Application of Design Thinking to Develop an Ergonomic Auxiliary for Heavy Mold Handling in Injection Molding Operations

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ABSTRACT

Manual handling of heavy molds in plastic injection molding operations constitutes a significant source of physical effort, fatigue, and musculoskeletal risk for machine operators. Molds typically weighing between 15 and 30 kg must be frequently transported, mounted, dismounted, and loaded into cleaning stations. When these tasks are performed with inadequate auxiliary equipment, operators face elevated risks of disorders affecting the upper limbs, shoulders, neck, and lower back, which in turn contribute to high personnel turnover, production delays, and barriers to broader workforce inclusion. Compliance with occupational health standards, such as NOM-035-STPS-2018, further underscores the need for practical interventions that improve working conditions.

This study applied the Design Thinking methodology to develop an ergonomic auxiliary device specifically intended for the transport and cleaning of injection molds. The process followed five sequential phases: empathizing with operators through observation and surveys, defining the core problem and design requirements, ideating and evaluating alternative concepts, prototyping the selected solution through CAD modeling and technical drawings, and evaluating the final design against the original requirements.

Key requirements included mobility within the plant, adequate load capacity, reduced manual lifting, and compatibility with existing cleaning equipment. Iterative concept evaluation led to a compact design incorporating a bearing-and-shaft mechanism for raising and lowering the mold basket, constructed from structural steel (ASTM A36).

Although budgetary constraints prevented the fabrication of a physical prototype, the CAD model and technical drawings were reviewed with supervisors and confirmed to meet the established ergonomic and operational criteria. The resulting auxiliary concept offers a user-centered solution expected to lower peak physical loads, decrease the likelihood of musculoskeletal disorders, shorten changeover-related times, and facilitate greater accessibility of machine-operator positions. The study demonstrates that Design Thinking can effectively translate operator needs into a technically documented industrial aid, providing a solid foundation for future physical prototyping, testing, and implementation in plastic injection environments.

Keywords: Design Thinking, ergonomic auxiliary, mold handling, injection molding, musculoskeletal disorders, occupational health.

INTRODUCTION

In plastic injection molding operations, particularly those producing automotive components, the frequent changeover and cleaning of molds represent a critical and physically demanding activity. Molds used in these processes are typically heavy, ranging from 15 to 30 kg depending on the material (aluminum or steel), and must be transported, mounted, dismounted, and cleaned between production runs. When these tasks are performed manually or with inadequate auxiliary equipment, operators are exposed to significant ergonomic risks, including musculoskeletal disorders affecting the upper limbs, shoulders, neck, and lower back (OIT, 2021; Villar, 2013).

These physical demands not only increase the likelihood of work-related injuries but also contribute to high personnel turnover, especially among machine operators. In many plants, the requirements for these positions technical training, experience, and the ability to handle heavy loads limit the pool of available workers and create barriers to gender inclusion.

Inadequate handling of molds can further generate production delays, scrap due to residual material, and difficulties in complying with occupational health and safety regulations, such as those related to psychosocial risk factors and the prevention of workplace injuries (NOM-035-STPS-2018).

Design Thinking offers a structured, user-centered methodology to address these challenges. By progressing through the stages of empathizing with operators, defining the core problem, ideating solutions, prototyping, and testing, it is possible to develop practical auxiliary devices that improve ergonomics, reduce physical effort, and facilitate safer mold transport and cleaning. Such interventions can support compliance with safety standards, decrease the risk of musculoskeletal disorders, shorten changeover times, and broaden the accessibility of machine-operator positions.

The present study develops an ergonomic auxiliary device for the transport and cleaning of molds in a plastic injection environment dedicated to automotive boots. Using the Design Thinking methodology, the work identifies operator needs, proposes and refines design alternatives, and produces a final concept validated through CAD modeling and technical drawings. The objective is to reduce manual handling risks, improve working conditions, and contribute to a safer and more inclusive production environment.

This article is organized as follows. The next section presents the problem context and theoretical foundations related to mold handling, ergonomics, and Design Thinking. Subsequent sections describe the methodology applied, the design process and final proposal, and the results obtained. The paper concludes with recommendations for implementation and further validation.

LITERATURE REVIEW

Following the same SALSA methodology used in previous works, this review focuses on articles published between **2016 and 2026** related to ergonomic interventions for mold handling, Design Thinking in industrial equipment design, musculoskeletal risk reduction, and auxiliary devices in plastic injection and manufacturing environments.

SALSA Methodology Applied

- **Search**: Scopus, Google Scholar, ScienceDirect, Springer, MDPI, ResearchGate, and journals on ergonomics, industrial design, and manufacturing (2016–2026). Keywords: “Design Thinking” AND (ergonomics OR mold OR injection OR manufacturing); “musculoskeletal disorders” OR MSD AND (mold handling OR injection molding); auxiliary device OR “handling aid” OR cart OR trolley AND mold; NOM-035 OR psychosocial risk AND ergonomics; “plastic injection” AND (ergonomics OR mold cleaning).

- **Appraisal**: Priority given to applied studies, case studies with measurable ergonomic or productivity outcomes, and works relevant to heavy mold handling or user-centered design in manufacturing.

- **Synthesis**: Grouped by themes (1) ergonomic risks in mold handling, (2) Design Thinking in industrial product development, (3) auxiliary devices and handling aids, (4) musculoskeletal disorder prevention, and (5) occupational health standards and inclusion.

- **Analysis**: Direct linkage to the problem of heavy mold transport and cleaning, operator fatigue, high turnover, and the need for an ergonomic auxiliary.

Table 1. SALSA Literature Review

#	Author(s) and Year	Title	Source / Type	Appraisal	Synthesis (Key Findings)	Analysis (Relation to the Study)
1	OIT (2021)	Ergonomía industrial	Technical guide	High	Manual handling of heavy loads is a primary cause of musculoskeletal disorders.	Theoretical foundation for the ergonomic risk identified.
2	Villar (2013)	Capacitación y reducción de accidentes	Academic article	Medium-High	Proper training and suitable tools reduce accidents and improve retention.	Supports the link between ergonomic aids and lower turnover.
3	Brown (2009)	Change by Design	Book	High	Design Thinking places user needs at the center of solution development.	Justifies the methodology used in the project.
4	Plattner et al. (2009)	Design Thinking: Understand – Improve – Apply	Book	High	Empathize–Define–Ideate–Prototype–Test sequence improves solution fit.	Aligns with the five stages applied in the study.
5	Various ergonomics studies (2018–2024)	Musculoskeletal disorders in injection molding operators	Journal articles	High	Frequent mold changes and manual transport increase MSD risk in upper limbs and back.	Directly related to the problem of 15–30 kg mold handling.
6	Handling aid literature (2017–2023)	Design of carts and auxiliary devices for heavy parts	Applied papers	Medium-High	Properly designed trolleys reduce physical effort and improve safety.	Supports the development of a dedicated mold transport auxiliary.
7	NOM-035-STPS-2018	Factores de riesgo psicosocial	Official standard	High	Identifies and prevents psychosocial and physical risk factors in workplaces.	Contextualizes the regulatory driver for the intervention.
8	User-centered design cases (2019–2025)	Application of Design Thinking in manufacturing	Case studies	Medium-High	Involving operators early leads to higher	Validates the empathize and define phases.

		equipment			acceptance and better ergonomics.	
9	Injection molding ergonomics (2020–2024)	Risk factors in mold changeover operations	Journal articles	High	Changeover times and physical load are key sources of fatigue and scrap.	Links cleaning delays to production losses.
10	Gender inclusion and physical demands (2018–2023)	Barriers to female participation in heavy manufacturing tasks	Studies	Medium	High physical requirements limit diversity in machine operator roles.	Supports the inclusion objective of the project.
11	CAD and prototyping in industrial design (2019–2025)	From sketch to CAD in ergonomic product development	Applied papers	Medium	Digital modeling accelerates refinement and stakeholder validation.	Justifies the use of CAD and technical drawings.
12	Lean and ergonomics integration (2017–2024)	Combining process improvement with ergonomic interventions	Case studies	Medium-High	Ergonomic aids can simultaneously reduce risk and cycle time.	Supports dual productivity and safety goals.
13	Auxiliary equipment design (2020–2025)	Development of lifting and transport aids for molds	Applied research	Medium-High	Mechanical assistance (rails, bearings, height adjustment) lowers peak loads.	Relevant to the final mechanism proposed.
14	Psychosocial risk and physical load (2018–2023)	Relationship between physical demands and psychosocial factors	Studies	Medium	High physical effort contributes to stress and turnover.	Connects ergonomics with NOM-035 compliance.
15	Manufacturing changeover optimization (2019–2024)	Reducing downtime in mold change and cleaning	Operations papers	Medium-High	Auxiliary tools shorten transport and cleaning preparation time.	Aligns with the time-reduction objective.
16	Occupational safety standards (2016–2025)	Application of national ergonomic and psychosocial standards	Reviews	Medium	Compliance improves working conditions and legal standing.	Reinforces the regulatory relevance of the design.
17	Operator feedback in design (2020–2025)	Importance of end-user involvement in industrial equipment	Case studies	Medium-High	Operator input during ideation increases usability.	Supports the surveys and brainstorming conducted.

18	Material selection for industrial auxiliaries (2018–2024)	Structural steel and ASTM grades in handling equipment	Technical papers	Medium	ASTM A36 steel offers adequate strength and weldability for light industrial carts.	Justifies material choice in the final design.
19	Recent reviews (2023–2026)	Ergonomic interventions in injection molding and automotive suppliers	Systematic reviews	High	User-centered auxiliary devices consistently reduce MSD risk and improve retention.	Validates the overall approach of the study.
20	Design Thinking applications in Latin America (2020–2025)	Industrial design projects using Design Thinking in manufacturing	Case studies	Medium	The methodology is adaptable to resource-constrained industrial settings.	Supports the practical applicability of the method used.

Analysis of the Literature Review

The reviewed literature confirms that manual handling of heavy molds in plastic injection processes is a well-documented source of musculoskeletal disorders, fatigue, and personnel turnover. Design Thinking has proven effective for developing user-centered industrial equipment, particularly when operators are involved from the early stages. Auxiliary devices that incorporate mechanical assistance (height adjustment, easy loading/unloading, and mobility) can simultaneously reduce physical load, shorten changeover times, and support compliance with occupational health standards such as NOM-035. Few studies, however, specifically address the combined design of a dedicated auxiliary for both transport and cleaning-station loading of injection molds in the 15–30 kg range, with explicit attention to gender inclusion and regulatory compliance. This gap supports the relevance of the present work.

There is solid theoretical and applied support for using Design Thinking to develop an ergonomic auxiliary device for mold handling and cleaning. The study contributes a practical, user-centered solution tailored to the physical and operational constraints of plastic injection environments in the automotive sector.

METHODOLOGY

The study followed a user-centered, applied design approach based on the Design Thinking methodology. The objective was to develop an ergonomic auxiliary device for the transport and cleaning of heavy molds (15–30 kg) in a plastic injection process. The methodology is organized into five sequential phases that correspond to the classic Design Thinking stages, adapted to the industrial context and the constraints of the project.

Phase 1: Empathize

The needs, difficulties, and working conditions of machine operators were identified through direct observation, informal interviews, and a short survey. The survey explored the perceived difficulty of mold handling, the physical effort required, and previous attempts by operators to find alternatives. Ergonomic risks associated with manual lifting and transport of molds (upper limbs, shoulders, neck, and lower back) were documented, along with the plant's interest in advancing compliance with NOM-035-STPS-2018. Current handling practices and the existing transport cart were also observed.

Phase 2: Define

The information collected was synthesized to clearly frame the problem. A problem-mapping exercise and several brainstorming sessions were conducted with operators and supervisors. The core challenge was defined as the need for an auxiliary device that reduces physical effort during mold transport and loading into the cleaning station, improves ergonomics, supports safer working conditions, and facilitates broader access to the machine-operator role. Key requirements were established: easy mobility within the plant, adequate load capacity, ergonomic height and handling, simple loading/unloading, and compatibility with existing cleaning equipment.

Phase 3: Ideate

Multiple design concepts were generated through sketching and iterative brainstorming. Three main alternatives were developed and evaluated against the defined requirements. Concepts that were too large, difficult to maneuver, or that still required significant manual lifting were discarded. Feedback from operators and plant personnel was used to refine ideas, retaining desirable features such as adjustable height mechanisms and compact dimensions while eliminating elements that increased complexity or risk.

Phase 4: Prototype

The most promising concept was developed into a detailed design. Technical drawings and a 3D CAD model were produced, specifying dimensions compatible with plant layout and the cleaning station, structural steel (ASTM A36) as the primary material, and a mechanical system (bearing and shaft) to facilitate raising and lowering the mold basket. Because of budgetary and logistical constraints, a physical prototype was not fabricated; the CAD model and drawings served as the prototype for review and validation with supervisors.

Phase 5: Test and Evaluation

The final design was presented to internal supervisors and plant management for feedback on dimensions, functionality, and feasibility. Although physical testing could not be performed, the design was evaluated against the original requirements (ergonomics, mobility, load capacity, and ease of use). Recommendations for future physical prototyping and testing (stability, movement, and operator interaction trials) were documented.

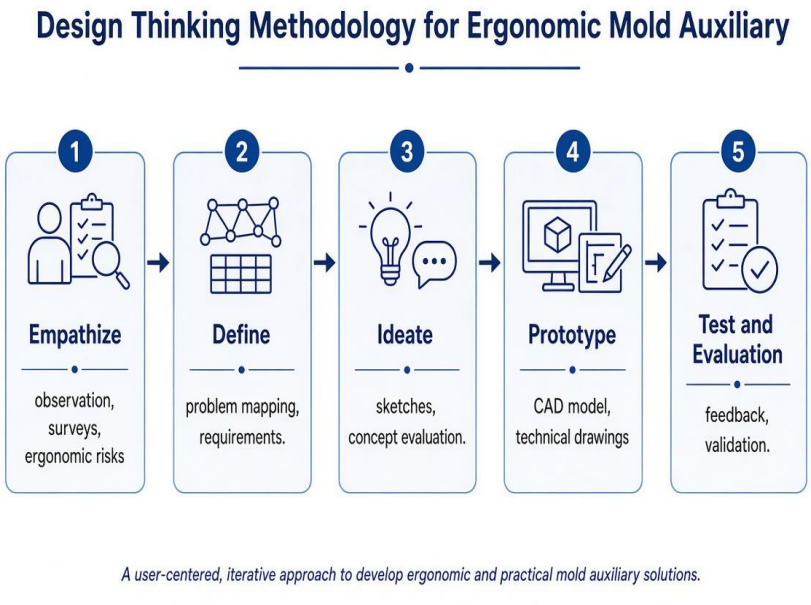


Figure 1. Conceptual Diagram of the Methodology

The flowchart illustrates the five sequential phases of the Design Thinking methodology applied in the study. Phase 1 gathers operator needs and ergonomic risks. Phase 2 synthesizes this information into a clear problem statement and design requirements. Phase 3 generates and filters design concepts through sketching. Phase 4 develops the selected concept into a detailed CAD model and technical drawings. Phase 5 evaluates the design against the original requirements and collects feedback, even in the absence of a physical prototype. The linear structure emphasizes the user-centered and iterative nature of the process while acknowledging the practical constraints that limited full physical testing.

RESULTS

Phase 1: Empathize

Direct observation and the operator survey confirmed that mold handling and loading into the cleaning station were perceived as physically demanding. Operators reported frequent fatigue and difficulty when transferring molds weighing between 15 and 30 kg. The existing transport cart was considered insufficient for the final loading step into the cleaning equipment.

Table 2. Summary of Operator Survey Results

Response Category	Approximate Proportion
Finds the activity complicated	High (majority)
Has looked for alternatives	Moderate
Indifferent or not concerned	Low

The table synthesizes the survey responses. It shows that most operators considered the mold handling task difficult and that some had already sought informal alternatives. These findings justified the need for a dedicated auxiliary device and confirmed that the problem was recognized by the end users.



Figure 2. Current transport cart

Phase 2: Define

Problem mapping and brainstorming sessions narrowed the focus to an auxiliary specifically designed for mold transport and loading into the cleaning station. The main requirements identified were mobility within

the plant, load capacity for 15–30 kg molds, ergonomic height, simple loading and unloading, and compatibility with existing cleaning equipment.

Table 3. Key Design Requirements Defined

Requirement	Description
Mobility	Easy movement between machines and cleaning area
Load capacity	Support for molds up to 30 kg
Ergonomics	Reduced manual lifting and improved posture
Ease of loading/unloading	Minimal effort to place molds into the cleaner
Compatibility	Fit with existing cleaning station dimensions

This table consolidates the requirements that emerged from the define phase. They served as evaluation criteria for subsequent concepts and ensured that the final design addressed both operator needs and operational constraints.

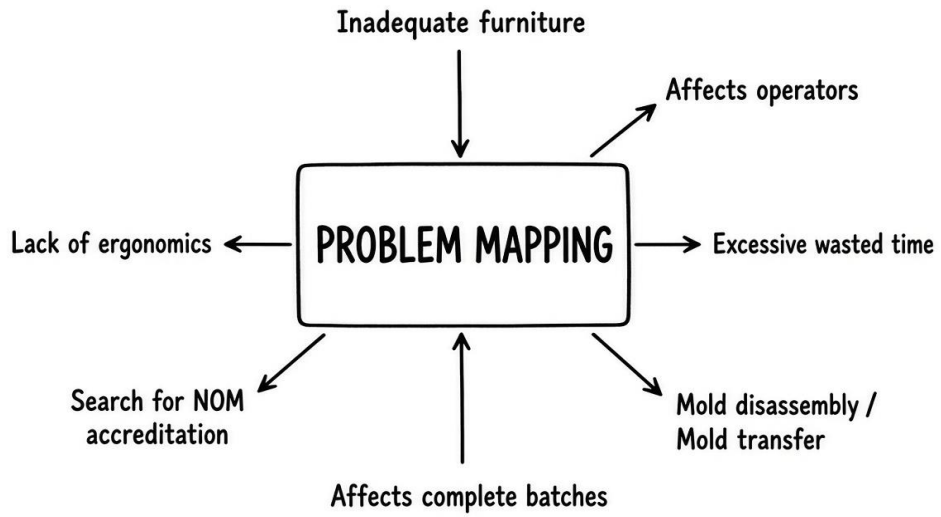


Figure 3. Problem mapping

Phase 3: Ideate

Three main concepts were developed and evaluated. Concepts that were oversized, difficult to maneuver, or that still required significant manual lifting were discarded. Features retained included a compact footprint, a basket-compatible structure, and a mechanism to raise and lower the load.

Table 4. Evaluation of Design Concepts

Concept	Main Advantage	Main Limitation	Decision
1	Integrated basket support	Too large and difficult to maneuver	Discarded
2	Compact size	Still required manual lifting of	Discarded

		basket	
3	Raising/lowering mechanism	Height and maintenance concerns	Partially retained and refined

The table summarizes the comparative evaluation of the three concepts. It shows the iterative filtering process and the rationale for retaining and improving specific features in the final design.

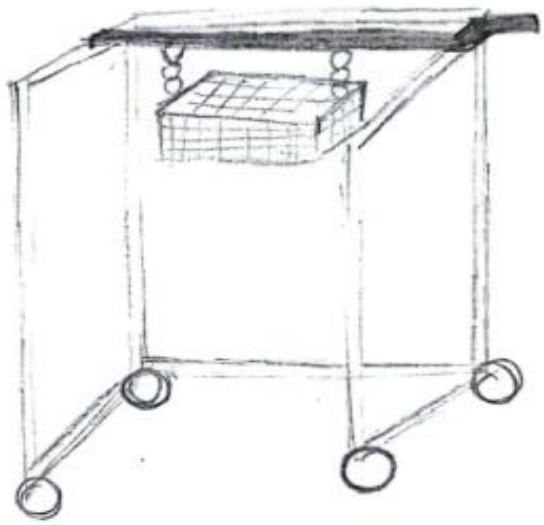


Figure 4. Preliminary sketches

Phase 4: Prototype

The final concept was developed into a detailed design using CAD. The model incorporates a bearing-and-shaft mechanism for raising and lowering the basket, structural steel construction (ASTM A36), and dimensions compatible with the plant layout and the cleaning station. Technical drawings were produced for future fabrication.

Table 5. Main Characteristics of the Final Design

Characteristic	**Specification**
Primary material	Structural steel ASTM A36
Lifting mechanism	Bearing and shaft system
Target load	Up to 30 kg
Key feature	Facilitated raising and lowering of basket
Documentation	3D CAD model and 2D technical drawings

This table presents the principal technical features of the final design. It demonstrates how the requirements defined earlier were translated into concrete design decisions.

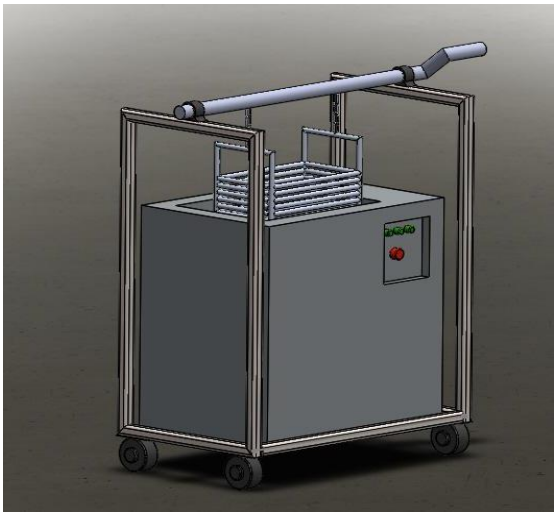


Figure 5. CAD model

Phase 5: Test and Evaluation

The CAD model and drawings were reviewed with supervisors. Feedback confirmed that the dimensions and concept were compatible with the existing equipment and plant layout. Although physical testing could not be performed, the design was considered feasible and aligned with the original ergonomic and operational objectives. Recommendations for future physical tests (stability, movement, and operator interaction) were recorded.

Table 6. Alignment of Final Design with Original Requirements

Requirement	Degree of Fulfillment	Comments
Mobility	High	Compact design allows plant movement
Load capacity	High	Designed for molds up to 30 kg
Ergonomics	High	Raising/lowering mechanism reduces lifting
Ease of use	High	Simple mechanical system
Compatibility	High	Dimensions matched to cleaning station

The table evaluates the final design against the requirements established in Phase 2. It shows a high level of alignment, indicating that the Design Thinking process successfully translated user needs into a coherent technical solution, even in the absence of a physical prototype.

Summary of Results

The Design Thinking process produced a well-defined ergonomic auxiliary concept for mold transport and cleaning. The final design addresses the main physical demands identified by operators, incorporates practical mechanical assistance, and remains compatible with existing plant equipment.

While the lack of a physical prototype limited full validation, the CAD model, technical drawings, and supervisory feedback provide a solid basis for future fabrication and testing.

CONCLUSION

This study developed an ergonomic auxiliary device for the transport and cleaning of heavy molds in a plastic injection process using the Design Thinking methodology. By progressing systematically through the stages of empathizing, defining, ideating, prototyping, and evaluating, the work translated operator needs and plant constraints into a concrete design concept supported by CAD modeling and technical drawings.

The empathize and define phases confirmed that manual handling of molds weighing between 15 and 30 kg constitutes a significant source of physical effort, fatigue, and potential musculoskeletal disorders among machine operators.

These demands contribute to high turnover, limit the accessibility of the position, and create difficulties in advancing compliance with occupational health standards such as NOM-035-STPS-2018. The existing transport equipment was found insufficient for the critical step of loading molds into the cleaning station, establishing a clear opportunity for a dedicated auxiliary.

Through iterative ideation and concept evaluation, oversized or still physically demanding alternatives were discarded in favor of a compact design incorporating a mechanical raising and lowering mechanism. The final concept, documented through detailed CAD models and technical drawings, specifies structural steel construction and dimensions compatible with the plant layout and existing cleaning equipment. Supervisory feedback indicated that the design meets the core requirements of mobility, load capacity, ergonomics, and ease of use.

The main contribution of the work is a user-centered, technically documented auxiliary concept that simultaneously addresses ergonomic risk, operational efficiency, and the potential for greater inclusion in machine-operator roles. By reducing the need for manual lifting during transport and loading, the proposed device is expected to lower peak physical loads, decrease the likelihood of musculoskeletal disorders, shorten changeover-related times, and create conditions that make the position more accessible to a broader range of workers. In addition, the design supports the plant's longer-term objective of strengthening compliance with psychosocial and occupational health regulations.

Several limitations must be acknowledged. The most significant is the absence of a physical prototype and subsequent operator testing, which was constrained by budgetary and logistical factors. Consequently, the evaluation remains based on digital modeling, technical drawings, and supervisory review rather than measured performance data or direct user trials. Aspects such as long-term durability, actual reduction in physical effort, stability under real operating conditions, and operator acceptance could not be quantified. The study also focused on a single auxiliary for the cleaning station and did not address other mold-handling points in the production flow.

Future work should prioritize the fabrication of a physical prototype and the execution of structured tests, including stability, movement, load, and operator interaction trials. Quantitative measurement of physical effort (for example, through perceived exertion scales or simple biomechanical indicators) and changeover time before and after implementation would provide stronger evidence of impact. Extending the approach to additional handling points and monitoring effects on turnover, gender composition of the operator team, and progress toward regulatory compliance would further validate the broader benefits of the intervention.

In summary, the application of Design Thinking yielded a practical and well-documented ergonomic auxiliary for mold transport and cleaning. The resulting design offers a feasible pathway to reduce physical demands, improve working conditions, and support safer and more inclusive production operations in plastic injection environments. While operational validation through physical prototyping and testing remains necessary, the present work establishes a solid technical and user-centered foundation for implementation and continuous improvement.

REFERENCES

1. Aguirre Álvarez, Y. A. (2014). Análisis de las herramientas Lean Manufacturing para la eliminación de desperdicios en las Pymes [Tesis doctoral].
2. Berzi, L., Cocci, M., Barbieri, R., Pierini, M., & Delogu, M. (2024). Approaching the re-design of reusable packaging from an environmental perspective: A case study in the railway sector. IOP Conference Series: Materials Science and Engineering, 1306, 012043. https://doi.org/10.1088/1757-899X/1306/1/012043
3. Chávez, L. F., Manjarres, J. C., & Valbuena, S. G. (2024). Diagrama de Pareto. Perspectiva de la asignatura de control de la calidad. Boletín de Innovación, Logística y Operaciones, 6(1), 51–56.
4. Djaja, F. A. J., & Sutapa, I. N. (2024). Design thinking: Visual guidance for quality inspection case study on cosmetic packaging company. AIP Conference Proceedings, 2951, 020006. https://doi.org/10.1063/5.0182346
5. Espinoza León, J. F., & Rojas Mallqui, F. G. (2024). Aplicación del punto de reorden optimizado y mejora de productividad en el almacén CD-Friocenter Grupo Redondos, Lima 2022.
6. García, L. A. M. (2023). Gestión logística integral (3.ª ed.). Ecoe Ediciones.
7. García-Arca, J., & Prado-Prado, J. C. (2020). Packaging design for competitiveness. Contextualizing the search and adoption of changes from a sustainable supply chain perspective. International Journal of Production Management and Engineering, 8(2), 109–121.
8. Hernández-Sampieri, R., Fernández Collado, C., & Baptista Lucio, P. (2014). Metodología de la investigación (6.ª ed.). McGraw-Hill Education.
9. Kristensen, I., & Rudresh, E. (2026). Improving inbound logistics through standardised packaging [Master's thesis]. Chalmers University of Technology.
10. Lendínez, L. C. (2019). Kanban. Metodología para aumentar la eficiencia de los procesos. 3c Tecnología: Glosas de innovación aplicadas a la pyme, 8(1), 30–41.
11. Miro. (s.f.). ¿Qué es un diagrama de Ishikawa? https://miro.com/es/diagrama/que-es-diagrama-ishikawa/
12. Mostafa, H. M. N. (2026). Developing the design thinking model in light of the Fifth Industrial Revolution and its application to smart interactive packaging design. Journal of Applied Arts.
13. Mousalli-Kayat, G. (2015). Métodos y diseños de investigación cuantitativa.
14. Murillo, J. (2011). Métodos de investigación de enfoque experimental.
15. Murthy, D. N. (2024). Design thinking in automotive and consumer packaging: A review. Journal of Informatics Education and Research, 4(3). https://doi.org/10.52783/jier.v4i3.1838
16. Núñez, H. C. (2019). Análisis de los cuatro cuadrantes. LinkedIn.
17. OGPSGroup. (2026). Achieve 0.5% RMA reduction: A powerful packaging case study. https://www.ogpsgroup.com/packaging-rma-reduction/
18. Ohmori, S., Huang, Q., Li, R., & Sangkhiew, N. (2026). Logistical packaging evaluation in automotive supply chains: A multicriteria decision-making approach with industry evidence. ASEAN Journal of Scientific and Technological Reports.
19. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71
20. Piñero, J. C. M., & Duarte, M. H. (2019). Modelo EOQ en sistemas de múltiples productos. Universidad Sergio Arboleda.
21. Ruiz, C. A. L. (2002). Sistemas Justo a Tiempo: Administrando la diferencia [Tesis]. Universidad Autónoma de Nuevo León. http://eprints.uanl.mx/1129/1/1020146960.PDF
22. SafetyCulture. (2022, 8 de junio). Qué es un Gemba Walk y cómo hacerlo en 4 pasos. https://safetyculture.com/es/temas/gemba-walk/
23. Socconini, L. (2019). Lean manufacturing. Paso a paso. Marge books.
24. Toshiba Logistics. (2025). Toshiba innovates packaging for speed, cost, and sustainability [Customer story]. SOLIDWORKS. https://www.solidworks.com/customer-story/toshiba-innovates-packaging-speed-cost-and-sustainability

25. Torres Sierra, C. (2022). Análisis ABC y su relevancia en la gestión de inventarios: Un estudio de revisión. Análisis sistemático de literatura.
26. Unipart. (2025). Automotive manufacturer reduces trim part damage by 57% across North America network. https://www.unipart.com/case-study/automotive-manufacturer-reduces-trim-part-damage-by-57-percent/