah D., Denise Donaldson, Nancy J. Lang, and Katrina Rose (2013). *The LATCH Manual: Using Lower Anchors and Tethers for Child Restraints, Eighth Edition*. Safe Ride News Publication, Seattle, Washington.

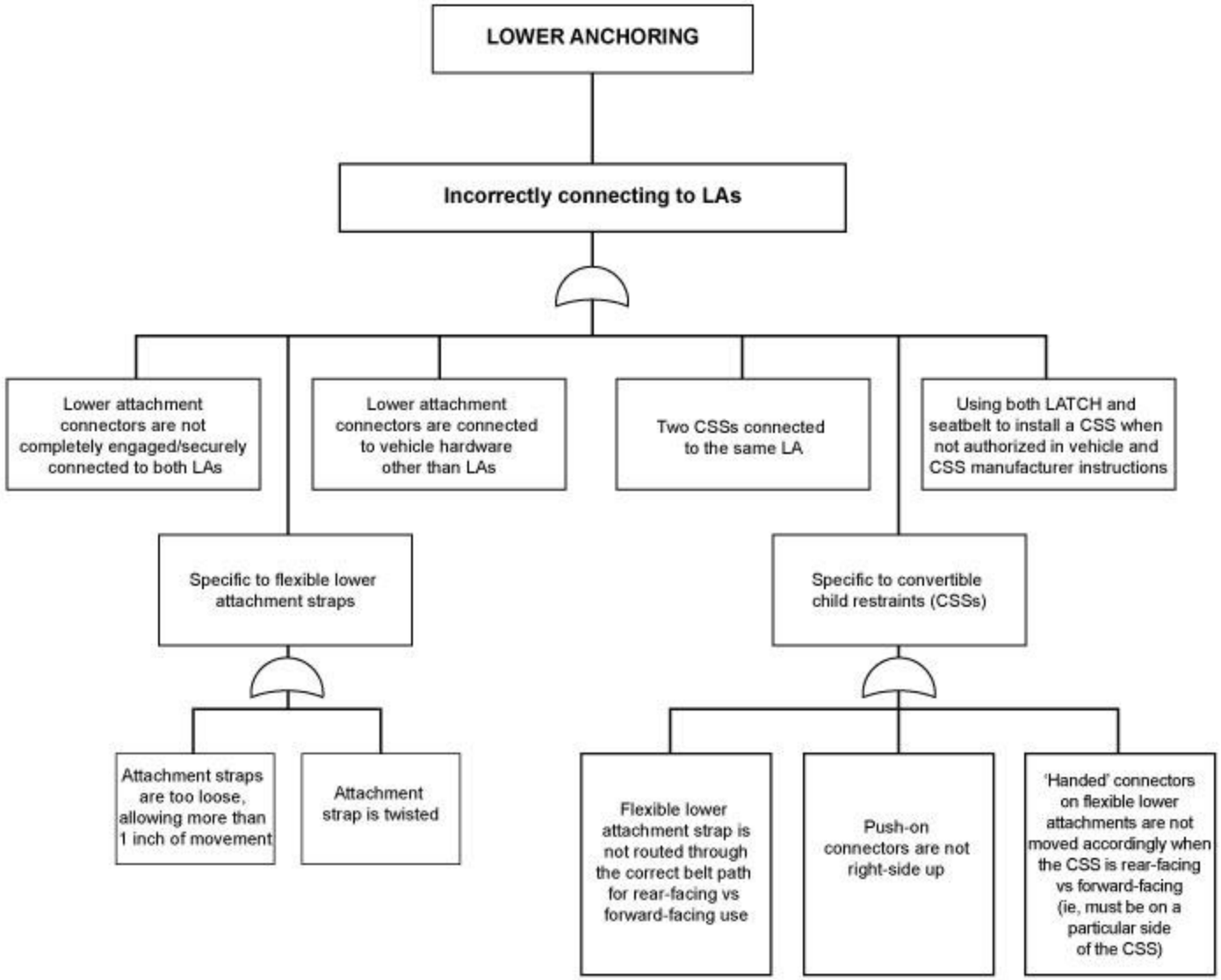
19. Smith, Edward, and Anne Koop (2011). *Guidance on Human Factors Safety Critical Task Analysis, First Edition*. The Energy Institute, London.

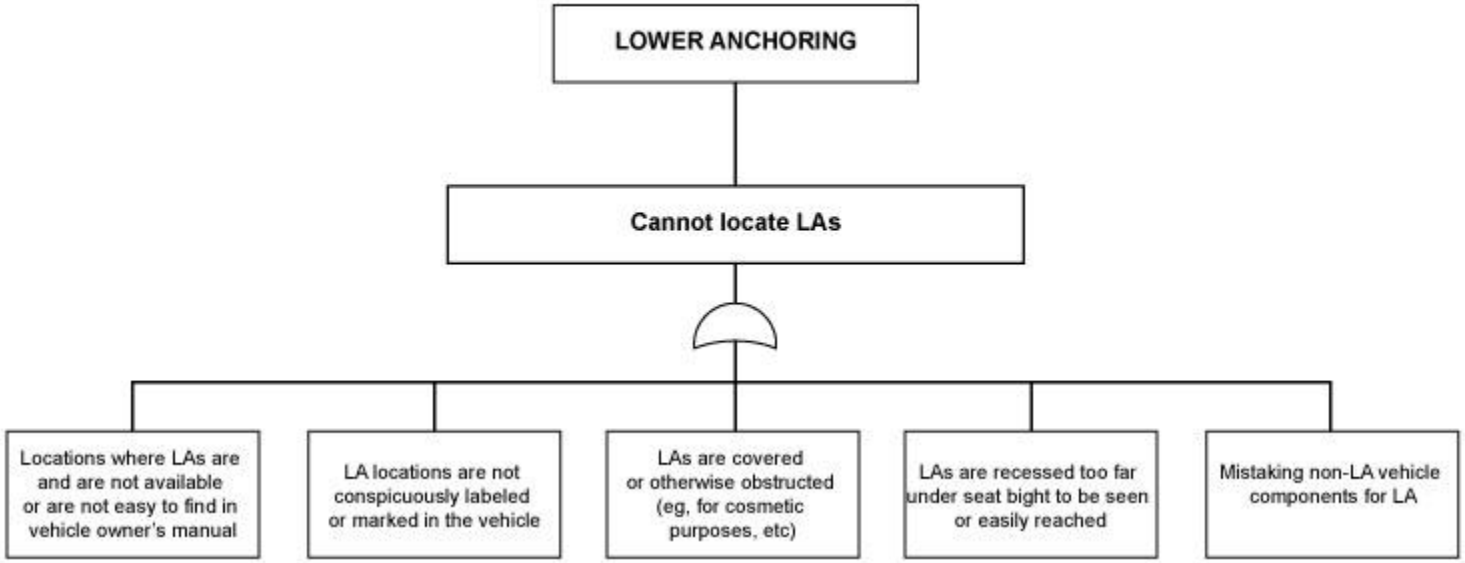
## Appendix

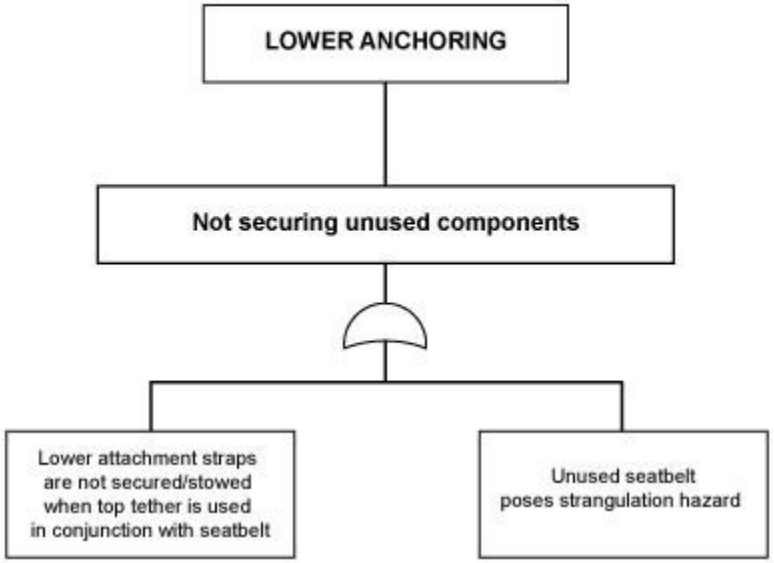
**FAULT TREE ANALYSIS FLOW CHART**

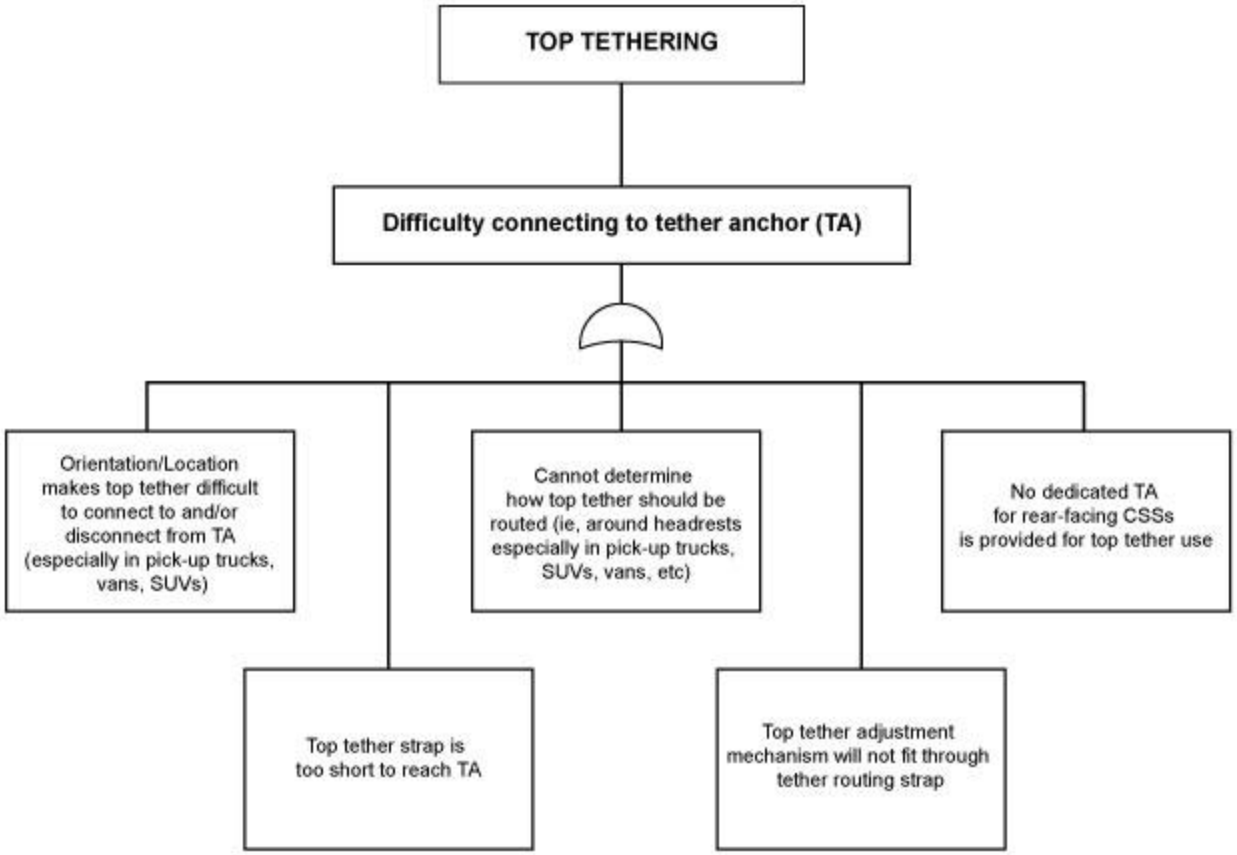


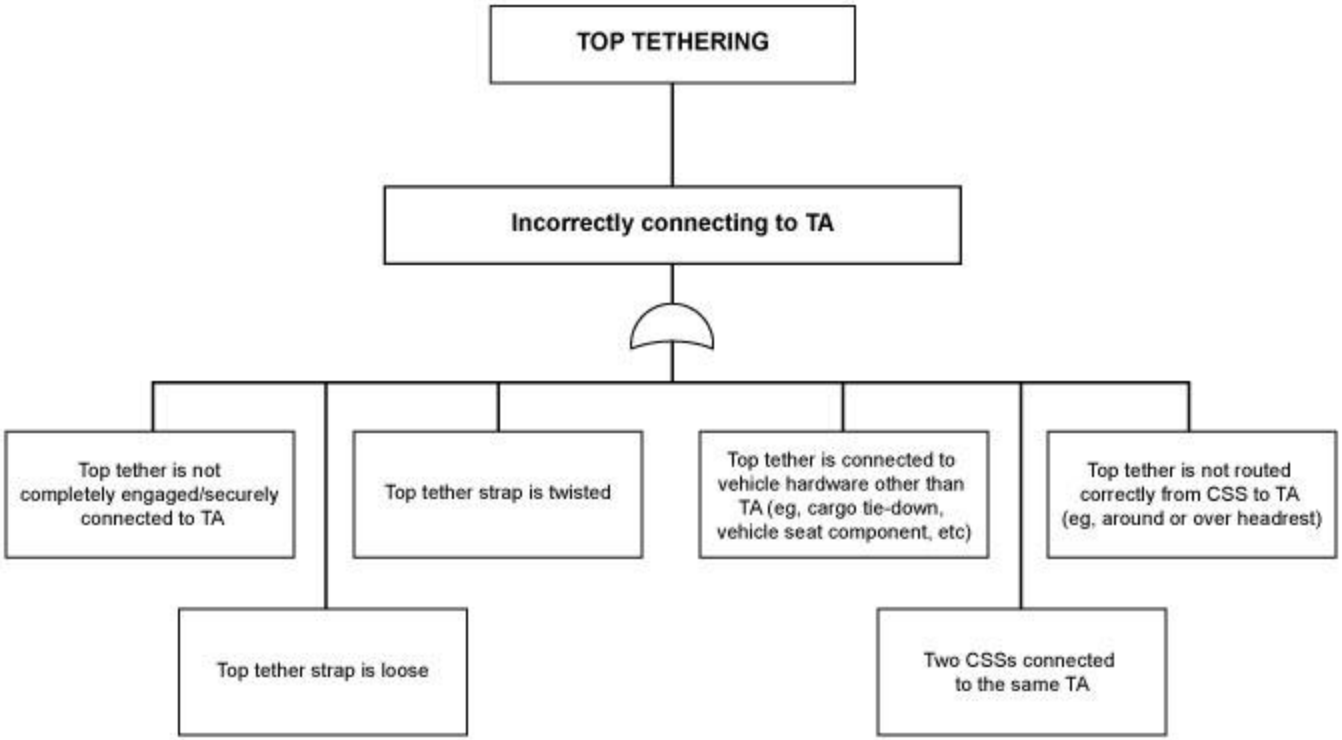

LOWER ANCHORING
Difficulty connecting to lower anchors (LAs)
Recessed LAs
are too far under seat
bight to be seen or reached
Vehicle seat padding
is too stiff to allow
for easy access to LAs

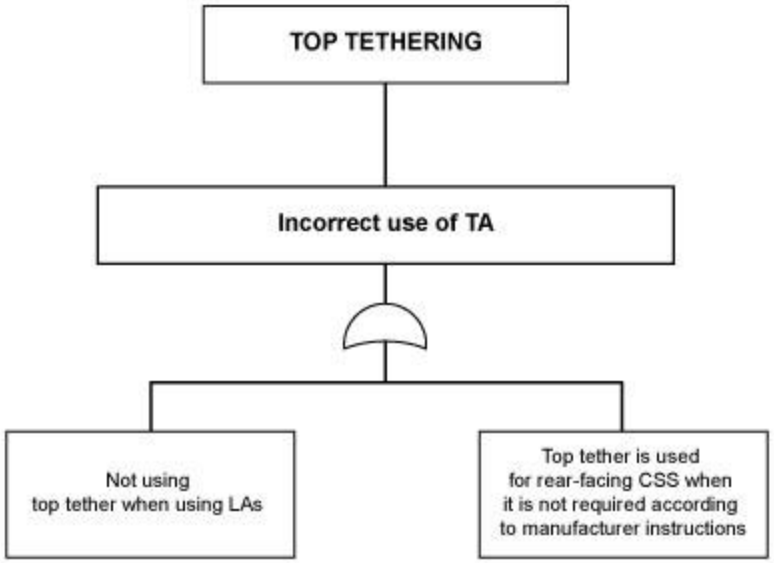

LOWER ANCHORING
Incorrectly connecting to LAs
Lower attachment connectors are not completely engaged/securely connected to both LAs
Lower attachment connectors are connected to vehicle hardware other than LAs
Two CSSs connected to the same LA
Using both LATCH and seatbelt to install a CSS when not authorized in vehicle and CSS manufacturer instructions
Specific to flexible lower attachment straps
Specific to convertible child restraints (CSSs)
Attachment straps are too loose, allowing more than 1 inch of movement
Attachment strap is twisted
Flexible lower attachment strap is not routed through the correct belt path for rear-facing vs forward-facing use
Push-on connectors are not right-side up
'Handed' connectors on flexible lower attachments are not moved accordingly when the CSS is rear-facing vs forward-facing (ie, must be on a particular side of the CSS)

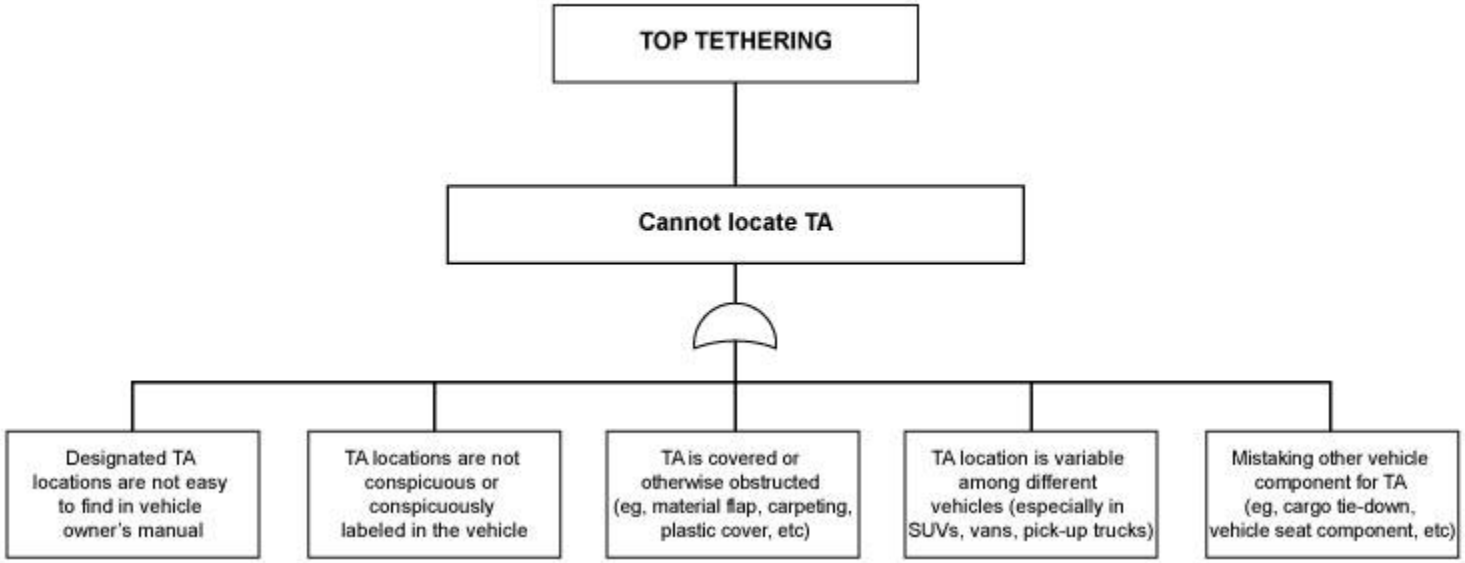

LOWER ANCHORING
Cannot locate LAs
Locations where LAs are and are not available or are not easy to find in vehicle owner's manual
LA locations are not conspicuously labeled or marked in the vehicle
LAs are covered or otherwise obstructed (eg, for cosmetic purposes, etc)
LAs are recessed too far under seat bight to be seen or easily reached
Mistaking non-LA vehicle components for LA

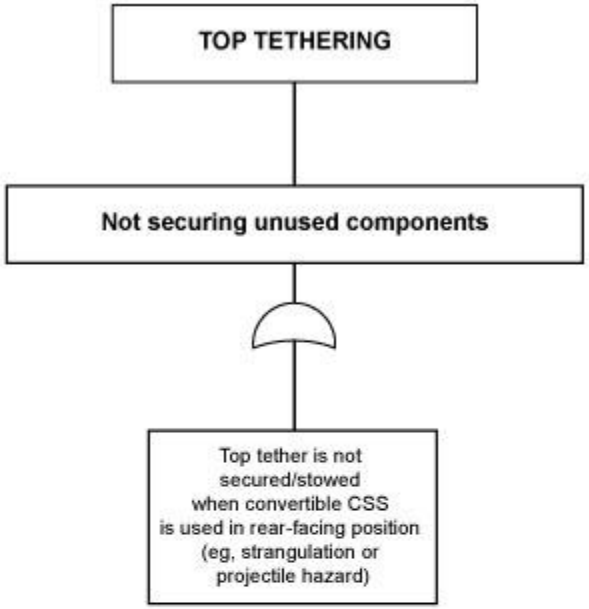

LOWER ANCHORING
Not securing unused components
Lower attachment straps are not secured/stowed when top tether is used in conjunction with seatbelt
Unused seatbelt poses strangulation hazard

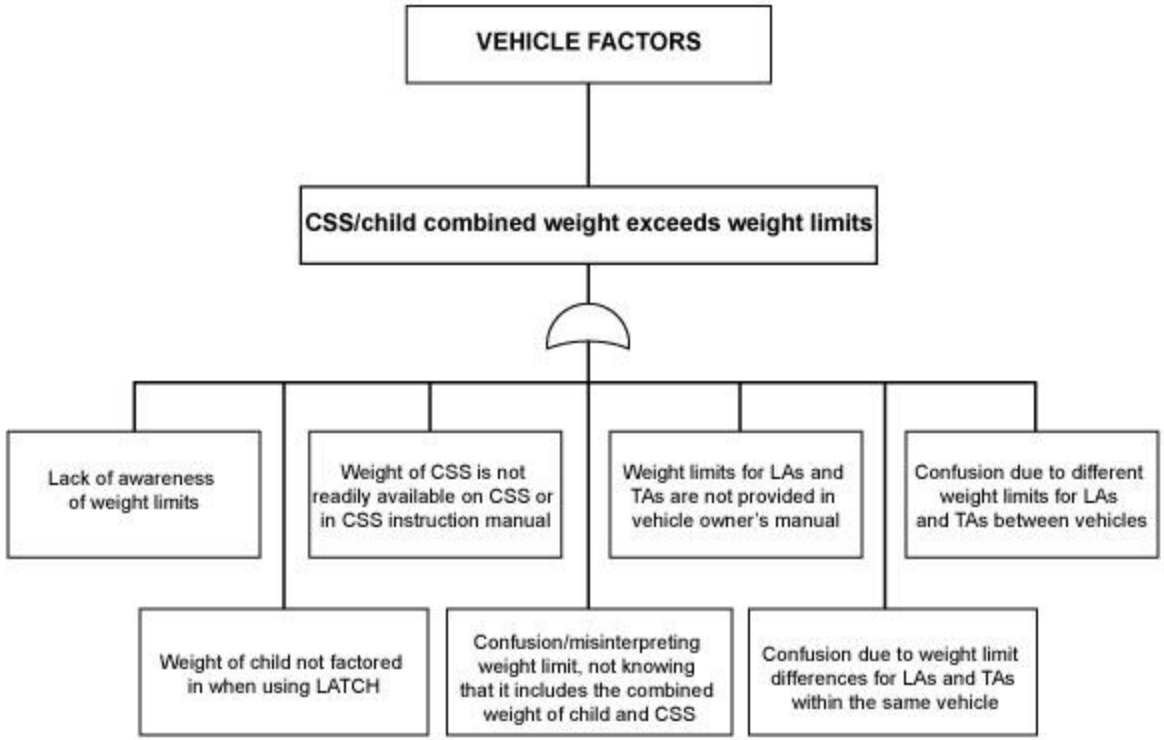

TOP TETHERING
Difficulty connecting to tether anchor (TA)
Orientation/Location makes top tether difficult to connect to and/or disconnect from TA (especially in pick-up trucks, vans, SUVs)
Cannot determine how top tether should be routed (ie, around headrests especially in pick-up trucks, SUVs, vans, etc)
No dedicated TA for rear-facing CSSs is provided for top tether use
Top tether strap is too short to reach TA
Top tether adjustment mechanism will not fit through tether routing strap

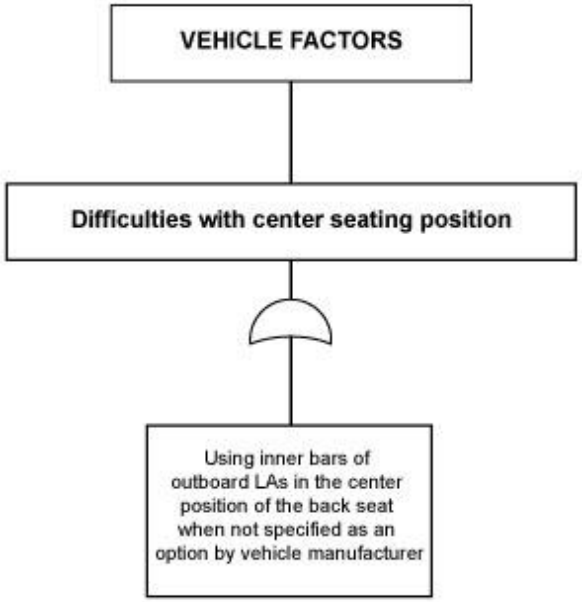

TOP TETHERING
Incorrectly connecting to TA
Top tether is not completely engaged/securely connected to TA
Top tether strap is twisted
Top tether is connected to vehicle hardware other than TA (eg, cargo tie-down, vehicle seat component, etc)
Top tether is not routed correctly from CSS to TA (eg, around or over headrest)
Top tether strap is loose
Two CSSs connected to the same TA

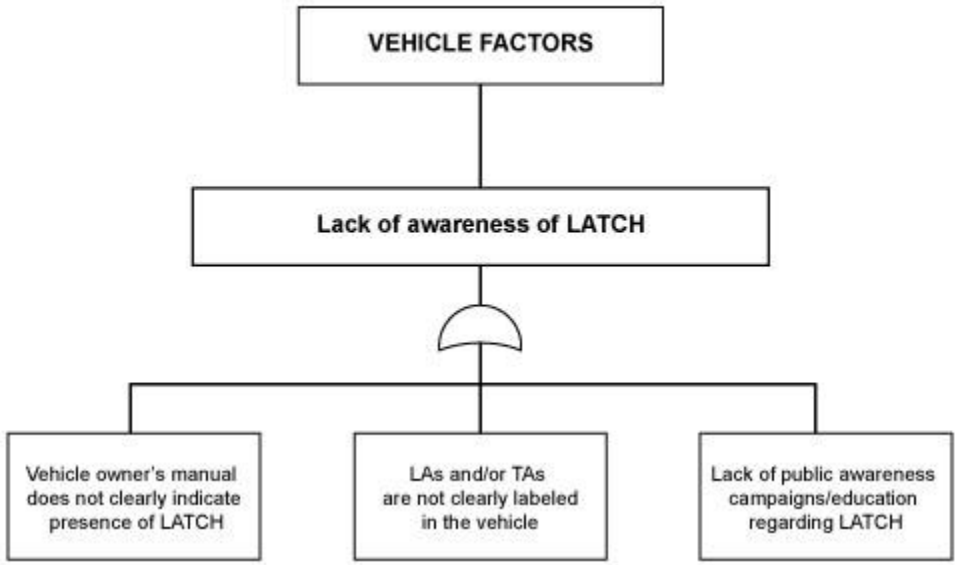

TOP TETHERING
Incorrect use of TA
Not using
top tether when using LAs
Top tether is used
for rear-facing CSS when
it is not required according
to manufacturer instructions


TOP TETHERING
Cannot locate TA
Designated TA locations are not easy to find in vehicle owner's manual
TA locations are not conspicuous or conspicuously labeled in the vehicle
TA is covered or otherwise obstructed (eg, material flap, carpeting, plastic cover, etc)
TA location is variable among different vehicles (especially in SUVs, vans, pick-up trucks)
Mistaking other vehicle component for TA (eg, cargo tie-down, vehicle seat component, etc)


TOP TETHERING
Not securing unused components
Top tether is not secured/stowed when convertible CSS is used in rear-facing position (eg, strangulation or projectile hazard)


VEHICLE FACTORS
CSS/child combined weight exceeds weight limits
Lack of awareness of weight limits
Weight of CSS is not readily available on CSS or in CSS instruction manual
Weight limits for LAs and TAs are not provided in vehicle owner's manual
Confusion due to different weight limits for LAs and TAs between vehicles
Weight of child not factored in when using LATCH
Confusion/misinterpreting weight limit, not knowing that it includes the combined weight of child and CSS
Confusion due to weight limit differences for LAs and TAs within the same vehicle


VEHICLE FACTORS
Difficulties with center seating position
Using inner bars of outboard LAs in the center position of the back seat when not specified as an option by vehicle manufacturer


VEHICLE FACTORS
Lack of awareness of LATCH
Vehicle owner's manual does not clearly indicate presence of LATCH
LAs and/or TAs are not clearly labeled in the vehicle
Lack of public awareness campaigns/education regarding LATCH