Project: Low-Cost Articulated Bath Chair

Mariane de Jesus Batista[1*], Marlon Coelho Pita[1], Lucas Santos Reis[1], Renata de Sousa Mota[1], Nilmar de Souza[1]
[1]*Center for Science and Technology in Energy and Sustainability, Federal University of Recôncavo of Bahia; Feira de Santana, Bahia, Brazil*

The project developed a prototype of an articulated bath chair using PVC pipes and 3D-printed components, aiming to meet the accessibility needs of older people. The applied methodology included market research, document analysis of accessibility standards (ABNT NBR 9050/2021), and three-dimensional modeling in Fusion 360 software. The use of additive manufacturing was essential for creating customized components, such as locks, which ensured the prototype's safety and functionality. The result was a low-cost, adaptable, and safe product, ready to be tested in a real environment, with the potential to improve the quality of life for older people and contribute to innovative practices in assistive technology.
Keywords: Accessibility. Articulated Bath Chair. Assistive Technology. 3D Printing. Elderly Care.

The aging of the Brazilian population has resulted from several factors, including the decrease in fertility rates and the increase in life expectancy, driven by improvements in healthcare and socioeconomic conditions. Although this trend is global, the demographic transition in Brazil is happening at a significantly accelerated pace.

According to the latest data from the 2022 Census, there has been a significant increase in Brazil's elderly population, which includes people aged 60 and over, representing 10.9% of the total population, a growth of 57.4% compared to 2010, when this age group made up 7.4% [1]. Additionally, the proportion of older people increased from 11.3% to 14.7% [2]. In contrast, the proportion of young people (0-14 years) has decreased, reflecting a drop in birth rates. Life expectancy at birth has also increased, reaching approximately 77 years, contributing to population aging.

This demographic shift has implications for various aspects of Brazilian society. On the one hand, increased life expectancy and decreased birth rates represent significant health and quality of life achievements. However, this scenario also brings specific challenges regarding accessibility and infrastructure adaptation when considering the elderly population. One of the critical issues that arise is the need for adequate facilities to ensure their safety and autonomy, particularly in the home environment, which increases the need to make spaces more accessible [3].

Accessibility in the home environment is a fundamental concern to ensure the quality of life and autonomy of people with reduced mobility and older people. Among the critical spaces that require adaptations, the bathroom stands out as a potentially risky area where a lack of accessibility can result in falls, injuries, and limitations in performing daily personal hygiene activities [3]. Thus, the articulated bath chair emerges as one response to this demand, offering a practical, economical, and adaptable alternative to make bathing more accessible and safer.

This article proposes to explore the feasibility and benefits of this solution, focusing on using PVC pipes as the primary material due to its low cost. This work aims to present a prototype of an articulated bath chair through a detailed project using PVC pipes, covering everything from design planning to prototype construction. The idea arose from a technical visit during the Gerontechnology course to a long-term care institution for older people in Feira de Santana/Bahia, where the feasibility of installing a bath chair to meet the needs previously assessed by students of the Assistive Technology and Accessibility Engineering course at the Federal

Received on 20 December 2024; revised 28 Jnauary 2025.
Address for correspondence: Mariane de Jesus Batista. Av. Centenário, 697 - Sim. Zipcode: 44042-280. Feira de Santana, Bahia, Brazil. E-mail: marianebatista@aluno.ufrb.edu.br.

J Bioeng. Tech. Health 2025;8(1):1-6

University of Recôncavo da Bahia was observed. This article is relevant as, besides promoting quality of life for this population, it offers an innovative proposal for contributing to knowledge and practices of accessibility in the home environment.

Materials and Methods

The method used in this article consists of action research, where researchers and participants cooperate or participate to solve a situation or problem [4]. This methodology was designed to bridge the gap between theory and practice, uniting both fields and developing knowledge guided by practical experience. One of the characteristics of this type of research is that it allows us to interfere in reality, occurring as part of the research process and not just as a consequence of the final work. Therefore, action research aims to produce knowledge and solve a practical problem [5,6]. The development of the articulated bath chair prototype followed these steps:

1. Benchmarking;
2. Documentary research on accessibility standards;
3. Development in Fusion 360 software;
4. Prototype construction.

The modeling process was carried out using the "Fusion 360" modeling software in the free student license version from Autodesk. Based on ABNT 9050/2021 standards, the normative specifications for product sizing were used to ensure that all measurements and structural characteristics met accessibility and safety requirements. These standards recommend that the bath seat be 70 cm long, 45 cm wide, and 46 cm from the floor [7].

The prototype was built using PVC pipes, a material chosen for its durability, water resistance, and ease of handling. In addition to these characteristics, PVC pipes are low-cost, lightweight, moisture-resistant, easy to handle, and readily available, making them ideal for constructing assistive devices in bathrooms. The prototype construction process included cutting the pipes, modeling and printing the parts with a 3D printer, assembling and fixing the parts, and strictly following the modeled design.

The list of construction materials was: i) 32mm PVC pipes; ii) pipe glue; iii) elbow and "T" type connectors of 32 and 40 inches, respectively; iv) reduction for the "T" type connections made in 3D printing; V) university chair seat (donation).

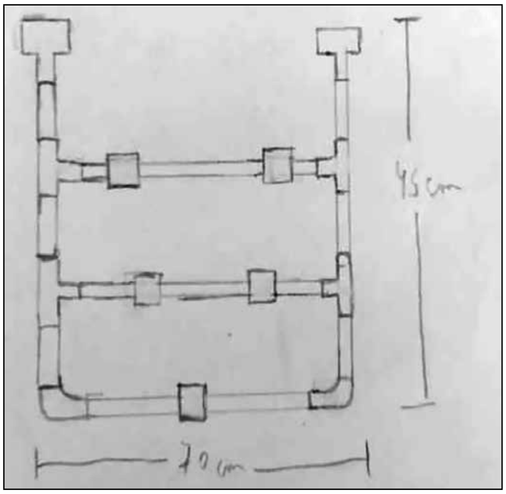
Results and Discussion

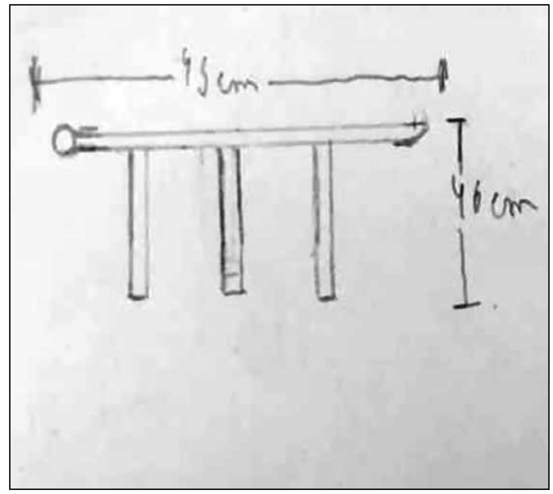
The market model found at the "PHD Support Bars" establishment has the following characteristics: stainless steel 304 finish, 1.¼ inch outer diameter, 1.5mm thickness (polished, brushed, or with white epoxy paint), and is priced at R$ 1,454.00.

Based on the existing market product (Figure 1), a sketch was made, incorporating fundamental technical drawing approaches to ensure the project's functionality. This sketch was the starting point for developing the articulated bath chair (Figure 2). Additionally, the manual sketch allowed for a

Figure 1. A market model of the articulated bath chair.

Figure 2. Initial sketches of the chair.





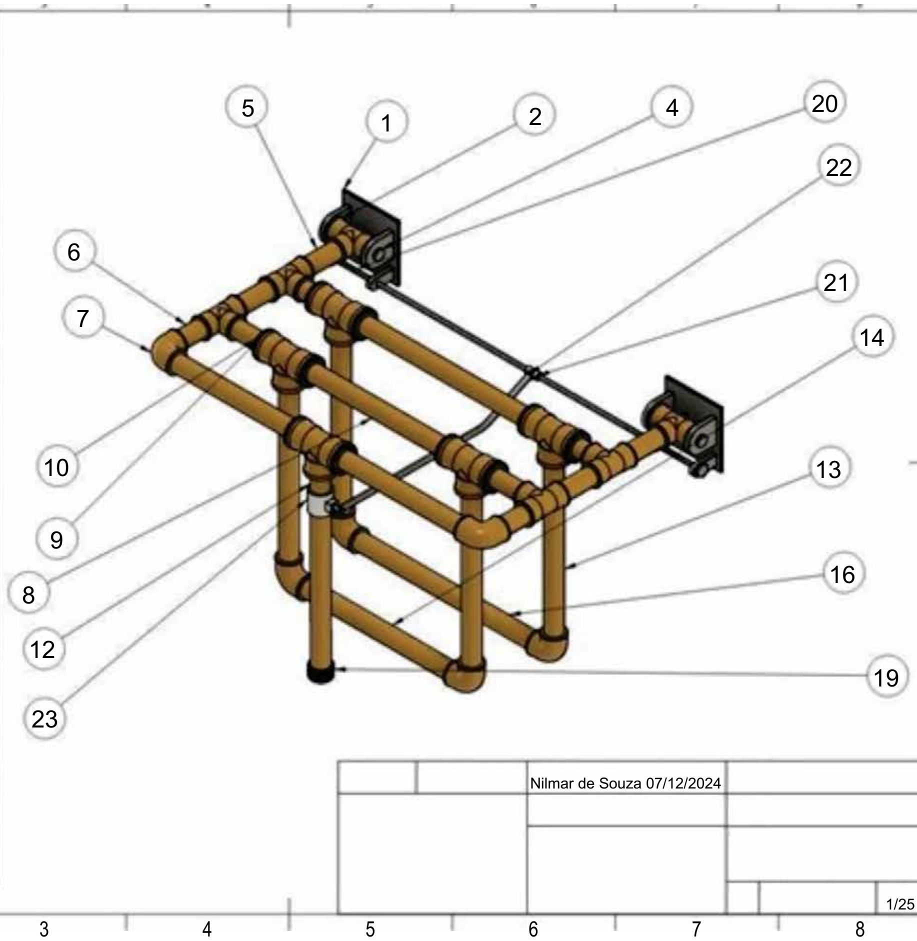
preliminary visualization of the design, facilitating the identification of possible improvements and necessary adjustments before the prototype construction in the software. Analyzing the existing market product also enabled the identification of essential features, such as fixation mechanisms, materials used, and innovative solutions that could be adapted or improved in the new project.

Furthermore, adopting a systematic approach to the design ensured compliance with current safety and accessibility standards, such as those specified by ABNT NBR 9050/2021. This standard provides guidelines for constructing accessible products, ensuring that all prototype measurements and structural characteristics are compatible with accessibility and safety requirements.

With the aid of Fusion 360 software, a 3D prototype was developed to provide a more realistic and detailed visualization of the project (Figure 3). Using this three-dimensional modeling software allowed for the creation of a virtual model that accurately reflects all the technical and structural specifications planned for the bath chair. Through Fusion 360, it was possible to simulate the prototype's dimensions, shapes, and mechanisms, facilitating the identification of potential flaws and making the necessary adjustments before the physical construction phase. Additionally, the software allows for structural and material strength analyses, ensuring that the final prototype meets the safety and durability criteria required for daily use by older people. Moreover, the three-dimensional visualization of the prototype aided communication among the development team members to enable a clear and shared understanding of the proposed design. The precision and detail obtained with Fusion 360 were crucial for fabricating customized parts and efficiently integrating the prototype's components.

The fourth stage of the process consisted of constructing the prototype according to the specifications developed in the previous phases. The prototype construction used PVC pipes, chosen for their durability, water resistance, and ease of handling, which are essential for application in humid environments such as bathrooms. The use of PVC is also justified by its cost-effectiveness and the possibility of customization and adaptation according to the project's specific needs. The construction process began with cutting the PVC pipes according to the detailed measurements in the three-dimensional model developed in Fusion 360 software. This stage required precision and care to ensure that all parts fit together perfectly, guaranteeing the prototype's stability and safety. Next, the parts were assembled and joined using appropriate fixation techniques, such as gluing and mechanical fittings, ensuring a robust and stable structure (Figure 4).

Figure 3. 3D design of the articulated bath chair.



Part List			
Item	qtd	Part No.	material
1	2	Wall support	steel
2	6	Tê_PVC	pvc piping
3	4	bearing	steel
4	2	pin	steel
5	4	tube_1	pvc piping
6	2	tube_2	pvc piping
7	6	knee	pvc piping
8	3	tube_3	pvc piping
9	5	Tê_2	pvc piping
10	10	support	abs plastic
11	5	reduction	pvc piping
12	1	foot_1	pvc piping
13	4	foot_2	pvc piping
14	1	foot base_2	pvc piping
16	1	foot base_3	pvc piping
19	1	base cover	rubber
20	1	flexor support	Steel AISI 1020 107 HR
21	1	support swivel	abs plastic
22	1	Rotac	Steel AISI 1020 107 HR
23	1	footres	abs plastic

In addition to the PVC parts, the prototype incorporated components produced through additive manufacturing and was designed using Fusion 360 software. 3D printing created customized components that would be unfeasible to produce using conventional manufacturing methods. Among the developed parts, the "locks" stand out—critical elements that limit the joints' movement, ensuring the bath chair's functionality and safety (Figure 5).

One of the difficulties encountered in the prototype construction was defining the seat, as the material needed to be waterproof, resistant to the user's weight, and compliant with ABNT NBR 9050/2021 standards. There were two alternatives: the first was to develop this material in the university's materials laboratory using fiberglass and resin, which, after a heating process, becomes highly resistant. The second alternative was to use one of the university chair seats that were no longer in use but in good condition. Due to the difficulty of developing the first option and the high cost, the second alternative was chosen for its feasibility in terms of time and available material. It is worth noting that the first option will be used for the final project, going through the proper process to ensure user safety (Figure 6).

Each construction phase was documented and reviewed to ensure compliance with the accessibility and safety standards established by ABNT NBR 9050/2021. This phase represented the project's materialization, transforming the drawings and virtual models into a prototype that would be fabricated into a functional and safe product ready to be used and evaluated in a real environment. This process highlighted the importance of each development stage, from planning and modeling to practical execution, culminating in a prototype that provides accessibility and safety for the end users (Figure 7).

According to the market value attributed to this product, it was R$1,454.00, making it unfeasible for a non-profit institution to purchase in a quantity that would meet all the bathrooms in the location. The chair replicated with low-cost materials offers an average cost of R$123.50, and the 3D printing would cost R$176.00, totaling R$299.50. It is worth noting that this is a prototype of a shower chair. Therefore, its cost may vary according to the availability of materials and the modifications that may be made to the project.

Conclusion

Developing an articulated shower chair using PVC pipes is a practical, economical, and adaptable

Figure 4. PVC pipes.

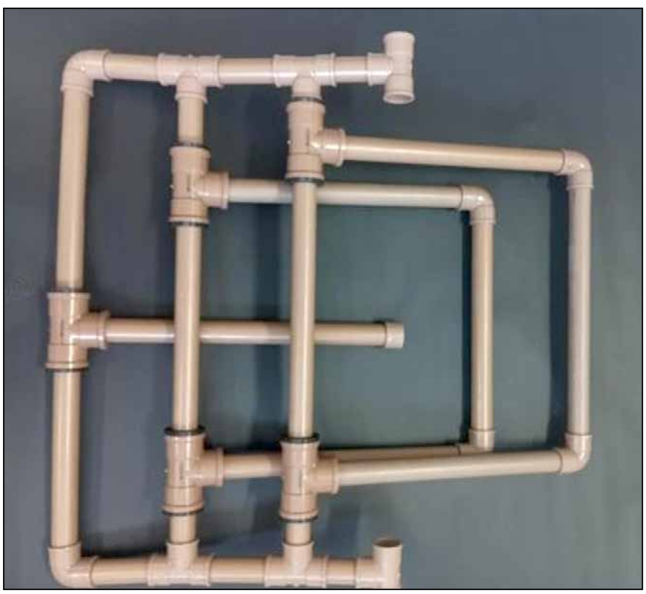


Figure 5. Lock in 3D modeling.

Figure 6. Reused university chair seat.

Figure 7. Final prototype.

solution to meet the needs of long-term care facilities. The method applied in this work involves detailed planning of the development stages (market research, document analysis of accessibility standards, and software modeling), resulting in creating a functional prototype and achieving the proposed objective.

In future work, the product's effectiveness will be evaluated based on feedback from users and healthcare professionals at the institution. This feedback will address aspects such as the suitability of the design to the needs of older people, ease of use, and durability of the material.

The results of this evaluation will be used to make possible improvements to the product and develop a construction manual that will be made available. Therefore, this project not only has the potential to promote the quality of life of older people but also contributes to knowledge and practices of accessibility, highlighting the importance of innovative and personalized solutions. By enabling the safe and independent execution of everyday tasks, the development of assistive technologies such as articulated shower chairs is essential to face the challenges of the aging population in Brazil. Hence, there is a need for a multidisciplinary and integrated population.

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