D4.3 – Ergonomics and Comfort Design of Products v1

This project has received funding from the European Union's Horizon Europe research and innovation programme under the grant agreement number 101147722. The European Union is not liable for any use that may be made of the information contained in this document, which is merely representing the authors' view.

Project Acronym:	AccesS
Project Full Title:	Enhancing Accessibility and Sustainability in Smart Cities and Smart Buildings: The Universal Accessibility Suite Initiative
Grant Agreement:	101147722
Project Duration:	36 months (01/06/2024 – 31/05/2027)

DELIVERABLE 4.3
Ergonomics and Comfort Design of Products v1

Work Package:	WP4 – Digitalization and Sustainable Design for the Built Environment
Task:	T4.3 Ergonomics and Comfort Design of Products
Document Status:	Final
File Name:	AccesS_D4.3 Ergonomics and Comfort Design of Products v1_CETEM
Due Date:	31.10.2025
Submission Date:	30-10-2025
Lead Beneficiary:	CETEM

Dissemination Level	
Public	☒
Sensitive	☐

Authors List

Leading Author(s)			
First Name	**Last Name**	**Beneficiary**	**Contact e-mail**
Raquel	Ortega Martínez	CETEM	r.ortega@cetem.es
Miguel Ángel	Silvestre Botella	CETEM	ma.silvestre@cetem.es
Alberto	Martí Romero	CETEM	a.marti@cetem.es
Francisco José	Melero Muñoz	CETEM	fj.melero@cetem.es

Co-Author(s)				
#	**First Name**	**Last Name**	**Beneficiary**	**Contact e-mail**
1	Eirini	Kontaki	FORTH	ekontaki@ics.forth.gr
2	Manos	Zidianakis	FORTH	zidian@ics.forth.gr
3	Eva	Fernández Palacios	MIW	eva.fernandez@voltiva.energy
4	Ariadni	Elmaloglou	QUE	a.elmaloglou@que-tech.com

Reviewers List

Reviewers			
First Name	**Last Name**	**Beneficiary**	**Contact e-mail**
Panagiota	Chatzipanagiotidou	CERTH	phatzip@iti.gr
Guido	van Arkel	BHA	g.vanarkel@bruco.org

Version History

v	Author	Date	Brief Description
0.1	All authors, CETEM	19.06.2025	Initial draft (ToC)
0.3	All authors, CETEM	25.08.2025	Evaluation parameters for furniture pieces described
0.4	All authors	16.09.2025	Draft versions with initial content for all sections
0.5	All authors, CETEM	21.10.2025	First draft of the document to be reviewed by D4.3 reviewers

0.7	All authors, CETEM	28.10.2025	Final version incorporating feedback from reviewers.
V1	Dimosthenis Ioannidis, CERTH	30.10.2025	Quality check. Available for submission to the EC

Legal Disclaimer

The AccesS project has received funding from the European Union's Horizon Innovation Action under grant agreement No 101147722. The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the European Climate, Infrastructure and Environment Executive Agency (CINEA) or the European Commission (EC). CINEA or the EC are not responsible for any use that may be made of the information contained therein.

Copyright

Executive Summary

The following deliverable presents the development of the two components of ErgoFlow, the library of optimized models and the furniture ergonomics assessment tool that ensure accessibility and comfort for users with disabilities or reduced mobility, enabling simulation-based testing and ensuring compliance with ergonomic principles and usability.

On the one hand, the ErgoFlow Evaluation Tool is a web tool that through the assessment of a series of weighted parameters (e.g., seat height, depth, reachability, clearances) that have been established following a methodology based on internationally recognized standards and guidelines on biomechanics, ergonomics, and accessibility (EN 1335, EN 17210, ISO 9241-5, ADA, etc.), allows for the evaluation of the ergonomics and accessibility of furniture pieces belonging to the seating and table surface categories.

The 65% ergonomic score threshold implemented in ErgoFlow effectively distinguishes between compliant and non-compliant products. The results show that adjustable and adaptable furniture achieves higher ergonomic ratings, while static or fixed-height designs reveal more limitations in accessibility.

On the other hand, the ErgoFlow library is a repository of 17 ergonomically validated furniture pieces ready for use in 3D design and simulation environments, all containing its ergonomic score, 3D file, and evaluation report.

With the development of ErgoFlow, the aim is to provide furniture designers with a tool that can help and support them in improving their understanding of the tight connection between ergonomics and accessibility, thus facilitating the adoption of universal design principles that enable the creation of products with innovative features.

ErgoFlow is fully aligned with the objectives of AccesS, which seeks to construct built environments and products with accessible features for individuals with disabilities and elderly persons to use them comfortably, and in particular with the second project's operational objective to: “Deliver digital innovations for the design of accessible, inclusive, and sustainable built environments”.

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

Term	Description
2D	Two-dimensional.
3D	Three dimensional.
.glb / GLB	GL Transmission Format Binary.
.png	Portable Network Graphics.
.jpeg	Joint Photographic Experts Group.
.jpg	Joint Photographic Experts Group.
.ifc / IFC	Industry Foundation Classes file.
Dorsiflexion	Upward bending of the foot or hand at the ankle or wrist.
Lordosis	Excessive inward curvature of the spine.
PDF	Portable Document Format.
Popliteal	Relating to or situated in the hollow at the back of the knee.
Popliteal height	Vertical distance from the floor to the underside of the thigh just behind the knee, with the subject sitting with their thighs horizontal and legs at a 90-degree angle to the upper body

1 Introduction

1.1 Scope and objectives of the deliverable

The purpose of deliverable D4.3 Ergonomics and Comfort Design of Products v1 is to outline the methodology and outcomes of the development of ErgoFlow, the tool for evaluating the ergonomics and comfort design of furniture products, as well as its library of ergonomically designed furniture. Specifically, it focuses on offering designers and manufacturers tools and resources to ensure that their products meet ergonomic standards, providing comfort, accessibility, and safety for all users, including those with disabilities and elderly adults.

ErgoFlow is divided into two main subcomponents: the ErgoFlow Evaluation Tool and the ErgoFlow Library. Together, these two components enable a comprehensive approach to creating and evaluating ergonomically adapted products that prioritize comfort and usability for all users, particularly those with specific accessibility needs.

Through ErgoFlow, the AccesS project aims to support furniture product designers in creating built environments and furniture products that not only comply with ergonomic principles and usability standards, but also include accessible features that allow individuals with disabilities and older adults to use them comfortably and independently, ensuring optimal comfort and reducing physical strain.

1.2 Structure of the deliverable

This deliverable is structured to provide a clear and logical progression from the objectives of the work to the detailed technical implementation. It starts by defining the scope and objectives, situating the deliverable within the wider project context, and highlighting its advancements beyond the current state of the art. This foundation helps the reader understand the purpose and relevance of the work.

The main sections focus on the development of the ErgoFlow subcomponents, first by describing the ErgoFlow Evaluation Tool, covering its scope, methodology, data sources, and practical demonstrations, and secondly, presenting the ErgoFlow Library, following a similar structure, showing how it complements the evaluation tool and extends its usability. The last section is devoted to main conclusions from the performed activities.

1.3 Relation to Other Tasks and Deliverables

This deliverable falls within the scope of T4.3 Ergonomics and Comfort Design of Products and goes hand in hand with deliverable D4.6 Ergonomics and Comfort Design of Products v2, which is a sensitive and edited version of this same document.

For the development of both the ErgoFlow tool and library as well as this document itself, the results obtained mainly from two tasks of WP1 have been used: T1.1 Technology Watch, Market Dynamics & Opportunities and T1.3 AccesS Architecture, System Requirements, and Integration.

Furthermore, the work from this task T4.3 is linked with the integration and implementation of Ergoflow in the AccesS Suite through T7.2 AccesS Inclusive Toolbox: Integration of Components, and its testing under T7.3 Inclusive Toolbox: Testing. The deployment and assessment of AccesS Suite and integrated tools takes place within WP10-WP12 and in that sense, results are also linked.

2 Ergonomics and Comfort Design of Products

ErgoFlow has been developed with a modern, scalable architecture that integrates best practices in full-stack web development. Designed as a modular monolith based on Next.js 15 [1], it combines both the frontend and backend in a single runtime environment, simplifying deployment and accelerating development cycles. The modular structure of the system ensures maintainability and flexibility, facilitating the reuse of logic, utilities, and shared types across different layers.

2.1 ErgoFlow Evaluation Tool

2.1.1 Scope and Methodology

The ErgoFlow Evaluation Tools aims to offer testing functionalities that assess the ergonomics, accessibility, and user comfort of furniture designs. Designers, architects, and product developers can upload 3D models of furniture to the ErgoFlow tool, where the system analyzes the models and generates a report that evaluates their ergonomic compliance, comfort, and accessibility. The tool also checks for adherence to EU safety standards and provides design recommendations to improve the product's ergonomics and usability, ensuring it meets the needs of individuals with disabilities and elderly adults.

It incorporates an automated evaluation system based on ergonomic and accessibility parameters determined through a thorough study and analysis of each parameter and cross-checked with values and recommendations established by leading entities in biomechanics, ergonomics, and accessibility. This allows objective verification of the accessibility level for the types of chairs and tables within the scope of the development.

2.1.2 Data Sources and Evaluation Criteria

The information sources that have been used to define the evaluation parameters of ErgoFlow include a wide variety of relevant references, such as academic literature, technical reports, and best practice guidelines. These sources have provided the foundation for establishing the criteria and parameters applied in the evaluation process.

- Business and Institutional Furniture Manufacturers Association (BIFMA). (2013, March 14). *Updated BIFMA Ergonomics Guideline now available* [2].
- EN 1335-1:2020+A1:2022 – Office furniture – Office work chair – Part 1: Dimensions – Determination of dimensions [3].
- EN 17210:2021. Accessibility and usability of the built environment – Functional requirements [4].
- EN 527-1:2011 – Office furniture – Work tables and desks – Part 1: Dimension [5].
- EN ISO 9241-5:2024 - Ergonomics of human-system interaction - Part 5: Workstation layout and postural requirements [6].
- Flores, C. (2001). *Ergonomía para el diseño* (1st ed.). Editorial Designio [7].
- García Molina, C., Moraga, R., Tortosa, L., & Verde, V. (n.d.). *Ergonomía y mueble. Guía de recomendaciones para el diseño de mobiliario ergonómico* [8].
- Instituto de Biomecánica de Valencia. (2020). *Ergonomía y mueble de oficina: Guía básica para prevencionistas* [9]

- Irish Wheelchair Association. (2020, November). *Best Practice Access Guidelines: Designing Accessible Environments* (Edition 4) [10].
- Openshaw, S., & Taylor, E. (2006). *Ergonomics and design: A reference guide*, Allsteel, Inc. [11]
- Sinpromi. (2022). *Mobiliario y mecanismos accesibles* [12].
- U.S. Department of Justice. (n.d.). *ADA standards for accessible design* [13].

Based on this information, a set of parameters has been defined for the types of furniture (seating and table surfaces) included in both the evaluation tool and the library. These parameters establish the criteria for assessing the ergonomic, comfortness, and accessibility aspects of each furniture category.

Each parameter carries a weight (from 1 to 3) according to its ergonomic importance. The parameter score is calculated by multiplying the individual score by its weight, and the total ergonomic score is the sum of all weighted scores. Each furniture model has a pre-defined maximum possible score, and to be deemed ergonomically acceptable, a model must achieve at least 65% of this maximum.

For example, when evaluating low benches without backrests, several ergonomic parameters are considered:

- The optimal range of the seat height is 45–48 cm, which earns 3 points; heights ranking slightly outside this range (42–45 cm or 48–51 cm) receive 2 points, and any other measurements get 1 point.

- The seat depth's score (the horizontal distance from the front to the back of the seat)depends on how well it supports ergonomic comfort, according to the predefined criteria.

- The seat width (the total usable sitting space) is assessed based on whether it provides adequate personal space and accessibility.

- The seat surface shape and material are assessed, with non-slip surfaces rated highest (3 points) for ensuring safety and stability. Additionally, rounded edges and corners are awarded 3 points for enhancing safety and comfort, while sharp or angular edges lower the score.

- Accessibility is another crucial factor in the evaluation, and benches are assessed for foot space to determine whether the height and depth below the seat allow wheelchair users to approach comfortably.

The following tables provide an overview of the set of parameters defined for the different types of furniture (seating and table surfaces).

Table 1. Evaluation parameters for low benches without backrest

LOW BENCHES WITHOUT BACKREST					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Seat height	45 cm ≤ H ≤ 48 cm	Seat height is the most critical parameter for any seat. The range of 45–48 cm is aligned with the popliteal height of most of the adult population (5th to 95th percentiles). This allows most users to sit with their feet flat on the floor and their knees at a 90-degree angle, or slightly higher.	This range is the most critical for wheelchair transfers, as it aligns with the average height of a wheelchair. It also facilitates the movement of sitting down and standing up for people with reduced mobility.	Correct height ensures optimal load distribution through the feet and thighs, preventing excessive flexion or extension of the knees.	3 - An error in this dimension directly affects blood circulation in the legs and lumbar posture, and would also make it difficult to transfer from a wheelchair or to stand up or sit down.
Seat depth	30 cm ≤ P ≤ 35 cm	The depth must be sufficient to support at least two-thirds of the length of the thigh, but without pressing on the popliteal fold. The range of 30–35 cm is ideal for a bench without a backrest, as it prioritizes ease of sitting down/standing up and avoids pressure on the back of the knees, which is critical in seats without the support of a backrest.	A reduced depth is crucial to facilitate lifting for people with limited mobility. Excessive depth forces the user to push themselves out of the seat or slide, increasing the risk of falling.	Supports the thigh without putting pressure on the popliteal fossa and ensures that the user's center of gravity remains forward, ready for the movement of standing up.	2 - Although not as critical as height, incorrect depth affects circulation (too deep) or stability/support (too shallow). This justifies a high weighting.
Seat width per person	60 cm ≤ A ≤ 65 cm	The width should accommodate the width of the largest user's hips (95th percentile) and allow for personal space. The range of 60–65 ensures lateral comfort and dignity for the user without being overly bulky, which is vital in waiting areas or high-traffic areas.	Accommodates larger users and provides additional space for users with crutches or canes to adjust their posture when sitting, improving stability.	Exceeds the 95th percentile for hip width, providing lateral space for clothing or support devices.	2 - Directly affects user comfort and feeling of crowding, as well as allowing for support devices.
Seat surface (shape)	Slightly concave	A slightly concave surface distributes body pressure more evenly and reduces pressure on the back of the thighs. This improves comfort,	A slightly concave surface helps users with limited balance or trunk control to maintain a stable seated position.	The concavity stabilizes the pelvis and reduces anterior sliding, maintaining correct posture of the spine and thighs.	1 - It is assigned a lower weighting because it is a desirable comfort feature, but the bench remains functional with a flat

LOW BENCHES WITHOUT BACKREST					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
		especially on benches without backrests.			surface if the main dimensions are correct.
Seat surface (material)	Complies	Improves user stability when sitting	Prevents the user from slipping or losing traction during the transfer process or when standing up, ensuring their safety.	Excessive smoothness increases slip risk, while high friction impedes transfers.	**2** - This is an important safety feature, preventing possible falls and injuries.
Edges and corners	Rounded minimum radius 2 mm.	Prevents injuries from accidental impacts, both for seated users and for people walking by.	For the visually impaired, this is a criterion that prevents injuries caused by users colliding with furniture.	Reduces risk of soft tissue injury; compliant with anthropometric interaction zones for contact surfaces in shared environments.	**1** - This is a safety criterion where non-compliance does not directly affect functionality.
Foot space depth	≥15 cm	The clearance or recess must be sufficient for the user to approach the bench and maintain an upright posture.	It allows users with motor disabilities to bring their center of gravity closer to the vertical of the seat before sitting down.	Allows adequate space for the lower leg and feet (based on anthropometric foot length ~26–30 cm) to move under the bench, improving approach angle and balance.	**2** - It is important for ease of approach and user transfer.
Foot space height	≥15 cm	The clearance at the base must be sufficient to allow the foot to be inserted and prevent the shoe from catching on the edge.	Allows users with motor disabilities to bring their center of gravity closer to the vertical of the seat before sitting down.	Ensures clearance for footwear and ankle dorsiflexion; aligns with typical foot height plus safety margin. Facilitates correct balance and reduces tripping risk.	**2** - As in the previous point, this is important for ease of approach and user transfer.
Table height type	Adjustable	Modern office ergonomics tends to alternate between sitting and standing positions. Adjustability is the primary requirement for achieving a dynamic posture, which reduces postural fatigue, minimizes prolonged static load on the spine, and prevents certain risks associated with a sedentary lifestyle.	Adjustability is essential to allow the table to adapt to the dimensions and working height of a user in a wheelchair or scooter, eliminating the barrier of fixed height and ensuring full accessibility to the work surface.	It allows for variation in static muscle load on the spine and leg muscle groups.	**3** - This is the most critical feature; a failure in the adjustment range compromises the postural health of the average user and may also negate the ability of wheelchair users to access and use the furniture.

Table 2. Evaluation parameters for standing desks

STANDING DESKS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Adjustable height (minimum and maximum range)	Lower limit ≤ 68 cm and upper limit ≥ 110 cm.	The design requires a wide operating range that efficiently covers anthropometric variability. This range ensures that the table can be used in a seated or standing position.	It must allow for height adjustment, ensuring compliance with the minimum clearance height so that the knees, thighs, and footrests of a wheelchair user can pass through without obstruction, ensuring front access.	The range covers from the 5th percentile popliteal height (seated ≈ 68 cm) to the 95th percentile elbow height (standing ≈ 110 cm), covering at least 90% of the adult population.	3 - This feature directly influences adaptability to different user heights. Furthermore, an incorrect value can also prevent use or access for wheelchair users.
Fixed height	105 cm ≤ H ≤ 115 cm	This range is defined as a compromise value for tables, which, being fixed, cannot be adjusted. The height is designed to align the surface with the average elbow height of the adult population when standing, facilitating a correct working posture with relaxed shoulders for most users.	Not applicable. A fixed-height standing work table automatically excludes wheelchair users and does not comply with accessibility principles.	Corresponds to the average elbow height of the adult population when standing.	1 - Its impact is low because the fixed solution is inherently inferior and only affects the comfort of average-height standing users.
Width	≥120 cm.	A minimum width of 120 cm is vital for functionality, ensuring the necessary space for essential office equipment, free space for writing or taking notes, and space for handling documents.	A generous width facilitates lateral approach and maneuvering of the wheelchair to the desk. In addition, it provides adequate space to accommodate appropriate support devices or accessibility accessories.	Accommodates the kinetic space of the arms and visual range for an efficient work setup.	2 - Affects task performance efficiency and user comfort, being a key factor for functionality in the workplace.
Depth	≥60 cm	Depth is critical for visual and postural ergonomics. A depth of 60 cm or more allows the monitor to be moved to a safe distance (approx. 60–70 cm), preventing eye strain and neck problems.	Adequate depth facilitates the placement of specialized or adapted keyboards and mice, keeping the monitor at the correct distance for users who cannot easily adjust their body position.	Based on focal length and optimal visual accommodation for prolonged tasks.	2 - Directly affects visual health and shoulder and neck posture.
Edges and corners	Rounded radius ≥ 2 mm.	Rounded edges are a standard feature for safety and comfort. They prevent compression of nerves and tendons	This is a key criterion for users with visual impairments. In the event of accidental collision,	Minimizes localized contact pressure on the soft tissues of the forearms.	2 - This is an important factor due to the risk of accidental collision faced

STANDING DESKS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
		when resting the forearms on the keyboard during use, reducing the risk of musculoskeletal disorders.	rounded edges minimize the risk of injury from impact or abrasion.		by users with visual impairments.
Lower clearance (width)	≥ 80 cm	Ensures sufficient space for the seated user's feet to move freely, which is essential for promoting dynamic posture and postural comfort.	A clear width of ≥ 80 cm is the minimum requirement for front access, allowing for the full width of a wheelchair and its movement.	Based on the width of a standard wheelchair, plus safety and maneuvering clearance.	2 - This is a key accessibility requirement for front approach. It directly affects the ability to access and the comfort of the seated user.
Clearance space (height)	≥ 70 cm.	This is the clearance height required for the comfortable passage of the thighs and knees of most seated users, preventing the user from having to lean forward or sit in an awkward position.	This measurement complies with accessibility standards to ensure that the thighs, knees, and footrests of a wheelchair can pass unobstructed under the table structure.	Accessibility criteria for knee clearance.	2 - Determines the usability of the table for wheelchair users and is essential for a person's sitting posture.
Clearance space (depth)	≥ 55 cm	Allows the user to sit and adopt the correct depth at the workstation, moving closer to the keyboard without their knees or feet colliding with structural elements, ensuring a working posture with correct back support.	This depth is necessary so that wheelchair users can position their bodies on the work surface without collisions, including with the footrests of the chair.	Ensures the necessary clearance for the leg, foot, and footrest when approaching the work surface.	2 - This is a critical factor for sitting posture and work table efficiency.
Automatic elevation	Yes	Automatic elevation minimizes physical effort and time spent changing posture, encouraging the use of dynamic posture.	This is an essential factor for the autonomy of users with motor disabilities or limited mobility, as it eliminates the need to rely on others to adjust the height of the table, a key principle of inclusive usability.	It eliminates the need to apply manual force, which can be difficult or impossible for people with certain disabilities.	3 - This is a determining factor in frequency of use and is also key to the autonomy and usability for users with reduced mobility.
Braille signage	Yes	Not applicable	It is crucial for tactile accessibility for blind users. Braille signage	Not applicable	3 - It is a design factor for the identification of user interfaces for the

STANDING DESKS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
			must identify the functions of the desk adjustment controls.		inclusion of users with visual impairments.
High-contrast signage	Yes	Not applicable	High contrast is essential for visual detection and safety for users with low vision. This facilitates the operation of the control interface and helps with the detection of the edges of the table.	Improves the figure-ground relationship and detectability of the interface, enabling safe and effective operation for users with low vision.	3 - This is key to the usability of the controls and interface for people with low vision.

Table 3. Evaluation parameters for reception counters

RECEPTION COUNTERS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Counter type	Two levels	A two-level counter is more ergonomically suitable because it allows for multiple types of transactions to be handled. The upper level is suitable for serving customers who are standing, while the lower level is optimal for tasks that require sitting.	The existence of a low level of interaction is a fundamental accessibility requirement. A user in a wheelchair or of short stature needs a work surface and service at a height suitable for interaction.	It responds to the need for different work planes: an elbow/chest height for standing service and a knee/table height for seated users.	3 - This is a critical feature; if there are not two levels, the counter excludes wheelchair users from comfortable and efficient interaction.
Table height - low level	Between ≥ 72 cm and ≤ 76 cm.	This range establishes the work surface, with a height of 72 to 76 cm being the standard height for a desk, ideal for an average person to write, read, or use a computer comfortably while seated.	This range is essential for wheelchair users. A height of 72 to 76 cm allows the forearms to rest comfortably on the table surface, facilitating writing and handling documents and/or objects.	This corresponds to the height of the work surface for most seated adults, ensuring a natural posture for the shoulders and elbows.	3 - An inappropriate height compromises the functionality and usability of the work table.
Table height - high level	Between ≥ 105 cm and ≤ 115 cm.	This range is defined for both standing service personnel and the public. This range is optimal for most people to	Not applicable	It aligns with the elbow height of the 50th to 95th percentile of standing adults, allowing for an	2 - If it is excessively low, it forces the user to bend their torso

RECEPTION COUNTERS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
		perform standing tasks with relaxed shoulders, minimizing fatigue. In addition, the elevated height allows internal devices (monitors, keyboards, etc.) to be protected from public view and reach.		ergonomically correct service posture.	uncomfortably; if it is too high, it makes service tasks difficult.
Depth - high level	Between ≥ 30 cm and ≤ 45 cm.	This depth allows for adequate work in the transaction area of the counter, allowing users to rest their arms, exchange documents, and temporarily place objects. A controlled depth ensures that users do not have to strain their position to reach documents or objects.	Not applicable	Based on the functional reach distance of the arm for service tasks.	2 - Affects the efficiency and functionality of the furniture.
Depth - low level	≥ 60 cm.	A depth of ≥ 60 cm at the lower level is ideal for allowing seated users, especially during tasks that require space, to have enough room to work.	Not applicable	Ensures the necessary clearance for large documents and a comfortable reading distance.	1 - Although useful, functionality is maintained with shallower depths, so its impact is minor.
Fixed counter height	Between ≥ 105 cm and ≤ 115 cm	This parameter applies when it is not a two-level counter, assuming a standing height aligned with the average elbow height.	Not applicable	It aligns with the elbow height of the 50th to 95th percentile of standing adults, allowing for an ergonomically correct service posture.	1 - Its impact is low in terms of accessibility.
Fixed counter depth	Between ≥ 40 cm and ≤ 50 cm	Reasonable depth for handling documents at a single-height counter	Not applicable	Based on the functional reach distance of the arm for service tasks.	1 - Its impact is low in terms of accessibility.
Edges and corners	≥2 mm radius	Provides basic safety to prevent injuries from accidental impacts, especially in high-traffic areas. It also improves user comfort when using the	It is an essential safety criterion for users with visual impairments and users with reduced mobility, preventing injuries from collisions.	Minimizes localized contact pressure on the soft tissues of the forearms.	2 - This is an important factor due to the risk of accidental collision faced

RECEPTION COUNTERS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
		counter by preventing muscle and tendon compression.			by users with visual impairments.
Braille signage	Yes	Not applicable.	This is an important requirement for the orientation and tactile accessibility of users with visual impairments. It should be used to clearly identify the counter and, if necessary, specific functional areas.	Not applicable.	1 - This is an interface factor that must be taken into account for inclusion, but it does not directly affect the functionality of the table.
Magnetic loop	Yes	Not applicable.	This is an essential feature for auditory accessibility, allowing users with hearing impairments who use hearing aids or cochlear implants to hear the reception staff's conversation without interference or background noise.	Not applicable.	2 - This is an audio interface factor that significantly improves communication and usability for users with hearing impairments.
Wheelchair clearance	Yes	Not applicable.	This is a critical measure for wheelchair users, allowing them to approach from the front without bumping their knees or feet.		3 - If this parameter is not met, the counter is unusable for wheelchair users, as they cannot get close enough to interact with it.
Clearance in lower height area (height)	≥ 70 cm.	Not applicable.	A clearance height of ≥ 70 cm is the accessibility standard to ensure that the thighs, knees, and footrests of a wheelchair user can pass through without obstruction.	Based on the height required for a wheelchair user.	2 - This is a key requirement for use by wheelchair users.

RECEPTION COUNTERS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Clearance in lower height area (depth)	≥ 60 cm.	Adequate clearance under the table allows the user to sit deep and move closer to the surface for writing or reading.	A clear depth of ≥ 60 cm is necessary for wheelchair users to place their footrests and knees under the counter, allowing them to bring their bodies closer to the interaction and work area.	Ensure sufficient clearance for the wheelchair footrest and the user's leg.	2 - This is a key factor for usability and for the wheelchair user's ability to reach the interaction zone.

Table 4. Evaluation parameters for armchairs

ARMCHAIRS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Seat height	Between ≥ 46 and ≤ 50 cm.	Seat height is the most important factor in facilitating sitting down and, above all, standing up. The range of 46 cm to 50 cm places the seat at the upper limit of the popliteal height, minimizing the muscle strength and load required on the knees to stand up.	This slightly elevated range is critical for transfers, aligning with the average height of wheelchairs and facilitating transfers for users with motor disabilities. It also makes it easier for older people or those with reduced mobility to sit down and stand up.	Corresponds to the popliteal height for the high percentiles of the population. A height greater than 46 ensures that the knee angle is ≈ 90º or greater, facilitating leg extension.	3 - An error in this dimension directly affects the user's ability to use the chair independently. If it is too low, it hinders mobility and transfer.
Seat depth	Between ≥ 50 and ≤ 60 cm.	The depth must be sufficient to support most of the thigh (at least 80% of the length of the femur), distributing the weight evenly, but without pressing on the popliteal fold. The range of 50 to 60 cm offers comfort without being excessively deep, which would make it difficult to get up.	A controlled (not excessive) depth is essential for people with limited mobility. Excessive depth forces the user to push themselves out of the seat or shift their center of gravity away from the vertical support point, increasing the risk of falling or difficulty in standing up.	Ensures that the back of the knee is free of pressure and that support is provided by the ischial tuberosity and the upper thigh.	2 - Incorrect depth can affect stability and safety when getting up from the chair, as well as negatively affecting blood circulation.

ARMCHAIRS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Seat width	Between ≥ 50 and ≤ 70 cm.	The seat width should be generous to accommodate the width of the hips of the largest user (95th percentile) and allow comfortable lateral space for minor postural adjustments. This range guarantees lateral comfort.	Adequate width provides additional space for users with support devices to adjust their posture when sitting.	Exceeds the 95th percentile hip width, providing lateral space for clothing and movement.	2 - Directly affects user comfort and dignity, as well as assisting users with reduced mobility in the process of sitting down and standing up.
Seat tilt	Between ≥ 0º and ≤ 5º.	A slight incline prevents sliding forward and aids stability. Inclines greater than 5º make it difficult to stand up.	An inadequate backward tilt requires much greater pushing effort to stand up, while a negative tilt can cause instability and increase the risk of falling for people with limited balance.	Ensures that the user's center of gravity remains at an optimal point of stability, facilitating the transition between postures.	2 - An incorrect tilt directly affects the user's stability or the effort required to stand up.
Backrest height	Between ≥ 60 and ≤ 90 cm.	A backrest height between 60 and 90 cm ensures adequate support for the upper back and shoulders, providing comfortable and relaxing support.	A sufficient backrest height provides a tactile reference and support for the user's torso when sitting, improving postural safety and balance for those with reduced mobility.	Supports the entire thoracic spine and, depending on the design, can provide cervical support, promoting restful postures with the lumbar curve in a neutral position.	1 - Affects long-term comfort and relaxation for the user.
Backrest height	Between ≥ 60 and ≤ 90 cm.	A backrest height between 60 and 90 cm ensures adequate support for the upper back and shoulders, providing comfortable and relaxing support.	A sufficient backrest height provides a tactile reference and support for the user's torso when sitting, improving postural safety and balance for those with reduced mobility.	Supports the entire thoracic spine and, depending on the design, can provide cervical support, promoting restful postures with the lumbar curve in a neutral position.	1 - Affects long-term comfort and relaxation for the user.
Seatback angle	Between ≥ 90º and ≤ 110º.	This angle is essential for user comfort. A 90º angle is formal, while a slightly reclined angle of up to 110º minimizes compression of the intervertebral discs and allows for relaxation. An excessive angle makes it difficult to sit up again.	The closer it is to 90º, the easier it is to get up; the effort required increases as the angle increases.	An angle close to 90º reduces the effort required to stand up. Angles close to 110º offer less disc pressure.	3 - This is a critical feature that directly affects the effort required to stand up and the user's back health.

ARMCHAIRS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Lumbar support of the backrest	Between ≥ 15 and ≤ 25 cm.	Lumbar support helps maintain the natural lordotic curve of the lower back. Adequate support prevents lower back pain and promotes a healthier resting posture.	Not applicable	The goal is to maintain the natural lumbar curvature while sitting. The key biomechanical principle is to counteract the body's natural tendency to flatten the lumbar lordosis when sitting without support.	2 - This feature provides comfort and prevents lower back pain.
Armrests (type)	Removable/detachable.	Removable and/or detachable fixed armrests maximize flexibility.	A removable armrest is the only design that allows a wheelchair user to perform a safe, unobstructed lateral transfer. At the same time, they provide an essential support point for pushing and lifting.	Facilitates transfer by eliminating the physical barrier.	3 - This feature determines whether the chair is accessible for wheelchair users to transfer.
Armrests (height)	Between ≥ 18 and ≤ 25 cm.	The height of the armrest should be such that it allows the forearms to rest while keeping the shoulders relaxed. The range of 18 to 25 cm above the seat is suitable for elbow support in a seated position.	Armrests provide support for sitting down and standing up, which is very helpful for people with reduced mobility.	The height of the armrest should provide support that minimizes tension in the shoulders, allowing for a natural and relaxed posture. It is based on the anthropometric measurement of the height of the elbow when seated.	2 - Setting the armrest height within the correct range significantly improves accessibility for people with reduced mobility.
Lumbar support height	Between ≥ 20 and ≤ 30 cm.	The position of the lumbar support should match the lumbar curve of the spine. The range of 20 to 30 cm from the part	Not applicable	Ensures that the support acts directly on the third and fourth lumbar vertebrae, maintaining the lordotic curve.	2 - Affects the comfort and health of the user's lower back.

ARMCHAIRS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Seat surface material	Non-slip.	The non-slip material improves postural stability and prevents micro-sliding that can lead to poor posture.	A non-slip material increases safety by preventing the user from slipping or losing traction during the transfer process or when getting up.	Not applicable	1 - This is an important feature, but its absence does not detract from functionality.
Edges and corners	Minimum rounded edge 2 mm radius.	Rounded edges are a basic safety requirement, preventing injuries from impacts or abrasions.	Rounded edges are vital for visually impaired users who may accidentally collide with furniture.	Not applicable.	2 - This is an essential safety factor.

Table 5. Evaluation parameters for restaurant/bar chairs

RESTAURANT / BAR CHAIRS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Seat height	Between ≥ 45 and ≤ 50 cm.	Seat height is the most critical parameter. The range of 45 to 50 cm is aligned with the popliteal height of most of the adult population, allowing users to sit with their feet flat on the floor and their knees at an angle of 90 degrees or slightly higher.	This range is critical for transferring from a wheelchair, as it aligns with the average height of wheelchairs and also makes it easier for people with reduced mobility to sit down and stand up.	The range of 45 to 95 cm aligns with the popliteal height of the 5th to 95th percentiles of the population.	3 - An error in this parameter would directly affect blood circulation and lumbar posture, and would make it difficult to transfer from a wheelchair and to sit down and stand up.
Seat depth	Between ≥ 40 and ≤ 45 cm.	The depth must be sufficient to support most of the thigh (two-thirds of the length of the femur) without pressing on the popliteal fold. This range provides adequate support, prioritizing ease of standing up.	Controlled depth is crucial to facilitate the action of lifting people with limited mobility.	Ensures that the thigh is supported without putting pressure on the popliteal fossa and keeps the user's center of gravity slightly forward, facilitating the transition to a standing position.	2 - Excessive depth can affect circulation. Reduced depths can create destabilization.

RESTAURANT / BAR CHAIRS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Seat width	Between ≥ 42 and ≤ 46 cm.	The seat width must accommodate the hips of the largest user (95th percentile). This range ensures comfort without being excessively bulky, which is vital for high-traffic environments.	Allows for larger users to be accommodated	Exceeding the 95th percentile for seated hip width.	2 - Directly affects comfort.
Seat tilt	Between ≥ 2º and ≤ 5º.	A slight tilt prevents sliding forward, avoiding compromising posture and circulation.	A controlled tilt is essential for stability. Excessive tilt makes it difficult to stand up, while a negative tilt would be unstable, increasing the risk of falling.	Ensures that the user's center of gravity remains at an optimal point of stability, while a tilt of less than or equal to 5º does not hinder the transition to a standing position.	2 - An incorrect tilt affects the user's stability and the effort required to stand up.
Backrest tilt	Between ≥ 90º and ≤ 100º.	For dining chairs, angles close to 90º are functional in supporting the torso in an upright position, ideal for eating and social interaction.	An angle close to 90º makes it easier for people with reduced mobility to get up.	Angles close to 90º reduce the effort required to straighten the spine.	2 - It directly affects the functionality of this type of furniture, as well as directly affecting the effort required to sit up.
Armrests	No.	They can interfere with the table and force incorrect postures during meals.	Armrests can act as a barrier that makes it difficult to transfer from a wheelchair.	Support is mainly transferred to the table, eliminating the need for a dedicated elbow-height armrest to relieve tension.	2 - It is important to dispense with this element in this type of furniture to ensure its functionality and avoid postural problems.
Lumbar support	Yes.	Lumbar support helps maintain the natural lordotic curve of the lower back, preventing fatigue and lumbar pain during prolonged use.	Not applicable.	Ensures that the support acts directly on the lordotic curve, maintaining a neutral posture.	2 - It is a desirable feature, but in this type of furniture, due to its usage times, it is not essential and does not detract from its functionality.

RESTAURANT / BAR CHAIRS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Lumbar support height	Between ≥ 15 and ≤ 25 cm from the seat.	The position of the lumbar support must coincide with the lumbar curve of the spine. This range is located in the most effective area, between the third and fourth lumbar vertebrae.	Not applicable.	Ensures that the support acts directly on the lordotic curve, maintaining a neutral posture.	2 - Affects the comfort and health of the user's lower back.
Seat surface material	Non-slip.	Non-slip material improves postural stability and prevents micro-sliding, which can lead to incorrect posture or the need to constantly readjust position.	A non-slip material prevents the user from slipping or losing traction during the transfer process or when getting up, ensuring their safety at the most vulnerable moment of use.	Not applicable.	2 - Prevents possible falls and injuries.
Edges and corners	Minimum rounded radius of 2 mm.	Rounded edges are a basic safety requirement, preventing injuries from accidental impacts, both for seated users and for people walking by.	Rounded edges are vital for visually impaired users who may accidentally collide with furniture. They also protect wheelchair users or those with walkers in the event of a collision.	Not applicable.	2 - In a high-traffic environment, this is an important safety factor.

Table 6. Evaluation parameters for restaurant/bar tables

RESTAURANT / BAR TABLES					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Table height	Between ≥ 73 and ≤ 78 cm.	Table height is essential for comfort while eating and socializing. A height range of 73–78 cm allows most users to sit comfortably on chairs with seat heights of approximately 45 cm, maintaining an optimal distance	This height ensures that the table surface is positioned at a functional level for eating or interacting, preventing it from being too low or too high relative to the user's torso.	The selected range ensures anthropometric compatibility between the seat and work surface, based on the average seated elbow height (P50 percentile).	3 - An incorrect dimension directly affects the usability of the furniture.

RESTAURANT / BAR TABLES					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
		between the thighs and the underside of the tabletop.			
Minimum dimensions	≥ 1800 cm².	A surface area of 1800 cm² per diner is the minimum required to accommodate cutlery and plates, allowing elbow movement and ensuring comfort and functionality.	It is important to maintain this minimum space so that users with limited fine motor control can maneuver their arms comfortably while eating.	Based on seated body anthropometry (shoulder and hip width) and the biomechanics of eating movements (reach and elbow motion).	2 - Directly affects user comfort, social interaction, and dignity.
Edges and corners	Rounded, minimum radius of 2 mm.	Rounded edges are a basic safety requirement, preventing injuries from impacts or abrasions, especially in environments with constant movement.	It is an essential safety criterion for users with visual impairments who may accidentally collide with the table.	Not applicable.	2 - An essential safety factor.
Under-table clearance (width)	≥ 90 cm.	A free width of 90 cm or more provides ample legroom for diners and facilitates access.	This width ensures that a wheelchair can fit comfortably, allowing users to approach without lateral obstructions.	Based on the width of a wheelchair plus the required safety and maneuvering clearance.	2 - A key requirement for frontal approach. Insufficient width prevents wheelchair access.
Under-table clearance (height)	≥ 70 cm.	This is the clearance height needed for the comfortable passage of thighs and knees of most users seated on standard chairs with seat heights around 45 cm.	A clearance height of at least 70 cm meets accessibility standards, ensuring that wheelchair thighs, knees, and footrests fit comfortably under the table.	Complies with accessible design standards for knee clearance height.	2 - Essential for proper wheelchair positioning.
Under-table clearance (depth)	≥ 60 cm.	Adequate depth clearance under the table allows users to sit comfortably and approach the surface for eating.	A depth clearance of ≥ 60 cm ensures that wheelchair footrests and knees can fit under the table edge, allowing the user to bring their torso and arms close to the surface.	Ensures sufficient space for wheelchair footrests and the user's legs when approaching the table.	2 - A critical factor for usability and for enabling wheelchair users to reach the eating area.

Table 7. Evaluation parameters for bar counters

BAR COUNTERS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Bar height type	Two levels.	A two-level design allows the bar to adapt to multiple modes of use: standing users, users seated on high stools, users seated on standard chairs, or wheelchair users.	Having a lower level is essential for accessibility, as it provides a service surface at the appropriate height for interaction with people in wheelchairs.	The variation in bar height allows for the correct alignment of the user's limbs with the support surface.	3 - This is a critical accessibility factor, as the absence of the lower level excludes wheelchair users from using this type of furniture.
Bar height (lower level)	Between ≥ 75 and ≤ 85 cm.	Provides an adequate support surface for users seated in standard chairs.	This range is aligned with the height of the work surface for wheelchair users, allowing room for the chair to be accommodated underneath.	The lower limit of 75 cm allows for a sufficient lower height for wheelchair users to pass their knees/thighs underneath, while the upper limit of 85 cm prevents users from adopting an awkward posture by raising their shoulders excessively.	3 - This is a key factor in functionality and usability for people with motor disabilities.
Bar height (upper level)	Between ≥ 110 and ≤ 115 cm.	Standard height range for standing use.	Not applicable.	The range is aligned with the elbow height of the majority of the adult population when standing (5th to 95th percentile), optimizing support biomechanics and minimizing shoulder strain.	3 - Outside this range, users are forced to adopt uncomfortable and awkward postures.
Bar height for a single level	Between ≥ 110 and ≤ 115 cm.	Compromise solution for a single-level bar.	Not applicable.	The range is aligned with the elbow height of the majority of the adult population when standing (5th to 95th percentile), optimizing support biomechanics and minimizing shoulder strain.	1 - This is not an optimal solution.
User zone depth	≥ 17 cm.	Providing depth at the front of the bar allows users standing or sitting on high stools to approach the	Not applicable.	Seeks to achieve greater balance in the user's center of gravity, making it easier for them to approach the	2 - Not having this depth compromises the postural ergonomics of

BAR COUNTERS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
		surface and maintain postural balance.		surface and helping them maintain better postural balance.	users standing or sitting on high stools.
Footrest	Yes.	Encourages a dynamic posture, allowing both users sitting on high stools and users standing to alternate the position of their feet.	Not applicable.	Foot support helps improve postural stability when sitting on high stools or standing. It relieves lumbar tension and pressure under the thighs when sitting.	**1** - Affects comfort, but is not key to the functionality and usability of the furniture.
Footrest height	Between ≥ 18 and ≤ 22 cm.	Provides comfortable intermediate support for standing users.	Not applicable.	The range allows for proper knee flexion and foot support that allows for shifting body weight.	**1** - Affects comfort of support, but is not key to the functionality and usability of the furniture.
Edges and corners	Minimum rounded 2 mm radius.	Prevents injuries from collisions and avoids excessive pressure during contact with the forearms.	It is a safety criterion that prevents injuries from collision or abrasion, especially for visually impaired users in high-traffic environments.	Minimizes the risk of tissue damage in contact areas and vascular/nerve compression.	**2** - Prevents possible collision injuries and damage or discomfort from pressure during prolonged use.
Braille signage	Yes.	Not applicable.	Allows blind or low-vision users to identify areas such as payment areas, accessible service areas, etc.	Uses the sense of touch to convey messages.	**2** - Interface factor that affects the autonomy of blind users.
Magnetic loop	Yes.	Not applicable.	Improves the quality of communication for people with hearing impairments who use compatible hearing aids. In noisy environments, it is a very helpful feature.	Not applicable.	**2** - Interface and communication factor that improves interaction with people with hearing disabilities.
Lower clearance (width)	≥ 80 cm.	Not applicable.	Minimum space required for wheelchair access to the lower level from the front.	Accommodates the width of the wheelchair.	**3** - If the width is insufficient, it prevents the wheelchair from entering the accessible service area.

BAR COUNTERS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Lower clearance (height)	≥ 70 cm.	Not applicable.	Standard dimension that guarantees the passage of the knees, thighs, and footrests of wheelchair users.	Not applicable.	3 - If the vertical clearance is insufficient, the accessible service area is unusable for wheelchair users.
Lower clearance (depth)	≥ 60 cm.	Not applicable.	Space required for wheelchair users to approach the surface, reach objects, and perform transactions.	Not applicable.	2 - If the depth is insufficient, wheelchair users are forced to adopt awkward postures.

Table 8. Evaluation parameters for work chairs

WORK CHAIRS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Seat height (type)	Adjustable.	Height adjustment is essential for office ergonomics. It allows the user to align their popliteal height with the floor, ensuring that the feet are flat and the knees are at an angle close to 90°, minimizing pressure on the back of the thigh and ensuring adequate blood circulation during prolonged sitting periods.	Adjustability is critical for wheelchair transfers, as the user can set the chair height to match the wheelchair height as closely as possible, facilitating lateral transfer. It is also essential for accommodating users with dimensions in extreme percentiles.	Adaptability ensures optimal biomechanical performance; the height range should cover from the 5th percentile female popliteal height to the 95th percentile male popliteal height.	3 - One of the most critical features of a work chair intended for prolonged use, where adaptability is essential to prevent posture-related disorders.
Seat height (adjustment range)	Lower limit ≥ 40 cm and upper limit ≥ 55 cm.	This broad range covers the 5th to 95th percentile popliteal height of the adult population, ensuring compatibility with most users.	The lower limit allows the chair to be low enough for very short users. The upper limit assists in wheelchair transfers.	The biomechanical goal, once height is adjusted, is for the user's feet to rest flat on the floor, knees flexed at 90°, and thighs horizontal.	3 - An insufficient range excludes users at population extremes and compromises ergonomic posture for all.

WORK CHAIRS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Seat height (fixed)	Between 45 and 48 cm.	A fixed work chair is a poor solution from an ergonomic and accessibility perspective. This range represents the optimal compromise for a non-adjustable chair, aligned with the popliteal height of most people to allow a reasonably correct posture.	Not applicable.	The average popliteal height is used to ensure that at least 50% of the population can sit correctly, promoting even pressure distribution, foot support, and proper knee angle.	1 - Considered a sub-optimal design solution from an ergonomic standpoint.
Seat depth (type)	Adjustable.	Allows the user to align the seat depth with thigh length, ensuring that support covers at least two-thirds of the thigh without pressing against the popliteal fold.	Allows shorter users to sit fully back while maintaining space behind the knees.	The key measurement is buttock-popliteal length. Adjustable depth is essential to accommodate both shorter and taller users.	2 - An essential comfort and adaptability feature for advanced ergonomic adjustment.
Seat depth (adjustable)	Lower limit ≥ 40 cm and upper limit ≥ 47 cm.	The 40–47 cm range covers the needs of most of the population.	Not applicable.	The range is based on the population's buttock-popliteal length, covering the 5th to 95th percentiles. It ensures lumbar support contact and distributes weight along the thigh's surface, avoiding compression of vessels and nerves.	2 - An incorrect range causes knee pressure or lack of lumbar support.
Seat depth (fixed)	Between 40 and 42 cm.	This compromise range minimizes negative effects in non-adjustable chairs.	Not applicable.	A shorter seat depth is a compromise solution to prevent pressure in the popliteal area for users of medium to short stature.	1 - Not an optimal solution.
Seat width	Between 45 and 52 cm.	The width should be comfortable and allow occasional movement.	Not applicable.	This dimension aligns with average hip width plus a safety allowance to ensure comfort and lateral stability.	2 - Insufficient width compromises comfort.
Backrest tilt (adjustable)	Yes.	Allows alternating postures, promoting dynamic sitting and adaptation to the task performed.	Not applicable.	Helps modulate the load on lumbar discs and vary the hip angle.	3 - Directly affects comfort and back health.

WORK CHAIRS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Backrest tilt (fixed range)	Between 95° and 100°.	This is the optimal range for an upright working posture.	Not applicable.	An angle between 95° and 100° represents the neutral working posture, maintaining lumbar support contact.	**1** - Not an optimal solution.
Backrest tilt (adjustable range)	Lower limit ≤ 95° and upper limit ≥ 135°.	Allows switching between working and full recline/resting postures.	Not applicable.	A wide recline range ensures dynamic posture functionality, relieving back tension by changing the torso-hip angle.	**3** - Ranges outside these limits would restrict dynamic posture functionality or result in non-ergonomic positions.
Lumbar support	Yes.	Maintains the natural lordotic curve.	Not applicable.	Lumbar support prevents spinal flattening, muscle fatigue, and lower back pain.	**2** - Provides comfort and prevents back disorders.
Lumbar support type	Adjustable.	Height adjustment is necessary to adapt to human diversity.	Not applicable.	The height of the lumbar curve (lordosis) varies significantly among individuals and requires centering near the inflection point.	**2** - Improves comfort and support precision.
Lumbar support height (adjustable)	Lower limit ≤ 15 cm and upper limit ≥ 25 cm.	Range covers lumbar area for the 5th to 95th percentiles.	Not applicable.	The 15–25 cm range from the seat corresponds to vertebrae L3–L5, maintaining the necessary area to support lordosis.	**2** - Ensures correct support positioning.
Lumbar support height (fixed)	Between 15 and 25 cm.	Compromise range for fixed support.	Not applicable.	Set within the range between extreme percentiles.	**1** - Not an optimal solution.
Armrests	Yes.	Essential for forearm support and reducing shoulder and neck load.	Key accessibility factor, especially for mobility. Armrests provide essential leverage for users with reduced mobility when sitting or standing, and safe support points for transfers	Offloads arm weight, reducing shoulder and neck strain and promoting a neutral posture with elbows close to the body.	**2** - Important for chair ergonomics and accessibility.

WORK CHAIRS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
			to or from wheelchairs or other assistive devices.		
Armrests (removable type)	Yes.	Not applicable.	Key to enabling lateral transfers for wheelchair users.	Removing the physical barrier is a biomechanical requirement for weight transfer between the wheelchair and the office chair.	2 - Key accessibility factor for transfers.
Armrests (adjustable type)	Adjustable.	Necessary to prevent shoulder elevation if too high, leaning if too low, and to interoperate with desk height without interference.	Adjustable height allows users to position armrests where they can apply the most leverage, essential for people with reduced mobility.	Height adjustment ensures the forearm is supported without excessive shoulder abduction.	2 - Improves shoulder ergonomics and accessibility.
Armrest height (adjustable range)	Lower limit ≤ 18 cm and upper limit ≥ 25 cm.	Must be adjustable to align with work surface height, independent of seat height.	Covers the range needed for armrests to optimally function as support points during sit-to-stand actions.	Based on seated elbow height and its relationship to workspace dimensions.	2 - Essential for ergonomic and accessibility performance.
Armrest height (fixed)	Between 18 and 25 cm.	Compromise range for fixed armrests.	Not applicable.	Based on seated elbow height.	1 - Not an optimal solution.
Armrest length	≥ 20 cm.	Provides sufficient forearm support.	Not applicable.	Ensures support for the elbow and proximal forearm, the key area for offloading upper limb weight.	1 - Affects comfort of arm support.
Seat surface material	Non-slip.	Improves postural stability.	Key for safety during transitions from sitting to standing, and for users with limited postural control, preventing slipping.	Adequate surface friction.	2 - An active safety factor preventing falls and injuries in users with mobility difficulties.
Wheel type	Self-locking.	Self-braking wheels lock when the user stands up.	Essential for users with reduced mobility; locking prevents the chair from sliding during sit-to-stand transfers.	At the moment of greatest instability in the user's center of gravity (sitting/standing), the self-locking system activates.	3 - An essential safety feature.

WORK CHAIRS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Rounded edges and corners	Rounded ≥ 2 mm.	Prevents injuries from accidental impacts.	Safety criterion to prevent injury from collisions or abrasions, especially for users with visual or mobility impairments.	Minimizes contact injury risk from sharp angles.	2 - Important for users with perception or mobility difficulties.
Marked controls	Braille or raised markings.	Not applicable.	Necessary for blind or visually impaired users to identify key adjustment functions.	Allows tactile identification of controls.	2 - Facilitates autonomous usability, especially at initial use.
Table height type	Adjustable.	Height adjustment is essential for work ergonomics, allowing the table to adapt to the sitting posture.	Allows wheelchair users to adjust the height to ensure the necessary clearance under the tabletop.	The height of the work table should be equal to the height of the user's elbow when seated, ensuring that the forearm is parallel to the floor. Height adjustment allows this parameter to be adapted to 95% of the population.	3 - This is the most critical factor; lack of height adjustment can lead to forced postures, affecting health, especially during prolonged work.

Table 9. Evaluation parameters for work tables

WORK TABLES					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Adjustable table height (range)	Lower limit ≤ 65 and upper limit ≥ 77 cm.	This range covers the seated elbow height for the adult population.	The range ensures accessibility for both short people and wheelchair users.	The adjustment range allows for neutral biomechanics of the shoulders and elbows.	3 - An insufficient range compromises the ergonomic posture for users at the extremes of the population, rendering the adjustment function useless.

WORK TABLES					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Table height (fixed)	Between ≥ 72 and ≤ 73.5	This range corresponds to the best compromise for a non-adjustable table.	It allows wheelchair access as long as the structure is adjusted to a minimum height of 70 cm.	The range is set at the average seated elbow height.	**1** - It is not an optimal solution.
Table top length	≥ 115 cm.	The established length provides the necessary space for standard work equipment and allows for comfortable lateral reach.	Ensures sufficient space for assistive devices, such as Braille keyboards or large screens, and allows wheelchair users to turn slightly to reach objects.	The range is adjusted for bilateral work.	**2** - Affects the functionality of the furniture.
Depth of tabletop	≥ 60 cm.	This value is key to maintaining optimal viewing distance from the monitor and providing sufficient support for the forearms.	Enables a design with the minimum depth for wheelchair users.	Ensures that the primary work area is within easy reach, keeping the monitor at the appropriate focal distance.	**2** - Incorrect distance may force uncomfortable reaching postures or prevent proper placement of equipment.
Edges and corners	Rounded with a radius ≥ 2 mm.	Rounded edges prevent contact pressure on the wrists and forearms, especially during prolonged work.	In the field of accessibility, it is a safety criterion to prevent injuries from bumps or abrasions, especially for users with visual impairments.	Minimizes the risk of tissue damage and vascular/nerve compression.	**2** - Prevents possible collision injuries and damage or discomfort from pressure during prolonged use.
Lower clearance (width)	≥ 90 cm.	Provides sufficient space to accommodate the user and allows for lateral movement while seated.	Ensures that the wheelchair can be positioned with clearance in the front working position.	Accommodates the width of the wheelchair plus clearance for safety and maneuvering.	**2** - This is a necessary requirement for the accessibility of the furniture.
Lower clearance (height)	≥ 70 cm.	This height limit allows seated users to comfortably pass their thighs and knees through.	A clearance height of ≥ 70 cm is an accessibility standard that guarantees accommodation for a wheelchair.	Complies with the clearance height required for knee clearance as specified by the 95th percentile.	**3** - If the vertical clearance is insufficient, the workstation becomes unusable for wheelchair users.
Lower clearance (depth)	≥ 60 cm.	Allows the user to approach the work surface.	The established depth value is necessary to accommodate the footrest and knees of the	Clearance necessary to approach the edge of the table.	**2** - If the depth is insufficient, forced postures will be generated.

WORK TABLES					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
			wheelchair user, ensuring their working position.		

Table 10. Evaluation parameters for high work stools

HIGH WORK STOOL					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Seat height (type)	Adjustable.	Height adjustment is essential to align the seat height with the height of the work area, allowing the user to maintain an optimal working posture.	The height should be adjusted to minimize the vertical distance between the seat and the buttocks, facilitating access.	The seat height should ensure that the user can reach the work surface while maintaining proper elbow height and that their feet are supported on the footrest.	3 - This is a critical parameter. A stool that is not height-adjustable excludes a large part of the population from proper use, forcing incorrect postures.
Fixed seat height	Between ≥ 75 and ≤80 cm.	Compromise range for a non-adjustable stool.	Not applicable	Aligns the seat so that the average user can work with a surface height of ≈ 105 cm.	1 - This is not an optimal solution.
Adjustable height range	Lower limit ≥ 60 and upper limit ≤ 85 cm.	The stool must be adjustable to allow diverse users (P5 – P95) to align their elbows with the work surface. This range promotes dynamic height by allowing the user to alternate between sitting and standing.	Accessibility in this context refers to the ease with which it can be used by people of different heights, allowing them to move from a standing to a sitting position and vice versa comfortably and effortlessly.	The range allows for a correct seated elbow height for a wide range of the population in an elevated posture, optimizing upper limb biomechanics and minimizing shoulder strain.	3 - An insufficient range compromises ergonomic posture for a certain group of users.
Seat depth	Between ≥ 38 and ≤ 45 cm.	The depth should be sufficient to support most of the thigh, but should be less than in office chairs to facilitate the action of standing up.	A moderate depth facilitates weight transfer and movement when standing up, which is crucial in high seats where balance is important.	The established range ensures that most of the thigh is supported by the seat without pressing on the popliteal crease.	2 - Incorrect depth affects circulation or stability.

HIGH WORK STOOL					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Seat width	Between ≥ 40 and ≤ 50 cm.	It should accommodate the width of the P95 user, with space for lateral movement without being bulky.	Ensures that the seat base is sufficiently stable for larger users and provides adequate lateral support.	The width is based on the seated hip width for the 95th percentile plus a clearance.	2 - Affects both the comfort and stability of the furniture.
Backrest tilt	Between ≥ 95º and ≤ 105º.	Allows for a primarily upright posture, prioritizing working positions and minimizing disc load for that position.	Not applicable.	Angles between 95º and 105º offer optimal neutral postures for the spine when working, promoting natural lordosis and reducing lumbar disc compression.	3 - Essential for lumbar health during prolonged use.
Lumbar support	Yes.	Lumbar support helps maintain the natural lordotic curve, preventing lumbar discomfort.	Not applicable.	The support prevents straightening of the spine, maintaining muscle balance and reducing pressure on the intervertebral discs.	2 - Key to comfort and prevention of lumbar injuries.
Type of lumbar support	Adjustable.	Required to precisely adjust to lumbar height variability.	Not applicable.	Lumbar support must act at the inflection point of the lordosis to be effective.	2 - Makes lumbar support effective and improves comfort.
Lumbar support height range (adjustable)	Lower limit ≤ 15 and upper limit ≥ 25 cm.	Covers the range of positions necessary for support.	Not applicable.	This range, measured from the seat, corresponds to the L3-L4-L5 vertebrae, the key region for maintaining natural lordosis.	2 - Ensures individualized and precise positioning.
Lumbar support height (fixed)	Between ≥ 15 and ≤ 25 cm.	Compromise range for fixed support.	Not applicable.	It is located at the average lumbar height for general support.	1 - Not an optimal solution.
Footrest	If available.	This is an essential feature in high stools. It provides stability and prevents pressure under the thighs.	It provides the necessary support for stability and balance when sitting down and standing up, reducing the risk of falling.	Foot support is crucial for postural stability when sitting. Without it, pressure on the back of the thigh increases and circulation is compromised.	3 - This is a critical factor for stability and comfort in this type of seat.

HIGH WORK STOOL					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Footrest height	Between ≥ 40 and ≤ 45 cm.	Distances within the established range allow the knees to form an angle close to 90º or slightly less, ensuring correct posture.	Not applicable.	Ensures that the distance between the seat and the footrest is adjusted to the popliteal height of the users.	2 - Incorrect height forces postures that compromise circulation and stability.
Seat surface material	Non-slip.	Improves postural stability.	In high seats, this is an important feature that prevents the user from slipping or losing traction, ensuring safety when sitting down and standing up.	Adequate friction ensures stability and postural control in high seats where the center of gravity is higher.	2 - Factor that improves safety and facilitates postural control during use.
Wheels	Yes.	Facilitates and allows effortless mobility around the workplace.	Not applicable.	Not applicable.	1 - Mobility and efficiency factor that is not as relevant as it is in chairs that require greater mobility.
Type of wheels	Self-locking.	This is a safety feature that locks the wheels when the weight is lifted off the seat.	This is critical for the safe use of the wheeled stool, preventing it from moving when sitting down or standing up.	Braking is a biomechanical requirement for weight transfer and balance.	2 - Highly important factor in seats of this type equipped with wheels.
Edges and corners	Rounded edges ≥ 2 mm.	Prevents injuries from bumps or pressure on the edges.	Safety criterion to prevent injuries from collision or abrasion, especially for users with visual impairments.	Minimizes the risk of tissue damage from contact when sitting down, standing up, or moving around the furniture.	2 - Important factor for work environments with mobility.

HIGH WORK STOOL					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Signaling controls	Braille or relief.	Not applicable.	Tactile signage on controls helps blind or low-vision users identify adjustment functions, especially when using them for the first time.	Allows identification by touch.	2 - This is an interface factor that does not directly affect functionality.

Table 11. Evaluation parameters for conference tables

CONFERENCE TABLES					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Table height	Between ≥ 72 and ≤ 76 cm.	This range establishes the optimal table height for sitting in standard chairs.	This range aligns with the height necessary to allow a design where the thighs and knees of the wheelchair user pass under the table surface, while ensuring its function for writing or handling documents.	The height range is aligned with the seated elbow height for most of the adult population, allowing the forearm to rest in a neutral position.	3 - This is the most critical factor in this type of furniture. A design with a height outside the range would force users into awkward postures, compromising both the function of the furniture and the postural health of users.
Available width per person	≥ 75 cm.	Ensures adequate personal space for documentation, arm placement, and use of electronic devices without interfering with other users.	Adequate width is important for comfort, especially for users who may require extra space due to limited movement.	Based on seated shoulder width and the space required for bilateral manipulation of documents and devices.	2 - Insufficient width affects the comfort and functionality of the furniture.
Edges and corners	Minimum rounded radius of 2 mm.	Rounded edges prevent contact pressure on the wrists and forearms, especially during prolonged work.	In the field of accessibility, it is a safety criterion to prevent injuries from bumps or abrasions, especially for users with visual impairments.	Minimizes the risk of tissue damage and vascular/nerve compression.	2 - Prevents possible injuries from collision and damage or discomfort from

CONFERENCE TABLES					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
					pressure during prolonged use.
Lower clearance (width)	≥ 90 cm.	Provides sufficient space to accommodate the user and allows for lateral movement while seated.	One or more areas of the table with a width within this range ensure accessibility for wheelchair users.	Accommodates the width of the wheelchair plus a safety and maneuvering clearance.	2 - Insufficient width would make the furniture inaccessible to wheelchair users.
Lower clearance (height)	≥ 70 cm.	The range ensures comfortable passage for the thighs and knees of most users.	The established range is an accessibility standard that ensures that the thighs, knees, and footrests of a wheelchair can pass under the edge of the table without colliding.	Complies with the clearance height required for knee clearance as required by the 95th percentile.	3 - If the vertical clearance is insufficient, the wheelchair user cannot get close enough, rendering the workstation unusable.
Lower clearance (depth)	≥ 60 cm.	Allows the user to sit deep and get close to the work surface.	The established depth range is required so that wheelchair users can place their knees and thighs under the table surface, ensuring that they can bring their body and arms close to the work surface.	Clearance required to approach the edge of the table.	2 - Insufficient depth will result in forced postures.

Table 12. Evaluation parameters for stackable chairs

STACKABLE CHAIRS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Seat height	Between ≥ 46 and ≤ 50 cm.	Seat height is the most critical parameter in a chair. This range aligns with the popliteal height of the majority of the adult population (5th to 95th percentiles), allowing most	This range is key when transferring from a wheelchair, as it aligns with the average height of wheelchairs. It also makes it easier for people with	Ensures even weight distribution and prevents pressure on the back of the thigh, maintaining proper blood circulation.	3 - Values outside the range directly affect blood circulation in the legs and affect lumbar posture, as well as

STACKABLE CHAIRS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
		users to sit with their feet flat on the floor and their knees at a 90° angle or slightly higher.	reduced mobility to sit down and stand up.		making it difficult to transfer or sit up.
Seat depth	Between ≥ 40 and ≤ 45 cm.	The depth should support most of the thigh without putting pressure on the popliteal fossa. This range is suitable for general use.	A depth that is not excessive is important to facilitate lifting people with limited mobility.	It allows the thigh to be supported without compromising circulation in the popliteal fossa.	2 - Incorrect depth affects circulation (excessive depth) or stability/support (too short).
Seat width	Between ≥ 42 and ≤ 46 cm.	Accommodates the hip width of the average user without being excessively bulky for stackable chairs for mass use.	Provides a stable seat for most users.	Based on seated hip width (95th percentile) plus reduced clearance for movement and clothing.	2 - Directly affects comfort.
Seat tilt	Between ≥ 2º and ≤ 5º.	A slight backward tilt helps stabilize the pelvis and prevents sliding forward.	Not applicable.	Ensures that the seat does not force the pelvis into excessive retroversion or cause the user to slide.	2 - Affects postural stability and comfort.
Backrest tilt	Between ≥ 90º and ≤ 105º.	This range allows for an upright but slightly reclined posture, which is optimal for work and situations that require attention.	An angle close to 90º makes it easier for people with reduced mobility to get back up.	Angles close to 90º reduce the effort required to straighten the spine.	3 - It directly affects the functionality of this type of furniture, as well as directly affecting the effort required to sit down.
Armrests	Yes.	Armrests reduce the load on the back and shoulders.	Armrests are key, acting as levers for transferring and lifting people with reduced mobility.	They help to relieve the weight of the arms, preventing overloading of the shoulder and neck muscles, reducing fatigue, and promoting a neutral posture by keeping the elbows close to the body.	2 - An important factor for the autonomy of users with motor disabilities.
Armrests (type)	Removable.	Not applicable.	Key to enabling lateral transfer of wheelchair users.	The removal of the physical barrier is a biomechanical requirement for	3 - Key accessibility factor for transfer.

STACKABLE CHAIRS					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
				weight transfer between the wheelchair and the office chair.	
Armrest height	Between ≥ 20 and ≤ 25 cm.	Within this range, compromise heights are ensured to allow the user's shoulders to remain relaxed when resting their arms.	Not applicable.	Based on seated elbow height.	2 - Affects user comfort.
Lumbar support	Yes.	Maintains the natural lordotic curve.	Not applicable.	Support in the lumbar area prevents straightening of the spine, preventing muscle fatigue, lower back pain, and various back conditions.	2 - This is a feature that provides comfort and prevents back pain.
Lumbar support height	Between ≥ 18 and ≤ 22 cm.	Compromise range for fixed support.	Not applicable.	Determined as a fixed value within the range between the most extreme percentiles.	2 - Ensures the placement of lumbar support for the majority of the adult population.
Seat surface material	Non-slip.	Improves the user's postural stability.	Key to safety during transfer from sitting to standing and for users with limited postural control, preventing slipping.	Adequate surface friction.	2 - This is an active safety factor that prevents falls and injuries to users with mobility difficulties.
Edges and corners	Minimum rounded radius of 2 mm.	Rounded edges are a basic safety requirement, preventing injuries from accidental impacts, both for seated users and for people walking by.	Rounded edges are vital for visually impaired users who may accidentally collide with furniture. They also protect wheelchair users and people with walkers in the event of a collision.	Not applicable.	2 - This is an important safety factor.

Table 13. Evaluation parameters for display cases

DISPLAY CASES					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Counter height	Between ≥ 100 and ≤ 125 cm.	Establishes the height for dispensing products, allowing staff to maintain a comfortable working posture.	A height ≤ 125 cm allows wheelchair users or people of short stature to access the dispensing surface.	The height must be aligned with the working height that allows for vision and interaction with the customer and the exchange of products. In addition, it must coexist with the display area where the operator's work is centered.	3 - This is one of the critical factors. If it is too high, it hinders interaction and product exchange; if it is too low, it hinders operations on the display surface.
Depth of the dispensing surface	Between ≥ 25 and ≤ 45 cm.	Defines the area where the transaction takes place. It must be deep enough to allow products to be placed, but without the operator or user having to stretch.	Ensures that wheelchair users can reach the transaction point.	The range is based on the comfortable reach zone (primary reach).	2 - Excessive depth makes the transaction and reach difficult for the customer, while insufficient depth does not provide enough support space.
Maximum depth of display space	≤ 70 cm.	Ensures that the employee can access and replenish products at the back of the counter without stretching or straining.	Not applicable.	The limit of ≤ 70 cm is based on the functional reach of the arm for most of the population.	2 - If it is too deep, it compromises the ergonomics of the operator and correct restocking.
Height of display space	Between ≥ 90 and ≤ 95 cm.	Ensures that products are displayed in the primary field of vision of the average customer and, at the same time, are within the operator's handling zone.	The upper limit of ≤ 95 cm is necessary to ensure that wheelchair users can have an acceptable viewing angle of the products displayed on the base.	The height should prevent the operator from working at heights below 90 cm and prevent standing users from having to bend over to view the product.	3 - Products outside this range are difficult for wheelchair users or standing users to see and can cause musculoskeletal damage to the operator during prolonged work handling delicate or heavy products.

DISPLAY CASES					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Depth of user foot space	≥ 30 cm.	Allows the user to bring their center of gravity closer to the counter while maintaining an upright posture.	Ensures that a wheelchair user can approach the counter, allowing the feet and footrests of the chair to be accommodated, avoiding excessive stretching.	Bring the center of gravity closer to the dispensing area to avoid excessive stretching.	3 - This is an important parameter for avoiding strain on the user's back and neck and prevents wheelchair users from getting closer.
Depth of the operator's foot space	≥ 21 cm.	Allows the operator to approach the counter and the customer while maintaining an upright posture during product transfers.	Not applicable.	Clearance is essential to ensure balance and weight transfer between the operator and the user.	2 - If insufficient, it forces the operator into an uncomfortable and incorrect posture during prolonged use, causing possible musculoskeletal problems.
Height of user's foot space	≥ 25 cm.	Prevents footwear from catching on the lower edge when approaching.	This is a vital height for the footrests of a wheelchair to pass through.	Ensures the necessary vertical clearance for frontal approach.	3 - This is an important parameter for preventing strain on the user's back and neck and prevents wheelchair users from moving closer to the counter.
Height of the operator's foot space	≥ 15 cm.	Prevents footwear from catching on the lower edge when approaching.	Not applicable.	Provides the necessary space for foot movement, improving postural comfort during product transactions.	2 - Affects the operator's comfort and postural health.
Edges and corners	Minimum rounded ≥ 2 mm radius.	Prevents contact injuries when leaning or bumping into objects.	Safety criterion to prevent injuries from collision or abrasion, especially for visually impaired users and users with reduced mobility.	Minimizes the risk of damage from contact with sharp angles in the service and dispensing area.	2 - Important safety factor in customer service areas.

DISPLAY CASES					
Evaluation parameter	**Value range - Optimal (Score 3)**	**Ergonomic justification**	**Accessibility justification**	**Biomechanical/Anthropometric rationale**	**Impact of weighting**
Braille signage	Yes.	Not applicable.	Allows blind or low-vision users to identify the type of business, specific product areas, or the payment area through touch.	Uses the sense of touch for spatial orientation and interaction.	2 - Interface factor that guarantees the autonomy of blind users.
Magnetic loop	Yes.	Not applicable.	Improves the quality of communication for people with hearing impairments who use compatible hearing aids.	Not applicable.	2 - Interface and communication factor that improves interaction with people with hearing impairments.

2.1.3 Progress beyond the State of the Art and State of Play

The current state of the art in the realm of ergonomic assessment tools primarily consists of manual or semi-automated tools designed to evaluate office furniture, especially chairs and workstations, based on ergonomic principles related to posture, comfort, and adjustability.

- Checklist-based tools: the Cornell Ergonomic Seating Evaluation Form [14] and the Worksite International Assessment Forms [15] are printable or digital forms that can be filled manually either by evaluators or users, and that are based on subjective observations and basic anthropometric guidelines.
- Self-assessment tools: the POSE™ Personal Office Seating Evaluation [16] and the Olivier Girard Online Assessment [17] allow users to assess their posture and workspace through online questions or visual guides, providing limited or general feedback without precision.

The main differentiation between the ErgoFlow tool and other existing tools is that they rely on subjective information provided by the user or use checklists. However, ErgoFlow performs an automated evaluation using quantifiable ergonomic and accessibility parameters based on internationally recognized standards in biomechanics, ergonomics and accessibility, which ensures consistency and reliability in the analysis of furniture.

On the other hand, the existing tools analyzed and included in the state of the art are mainly focused on office chairs and furniture associated with work environments, while ErgoFlow has a wider scope of application by including seats and tables surfaces belonging to different types of public and private spaces, and can therefore be used in different contexts.

While most of the aforementioned tools use static forms or 2D evaluations, ErgoFlow enables the designer to upload the 3D model of the furniture piece to be analyzed online, which allows a better visual and spatial understanding of ergonomic compliance.

Finally, while current tools focus exclusively on ergonomics, ErgoFlow merges this dimension with that of accessibility, thus promoting the principles of inclusive design in furniture.

2.1.4 Overview and Demonstration

Below, we present an overview of the ErgoFlow Evaluation Tool user interface, with a detailed explanation of its functionalities and usage. It is important to note that authentication, both for the Evaluation Tool and the Library, will be provided through the Universal Access Suite, which will offer a single sign-on mechanism.

2.1.4.1 Project Setup

The first step in setting up a project is for the user to select the type of furniture they want to work with from the list provided. Options include 13 seating and table items such as low benches, work chairs, worktables, conference tables, and more. After selecting the furniture type, the user can also upload a reference image of their design, that will later be used for the project library. The maximum file size for images is 10 MB, and accepted formats include .jpg, .png, and .jpeg.

Next, the user can also upload a 3D model in .glb format. The .glb format was selected for its portability, compression efficiency, and open-source nature, and allows the user to view the design in three dimensions, making it easier to rotate, zoom, and pan to inspect the furniture from every angle and

visualize the overall design. Moreover, it is a widely adopted standard format that can be exported from most 3D design programs, and the tool will contain a short manual for users on how to export and import in .glb, and in future improvements of the tool, the possibility of adding other formats such as .ifc will be considered.

The maximum file size for 3D models is 10 MB. This limit was deemed the most appropriate given the .glb compression level, as it allows optimized models to be uploaded while ensuring the web tool functions properly.

Finally, the user must enter a unique project name. Giving the project a clear and descriptive name helps the user stay organized and makes it easier to identify the design in the future, especially when working on multiple projects simultaneously.

Figure 1. ErgoFlow Evaluation Tool - Project setup

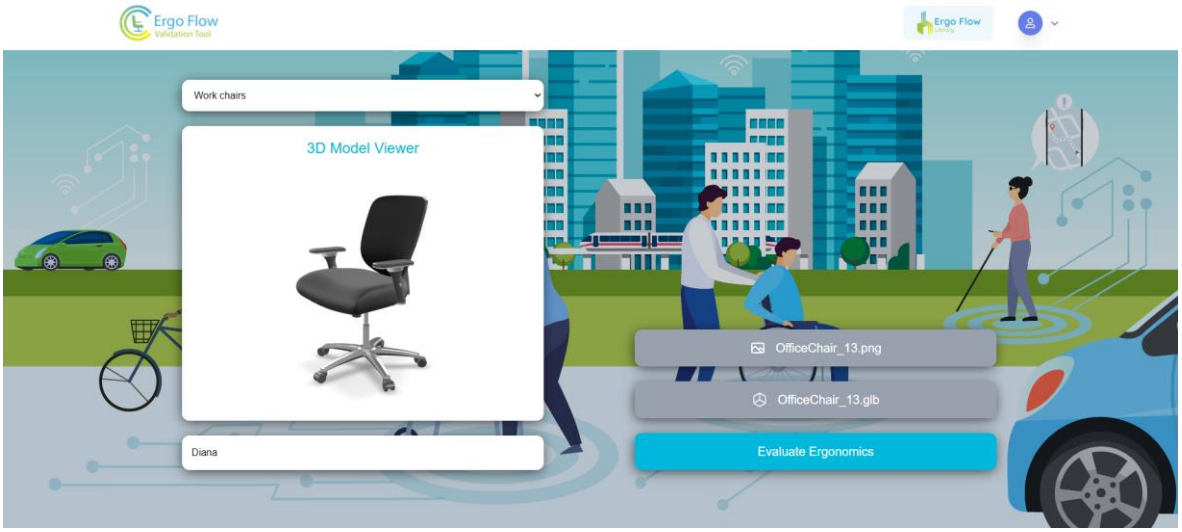


Figure 2. ErgoFlow Evaluation Tool - Model interaction

2.1.4.2 Parameters Input

To complete the ergonomic evaluation, the user must enter manually the required parameters for the furniture model. For example, if the user is evaluating low benches without backrests, they would need to provide details such as seat height (vertical distance from the floor to the top of the seat surface), seat depth (horizontal distance from the front edge to the back of the seat), seat width (total width of the seating area), seat surface shape (flat, slightly curved, contoured, etc.), and seat surface material (indicating whether it is non-slip or has a non-slip coating).

The user should also specify whether all edges and corners are smooth or rounded to prevent discomfort or injury, and confirm if the foot space for wheelchair access is sufficient to accommodate users or allow easy approach. The user can also enter the values manually by typing them in or use the slider bar. While entering data, the user can also continue rotating, zooming, and inspecting the 3D model in the viewer. If the user is unsure about the definition of any parameter, they can hover the mouse over the information icon (ℹ) next to each field to see a short explanation.

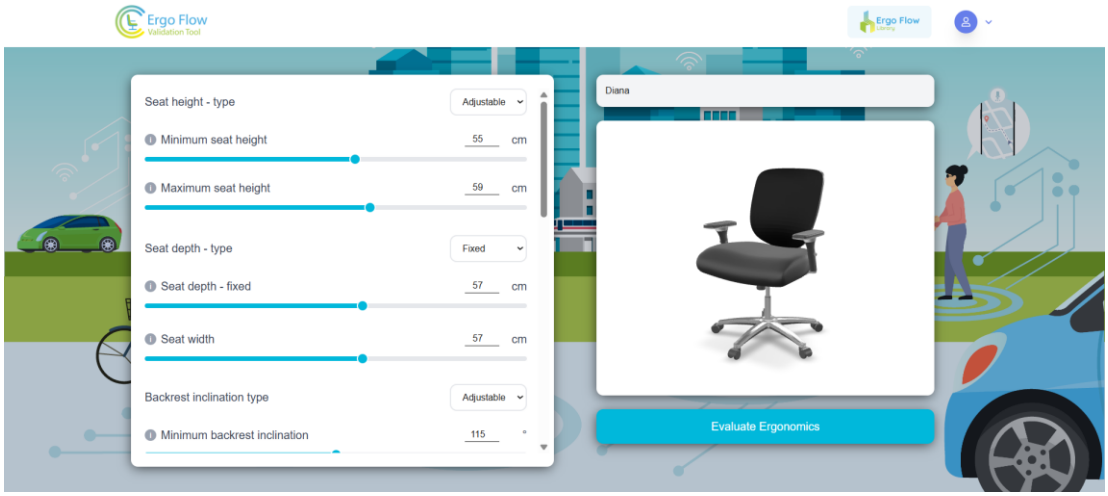


Figure 3. ErgoFlow Evaluation Tool - Insertion of model parameters for evaluation

2.1.4.3 Ergonomics, Comfort and Accessibility Evaluation

After entering all parameters, the user will click “Evaluate Ergonomics” to generate the results. The system will provide both a visual and numerical summary of the furniture model’s ergonomic assessment. Each parameter is represented on a color scale, where higher intensity green indicates better ergonomic performance. Parameters outside the optimal range will appear in lighter tones of green.

The user can also review the parameter ranges and scores, where values corresponding to 3 points represent the optimal ergonomic zone for each parameter. This helps the user understand how closely the model aligns with ergonomic standards.

The ergonomic score displays the percentage of the maximum possible score achieved by the model. A score of 65% or higher indicates that the model meets the ergonomic threshold. The user can also download a detailed PDF test report, which includes all entered parameters and total score, as well as bibliography for making the model more ergonomic and accessible and for safety regulations for furniture testing. If the model scores 65% or higher, the user can also upload it to the ErgoFlow Library, allowing them to share their design.

Figure 4. ErgoFlow Evaluation Tool - Ergonomics evaluation

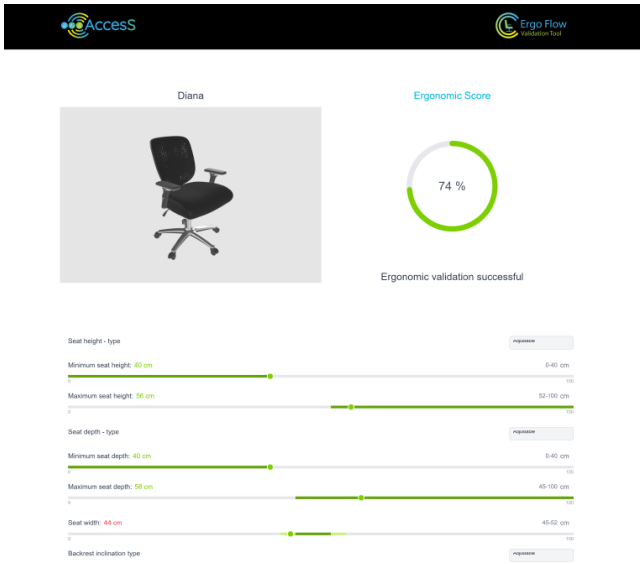


Figure 5. ErgoFlow Evaluation Tool - Ergonomics evaluation report

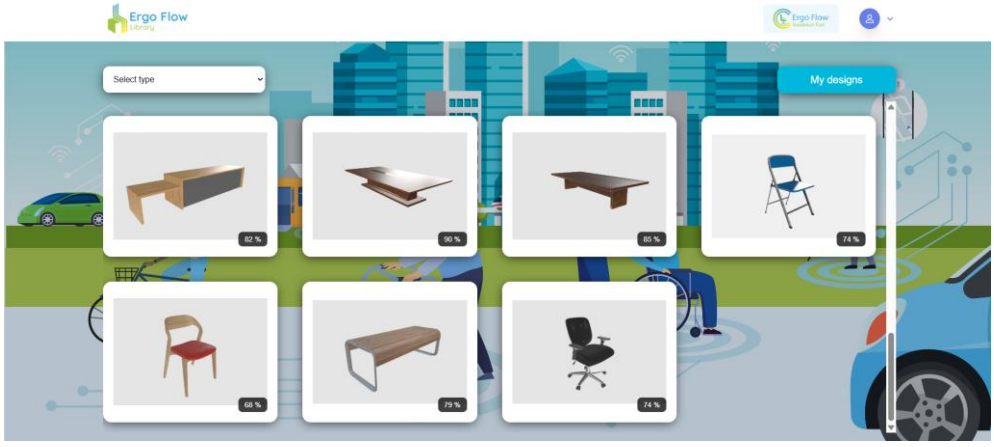


Figure 6. ErgoFlow Evaluation Tool - Model uploaded to the ErgoFlow Library

2.2 ErgoFlow Library

2.2.1 Scope and Methodology

The ErgoFlow Library provides access to a library of furniture items that have been evaluated according to ergonomic principles and usability standards. Designers can browse the collection of 3D models, download items, and incorporate them into their projects or Building Information Modelling (BIM) scenarios. The library supports both the upload and download of 3D models of ergonomically designed furniture based on specific project requirements and use cases of the AccesS project, helping designers efficiently integrate ergonomically compliant products into their designs.

It complements the ErgoFlow Evaluation Tool by providing a database of models with verified accessibility levels, enabling direct incorporation into projects and facilitating compliance with requirements in this area.

2.2.2 Data Sources

The furniture pieces included in the ErgoFlow Library have been selected in collaboration with the six demonstration sites of the project. An online questionnaire was distributed among these demonstration sites to ensure that the ErgoFlow tool includes ergonomic furniture that meets the specific needs of each location. This information has been used to design 3D furniture models that are not only ergonomic, but also practical, tailored to the requirements of each demonstration site, and created to enhance comfort and usability for people with diverse needs.

In total, the library currently contains 17 furniture pieces: low benches without backrests, standing desks, reception counters, filing cabinets, articulated beds, nightstands, wardrobes, armchairs, restaurant chairs, restaurant tables, work chairs, office tables, high stools, display cases, bar counters, conference tables, and stackable chairs.

Table 14. Furniture selection by demo site

	Demo Site 1: The Christo and Jeanne-Claude Center	Demo site 2: The Brancacci Chapel	Demo site 3: Droom je Thuis Foundation	Demo site 4: Casa Girasole	Demo site 5: The Palazzo di Città	Demo site 6: Mercado de Verónicas
Low benches without backrest	✓	✓				
Standing desk		✓			✓	
Reception counter		✓				✓
Filling cabinet		✓			✓	
Articulated bed			✓	✓		
Nightstand			✓	✓		
Wardrobe			✓	✓		
Armchair			✓	✓		

Restaurant/bar chair	✓	✓	✓	✓		✓
Restaurant/bar table			✓	✓		✓
Work chair	✓	✓			✓	
Work table	✓				✓	
High work stool	✓					✓
Display case						✓
Bar counter						✓
Conference table	✓				✓	
Stackable chair					✓	

2.2.3 Overview and Demonstration

Below, we present an overview of the ErgoFlow Evaluation Tool user interface, with a detailed explanation of its functionalities and usage.

2.2.3.1 Library

On the first screen, users can visualize the entire catalogue of furniture pieces designed specifically for the AccesS project. The user can also click on “Select Type” to filter the available models by furniture category. This feature helps narrow down the options, making it easier to find and download the specific type of furniture the user is interested in.

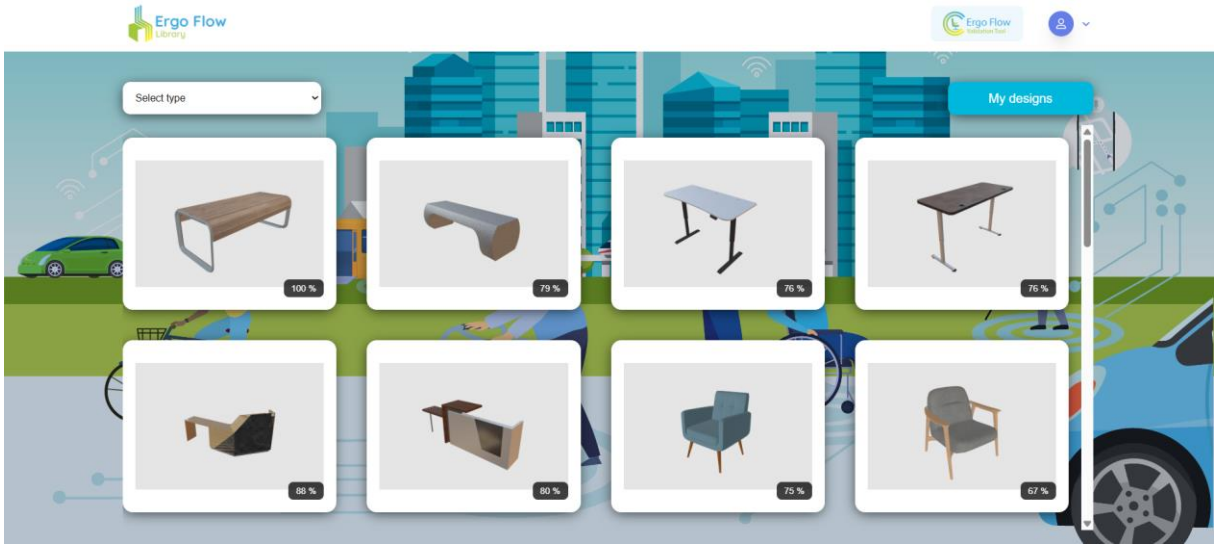


Figure 7. ErgoFlow Library - Overview

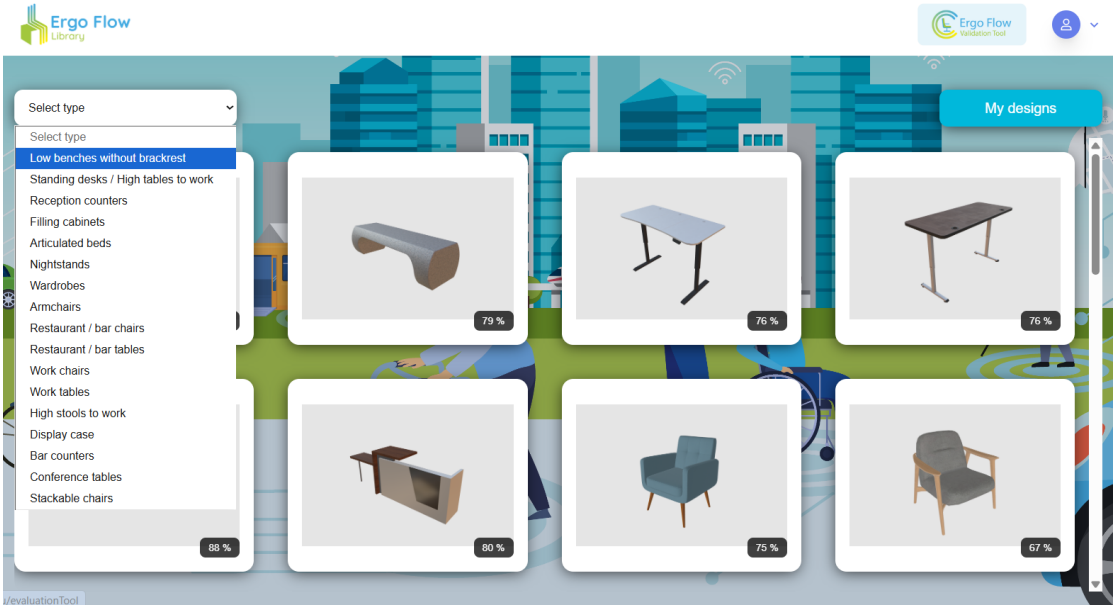


Figure 8. ErgoFlow Library - Furniture type filter

2.2.3.2 Detailed model

Each model is available for individual download. Along with the 3D model, the ergonomic score for each furniture piece is also included, and the evaluation report can be downloaded. This score provides a quick overview of how well the model meets ergonomic standards, helping the user identify which designs offer the best comfort, usability, and accessibility.

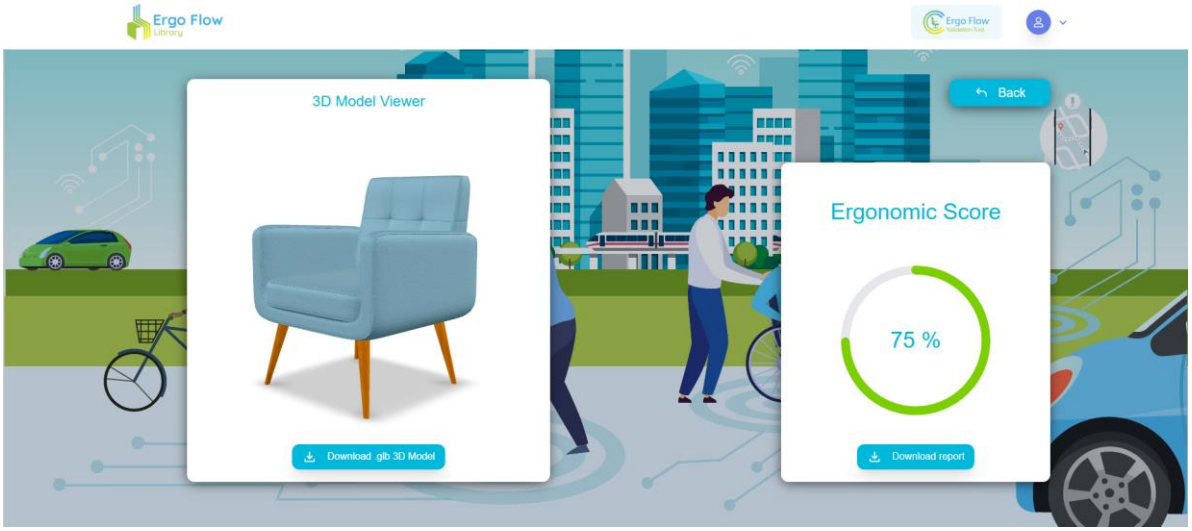


Figure 9. ErgoFlow Library - Model example

2.2.3.3 My designs

On the first screen of the library, the user can also click on “My Designs” to view all their previously uploaded designs. This section allows the user to easily manage their projects: they can upload new designs, review existing ones, or delete those no longer needed.

In this area, it is also possible for the user to see the ergonomic score of each design. This score provides a clear indication of how well each model meets ergonomic standards, helping the user assess the overall quality and usability of their creations and identify opportunities for improvement.

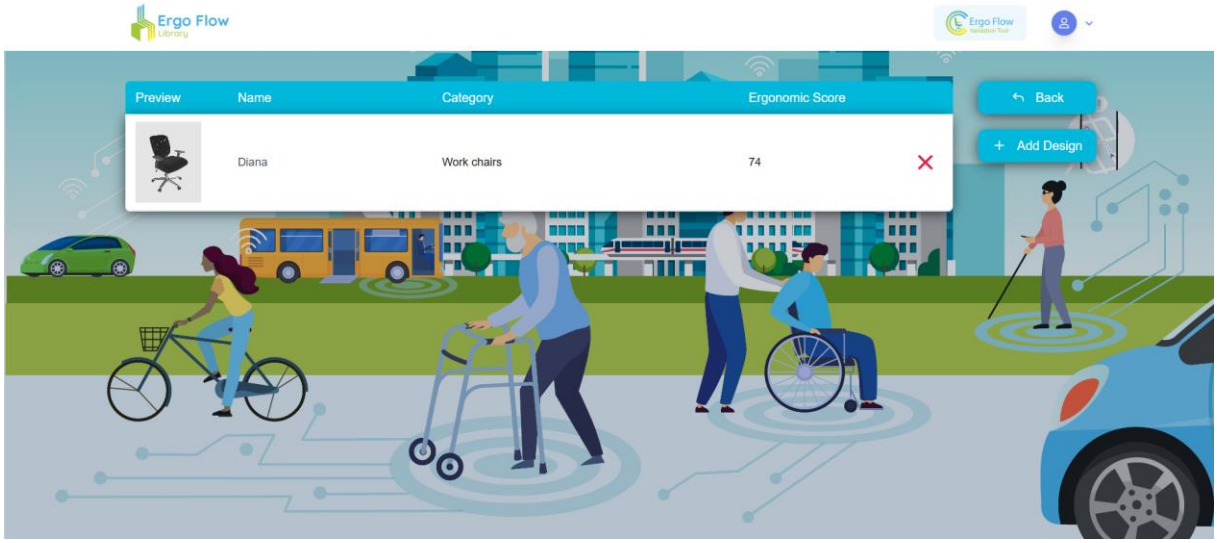


Figure 10. ErgoFlow Library - My designs

3 Conclusions

The results obtained with the development and preliminary validation of ErgoFlow demonstrate the practicality and effectiveness of an online tool capable of providing objective ergonomic evaluations based on a series of parameters established through a solid methodology grounded in internationally recognized standards and established guidelines, which reduces the subjectivity of other existing tools that require manual evaluation or even self-evaluation. In addition, the development of two complementary modules within ErgoFlow, the evaluation tool and the library, demonstrate a solid workflow, from product evaluation to its upload to an online repository.

Both elements coupled together will encourage product designers and manufacturers to innovate and provide products promoting accessibility by assisting them in designing and producing furniture items that can ensure ergonomics, accessibility, comfort, and usability for all users, especially the elderly or individuals with different types of disabilities.

The tool proves to be effective for furniture product designers to detect critical dimensions within each of the types of furniture included, with a special focus on those related to ergonomics and accessibility. The robustness of the weighting system shows that parameters related to, for example, seat height or user space dimensions have the greatest impact on the overall ergonomic index, and that even the slightest deviations in these critical dimensions have a significant effect on ergonomics, usability, and user comfort.

The results of establishing the parameters detailed in the previous pages reveal that adjustable furniture generally obtains higher ergonomic and accessibility scores, while fixed elements show less adaptability and, as a result, lower accessibility scores, highlighting the importance of incorporating adjustability and anthropometric flexibility as a fundamental element when designing inclusive furniture products.

On the other hand, ErgoFlow's library component and its integration with the evaluation tool ensures that all uploaded models belonging to the categories of chairs and tables have undergone prior quantitative ergonomic evaluation and validation.

Furthermore, the inclusion of ergonomic scoring and evaluation reports ensures the consistency and credibility of the models contained in the library, increasing transparency and allowing users to select products based on ergonomic and accessible design rather than aesthetics alone.

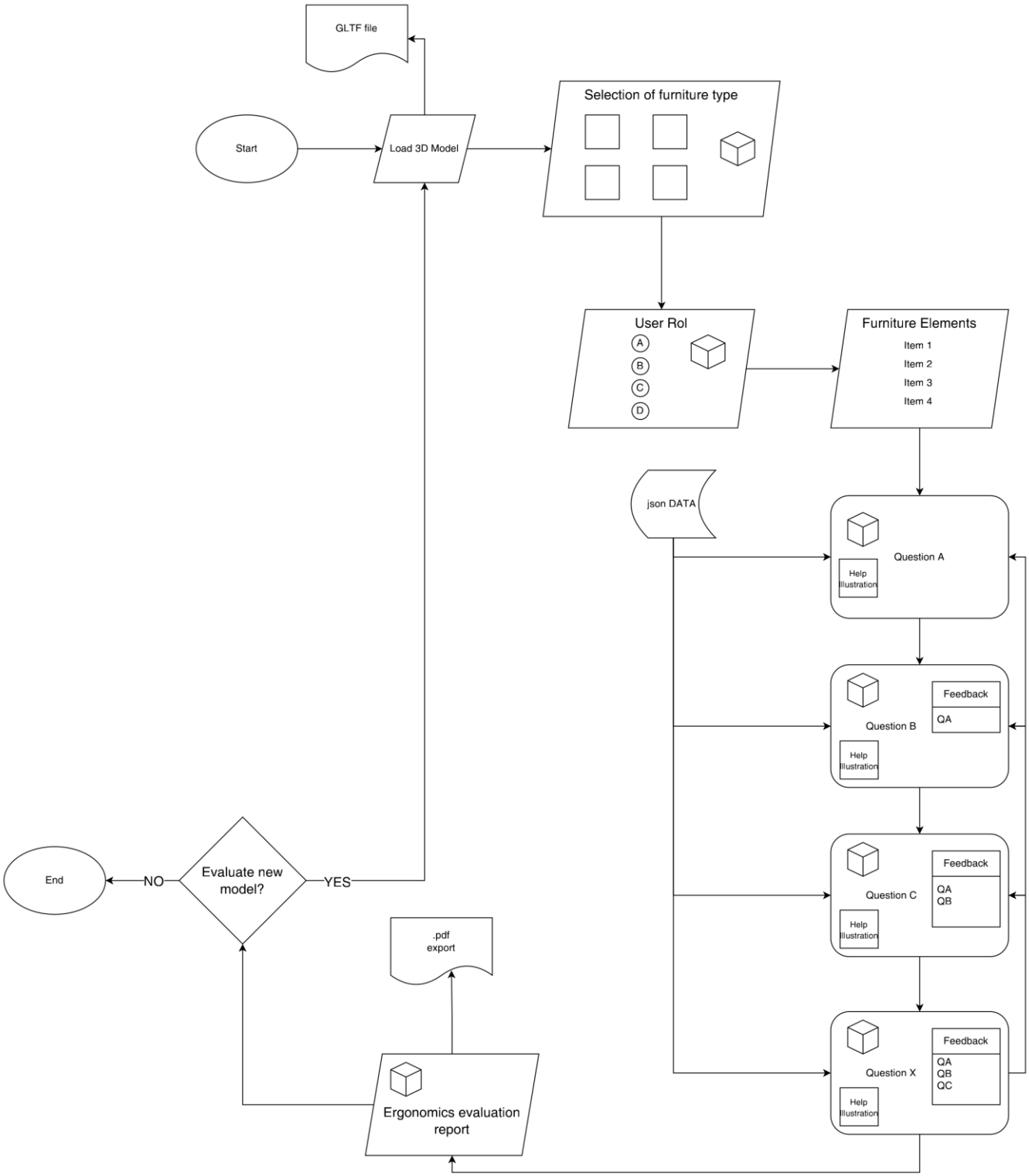
This will further support the tool's potential use as an educational resource for designers and manufacturers, as it clearly showcases the close connection between geometric dimensions, ergonomic design, and accessibility performance.

Ultimately, ErgoFlow showcases how incorporating ergonomic principles and accessibility features into the design of products and environments to ensure optimal comfort and reduce physical strain for all types of people will contribute to encourage the inclusion of universal and human-centered design principles in furniture, thus achieving the vision behind the AccesS project.

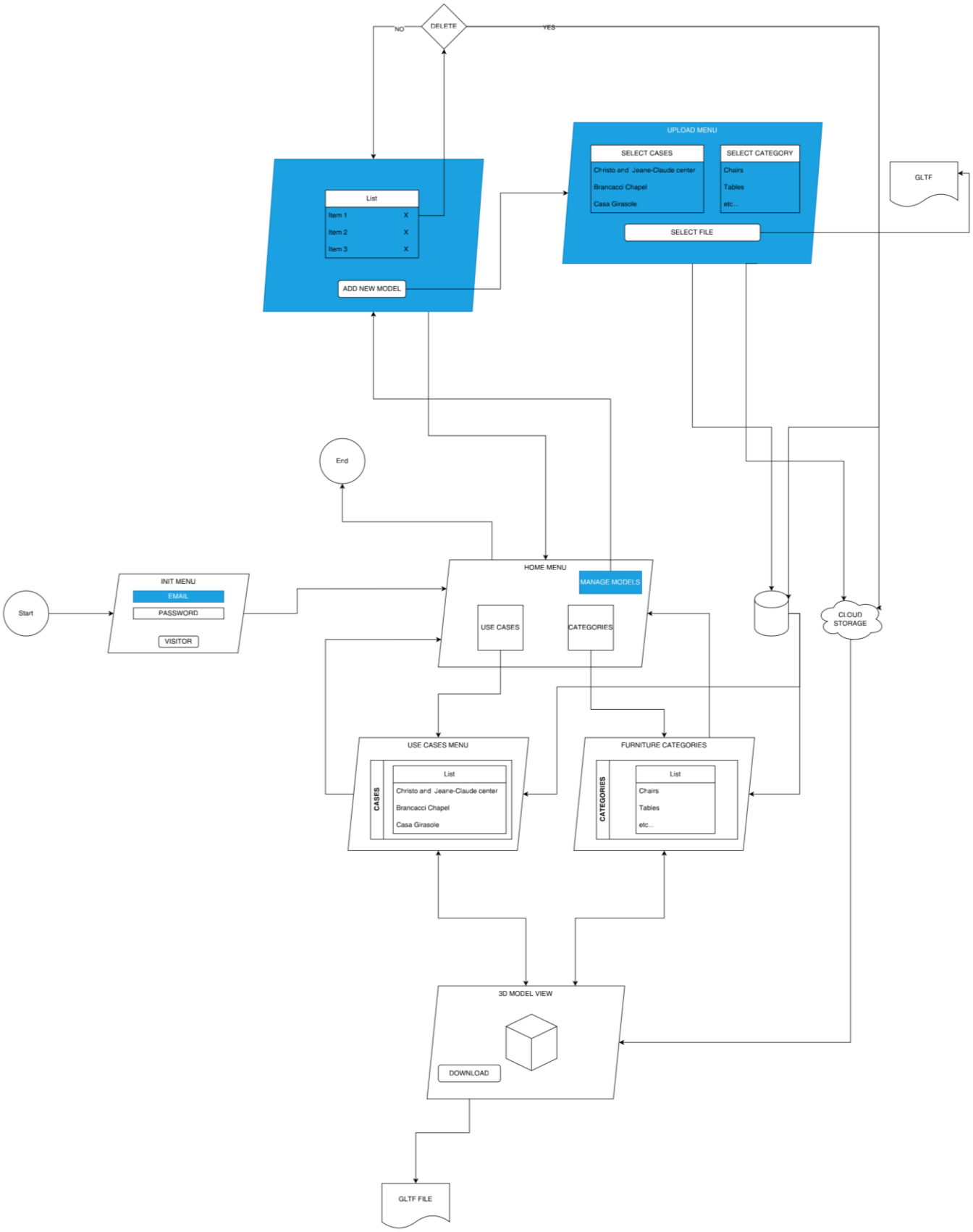
4 References

1. Vercel. (n.d.). *Next.js: The React framework for production*. Next.js. https://nextjs.org/
2. Business and Institutional Furniture Manufacturers Association (BIFMA). (2013, March 14). *Updated BIFMA Ergonomics Guideline now available*.
3. EN 1335-1:2020+A1:2022 – Office furniture – Office work chair – Part 1: Dimensions – Determination of dimensions.
4. EN 17210:2021. Accessibility and usability of the built environment - Functional requirements.
5. EN 527-1:2011 – Office furniture – Work tables and desks – Part 1: Dimension.
6. EN ISO 9241-5:2024 - Ergonomics of human-system interaction - Part 5: Workstation layout and postural requirements.
7. Flores, C. (2001). *Ergonomía para el diseño* (1st ed.). Editorial Designio.
8. García Molina, C., Moraga, R., Tortosa, L., & Verde, V. (n.d.). *Ergonomía y mueble. Guía de recomendaciones para el diseño de mobiliario ergonómico*.
9. Instituto de Biomecánica de Valencia. (2020). *Ergonomía y mueble de oficina: Guía básica para prevencionistas*.
10. Irish Wheelchair Association. (2020, November). *Best Practice Access Guidelines: Designing Accessible Environments* (Edition 4).
11. Openshaw, S., & Taylor, E. (2006). *Ergonomics and design: A reference guide*, Allsteel, Inc.
12. Sinpromi. (2022). *Mobiliario y mecanismos accesibles*.
13. U.S. Department of Justice. (n.d.). *ADA standards for accessible design*.
14. Hedge, A. (2007). *Cornell ergonomic seating evaluation form*. Cornell University Ergonomics Web.
15. Worksite International, Inc. (n.d.). *Ergonomic worksite analysis — Employee ergonomic evaluation request form*.
16. Ergonomic Seating Solutions. (n.d.). *POSE™ personal office seating evaluation: Chair fitting system*.
17. Girard, O. (n.d.). *Free office ergonomics assessment: At home, at work*.

ANNEX A: ErgoFlow Evaluation Tool - Low fidelity prototype



ANNEX B: ErgoFlow Library - Low fidelity prototype



Enhancing Accessibility and Sustainability in Smart Cities and Smart Buildings: The Universal Accessibility Suite Initiative

www.euproject-access.eu/en/

@EU project AccesS

@EUprojectAccesS

@EUprojectAccesS

This project has received funding from the European Union's Horizon Europe research and innovation programme under the grant agreement number 101147722. The European Union is not liable for any use that may be made of the information contained in this document, which is merely representing the authors' view.