

1 **Title:**

2 What Drives the Effective Integration of Lift Assists in Automotive Assembly? Perspectives
3 from Operators, Ergonomists, and Manufacturers

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5 **Authors:**

6 Ahmad Raza Usmani ^a, Sunwook Kim ^a, Marty Smets ^b, and Maury A. Nussbaum ^{a*}

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8 **Associations:**

9 ^a Department of Industrial and Systems Engineering, Virginia Tech, Blacksburg, VA 24061, USA

10 ^b Manufacturing Technology Development, Ford Motor Company, Glendale, MI 48239, USA

11

12 * Corresponding Author: Dr. Maury A. Nussbaum, Department of Industrial and System
13 Engineering, Virginia Tech, 521 Whittemore Hall (MC 0118), 1185 Perry Street, Blacksburg, VA
14 24061, USA

15 Phone: 540-231-6053; Email: nussbaum@vt.edu

16

17 **ORCID iDs:**

18 Ahmad Raza Usmani <https://orcid.org/0000-0003-0675-7074>

19 Sunwook Kim <https://orcid.org/0000-0003-3624-1781>

20 Marty Smets <https://orcid.org/0000-0003-0974-6514>

21 Maury A. Nussbaum <https://orcid.org/0000-0002-1887-8431>

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1 **Abstract**

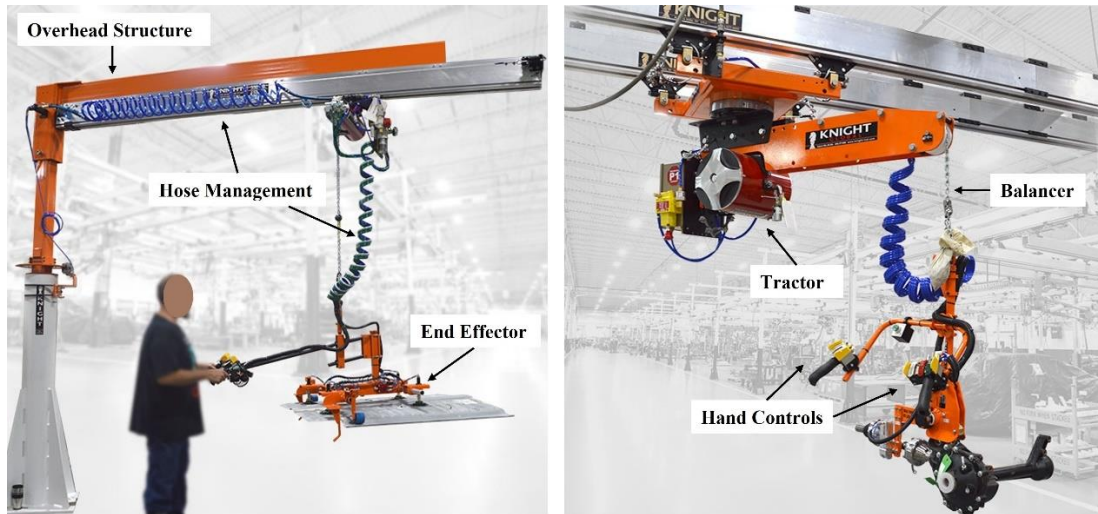
2 Automotive assembly workers experience elevated risks of work-related musculoskeletal
3 disorders due to frequent material handling. Lift assists (LAs) can reduce these risks by offsetting
4 payload weights. However, integrating LAs into complex workflows can be challenging, and
5 workers may choose not to use LAs to achieve other objectives. We interviewed 16 operators,
6 nine ergonomists, and six LA manufacturers to capture diverse viewpoints. Content analysis
7 revealed perspectives on LA usability, design, implementation, and operational concerns.
8 Operators noted physical demands in initiating, turning, or stopping LAs, and emphasized
9 lightweight designs, simplified controls, and structured training. Ergonomists reported
10 retrofitting LAs into workflows not designed for LAs, creating integration challenges. LA
11 manufacturers described balancing ergonomic goals with operational demands and evolving
12 requirements, emphasizing the need for better design feedback. Our findings suggest that heavy
13 equipment, complex controls, and limited training hinder successful LA implementation; we
14 offer recommendations to improve future LA design and implementation.

15 **Keywords:** Automotive Assembly, Material Handling Devices, Lift Assists, Hoists, Low Back,
16 Physical Demands, Usability

1 **1.0 Introduction**

2 Work-related musculoskeletal disorders (WMSDs) remain a prevalent concern in many
3 occupational sectors (Da Costa & Vieira, 2010). In the United States, direct costs of WMSDs to
4 employers are estimated at ~\$2.24 billion annually (Liberty Mutual Insurance, 2023). A major
5 risk factor for WMSDs is manual material handling (MMH), which includes tasks such as lifting,
6 lowering, and carrying loads (Bao, 2015; Hoogendoorn et al., 2000; Hoy et al., 2010). Lifting
7 from elevated surfaces or at extended horizontal distances increases WMSD risks (Jorgensen et
8 al., 2005; Waters et al., 1994), particularly when combined with non-neutral postures. Heavier
9 payloads further elevate risk, with studies linking increased load mass to higher incidence of
10 WMSDs (Chaffin & Park, 1973; Coenen et al., 2014). While safe lifting limits are typically set
11 between 23–25 kg (~51–55 lbs.) depending on task conditions (NIOSH, 2007; Visser et al.,
12 2015), repeated handling of lighter loads can also contribute to WMSD risks (Garg & Moore,
13 1992; Marras & Granata, 1997).

14 Automotive assembly workers frequently engage in manual handling of automotive
15 components, often working in constrained postures, exposing them to an elevated risk of
16 WMSDs (Punnett et al., 1991; Vandergrift et al., 2012). Since the mass and shape of automotive
17 components are determined by the functional and structural requirements of the vehicle, reducing
18 exposure to repetitive load handling needs to be carefully managed. Ergonomic interventions
19 therefore serve as more feasible and effective solutions to reduce physical demands (Verbeek et
20 al., 2012). Among such interventions, material handling devices such as Lift Assists (LAs) are
21 commonly used in automotive assembly. LAs are mechanical manipulators designed to support
22 the movement and placement of automotive components, with these actions controlled either
23 fully by operators, partially assisted, or even fully motor driven. By offsetting gravitational
24 loads, and in some cases the forces required to transfer an automotive component, LAs can
25 reduce the physical exertion required and thereby mitigate the risk of WMSDs (Glock et al.,
26 2021). LAs vary in design—for example, operating on overhead rails or pivoting arms, or being
27 manual/power-assisted (Figure 1)—but these devices typically comprise an overhead structure,
28 tractor, hose management, arm, balancer, end effector, and hand controls (Prange, 2025). The
29 specific design and mechanisms selected are based on task requirements.



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 2 Figure 1. Common types of Lift Assists used in automotive assembly. A jib crane system (left) and an
 3 overhead bridge crane-mounted system (right) are shown, with their key elements labeled. (Images used
 4 with permission from knightglobal.com)

5 LA can improve trunk posture and body kinematics (Mirka et al., 2002) as well as
 6 reduce physical demands and perceived exertion during material handling tasks (Lowe et al.,
 7 2020; Wurzelbacher et al., 2020). However, realizing these benefits in practice remains
 8 challenging, especially because our understanding remains limited of how different LA designs
 9 affect the biomechanical demands of different material handling tasks. Existing studies indicate
 10 that LA effectiveness depends on both the design and working mechanism, as well as the specific
 11 lifting task involved (Nussbaum et al., 2000; Resnick & Chaffin, 1997). Although LAs alleviate
 12 the payload weight, operators still need to exert physical effort to manage the inertia of the
 13 payload and manipulator system when starting or stopping movements, or when changing
 14 directions. These actions can require hand forces equivalent to 30–50% of maximum capabilities
 15 (Nussbaum et al., 2000; Resnick & Chaffin, 1997; Resnick & Chaffin, 1996; Woldstad &
 16 Chaffin, 1994). Furthermore, integrating LAs into a workflow presents several challenges,
 17 including worker resistance, increased task completion times, and the need for additional training
 18 (Chaffin et al., 1999; Nussbaum et al., 2000). Despite these known issues, a comprehensive
 19 understanding of how specific LA design approaches and workflow parameters influence
 20 biomechanical demands and user experience across diverse industrial tasks is lacking, critically
 21 hindered by the underexplored perspectives of key stakeholders—operators, ergonomists, and
 22 LA manufacturers—despite their essential roles in LA design, implementation, and utilization.

23 We aimed in the current work to provide an enhanced understanding of the factors
 24 influencing LA use in automotive assembly. To achieve this, we completed semi-structured
 25 interviews with three key stakeholder groups (i.e., operators, ergonomists, and LA
 26 manufacturers). This approach enabled us to explore the unique perspectives of each group, and
 27 thereby to learn about perceived benefits, challenges, limitations, concerns, and preferences
 28 related to LA design, implementation, and daily operation.

29

1 **2.0 Methods**

2 **2.1 Participants**

3 Participants were recruited through our industry partner, Ford Motor Company (MI,
4 USA), focusing on three key stakeholder groups involved in the use of the LAs. The first group,
5 *operators*, included automotive assembly line workers who utilized LAs at their workstations.
6 The second group, *ergonomists*, included professionals at Ford responsible for implementing and
7 evaluating ergonomic practices in plant operations, particularly those related to integrating LAs
8 into workflows. The third group, *LA manufacturers*, consisted of professionals involved in the
9 design and development of LA systems for industrial use.

10 We used snowball sampling (Goodman, 1961) and continued recruitment until qualitative
11 data saturation was reached; that is, when additional interviews no longer yielded new or
12 meaningful information. Saturation occurred after interviews with 16 operators (13 males and
13 three females), nine ergonomists (seven males and two females), and six LA manufacturers (all
14 males, from two different companies). Self-reported operator characteristics included [mean
15 (SD)]: age 46.1 (11.9) years, body mass 99.4 (23.4) kg, stature 177.8 (7.8) cm, and work
16 experience 14.4 (11.5) years. Ergonomists and LA manufacturers reported overall experience of
17 19.3 (6.5) and 28.0 (7.0) years, including 6.9 (4.0) and 19.0 (1.0) years in their current roles,
18 respectively. The study protocol was approved by the UAW-Ford National Joint Committee for
19 Health and Safety and the Institutional Review Board at Virginia Tech (IRB-22-834), and verbal
20 informed consent was obtained from all participants prior to participation, following a clear
21 explanation of study aims and procedures.

22

23 **2.2 Data Collection**

24 We conducted semi-structured online interviews via Webex (Cisco, CA, USA) from
25 October, 2022 to November, 2023. Each interview session lasted approximately 30 minutes and
26 was facilitated by a primary interviewer (MN), with one or two additional investigators present
27 to ask supplementary questions as needed. The interview scripts were customized with core
28 questions for all groups, and specific sections were tailored to each stakeholder group (see
29 Appendix I). Specifically, operators discussed their preferences regarding LA use or avoidance
30 and the factors influencing their decisions. Ergonomists were asked about the broader
31 implications of implementing LAs, particularly their effect on workflow and ergonomic
32 outcomes. LA manufacturers were asked to share their design process, as well as challenges and
33 constraints associated with developing LA systems. All interviews were video recorded for
34 subsequent detailed analysis.

35

36 **2.3 Data Analysis**

37 Interview recordings were transcribed verbatim using automated transcription software
38 (OpenAI Whisper, California, USA). The lead author (ARU) manually reviewed each transcript

1 against the original recording to correct any errors. Using a grounded theory approach (Strauss &
2 Corbin, 1994), two investigators systematically reviewed the corrected transcripts multiple times
3 to develop a deep understanding of the data. During this process, key patterns in participant
4 responses were identified and distilled into preliminary codes relevant to the study objectives,
5 based on the content analysis approach informed by Hsieh & Shannon (2005). These initial codes
6 were then discussed and organized by the research team to create a preliminary coding
7 framework. The team collaboratively reviewed and refined this framework multiple times until
8 consensus was reached on its structure and code definitions. The lead author then systematically
9 applied the finalized framework to all transcripts, with regular team discussions to review
10 emerging patterns, discuss challenging segments, and ensure consistent interpretation. Finally,
11 themes and categories were iteratively developed and refined, by organizing and analyzing
12 related codes to capture meaningful patterns within and across the different stakeholder groups
13 regarding their LA experiences and perspectives. Direct quotes provided below are verbatim
14 from respondents, excepting minor edits that were made to enhance clarity.

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16 **3. Results**

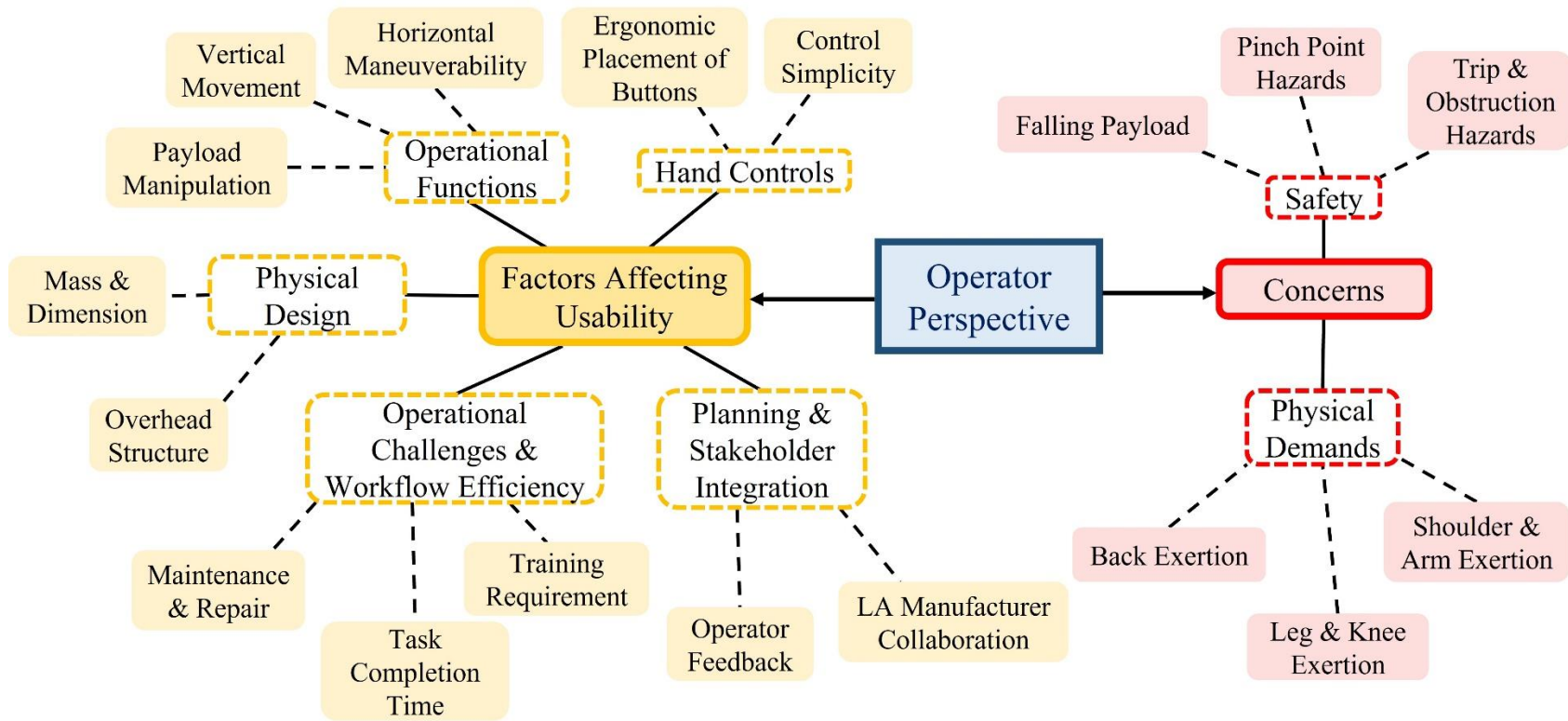
17 We first present the themes identified for each stakeholder group (operators, ergonomists,
18 LA manufacturers), as detailed below and illustrated in Figures 2–4. Findings are then presented
19 in subsequent sections (3.1–3.4) structured around overarching, cross-group themes, integrating
20 perspectives from all three groups wherever relevant.

21 Operator responses were organized into two main categories and seven associated themes
22 (Figure 2), including:

- 23 • *Hand Controls*: Complexity and placement of control buttons (e.g., for lifting, lowering,
24 clamping, or rotating), and the effects of these features on usability.
- 25 • *Operational Functions*: Maneuvering the LA and manipulating the payload, and how
26 these aspects affect usability.
- 27 • *Physical Design*: Effects of LA size, weight, and structural features on usability.
- 28 • *Operational Challenges and Workflow Efficiency*: Practical challenges in operating LAs,
29 including maintenance, task completion time, and training requirements.
- 30 • *Planning and Stakeholder Integration*: Mechanisms for collecting and incorporating
31 operator feedback and input during the design and manufacturing phase of LAs.
- 32 • *Physical Demands*: Exertion on body parts (e.g., the back, lower limbs, and upper limbs)
33 during LA use.
- 34 • *Safety*: Concerns and risks associated with LA use, including falling payloads, pinch
35 points, and tripping hazards. (Note: Given our primary focus on ergonomics and usability,
36 we do not present detailed results related to this theme.)

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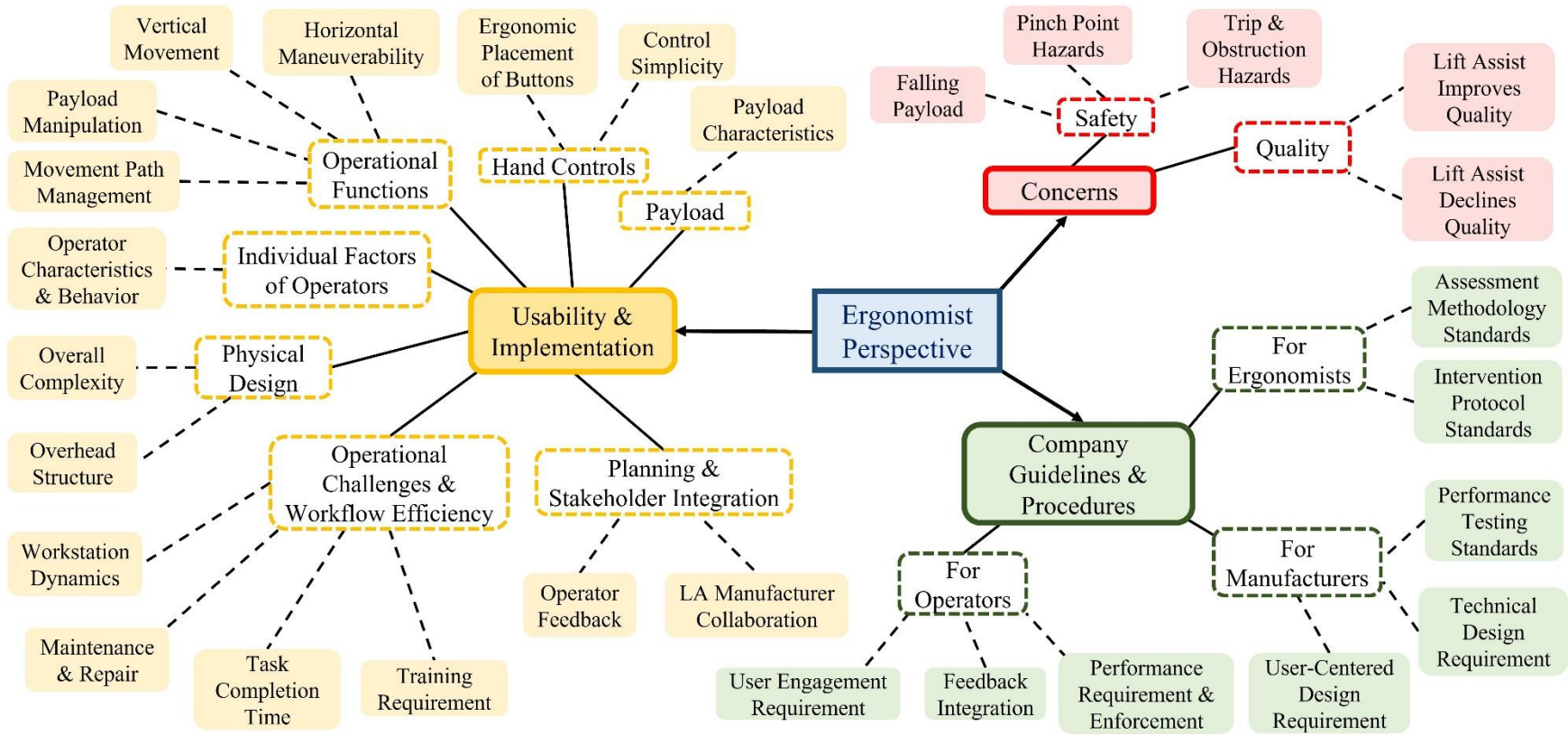
Figure 2. Schematic representation of operator perspectives on Lift Assists, illustrating two main categories (solid-line rounded boxes), seven themes (dashed-line rounded boxes), and corresponding codes.

1 The responses from ergonomists were grouped into three main categories containing 12
2 themes (Figure 3), covering:

- 3 • *Payload*: Influence of payload characteristics on the effective LA use.
- 4 • *Hand Controls*: Effects of control complexity and placement on usability.
- 5 • *Operational Functions*: Essential functional features and effects of these features on
6 usability.
- 7 • *Individual Factors of Operators*: Influence of operator characteristics (e.g.,
8 anthropometry, physical capability, preferences, and attitudes) on the effective use of LA.
- 9 • *Physical Design*: Effects of LA structure and design features on usability.
- 10 • *Operational Challenges and Workflow Efficiency*: Practical challenges affecting LA
11 operations (e.g., workstation dynamics, maintenance, task completion time, and training).
- 12 • *Planning and Stakeholder Integration*: Influence of planning, early collaboration, and
13 operator feedback on usability and user acceptance.
- 14 • *Quality*: Effects of LA use on payload (i.e., automotive components) quality, including
15 improvements in placement accuracy and potential damage (e.g., scratches, dents).
- 16 • *Guidelines for Operators*: Recommended practices and responsibilities for the safe and
17 effective use of LAs by operators.
- 18 • *Guidelines for LA Manufacturers*: Design requirements and standards to guide the
19 development of effective LAs.
- 20 • *Guidelines for Ergonomists*: Ergonomic assessment standards, protocols, and
21 methodologies used to support the evaluation, design, and implementation of LAs.
- 22 • *Safety*: Concerns regarding risks such as falling payloads, pinch point hazards, and
23 tripping or obstruction. (As noted above, additional details are not presented on this
24 theme.)

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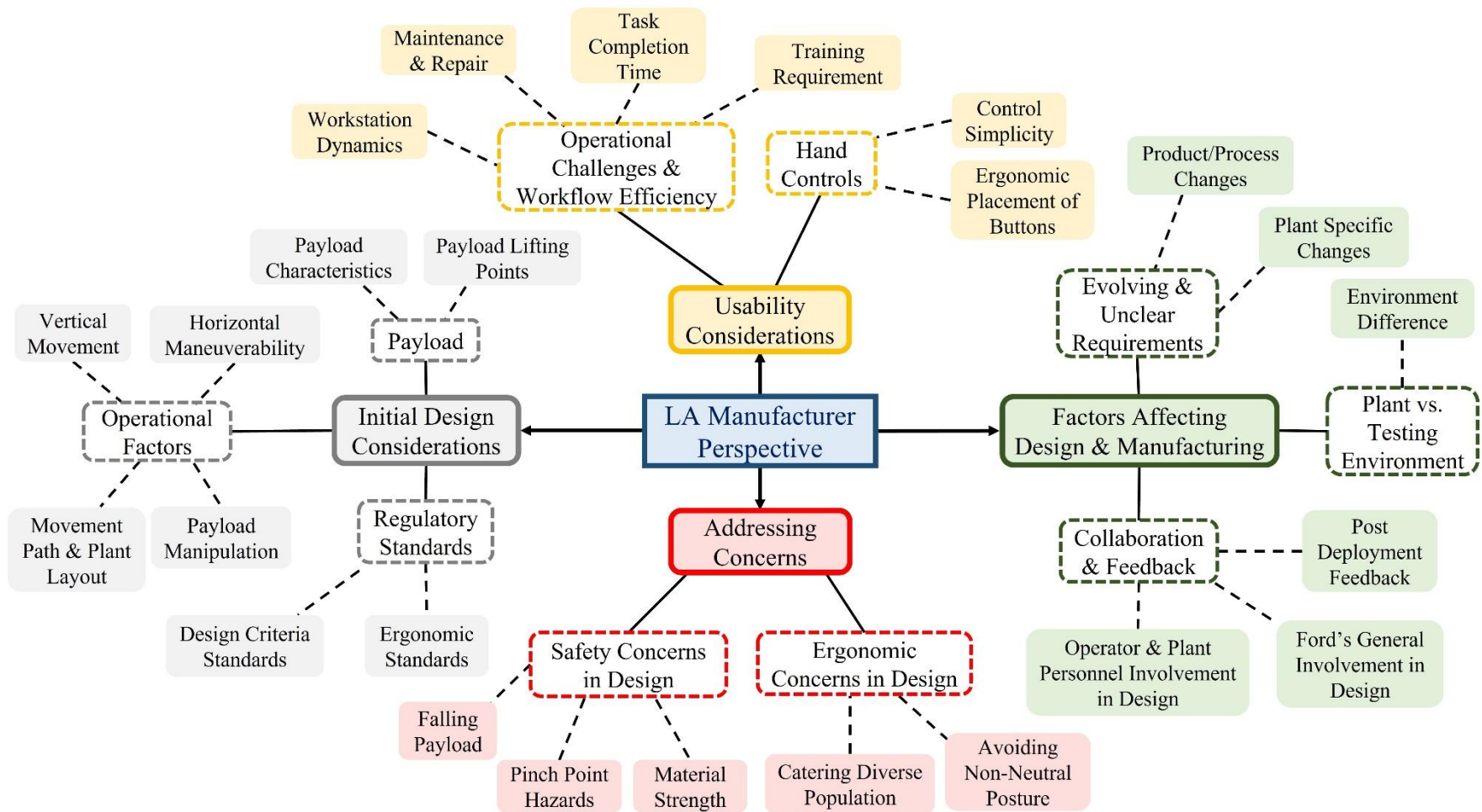
Figure 3. Schematic representation of ergonomist perspective on Lift Assists, illustrating three main categories (solid-line rounded boxes), 12 themes (dashed-line rounded boxes), and corresponding codes.

1 LA manufacturer responses were grouped into four categories containing 10 themes
2 (Figure 4), as follows:

- 3 • *Payload*: Consideration of payload characteristics during LA design.
- 4 • *Operational Factors*: Influence of plant layout, environment, and workstation dynamics
5 on LA design.
- 6 • *Regulatory Standards*: Adherence to ergonomic and regulatory requirements in design.
- 7 • *Hand Controls*: Usability considerations related to the design of hand controls.
- 8 • *Operational Challenges and Workflow Efficiency*: Influence of workplace constraints on
9 usability, including maintenance requirements, workstation dynamics, and training needs.
- 10 • *Evolving and Unclear Requirements*: How evolving and unclear requirements affect the
11 design and development of LAs.
- 12 • *Plant vs Testing Environment*: Discrepancies between plant conditions and testing
13 facilities, and design adjustments during real-world deployment.
- 14 • *Collaboration and Feedback*: Role of early input from operators, plant personnel, and
15 internal company teams, along with post-deployment feedback, in improving LA design
16 and deployment.
- 17 • *Ergonomic Concerns in Design*: Integration of ergonomic considerations into LA design.
- 18 • *Safety Concerns in Design*: Incorporation of safety considerations into LA design. (As
19 noted above, additional details are not presented on this theme.)

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3 Figure 4. Schematic representation of LA manufacturer perspective on Lift Assists, illustrating four main categories (solid-line rounded boxes), 10
 4 themes (dashed-line rounded boxes), and corresponding code

1 3.1 Factors Affecting Usability

2 Table 1 summarizes key factors influencing LA usability, categorized by stakeholder
 3 group. The overarching cross-group themes include: *Hand Controls*, *Operational Functions*,
 4 *Physical Design of LA*, *Payload Characteristics*, and *Operational Challenges and Workflow*
 5 *Efficiency*.

6 Table 1. Factors affecting Lift Assist (LA) usability as identified by operators, ergonomists, and
 7 LA manufacturers. In the header row, “*N*” indicates the total number of participants interviewed
 8 per stakeholder group. In each cell, “*n*” indicates the number of respondents within that group
 9 who mentioned the corresponding point.

Factors	Operators (<i>N</i> =16)	Ergonomists (<i>N</i> =9)	LA Manufacturers (<i>N</i> =6)
<i>Hand Controls</i>			
a. Simplicity	Preferred simple, intuitive controls with fewer buttons (<i>n</i> =5).	Reported complex controls discourage operators from using LAs (<i>n</i> =4).	Prioritized standardization and fewer buttons (<i>n</i> =2)
b. Ergonomic Placement of Buttons	Favored thumb-operated buttons on handlebars to reduce grip effort and reach (<i>n</i> =6).	Recommended intuitive layouts, consistent positioning, and adjustable handlebars (<i>n</i> =6).	Reported handle design iterations during buy-offs (i.e., final design approval stages); noted adjustable handles increase weight and inertia (<i>n</i> =4).
<i>Operational Functions and Processes</i>			
a. Horizontal Maneuverability	Found heavy hoists difficult to pivot and stop. Preferred manual movement for control. Powered movement reduced effort but limited movement flexibility. Suggested lighter designs (<i>n</i> =6).	Reported that advanced systems (e.g., servomotor driven hoists) improved intuitiveness but faced resistance due to slower speeds and learning curves. Experienced operators preferred simpler systems (<i>n</i> =6).	Emphasized balancing robustness and ease of movement. Used torque tubes for precise tasks, and lightweight cables for center of gravity lifts (<i>n</i> =2).
b. Vertical Movement	Cited slow speeds and unexpected movements as concerns, often requiring manual intervention (<i>n</i> =3).	Acknowledged ergonomic benefits of servomotors but noted inefficiencies in multi-axis movements; recommended simpler systems for safer operation (<i>n</i> =6).	Highlighted system trade-off: servos precise but costly, and required maintenance; pneumatics provided cushioning but lacked precision; electric cylinders cost-effective for moderate-precision tasks (<i>n</i> =3)
c. Payload Manipulation (Clamping,	Reported challenges with limited visibility, fragile payloads, and awkward payload geometries. Correct positioning of the	Emphasized need for simplicity, precision, and maintaining payload orientation	Identified payload reorientation as a major challenge. Recommended single and rigid lift points

Rotating, and Positioning)	payload on moving line often required trial and error, leading to elevated physical exertion ($n=9$).	from dunnage to assembly. Reorienting payloads increased complexity, and reduced visibility ($n=8$).	to minimize operator exertion and eliminate unnecessary motions ($n=2$).
d. Movement Path and Plant Layout	-	Advocated straight-line paths to reduce walking and enhance task flow, while cautioning that overly constrained layouts could restrict lower-body movement and increase physical exertion, particularly when handling heavy payloads ($n=3$).	Stressed better understanding of workstation layout during the design process ($n=5$).
<i>Physical Design of LA</i>			
a. Mass, Dimension, and Complexity	Reported shoulder exertion from handling heavy, bulky LAs. Recommended better weight distribution to enhance maneuverability and reduce fatigue ($n=5$).	Noted simplified, intuitive tools eased training and integration. Often over-engineered, even when handling very light payloads. Complexity also stemmed from making LAs compatible with different payloads ($n=9$).	-
b. Overhead Structure and Host Management System	Reported challenges with cables, chains, and suspension systems, such as frequent cable tangling. Preferred free-hanging chains to improve maneuverability. ($n=3$).	Noted poorly articulated systems and coiled cables in jib crane systems increased operator resistance. Recommended ceiling-mounted or bridge-and-rail systems with festoon cables ($n=5$).	-
<i>Payload Characteristics</i>	-	Typically used for payloads over 13–18 kg (~30–40 lbs.) and often bypassed for 6–12 kg (~15–30 lbs.) because operators do not perceive the latter as physically demanding and prefer manual handling to	Emphasized integrating finalized payload size, weight, and lifting points. Recommended standardized, well-placed lift points to simplify tooling, and early collaboration with product teams to avoid clearance challenges ($n=3$).

			save time. Recommended accounting for user variability when setting weight thresholds for LA use (<i>n</i> =7).
Operational Challenges and Workflow Efficiency			
a.	Workstation Dynamics	-	Highlighted challenges of tight, cluttered workstations, including poor reach zones and suboptimal post placement, restricting maneuverability. Stressed that constrained layouts may reduce walking but increase physical demands (<i>n</i> =5).
b.	Maintenance	Reported problems, including air pressure loss, worn LA elements, and stuck controls. Recommended preventative maintenance for common failures (<i>n</i> =11).	Noted that poor maintenance reduced maneuverability, prompting operators to revert to manual handling, especially for payloads in 6–12 kg (~15–30 lbs.) range. It also compromised product quality, causing scratches or dents (<i>n</i> =3).
c.	Task completion Time	Reported mixed effects: three said that LAs slowed operations, three reported no effects on task completion time, and one said it depended on the task (<i>n</i> =7).	Emphasized aligning LAs with cycle times, minimizing disruptions, and simplifying designs to promote LA use over manual lifting (<i>n</i> =9).
d.	Training Requirements	Reported typical training durations from a few hours to two weeks. Emphasized hands-on practice essential for proficiency in controls, maneuverability, and payload placement (<i>n</i> =15).	Recommended that designers lead hands-on training sessions for operators, line leaders, and maintenance teams. Incremental training over a week proved effective, but inconsistent training for transient staff remained a challenge (<i>n</i> =5).

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3.2 Concerns and considerations

Quality

Majority of the ergonomists (~56%) noted that LAs can improve quality by ensuring precise alignment, minimizing operator error, and reducing the chance of damage (e.g., scratches and dents) or improper installation. LAs were considered especially beneficial for large, heavy, or delicate payloads, where guided placements prevent damage. Features such as alignment aids and operator training further support quality improvements. For instance, one ergonomist mentioned: *“I think it improves quality when a lift assist is used correctly. Especially when loading, let's say, A-class surface parts (automotive component surfaces) to the vehicle [Note: such a surface is visible to the customer, and is thus under the highest scrutiny.] We had a lift assist for a roof panel. So, if you loaded it by hand, you ended up scraping across the crossbar of the vehicle. Versus a lift assist that would be able to load it down straight into design position. From a quality perspective, you eliminate that risk of scratches on the vehicle by using your lift assist.”* However, most ergonomists (~67%) also mentioned that poorly designed or overly complex LAs could negatively affect quality, such as due to misalignments or defects on the automotive component being lifted. Lack of hard stops, poor visibility, and rushed handling contributed to these defects, highlighting the need for ergonomic designs and comprehensive training. Commenting on the potential negative effects, one ergonomist explained: *“I think a poorly designed lift assist can degrade the quality both of the operator's work as well as the product itself. If it's not designed properly or if the team is looking to save costs and eliminate the positive triggers or switches or anything of that nature, that can create an operator's ability to either clasp or grab a part in a manner that it's not designed to.”*

Physical Demands and Ergonomic Considerations

Almost 56% operators reported physical exertion in the back, legs, knees, shoulders, and arms, stemming from non-neutral postures and the effort required for horizontal maneuvering, pivoting, and controlling LA momentum. One operator explained: *“Your knees start hurting because you're pivoting too much while trying to stop the overhead hoist.”* Almost all ergonomists (~89%) noted variability in usage linked to operator characteristics. For example, they reported observing that operators with greater stature and body mass often appear to prefer manual lifting for payloads up to 6–18 kg (~15–40 lbs.) to save time, while smaller operators relied more on LAs. As one ergonomist mentioned: *“There are a lot of parts (automotive components) that are more in between weights where you might get somebody on the stronger end of the spectrum who feels that they can just hand load. Whereas somebody on the weaker end of the spectrum would prefer to have a lift assist.”* Note that LAs were still implemented in such cases, even though usage varied across operators. They also noted that experienced operators often resisted LA use due to familiarity with manual handling. Some LA manufacturers (~33%) emphasized the importance of designing for diverse anthropometries to ensure usability across operators, underscoring how physical variability may affect both the adoption and

1 **effective use of LAs.** Minimizing non-neutral postures (e.g., extensive bending, overreaching,
2 awkward hand positions) was a priority. Strategies to achieve this goal included adjustable
3 handles and dunnage heights, though LA manufacturers acknowledged challenges of balancing
4 ergonomics with practical trade-offs such as increased costs and ensuring compatibility with
5 existing workstations.

7 **3.3 Coordination, Integration, and Validation**

8 Feedback from Operators and Plant Personnel

9 All stakeholder groups consistently highlighted the importance of operator feedback.
10 Some operators (~31%) expressed frustration with tools implemented without their input and
11 emphasized the need for early consultation. They also provided feedback on training methods,
12 preferring LA manufacturer-led hands-on training to prevent potential information loss often
13 associated with peer-to-peer training. Similarly, ~56% ergonomists reinforced early operator
14 engagement in design, testing, and implementation to enhance usability, recommending input
15 from both experienced and novice operators for diverse perspectives. Majority of the LA
16 manufacturers (~67%) also stressed early involvement of operators, plant personnel, and the
17 plant LA acquisition team to integrate feedback, minimize late-stage issues, and ensure smoother
18 deployment. However, LA manufacturers also reported challenges such as inconsistent
19 participation, delayed involvement, and internal communication gaps, requiring proactive
20 collaboration for improved LA usability.

21 Evolving requirements and changes in product and processes

22 LA manufacturers noted challenges from evolving requirements, including non-finalized
23 design requirements, shifting tolerances, and frequent product/process changes, leading to
24 inefficiencies, redesigns, and added costs. Adapting tools for lifting different payloads further
25 complicated the design process. One of the LA manufacturers explained: *“You get a particular
26 plant and you've got three different models coming down one assembly line. Now that fixture that
27 was supposed to pick up one particular door (payload) in one plant, it now has to pick up three
28 different doors, where each door has a different pick point. So, that adds complexity and a lot
29 more weight to the fixture because you need sets of details so that you're able to pick up various
30 models.”* A vast majority of the LA manufacturers (~83%) identified clearer processes, finalized
31 data for the payload (i.e., automotive component), 3D workstation layouts and modular designs
32 as critical for minimizing rework and ensuring effective implementation. As one of the LA
33 manufacturers mentioned: *“Have your process down before it gets to us. We get statement of
34 works that we read, and the ones with good statement of works tend to work a lot better.”*
35 Consequently, consistent coordination between the LA manufacturers, layout engineers, process
36 engineers, and ergonomists was deemed essential to align requirements and avoid last-minute
37 adjustments.

38 Testing and Validation in Controlled vs. Plant Environments

1 Some LA manufacturers (~33%) highlighted challenges in replicating plant conditions
2 during controlled testing, a factor often leading to discrepancies that affect LA usability and
3 design. They noted that despite efforts to simulate realistic setups, unforeseen obstacles (e.g., air
4 ducts) may emerge post-deployment, requiring adjustments and redesigns. One of the LA
5 manufacturers mentioned: *“Sometimes you will shift a tool and say oh whoa, we missed that air
6 duct in the way, and then we’ll have to, again, fluid design our way out of it. At that point, now
7 again you’re changing a design that might not be quite how you intended it, but we have to get
8 around this air duct.”*

10 **3.4 Company Guidelines, Procedures, and Standards**

11 Both LA manufacturers and ergonomists emphasized the need for clear guidelines for LA
12 design, implementation, and use to ensure compliance with safety, regulatory, and ergonomic
13 standards. Most of the LA manufacturers (~67%) specifically described navigating company
14 internal design specifications, and regional requirements (such as seismic standards), often
15 balancing safety, robustness, and usability through iterative adjustments. They also described
16 establishing standardized dimensions—such as for handles—by incorporating a range of working
17 heights and operating force (push, pull, etc.) thresholds to account for operator variability, while
18 noting that advanced trolley systems can reduce exertion and improve functionality. From the
19 perspective of ~44% of the ergonomists, there was a need for refining guidelines to address
20 practical gaps and avoid overengineering, which they suggested could reduce operator resistance.
21 They emphasized early engagement of operators to align designs with practical needs. Some of
22 the ergonomists (~33%) also suggested mandating LA use for payloads in the range of 13–18 kg
23 (~30–40 lbs.), citing insufficient current enforcement as a concern.

24 To reduce testing discrepancies between designer facilities and plants, ~44% ergonomists
25 proposed adaptable designs validated in operational environments. Both LA manufacturers and
26 ergonomists stressed the need for robust performance testing. While LA manufacturers reported
27 relying on ergonomic standards, ergonomists emphasized that existing tools such as force gauges
28 and ergonomic checklists, though widely used, may not adequately capture the actual physical
29 demands and LA usability. As one ergonomist explained *“You’re using your core muscles to turn
30 the lift assist. It’s hard to get an accurate value with the force gauge on what that actually
31 entails. One of the complaints we’ve heard is for the vehicle door, where you have to make that
32 twist or turn motion. And if the lift assist is too heavy or doesn’t function properly, that will
33 sometimes get to be a high effort. And it’s a hard one to measure with your force gauge.”*
34 Ergonomists highlighted the need for complementary assessments to ensure that devices deemed
35 acceptable during buy-offs (i.e., final design approval stages) are actually adopted and
36 consistently used in production environments. Finally, establishing clear intervention protocols
37 throughout the LA lifecycle was deemed essential by ~77% ergonomists, to prevent
38 underutilization and maintain efficiency.

40 **4. Discussion**

1 We sought to better understand the benefits, concerns, challenges, and preferences
2 associated with different aspects of LAs in automotive assembly by capturing perspectives from
3 operators, ergonomists, and LA manufacturers. Stakeholder interviews revealed three key
4 categories wherein changes are needed to improve user acceptance: *physical elements; processes*
5 *and workflow*; and *planning, management, and policies*. The following sections elaborate on
6 each category, integrating qualitative inputs with existing evidence to identify design and
7 implementation considerations that are likely to influence LA usability and operational
8 efficiency.

10 4.1. Physical Elements of Lift Assist

11 Stakeholder interviews revealed that the physical design of LAs substantially influenced
12 operator perspective towards the LAs. Approximately 31% operators reported that excessive
13 mass and bulkiness of LAs increased shoulder exertion and made manual maneuvering more
14 difficult. All the ergonomists emphasized the importance of simplified, lightweight designs to
15 facilitate integration and reduce the training burden. These perspectives align with prior evidence
16 that for manually maneuvered LAs, heavier manipulators and payloads increased push and pull
17 forces, elevate physical demands, and reduce task efficiency (Marras et al., 1995; Nussbaum et
18 al., 1999, 2000; Resnick & Chaffin, 1996). Strategies to reduce LA mass include the use of
19 lightweight materials and refining the design of LA joints, thereby enhancing usability without
20 compromising material strength. While minimizing LA mass can reduce physical demands on
21 operators, precision and quality requirements for vehicles must also be considered. For example,
22 certain high-precision tasks, such as fitting doors with tight body panel gaps, require heavier,
23 motor-driven LAs with advanced positioning systems to achieve strict dimensional tolerances.
24 Thus, when LAs are maneuvered manually, minimizing LA mass is critical; however, if higher
25 mass LAs are needed to meet quality and safety standards, incorporating motor driven LAs helps
26 offset physical demands on operators. LAs are generally designed to accommodate variability
27 rather than an average operator. Vertical handle heights are often specified across a broad range,
28 and manufacturers typically provide vertical adjustability so that operators can set the handles to
29 their preferred height. This approach acknowledges that the operator assigned to a job may differ
30 in stature, mass, and strength. After product launch, features are sometimes tailored to address
31 the needs of the specific operators working in those roles. Designing for variability ensures that a
32 wider range of operators can effectively use the LAs, since relying on an average user would
33 systematically exclude many individuals (Burgstahler, 2009; de Vries & Parkinson, 2014; Gandy
34 et al., 2003).

35 Our interviews revealed that in addition to LA mass, the overhead structure and hose
36 management system also affects the ease of maneuverability. Both operators (~19%) and
37 ergonomists (~56%) reported that excessive momentum when using poorly articulated overhead
38 track systems in jib cranes limits control and increases physical demands, indicating a need for
39 friction-optimized tracks or integrated braking to improve precision without increasing physical
40 effort. These stakeholder concerns are corroborated by experimental evidence. For instance,
41 Resnick & Chaffin (1997) found that movement time using a hoist with an overhead rail was

1 45% slower than one with a fixed pivot and 21% slower than an articulated arm. Although
2 overhead rails reduced peak forces compared to fixed pivots, they also increased task completion
3 times, making these designs less suited for short, repetitive tasks. Nussbaum et al. (2000)
4 similarly reported that hoists with overhead tracks increased task completion time by up to 63%
5 compared to manual handling, though they reduced peak hand forces by 40–50%. In a recent
6 field study of automotive assembly, Prange (2025) found a mean increase of 56% in task
7 completion time when using lift assists compared to manual handling. Such findings support
8 current stakeholder inputs that poorly optimized overhead configurations can negatively affect
9 usability, highlighting the need for system designs that balance load reduction with operator
10 control and efficiency. Although maneuverability could be improved by refining trolley designs
11 or by incorporating more responsive bearings, such modifications may be constrained by cost
12 and compatibility with existing infrastructure.

13 Both operators (~69%) and ergonomists (~78%) emphasized the importance of intuitive,
14 responsive hand controls, noting that LAs with excessive buttons or poorly organized interfaces
15 increased cognitive demands and task completion times. These preferences align with previous
16 research on human-machine interface design. For example, limiting controls to only those
17 relevant to the task requirements can enhance user performance in high-demand environments by
18 minimizing unnecessary cognitive processing (Dadashi et al., 2017). Moreover, overly complex
19 control schemes often lead to feature fatigue, wherein increased functionality reduces long-term
20 usability and satisfaction (Thompson et al., 2005). This complexity could also increase the
21 cognitive load on operators (diverting mental resources from the primary task) and thus might
22 lead to time pressure and frustration; workplace stressors that can negatively affect worker well-
23 being (Mühlenmeier et al., 2022; Sonnentag, 2001). However, it is important to note that
24 additional buttons or triggers are sometimes added to meet safety requirements, and thus intuitive
25 design must be carefully balanced with safety specifications.

26

27 4.2 Processes and Workflow

28 Stakeholder input revealed that LAs are often retrofitted into existing workstations rather
29 than integrated during the design phase, leading to spatial layouts that hinder their effective use.
30 During rebalancing between workstations, for example, some LAs may be relocated to
31 workstations with layouts different from those for which the LAs were originally designed,
32 further compounding these challenges. From a systems ergonomics perspective, such retrofitting
33 and relocations are component-level interventions that may fail to align with the broader work
34 system—including spatial layout, process flow, and production demands—thereby limiting both
35 efficiency and usability. Poorly integrated LAs can disrupt task flow, reduce productivity, and
36 increase frustration. When operators maneuver LAs, workspace constraints can prevent straight-
37 line movements, forcing operators to reorient payloads during transfers and navigate tightly
38 spaced areas—sometimes without sufficient space to even take a single step with the LA. These
39 constraints can result in compensatory torso twisting, which increases trunk asymmetry and
40 elevates the risk of low back injury (Granata & Marras, 1995; Van Dieën, 1996). Accordingly,
41 effective LA integration must be framed as a system-wide activity (requiring collaboration
42 among engineers, ergonomists, and management) to fully align the tool with task sequences,

1 **spatial layouts, and worker interactions in support of efficient and safe operations.** These insights
2 align with established ergonomic frameworks advocating for system-level integration of assistive
3 technologies. For example, Wilson (2014) highlighted the need for a systems ergonomics
4 approach that recognizes interdependencies among people, tasks, tools, and environments,
5 ensuring integration is contextually grounded, purposeful, and adaptable to operational demands.
6 In addition to integrating LAs, workstations should include other ergonomic features—such as
7 unobstructed straight paths and adjustable heights—to improve the usability of the LAs as an
8 ergonomic intervention, **thereby reducing both physical and cognitive** demands on operators
9 (Hedge, 2016; Lambrosa, 2022).

10 Several other process-related factors seem to influence LA effectiveness and adoption.
11 One key factor is the adequacy of training procedures, which should be improved to ensure
12 operators use LAs as intended and without increasing physical demands. Consistent stakeholder
13 inputs (including ~94% operators, all ergonomists, and ~83% LA manufacturers) indicated a
14 need for consistency when applying standardized training protocols and modules, ideally
15 designed by the LA manufacturers in consultation with ergonomists and plant engineers. To
16 maintain consistency, dedicated plant personnel should demonstrate these training sessions, and
17 all new LA operators should complete such training before operation. This is particularly
18 important for temporary or substitute workers, who may have varying levels of experience and
19 knowledge. Maintenance practices also influence operator workload. Poorly maintained LAs are
20 harder to maneuver and less reliable. Therefore, LA manufacturers should provide detailed
21 maintenance schedules aligned with plant capabilities, and maintenance tasks should be routinely
22 implemented to sustain performance. Finally, operational efficiency appears to be a key barrier to
23 LA adoption. In high-throughput environments—such as automotive assembly—any tool that
24 slows task completion risks rejection. Ergonomists explained that LAs are often unused for this
25 reason. Although LA manufacturers reported conducting time studies, these studies are typically
26 carried out in controlled environments or on surrogate/similar LAs that may not reflect an
27 identical process. To ensure ecological validity, real assembly plant constraints—such as moving
28 lines, spatial limitations, and concurrent tasks—must be incorporated into design validation
29 (Payne & Harvey, 2010).

31 **4.3 Company Guidelines Planning and Management**

32 LA integration into the workflow is shaped by internal ergonomic standards, given the
33 absence of comprehensive external regulations. LA manufacturers reported relying on in-house
34 criteria to design or select LAs, such as acceptable operating forces (push, pull, etc.), handle
35 placement, and structural stability. Some ergonomists (~33%) highlighted the need for consistent
36 enforcement, as operators often bypass LAs for automotive components in the range of 13–18 kg
37 (~30–40 lbs.), particularly under time pressure. Observational studies in healthcare contexts
38 indicate similar trends: even when lifting devices are available, usage rates lag (<70%) unless
39 formal protocols and managerial support are in place (Koppelaar et al., 2011). These findings
40 underscore that in addition to training and audits, formal enforcement policies and accountability
41 structures are essential to ensure consistent LA utilization.

42 LA manufacturers noted conducting performance tests prior to deployment, but as
43 mentioned in the previous section, ergonomists questioned the relevance of these tests to actual
44 assembly conditions. Without validation in real working environments, LAs may meet technical

1 specifications but fail to support routine use. To address this gap, company policies should
 2 require that LA manufacturers test LAs under representative task conditions before approval.
 3 Embedding such requirements into procurement processes would help align device performance
 4 with usability in realistic assembly plant settings.

5

6 **4.4 Recommendations and Future Research Directions**

7 Drawing from stakeholder interviews and existing literature, we propose a structured
 8 implementation framework to improve the design, adoption, and sustained use of LAs in
 9 automotive assembly plants. As summarized in Table 2, near-term actions are recommended for
 10 each of several phases of the LA life cycle, from a needs assessment to policy and enforcement.

11 Table 2. Recommended implementation framework to enhance Lift Assist implementation.

Phase	Action
Needs Assessment	Identify automotive components where manual handling may elevate physical demands based on load and usage frequency.
Collaborative Development	Communicate finalized payload data (e.g., lifting points), process details, plant-specific requirements, and clear workstation layouts to LA manufacturers, ensuring collaboration on LA design concepts to prevent redesigns and enable efficient integration.
Integrated Workspace Design	Explore potential workstation layout refinements with LA manufacturers, in consultation with layout engineers, process engineers, and ergonomists, provided these changes can accommodate simpler LA designs more effectively.
Operator Involvement	Involve experienced operators early in design stages and throughout the implementation process to provide task-relevant feedback on control layout, handling ease, maneuverability, and general usability.
Design Simplification	Ensure LA designs, features, and controls are intuitive and task-relevant, while meeting quality, efficiency, and safety needs.
Prototyping and Iteration	Develop and iteratively refine prototypes, incorporating operator and ergonomist input to ensure usability and functionality.
Realistic Testing	Conduct in-context testing under real moving-line conditions to replicate actual cycle times and spatial constraints.
Ergonomic Evaluation	Perform biomechanical and usability assessments under realistic task and time pressure to evaluate exertion levels, postural risks, and maneuverability challenges.
Training Development	Develop standardized training protocols in collaboration with operators, process engineers, and LA manufacturers. Ensure consistent implementation across users.

Maintenance Planning	Establish clear maintenance schedules aligned with plant capabilities, supported by documentation and training from LA manufacturers.
Policy and Enforcement	Develop organizational policies mandating LA use for designated tasks, with monitoring mechanisms to ensure adherence and resolve barriers to use.

1

2 We recommend that future research should quantify how the identified challenges—such
3 as maneuverability difficulties, control complexity, and spatial constraints—directly affect
4 operator biomechanics and their perception. For example, comparative biomechanical
5 assessments when using various LAs across different workstation layouts would be
6 quantitatively informative. Such studies can help clarify how these factors influence physical
7 demands (e.g., muscle activity, hand forces, kinematics) and operator perception, thus informing
8 targeted improvements. **Future research should also examine if/how safety-related features could
9 influence both user acceptance and the effectiveness of LA implementation.**

10

11 **5. Conclusions**

12 Automotive assembly tasks often require handling of large and heavy automotive
13 components in constrained workspaces, which elevates physical demands on workers and
14 increases the risk of WMSDs. LAs are often introduced to mitigate these demands, however
15 effectively integrating this technology into workflows is often challenging. In this study, we
16 captured perspectives from operators, ergonomists, and LA manufacturers to identify the factors
17 influencing LA design, usability, and integration into automotive assembly processes. We found
18 that the physical design of LAs—particularly excessive mass, bulky structures, and complex
19 hand controls—could adversely affect physical demands and maneuverability and thereby
20 contribute to operator resistance. Challenges related to overhead structures and poorly optimized
21 hose management systems further compromised maneuverability. Process-related problems—
22 such as retrofitting LAs into existing workstation layouts, inconsistent training, and inadequate
23 maintenance—disrupted workflow, increased task completion times, and ultimately discouraged
24 operators from using LAs despite the potential ergonomic benefits. Limited early operator
25 involvement, evolving design requirements, and insufficient real-world testing and validation by
26 LA manufacturers, were also identified as barriers to developing LAs that align with operator
27 needs and preferences. Moreover, ergonomists emphasized the need for reliable enforcement
28 mechanisms to ensure consistent LA use, particularly for mid-weight objects, for operators often
29 bypass LAs under time pressure. Based on these findings, we proposed a structured framework
30 outlining key actions throughout the LA lifecycle, including early needs assessments,
31 collaborative development, integrated workspace design, simplified controls, realistic in-plant
32 testing, and standardized training and maintenance programs. Overall, addressing these
33 multidimensional considerations may enhance LA usability, promote operator acceptance, and
34 support effective integration of LAs into automotive assembly plants, ultimately reducing
35 physical demands on assembly workers.

1

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