A REDESIGNED PLASTIC CAR SEAT LEVER: INTEGRATING USER NEEDS AND TECHNICAL SPECIFICATIONS THROUGH QUALITY FUNCTION DEPLOYMENT

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ABSTRACT

The automotive industry frequently struggles to strike a balance between assembly efficiency and structural strength in plastic components. PT. XYZ, a seat manufacturer, encountered this issue with their D01 car seat lever, which had a robust strength of 22.1 kgf but a lengthy assembly time of 2.5 minutes. A subsequent redesign, model D42, improved efficiency by reducing assembly time to 1.8 minutes and consolidating two parts into one. However, this new design had a critical flaw, as its average tensile strength of 16.8 kgf fell short of the required 18.5 kgf standard, making it susceptible to failure. The objective of this study was to redesign the lever to meet the 18.5 kgf strength requirement, improve assembly efficiency, and satisfy user needs with the Quality Function Deployment (QFD) method. Data was gathered from 20 respondents, including car users, technicians, and engineers, via questionnaires. The analysis showed that users prioritized durability, ease of use, accessibility, and ergonomics. The new prototype, developed using QFD principles, successfully endured a tensile force of 22.5 kgf, exceeding the safety standard and fulfilling user expectations for functionality and comfort.

***Keywords**: Redesign; Quality Function Deployment (QFD); Seat Lever; Tensile Strength*

ABSTRAK

Industri otomotif sering kali berjuang untuk mencapai keseimbangan antara efisiensi perakitan dan kekuatan struktural pada komponen plastik. PT. XYZ, produsen kursi, menghadapi masalah ini dengan tuas kursi mobil D01 mereka, yang memiliki kekuatan yang kuat sebesar 22,1 kgf tetapi waktu perakitannya lama, yaitu 2,5 menit. Desain ulang berikutnya, model D42, meningkatkan efisiensi dengan mengurangi waktu perakitan menjadi 1,8 menit dan menggabungkan dua bagian menjadi satu. Namun, desain baru ini memiliki kelemahan kritis, karena kekuatan tarik rata-ratanya sebesar 16,8 kgf tidak memenuhi standar 18,5 kgf yang disyaratkan, sehingga rentan terhadap kegagalan. Tujuan dari penelitian ini adalah mendesain ulang tuas untuk memenuhi persyaratan kekuatan 18,5 kgf, meningkatkan efisiensi perakitan, dan memenuhi kebutuhan pengguna dengan metode Quality Function Deployment (QFD). Data dikumpulkan dari 20 responden, termasuk pengguna mobil, teknisi, dan insinyur, melalui kuesioner. Hasil analisis menunjukkan bahwa pengguna memprioritaskan daya tahan, kemudahan penggunaan, aksesibilitas, dan ergonomi. Prototipe baru yang dikembangkan dengan menggunakan prinsip-prinsip QFD ini berhasil menahan gaya tarik sebesar 22,5 kgf, melebihi standar keamanan dan memenuhi harapan pengguna akan fungsionalitas dan kenyamanan.

***Kata Kunci**: Perancangan ulang; Pengembangan Fungsi Kualitas (QFD); Tuas Kursi; Kekuatan Tarik*

INTRODUCTION

In the automotive industry, user comfort and safety are critical elements in the design of vehicle interiors. One of the main components that plays an essential role in both aspects is the car seat. Both drivers and passengers require seats that not only support ergonomic posture but also provide optimal comfort for both short and long journeys. An important feature frequently integrated into car seats is the seat lifter, which allows for the adjustment of seat height to suit individual users. This adjustment is crucial to ensure proper visibility and ergonomic interaction with other vehicle components such as the steering wheel, pedals, transmission lever, and instrument panel. Improper seating posture is closely related to physiological and musculoskeletal factors, including joint angles, muscle contraction, pressure distribution, and sitting posture (Wolf et al., 2022); Caballero-Bruno et al., 2022).

One of the adjustment items that a car seat has is the lifter. Lifter can be used to adjust the seat height to provide comfortable driving positions. Seat lifters can be classified into manual and automatic mechanisms. Automatic systems are commonly found in mid-range and luxury vehicles, while manual mechanisms remain widely used in more affordable segments, particularly in markets such as Indonesia. The manual type typically relies on a lever connected to the seat lifter module, requiring repeated operation to adjust the height. Although simpler and less costly to manufacture, this system requires greater effort to operate and often lacks the precision of electric motor-driven mechanisms (Kumar et al., 2023); Nelfiyanti et al., 2021)

(a) (b)

Figure 1. (a) Manual Mechanism; (b) Automatic Mechanism

PT. XYZ has not yet developed automatic part designs and continues to rely on manual seat lifter constructions. Based on the previously developed model (D01), the seat lever was made entirely of injection-molded plastic, consisting of two components fastened directly to the seat frame with bolts. While this design achieved sufficient strength, with an average tensile strength of 22.1 Kgf, it required two separate molds, leading to higher production costs and longer assembly times. To improve efficiency, a new design (Model D42) combined a press part (steel) with a plastic injection part, assembled using a snap-fit method. This reduced the number of plastic injection components and shortened assembly cycle time, as shown below.

Table 1. Part quantity and assembly lead time

Parameter	D01 Model	D42 Model
Injection Part (Qty)	2 pcs	1 pc
Assembly Lead Time	2.5 minutes	1.8 minutes

Based on Table 1.1, it can be observed that Model D42 is more efficient in the assembly process, as it requires a shorter cycle time and fewer injection parts. However, Model D42 introduces a new problem, namely a reduction in tensile strength. The tensile test results show that Model D42 has an average strength of only 16.8 N, which is lower than that of Model D01 at 22.1 N. Furthermore, Model D42 does not meet the company's tensile strength standard of 18.5 kgf, indicating that the car seat lever of Model D42 is prone to detachment during use.

Table 1. Tensile strength test results

Model	Tensile Strength Average	Judgement
D01	22.1 Kgf	OK
D42	16.8 Kgf	NG

This study uses the Quality Function Deployment (QFD) method to redesign a car seat lever. By translating user needs into technical specifications, this approach ensures the new design improves production efficiency, meets strength standards, and enhances both safety and user satisfaction (van den Boom-Stoop et al., 2024); Zhang et al., 2024). A car seat is made up of several key components that work together. Its main frame provides the structural support for the entire seat. It includes adjustment mechanisms such as the back adjuster (for reclining), seat lifter (for height adjustment), and seat track (for forward and backward movement) (Kim et al., 2024); Purba et al., 2020; Havelka et al., 2021).

These are operated by levers. Finally, the seat features cushions for comfort and an outer cover made of fabric or leather, enhancing both aesthetics and a finished look.

Vehicle Seats

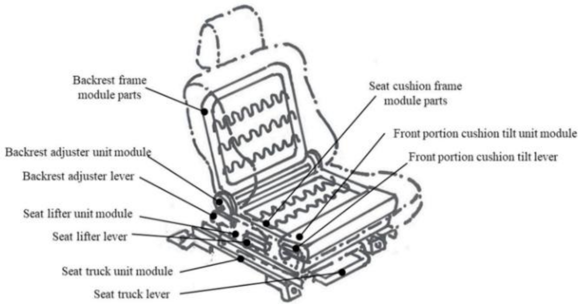


Figure 2. Four-Wheel Vehicle Seat

Figure 2. illustrates the components of a four-wheeled vehicle seat. The car seat is composed of several materials, including press parts, foam parts, injection parts, and fabric/leather parts. The following provides an explanation of each component (Kikumoto et al., 2021).

Injection Molding

Injection molding is a manufacturing process for thermoplastic materials, in which the polymer is melted through heating and shear within the machine barrel. Once melted, the material is injected into a mold cavity and subsequently cooled, typically using water or oil, until it solidifies and forms a product identical to the mold shape (Osswald & Hernández-Ortiz, 2019; Goodship, 2021). Plastics are polymers with large molecular structures formed through the process of polymerization. According to Shreve and Brink, plastics can be defined as materials composed of organic molecules that undergo polymerization, resulting in products with high molecular weight. The final outcome is a solid material which, at certain stages of production, can be shaped according to specific requirements (Nisah, 2018). Plastics are broadly classified into two categories: thermoplastics and thermosets. Thermoplastics can be reheated, melted, and reshaped multiple times without permanent chemical changes, making them recyclable. They are composed of polymer chains with weak intermolecular interactions, enabling mobility upon heating. Common examples include polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), and polyethylene terephthalate (PET) (Callister & Rethwisch, 2020; Osswald & Menges, 2021).The mold in injection molding consists of a fixed plate and a moving plate, with key components such as the cavity, core, ejector, guide pin, and sprue bushing. Based on their construction, molds are categorized into: two-plate molds (the simplest type), three-plate molds (with a floating plate for gate removal), slide molds (using slider pins), and unscrewing molds (for threaded products) (Purnama & Nur, 2018).

Quality Function Deployment (QFD)

Quality Function Deployment (QFD) is a structured method for product or service planning and development that enables development teams to clearly define customer needs and systematically evaluate each proposed capability based on its impact in fulfilling those needs (Vinodh & Rathod, 2019; Ginting & Wahyuni, 2022; Pino-Servian, 2025).

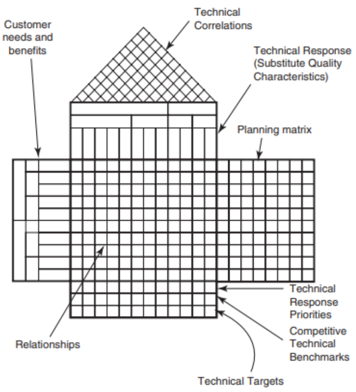


Figure 3. House of quality

RESEARCH METHODOLOGY

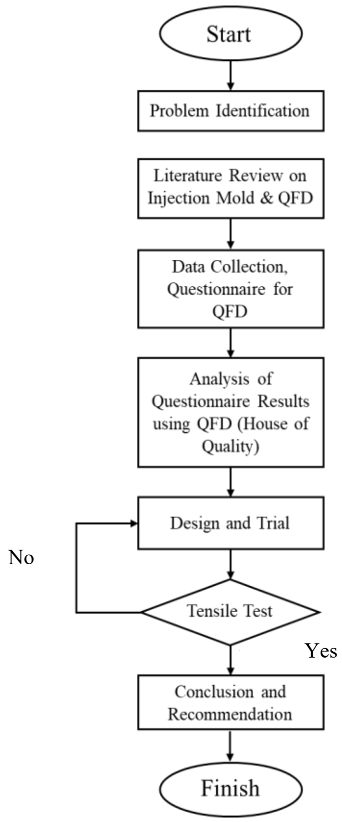


Figure 4. Project flowchart

The research process started with problem identification through direct observation, which revealed a decrease in the tensile strength of the new D42 car seat lever. A literature review on injection molding and the Quality Function Deployment (QFD) method was then conducted to establish a theoretical foundation. Data was collected via questionnaires from both car users and technical staff, and then analyzed using QFD to generate technical design specifications. Based on these specifications, a redesigned prototype was developed and subjected to a tensile test, with a minimum requirement of 18.5 Kgf. Unsuccessful parts were returned for further improvement. The project concluded with a summary of the findings and recommendations for implementing the new design.

RESULTS AND DISCUSSIONS

Respondents in this research project consisted of men (85%) aged 21–30 years (65%). All respondents had experience driving four-wheeled vehicles and had used car seat height levers, making the data collected relevant. After obtaining the questionnaire data and analyzing it using IBM SPSS with Pearson correlation, the questionnaire results revealed several key findings:

1. Seat lever durability was the most prioritized aspect, with 60% of respondents rating it as very important to ensure the lever does not easily break or detach.
2. Material sturdiness was also dominant (85% rated important–very important), emphasizing that material strength is a key requirement.
3. Ergonomics and grip comfort were considered crucial (65% stated very important), indicating that the design must be user-friendly.
4. Ease of access and placement were deemed very important by 70% of respondents, meaning that the lever's position should be strategic and easily reachable.
5. Aesthetic aspects (shape and color matching the interior) were also considered important (90% rated fairly–very important), although lower compared to strength and comfort factors.
6. Anti-slip texture received attention (55% rated very important), reflecting the need for grip safety.
7. A minimum tensile strength of 18.5 kgf (DTS Standard) was regarded as very important by 90% of respondents, emphasizing the safety factor.
8. Most respondents also supported a combination of metal and plastic materials (90% rated important–very important) to enhance lever strength.
9. Other features, such as ease of use (85%), adjustment convenience (75%), long-term durability (65%), and ergonomics (80%), all received dominant scores in the desirable to very desirable categories.

Comparison with competitors showed that PT XYZ's product excelled in terms of ease of use (score 5) and ergonomics (score 5). Product durability was also on par with the best competitors. However, weaknesses were found in ease of access and height/weight adjustment, where other competitors scored higher. This indicates that PT XYZ needs to improve these two aspects to remain competitive.

Table 3. Benchmark results

Parameter	PT. XYZ	M-Brand	S-Brand	B-Brand
Easy to Use	5	4	4	3
Easily Accessible	5	2	4	2
Easily Adjustable in Height/Weight	2	3	3	2
Durable for Frequent Use	4	3	2	4
Good Ergonomics	5	4	2	4

Based on Table 3, PT. XYZ has shown strong performance in several attributes. The company achieved the highest score in ease of use and ergonomics, highlighting user-friendly design and comfort. PT XYZ also performed well in durability, comparable to Competitor C. However, the product scored lower in accessibility and height adjustment, areas where Competitor B and Competitor A showed relative strength. Overall, PT XYZ leads in usability and ergonomic quality but requires improvement in access and adjustment features to match competitors' performance.

Analysis of Quality Function Deployment Based on Questionnaire

Based on the results of the questionnaire, the data were processed using IBM SPSS software with Pearson correlation analysis, which produced the relationships between the WHATs and the HOWs. These results were then used in the construction of the House of Quality (HoQ). The Results of the Pearson correlation analysis, we can conclude that customer requirements (WHATs) and technical responses (HOWs) show several key findings:

1. For the attribute "ease of use," the highest correlations are found with smooth operation (0.837) and grip comfort (0.801), indicating that ergonomic factors play a critical role in usability. In contrast, design compatibility with the car interior shows a low correlation (0.281), suggesting minimal influence on ease of use.
2. For "accessibility," strong relationships are observed with durability (0.657), smooth operation (0.711), and strength (0.666), highlighting the importance of mechanical reliability and smooth performance.

Meanwhile, design aspects again show a weaker influence (0.212).

3. In terms of "adjustability," correlations are generally lower compared to other attributes, with only design compatibility (0.612) showing a relatively strong relationship. This suggests that adjustability is less dependent on strength or durability, but more influenced by design factors.
4. For "durability under frequent use," strong correlations are observed with grip comfort (0.688), smooth operation (0.729), surface texture (0.730), and pulling strength (0.644). This indicates that both material quality and ergonomic aspects contribute significantly to product durability.
5. Finally, the attribute "ergonomics" shows the highest correlations across nearly all technical requirements, particularly with smooth operation (0.840), pulling strength (0.843), surface texture (0.755), and grip comfort (0.715). These findings emphasize that ergonomics is highly dependent on both mechanical performance and material selection.

Overall, the correlation analysis demonstrates that technical attributes such as smooth operation, grip comfort, surface texture, and pulling strength are consistently influential across multiple customer requirements. These factors should therefore be prioritized in the House of Quality (HoQ) to guide product development.

House of Quality

The HoQ analysis shows that the strongest relationship between user requirements and technical attributes in the car seat height lever design lies in three main aspects. First, resistance to a minimum pulling force of 18.5 kgf ensures durability and compliance with automotive safety standards. Second, ease of use is influenced by ergonomic grip, smooth lever movement, and non-slippery surface texture, which enhance comfort and prevent operational errors. Third, the balance between ergonomics and mechanical strength highlights the importance of designing a lever that is both robust and comfortable to handle. These attributes represent the main priorities in the QFD process for redesigning the plastic seat lever.

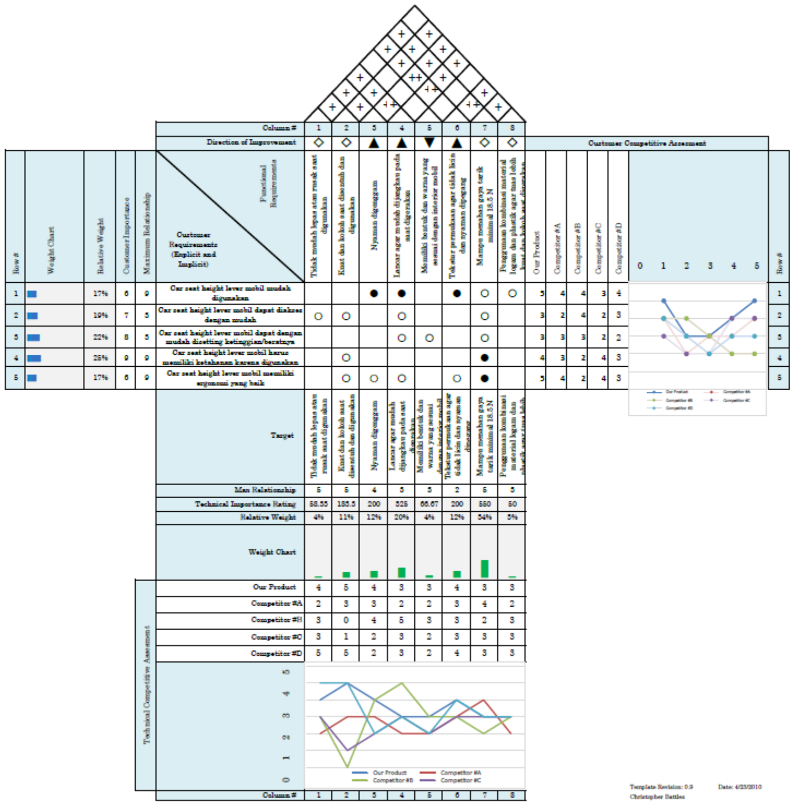


Figure 5. House of quality

The following are the calculations from the House of Quality:

Table 4. Benchmark results

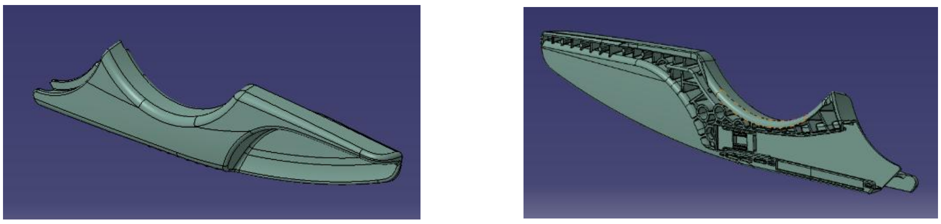
Requirements	Relative Weight	Customer Inportance	Relative Importance
Car seat height is easy to use	16,7%	6	1,0000
Car seat height is easy to access	19,4%	7	1,3611
Car seat height leve can be easily adjusted for height/weight	22,2%	8	1,7778
Car seat height lever must be durable due to frequent use	25,0%	9	2,2500
Car seat height lever has good ergonomics	16,7%	6	1,0000

Based on Table 4, the Relative Importance analysis from the Quality Function Deployment (QFD) process shows the following priority of user requirements for the car seat height lever: (1) durability as the most critical factor (2.2500), since the lever is frequently used and must remain reliable; (2) ease of height adjustment (1.7778), essential for functionality and comfort; (3) accessibility (1.3611), emphasizing convenient positioning and reach; and (4–5) ease of use and ergonomics (1.0000), which, while ranked lower, remain significant for daily comfort and usability. Overall, users prioritize strength, adjustability, and accessibility, with ergonomics and operational ease still considered important.

Redesign and Trial

From a Quality Function Deployment (QFD) analysis, the Seat Height Lever was redesigned based on user needs mapped in the House of Quality (HoQ). QFD identified key product attributes affecting customer satisfaction, including ease of use, accessibility, adjustability, durability, and ergonomics. The redesign evaluated limitations of the previous model and incorporated improvements such as non-slip surface texture, ergonomic dimensions for comfortable grip, and stronger materials to withstand a minimum pull force of 18.5 kgf. Priority technical attributes from the HoQ—material strength, grip comfort, smooth operation, and lever positioning—guided the redesign to better meet user needs and enhance overall product quality. The redesign process is divided into two main parts: the plastic part and the press part, to allow focused improvements on each component's characteristics and functions.

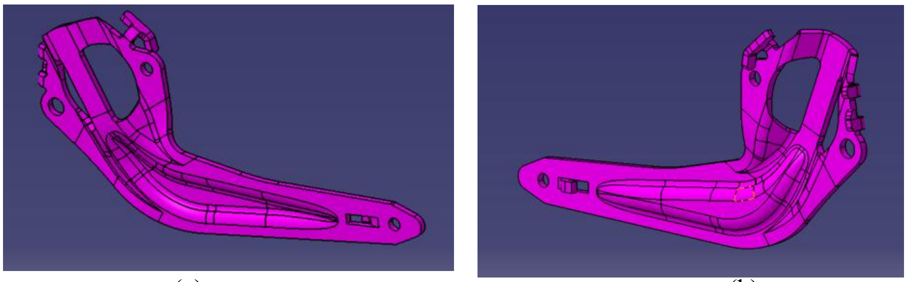
Plastic Part Design: Since the QFD analysis showed that ergonomics were already satisfactory compared to competitors, modifications focused on strengthening the connection with the press part to withstand a pull force of 18.5 kgf or more. This was achieved by adding ribs inside the snap-fit construction to reinforce the joint.



(a) (b)

Figure 6. (a) Plastic part front view; (b) Plastic part back view

Press Part Design: The press part serves as the internal structural component providing mechanical strength to the lever. It was enhanced with brackets on both upper sides to improve grip strength on the lifter gear, and the snap-fit connection was optimized to ensure a stronger bond with the plastic part.



(a) (b)

Figure 7. (a) press part front view; (b) press part back view

The combined design was realized as a prototype using rapid prototyping or appropriate manufacturing methods. The prototype will be tested for pull force durability, ergonomics, ease of use, and dimensional accuracy to ensure it meets technical specifications and user expectations.

Tensile Strength

To ensure the redesigned Seat Height Lever meets the specified technical requirements, particularly in terms of pull-force durability, mechanical testing was conducted using an Imada Push/Pull Force Gauge. This device, with a measurement range of 5 to 500 N, is suitable for evaluating both pulling and pushing forces on components like the seat height adjustment lever.

(a) (b)

Figure 8. (a) Tensile strength method; (b) Test result

The test results show that the redesigned Seat Height Lever can withstand a pull force of 22.5 kgf (220.7 N) on both sides, exceeding the minimum standard of 18.5 kgf (181.4 N). This demonstrates that the material and new design construction are reliable, minimizing the risk of structural failure during long-term use. Beyond strength, the study emphasizes ergonomics and user comfort. By applying Quality Function Deployment (QFD), user needs were successfully translated into technical specifications, resulting in a design that is both robust and user-oriented while supporting efficient assembly.

CONCLUSIONS

This study successfully identified user needs and expectations for the Seat Height Lever in manual seat lifters at PT. XYZ, revealing that users prioritize ease of use, comfortable grip, accessibility, and high durability. The minimum required pull force for the plastic lever was established at 18.5 kgf. Using Quality Function Deployment (QFD) and the House of Quality (HoQ), these needs were translated into technical specifications, including material strength, surface texture, ergonomic shape, and lever positioning. The redesigned Seat Height Lever prototype demonstrated improved durability, withstanding up to 22.5 kgf, while also enhancing ergonomics and user comfort.

Practical Implications include recommending PT. XYZ is to adopt the QFD-based redesign as a reference for future product development and highlight the importance of user-centered design in automotive components.

Suggestions for Future Research involve extending the study to other seat system components, incorporating multiple companies for broader benchmarking, and testing multiple prototype variants to ensure more comprehensive and reliable performance comparisons.

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