

Research Article

Design and Development of Work Chairs Using Quality Function Deployment, Analytic Hierarchy Process, and Ergonomic Techniques

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ABSTRACT

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Low back pain is a health issue that arises from risk factors such as an improperly sized desk and chair, as well as prolonged sitting at work. Therefore, to reduce the risk of low back pain, the Quality Function Deployment (QFD) technique has been applied to design work chairs, along with the Analytic hierarchy process (AHP) and ergonomics techniques, because the lack of application of QFD techniques alongside AHP and ergonomics is notable. The objective is to design and develop work chairs that meet the users' needs. QFD is a structured product development methodology that focuses on listening to the customer's voice and converting these needs into technical specifications that lead to product improvement. The AHP technique is then used to score the importance of technical requirements, and the ergonomics principle is applied, using relevant body proportions as data for designing and developing work chairs. The sample group consisted of 90 office workers. The results showed that the most important technical requirements, which are guidelines for designing and developing work chairs, include the materials selection, with a weight of 33.37%, followed by adjustable height, applying the principles of ergonomics, appropriate sizes and shapes, and having a stable and strong structure. The results of applying QFD techniques together with AHP and ergonomics resulted in users being more satisfied with the work chairs. Before the improvement, the satisfaction score was 2.96 points, and after the improvement, the satisfaction score increased to 4.04 points. The findings demonstrated that using ergonomic principles in the design and development of tools and equipment resulted in instruments that are well-suited to the proportions of the human body.

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1. Introduction

Back and neck pains or work-related muscular soreness is a health problem that many people have to face in their daily lives, whether they are office workers in government or private agencies who spend a lot of time sitting down. In particular, waist-related back pain could appear like a minor issue. However, if untreated for an extended period of time, it may develop into a health problem that interferes daily life and employment. Risk factors include improper work postures, inappropriate workstations and work environments, and daily behaviors, such as inappropriately sized work desks and chairs,

sitting for long periods of time, and hunching over. For example, research by Srijaroen (2022) studied the assessment of physical risks of office workers. The results of the research found that office workers are at risk of ergonomics, causing abnormalities in the musculoskeletal system from the work of office workers, which is caused by inappropriate workstations and working over extended lengths of time.

Improper workstations, such as desks that are too high and chairs that are too low, are one of the causes of back pain at work. This is due to the fact that employees bend, lean, or twist while working at desks or chairs that are not the proper size and

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cannot be modified to fit each employee's proportions. In addition, sitting for long periods of time causes aches and pains or fatigue from work, resulting in back pain and work-related injuries. Therefore, designing a work chair that is in line with the body proportions and the needs of the user is necessary to help reduce risk factors from such impacts and increase comfort at work. Although there are many styles of work chairs on the market, the designs do not support the body proportions and needs of the users, such as having inappropriate backrests, no armrests, and being unable to adjust the level. Solving this problem requires an efficient design method that meets the diverse needs of users. Therefore, ergonomic principles have been applied to the design and development of work chairs, along with Quality Function Deployment (QFD) techniques and the Analytical Hierarchy Process (AHP), to produce a work chair that is the right size for the human body proportions and meets the diverse needs of the users.

Since ergonomics principles is a science that adjusts work conditions to suit the operator or improves working conditions by systematically studying operators in the work environment. This is so that operators can work happily without pain, fatigue, injury, or illness due to work postures throughout the work period. Such as the research of Satieanrangsarith and Chaithanee (2024) who used body proportions as information in designing and improving work stations to be suitable for employees to reduce muscle fatigue and work injuries from sitting for long periods of time; and the research of Auesujaridwong *et al.* (2011) who used body proportions as information in designing and improving employees' work stations to reduce fatigue and work injuries from sitting for long periods of time; and the research of Phieboosilapa *et al.* (2023) designed and developed a welding table by applying the QFD technique together with the ergonomics principle, including the research of Jitman *et al.* (2021) who designed and developed an adjustable chair that caters to various user heights and postures. This combination of innovative design and ergonomic principles aims to enhance comfort and productivity in work environments, ultimately leading to improved overall well-being for users. ed a bamboo saw by applying the QFD technique together with the ergonomics principle.

QFD is a product design and development technique that is popularly used in the design and development of products or services. This is because the steps start from listening to the voices or needs of customers or users and then converting customer needs into technical requirements or specifications for components that need to be improved, resulting in products or services that meet customer needs. Such as the research of Rodjananugoon *et al.* (2023) the implementation of QFD has shown significant improvements in customer satisfaction and product quality. By prioritizing customer feedback throughout the development process, organizations can more effectively align their offerings with market demands and enhance their

competitive edge. who applied the QFD technique to the design and development of a bamboo table and chair set products in conjunction with Kansei engineering; the research of Rawangwong *et al.* (2023) who applied the QFD technique to the design and development of ceramic lamp products; and the research of Rawangwong *et al.* (2022) who applied the QFD technique to the design and development of bag-type bulrush reed products.

While the AHP is a technique that helps score the importance of each technical requirement by comparing pairs of technical requirements to see how they relate to customer needs. Then, the obtained data is used to create a comparison result metric table. After that, the importance weight of each column is calculated, and the average of each row is found. Then, the consistency or reasonableness of the comparison is checked (Ransikarbum, 2022; Tragkanont *et al.*, 2023). Such as the research of Cockalo *et al.* (2020) who used the QFD and AHP technique to defined customer demands and develop Industrial transmitter, and Rachman *et al.* (2024) who used the AHP technique to select strategies of building design. Including the research of Felice and Petrillo (2010) who used the AHP technique to the assessment of customer needs, and Cetin and Ucler (2023) who used the AHP-QFD to customer-focused aircraft seat design.

Since the integration of QFD techniques with AHP and ergonomics can help design and develop products that both meet user needs and support physical usage, this research focuses on integrating QFD and AHP with ergonomics to design and develop office chairs that meet the needs of users with diverse needs while reducing health risks and increasing work efficiency. The results will help create guidelines for designing and developing work chairs that are appropriate and sustainable, linking user needs with practical design principles.

2. Materials and Methods

2.1 Collecting and analyzing customer needs

Gathering and grouping customer needs regarding the characteristics of work chairs desired from related research and reports from various related agencies, including direct customer surveys, found that there were 8 characteristics of work chairs that users wanted, including (1) appropriate size and proportions (2) easy to move, (3) easy to adjust (4) comfortable to sit (5) does not slide when sit (6) not easily (7) strong and durable and (8) good weight loading. Then group them into categories using a tree diagram as shown in Figure 1.

2.2 Creation and verification of research tools

2.2.1 Creating a questionnaire is the process of taking the obtained data and creating a questionnaire, then checking the accuracy and reliability of the questionnaire by 3 experts.

2.2.2 Survey of user needs regarding the characteristics of the desired work chair. However, since the population is

unknown, the sample size was determined according to W.G. Cochran's formula, which is consistent with the research of Rawangwong *et al.* (2023) and Rawangwong *et al.* (2022) It was found that the sample size was calculated in the case of an unknown population according to W.G. Cochran's formula as in Equation (1).

$$n = \frac{P(1-P)Z^2}{d^2} \quad (1)$$

where n = sample size, P = proportion desired to be selected from the total population (given that $P = 0.30$), d = level of sampling error to be allowed (given that $d = 0.10$), and Z = confidence level (given that $Z = 1.65$), since there is a 90% confidence level.

$$n = \frac{0.30(1-0.30)1.65^2}{0.10^2} = 58$$

Therefore, the number of users who need to be asked about the characteristics of the desired work chair is at least 58 people.

This research asked about the needs of 90 users about the characteristics of the desired work chair.

2.2.3 Finding the geometric mean is the process of taking the data obtained from the survey and calculating the geometric mean to be used as the importance level (importance: IMP), which can be calculated from the formula.

$$IMP = \sqrt[n]{N_1 \times N_2 \times N_3 \times \dots \times N_n} \quad (2)$$

where N is the value obtained from the questionnaire and n = number of respondents.

2.3 The application of QFD technique to design work chairs, together with AHP has the following steps

2.3.1 Place the desired user characteristics of the work chair on the left side of the House of Quality (HOQ), which is phase 1 of QFD product planning, and use the geometric mean as the importance level (IMP) value as shown in Figure 2.

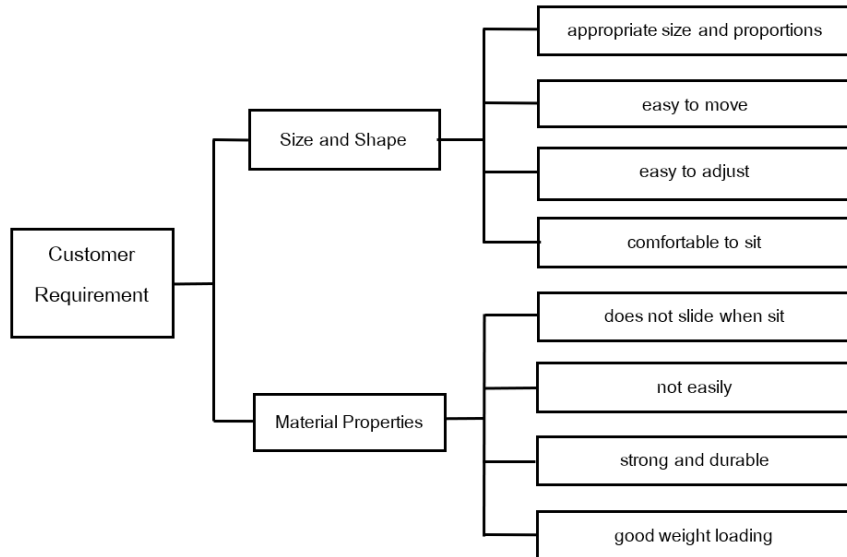


Figure 1 Grouping of customer requirement.

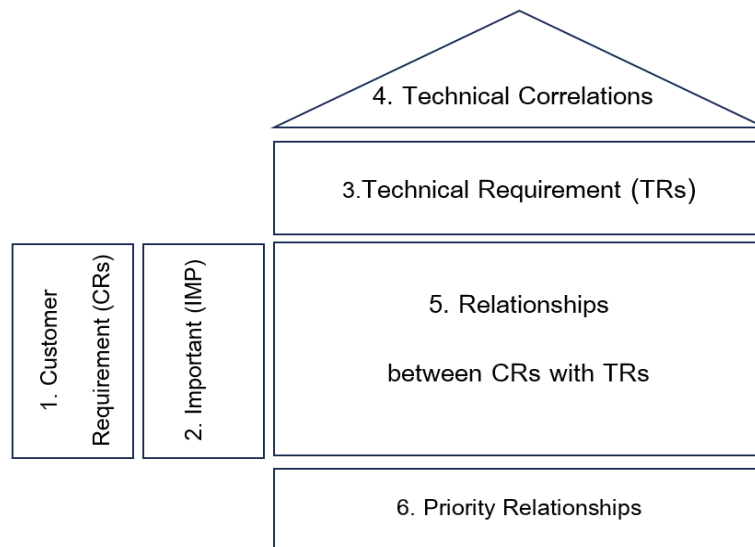


Figure 2 House of Quality (HOQ). (Rawangwong *et al.*, 2022)

2.3.2 The determination of technical requirements in accordance with user requirements. All user requirements must be met by technical requirements, but technical requirements may be repeated.

2.3.3 Evaluation of the relationship level between customer requirement and technical requirements by using AHP to assist in the evaluation, which has the following steps:

1) Create a comparison table and compare pairs of technical requirement, labeled 1 for equally preferred, 2 for equally to moderately, 3 for moderately preferred, 4 for moderately to strongly, 5 for strongly preferred, 6 for strongly to very strongly, 7 for very strongly preferred, 8 for very strongly to extremely, and 9 for extremely preferred.

2) Take the data obtained from the comparison and create a comparison result table, then calculate the importance weight of each column. After that, calculate the average of each row.

3) Calculation of the consistency of cause and effect (Consistency Index : CR) is a comparison between the calculated consistency index (CI) and the random inconsistency index (RI) as shown in Table 1. If the CR value is less than or equal to 0.10 or 10%, it is considered acceptable. However, if the CR value is greater than 0.10 or 10%, it is considered unacceptable. The weighting of the comparative scores in that criterion must be reviewed again until an acceptable CR value is obtained. The CR value can be calculated as in Equation (3).

$$CR = CI / RI \quad (3)$$

where

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (4)$$

and CI = Consistency Index, RI = Random Consistency Index, and λ_{max} is a value calculated by taking the sum of the diagnostic values of each criterion in each row and multiplying it by the sum of the average values in each horizontal row and then adding the products together or finding the sum between the results in the vertical and the average values of each row, which the result is equal to the total number of criteria that are compared. If the diagnostics in that criterion are completely consistent, it will result in the value $\lambda_{max} = n$.

4) Set the target values and direction for the development of the technical requirements by specifying the circle symbol (○) to mean that the specified value is appropriate, the upward arrow symbol (↑) to mean that the higher the specified value is better, and the downward arrow symbol (↓) to mean that the lower the specified value is better.

5) Evaluate the level of relationship between technical requirements by indicating a plus sign (⊕) to mean a positive relationship, which is a supportive relationship, and a cross sign

(⊗) to mean a negative relationship, which is a subtractive relationship.

6) Importance weight (IW), technical importance relative weight (%Relative), and ranking of technical requirements (TRs) according to their importance.

2.4 The application of ergonomic principles in designing and developing work chairs is the use of human body proportions as data in designing and developing work chairs that are suitable for workers (Auesujaridwong et al., 2011; Satieanrangsarith and Chaithanee, 2024), with details as follows:

2.4.1 Use the height from the floor to the lower thigh (popliteal height) as data to determine the height of the work chair so that the operator can sit and work comfortably for long periods of time without getting tired, using the principle of designing for the highest value (design for extreme value), that is, using the 95th percentile as data to design the work chair because it is a value that most people can use, as shown in Figure 3.

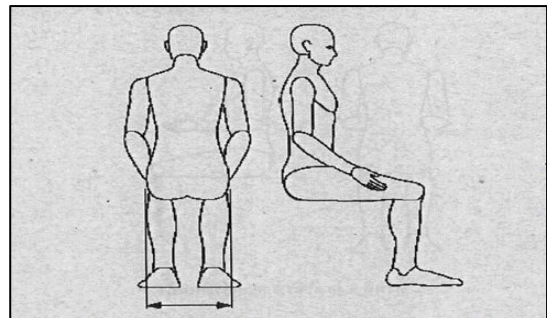


Figure 3 Popliteal height.

(Sukhothai Thammathirat Open University, 2012)

2.4.2 Use the distance from the buttock to the knee joint (buttock-knee length) as information for designing the depth of the work chair because it will allow the operator to sit and work with full hips, resulting in being able to sit and work for long periods of time comfortably without fatigue. The principle of designing for the maximum value (design for extreme value) will be used; that is, using the 95th percentile as information because it is a value that most people can use, as shown in Figure 4.

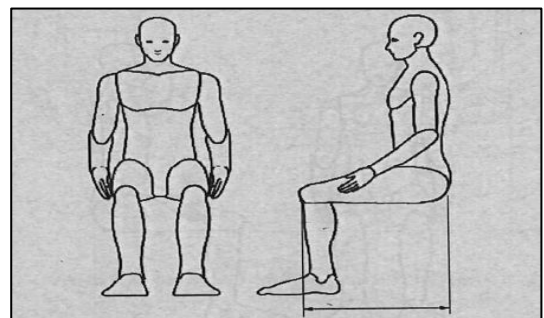


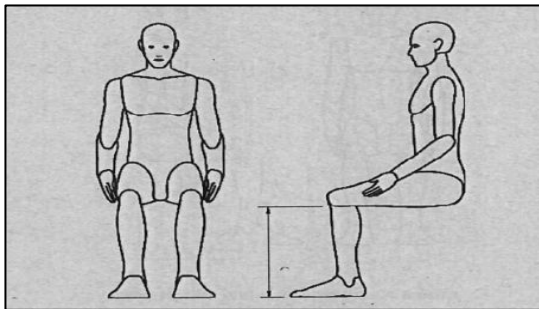
Figure 4 Buttock-knee length.

(Sukhothai Thammathirat Open University, 2012)

Table 1 Random consistency index (RI). (Ransikarbun, 2022)

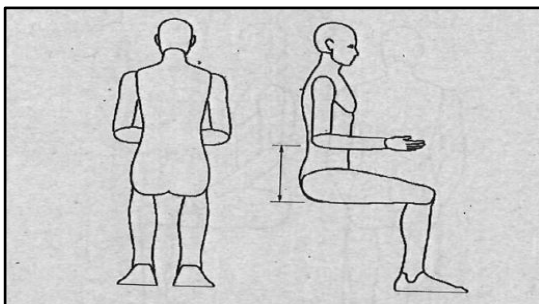
N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.46	1.49

2.4.3 Use the hip breadth while sitting (hip breadth) as information in designing the width of the chair because it will allow the operator to sit and work with full hips, making them sit comfortably without getting tired. The principle of designing for the maximum value (design for extreme value) will be used, which is using the 95th percentile as information because it is a value that most people can use, as shown in Figure 5.

**Figure 5** Hip breadth.

(Sukhothai Thammathirat Open University, 2012)

2.4.4 Use the height from the floor to the elbow (elbow rest height) as information to determine the level of the armrest to reduce fatigue while working. The design principle will be based on using the lowest value, which is the 5th percentile, as the design information because it is a value that most people can use, as shown in Figure 6.

**Figure 6** Elbow rest height.

(Sukhothai Thammathirat Open University, 2012)

2.4.5 Specify the use of memory foam as a material for making cushions and backrests of office chairs. Because memory foam is a porous material, it allows good air circulation. When sitting for a long time, there will be no dampness due to heat being trapped in the hip area. This allows one to sit and work continuously for a long time without getting dampness (Viriyatharakij *et al.*, 2014).

2.4.6 The backrest angle is set to 90-120 degrees because it allows one to sit and work continuously for long periods of time without getting tired and with efficient work.

2.5 Creating a prototype work chair

Creating a prototype work chair, is the application of data obtained from the QFD technique to the design of work chairs, together with AHP and ergonomics principles, to create a prototype work chair. Three prototype work chair shapes were created: the 5th, 95th percentile, and average.

2.6 Satisfaction testing of work chair users

Satisfaction testing of work chair users, with a total sample of 30 people, who were given the opportunity to try out the chairs before the improvements and the prototype work chairs that were created, with 10 people sitting in each type and then asked about their satisfaction.

3. Results and Discussion

3.1 From the survey of the needs of users regarding the characteristics of the desired work chairs by interviewing a total of 90 people using a questionnaire and calculating the geometric mean (geometric mean) to be used as the importance level (Importance: IMP), can be calculated as follows:

Appropriate size and proportions

$$= \sqrt[90]{5 \times 4 \times 4 \times \dots \times 5} = 4.01$$

Easy to move

$$= \sqrt[90]{3 \times 4 \times 4 \times \dots \times 5} = 3.90$$

The remaining calculations can be found in Figure 7.

3.2 Results from designing and developing work chairs by applying QFD techniques together with AHP and ergonomics, which have steps starting from studying user needs, converting user needs into technical requirements that need to be improved, finding the importance scores of technical requirements using AHP techniques, and applying ergonomics principles by using body proportions as data in designing and developing work chairs, the steps are as follows:

3.2.1 Determination of technical requirements in accordance with customer requirements, a total of 5 technical requirements can be determined: material selection, appropriate size and shape, adjustable height, apply ergonomic principles and stable and strong structure as shown in Table 3.

3.2.2 Compare technical requirement into a comparison table and compare them one by one to see how they affect customer needs.

For example, the customer's requirement case does not slide when sitting, with results as shown in Table 3.

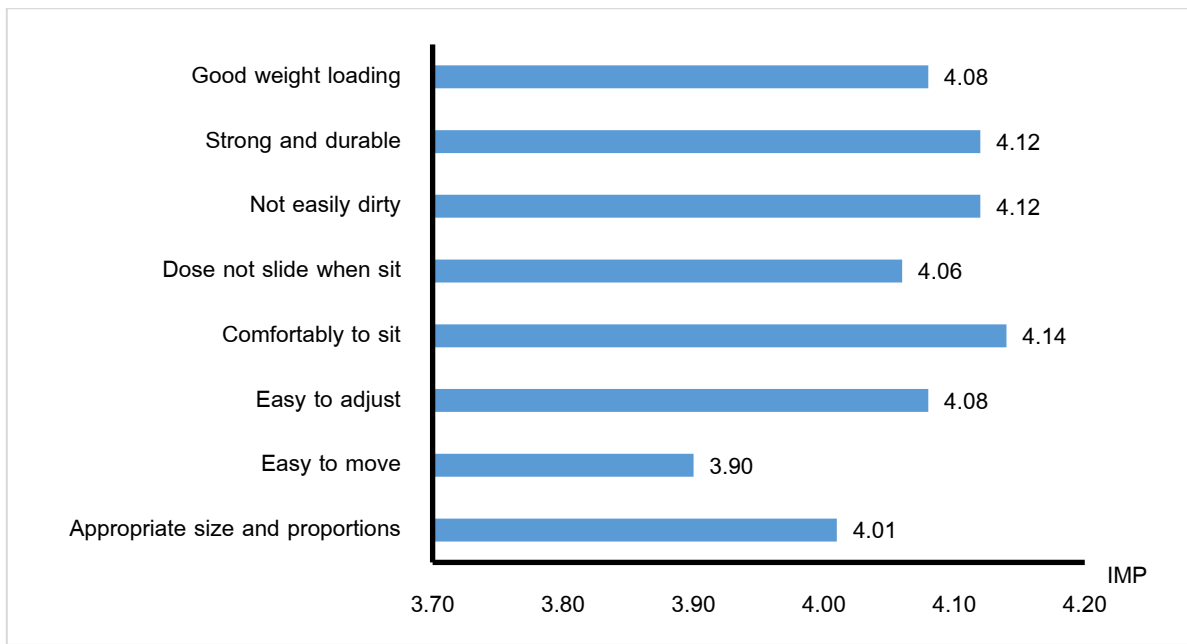


Figure 7 Results of a survey on the characteristics of work chairs that users want.

Table 2 The determination of technical requirements in accordance with customer requirements.

No	Customer Requirement (CRs)	Technical Requirement (TRs)
1	Appropriate size and proportions	Apply the principles of ergonomics
2	Easy to move	Appropriate size and shape
3	Easy to adjust	Adjustable height
4	Comfortably to sit	Material selection
5	Dose not slide when sit	Material selection
6	Not easily dirty	Material selection
7	Strong and durable	Material selection
8	Good weight loading	Stable and strong structure

Table 3 Pair-by-pair factor comparison the customer's requirement case does not slide when sitting.

Factor	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Factor
A			X															B
A			X															C
A							X											D
A			X															E
B								X										C
B								X										D
B								X										E
C									X									D
C									X									E
D									X									E

Remark: A = Material selection, B = Appropriate size and shape, C = Adjustable height, D = Apply ergonomic principles and E = Stable and strong structure.

Table 4 Vertical total score finding.

TRs \ TRs	A	B	C	D	E
A	1	7	7	7	7
B	0.14	1	1	1	1
C	0.14	1	1	1	1
D	0.33	1	1	1	1
E	0.14	1	1	1	1
Total	1.75	11	11	11	11

Table 5 The average of the technical specifications of each row.

TRs \ TRs	A	B	C	D	E	Average
A	0.57	0.64	0.64	0.64	0.64	0.62
B	0.08	0.09	0.09	0.09	0.09	0.09
C	0.08	0.09	0.09	0.09	0.09	0.09
D	0.19	0.09	0.09	0.09	0.09	0.11
E	0.08	0.09	0.09	0.09	0.09	0.09
Total	1.00	1.00	1.00	1.00	1.00	1.00

Table 6 Importance scoring results with the AHP technique of customer's requirement.

Technical Requirement (TRs) Customer Requirement (CRs)		IMP	A	B	C	D	E	CR
Material properties	1) Does not slide when sitting	4.06	0.62	0.09	0.09	0.11	0.09	5.89%
	2) Not easily dirty	4.12	0.62	0.09	0.09	0.11	0.09	5.89%
	3) Strong and durable	4.12	0.59	0.07	0.07	0.07	0.19	0.31%
	4) Good weight loading	4.08	0.39	0.11	0.08	0.09	0.33	7.68%
Size and shape	1) Appropriate size and proportions	4.01	0.05	0.13	0.38	0.38	0.05	8.29%
	2) Easy to move	3.90	0.23	0.49	0.09	0.09	0.09	1.40%
	3) Easy to adjustable	4.08	0.04	0.16	0.54	0.18	0.07	8.47%
	4) Comfortably to sit	4.14	0.10	0.08	0.37	0.37	0.06	2.16%

and can be calculated as follows in the Figure 8.



Figure 8 Results of design and development of work chairs.

3.2.3 Compare technical requirement one by one How the technical requirements affect the customer's needs.

For example, compare between material selection (A) and appropriate size and shape (B) affect the needs of customers in the case of does not slide when sitting, with results as shown in Table 3.

3.2.4 Then add up the scores vertically, can be calculated as follows;

$$A = 1 + 0.14 + 0.14 + 0.33 + 0.14 = 1.75$$

$$B = 7 + 1 + 1 + 1 + 1 = 11$$

The remaining calculations can be found in Table 4.

3.2.5 Weighing the importance of decision criteria in each column, can be calculated as follows:

$$A = 1/1.75 = 0.57, 0.14/1.75 = 0.08, 0.14/1.75 = 0.08, 0.33/1.75 = 0.19, 0.14/1.75 = 0.08$$

$$\text{Total} = 0.57 + 0.08 + 0.08 + 0.19 + 0.08 = 1.00$$

$$B = 7/11 = 0.64, 1/11 = 0.09, 1/11 = 0.09, 1/11 = 0.09, 1/11 = 0.09$$

$$\text{Total} = 0.64 + 0.09 + 0.09 + 0.09 + 0.09 = 1.00$$

The remaining calculations can be found in Table 5.

3.2.6 The average in the horizontal direction, can be calculated as follows:

$$A = (0.57 + 0.64 + 0.64 + 0.64 + 0.64) / 5 = 0.62$$

$$B = (0.64 + 0.09 + 0.09 + 0.09 + 0.09) / 5 = 0.09$$

The remaining calculations can be found in Table 5.

3.2.7 The calculation of the consistency index (CR) of cause and effect can be calculated as follows:

$$\lambda_{\max} = (1.75 \times 0.62) + (11 \times 0.09) + (11 \times 0.09) + (11 \times 0.11) + (11 \times 0.09) = 5.265$$

$$CI = (5.265 - 5) / (5 - 1) = 0.066$$

$$CR = 0.066 / 1.12 = 0.059 \text{ or } 6\%$$

Based on the results of the calculations, it was found that the CR value was 6%, it is considered can be concluded that the

comparison results are consistent. The remaining calculations can be found in Table 6.

3.2.8 Determine the importance score of each technical requirement, can be calculated as follows:

$$A = (4.01 \times 0.05) + (3.90 \times 0.23) + (4.08 \times 0.04) + (4.14 \times 0.10) + (4.06 \times 0.62) + (4.12 \times 0.62) + (4.12 \times 0.59) + (4.08 \times 0.39) = 10.77$$

$$B = (4.01 \times 0.13) + (3.90 \times 0.49) + (4.08 \times 0.16) + (4.14 \times 0.08) + (4.06 \times 0.09) + (4.12 \times 0.09) + (4.12 \times 0.07) + (4.08 \times 0.11) = 4.89$$

The remaining calculations can be found in Figure 8.

3.2.9 Weighting of importance (%) of each technical requirement, can be calculated as follows:

$$A = (10.77 / 32.27) \times 100 = 33.37\%$$

$$B = (4.89 / 32.27) \times 100 = 15.15\%$$

The remaining calculations can be found in Figure 8.

3.3 Using technical requirements as a guideline for designing and developing work chairs by considering important technical requirements first, with details as follows.

3.3.1 Material selection is the most important technical requirement, weighing 33.57%. Because the choice of material as a technical requirement influences many customer requirements, such as (1) Does not slide when sitting (2) Not easily dirty (3) Strong and durable (4) Good weight loading and (5) Easy to move, it has a higher priority score than other technical requirement. The materials used to make the work chair must be appropriate and consistent with the function of each part. The chair structure supports the weight of the sitter. General hot-rolled structural steel should be used, and the parts should be welded together. The seat and backrest support the weight of the sitter and allow the sitter to sit for a long time without getting stuffy and allow good ventilation. Therefore, memory foam is selected because its porous structure allows for good ventilation and air circulation, preventing stuffiness. Therefore, it is suitable for sitting for a long time.

3.3.2 Adjustable height is a technical requirement with the second most important weight, with an importance of 21.57%. Since workers have different body proportions, the chair is designed to be height adjustable, using the 5th and 95th percentiles as data. Therefore, it is set to be lower than the 5th percentile and higher than the 95th percentile. To allow flexibility in working, the chair is set to be adjustable in the range of 30-50 centimeters.

3.3.3 Applying the principles of ergonomics to the design and development of office chairs is a technical requirement with the third most important weight, with an importance weight of 17.65%, by using relevant body proportions as data in the design and development of office chairs.

3.3.4 Appropriate size and shape is a technical requirement with the fourth weight, with an importance weight of 15.15%. Since the work chair is a place where the operator has to sit and work continuously for a long time, the work chair must be designed with an appropriate size and shape. The seat pad must be rectangular and 25 millimeters thick. The backrest must be rectangular, with a backrest angle of 90-120 degrees, a height of 50 centimeters, and a backrest width of 45 centimeters. The chair legs must be rectangular, 25 millimeters wide, and 25 millimeters long, and the seat base must be rectangular.

3.3.5 Stable and strong structure is the last important technical requirement, with a weight of 12.24%. In order for the structure of the work chair to be stable and strong, to have a long service life and to be able to support the weight of the sitter without damage, the stress occurring in each leg of the chair and the pressure occurring on the work chair must be calculated.

From Figure 7, it was found that the technical requirement with the highest weight was being comfortable to sit, with an importance weight of 4.14 points, followed by strength & durable and not easily dirty, both with 4.12 points, followed by good weight loading, easily to adjust, does not slide when sit, appropriate size and proportion, and easy to move, with 4.08, 4.08, 4.06, 4.01, and 3.90 points (respectively).

From Figure 9, it was found that the materials selection (A) is the most important technical requirement, with an importance weight of 33.37 percent, followed by adjustable height (C), with an importance weight of 21.57 percent, followed by apply the principles of ergonomics (D), appropriate size and shape (B), and having a stable and strong structure (E) ,with importance weights of 17.65, 15.15, and 12.24 percent (respectively).

3.4 Applying ergonomic principles to the design and development of work chairs by using relevant body proportions as data in the design and development of work chairs, which are detailed as follows:

1) Use the height from the floor to the lower thigh (popliteal height) as data to determine the height of the work chair, which will use the design principles for the highest and lowest values, that is, using the 5th and 95th percentiles and the mean, which will determine the height of the chair as a range of data from 36 to 44 centimeters so that the worker can adjust the level according to the size and proportion of the body, as shown in Table 7.

2) Use the distance from the buttocks to the knee joint (buttock-knee length) as data for designing the depth of the work chair so that the operator can sit and work with full hips. The design principle will be used by using the lowest value, which is the 5th percentile, to cover almost the entire population because it is a value that most people can use. Use this data for designing, which is 39 centimeters, but minus the allowance

for space of 5 centimeters. Therefore, the depth of the chair is set to be 34 centimeters, as shown in Table 7.

3) Use the hip width while sitting (hip breadth) as information in designing the width of the chair because it will allow the operator to sit with full hips and sit comfortably without

getting tired. The design principle will use the highest value, which is the 95th percentile, as information, which is 43 centimeters, because it is a value that most people can use, as shown in Table 7.

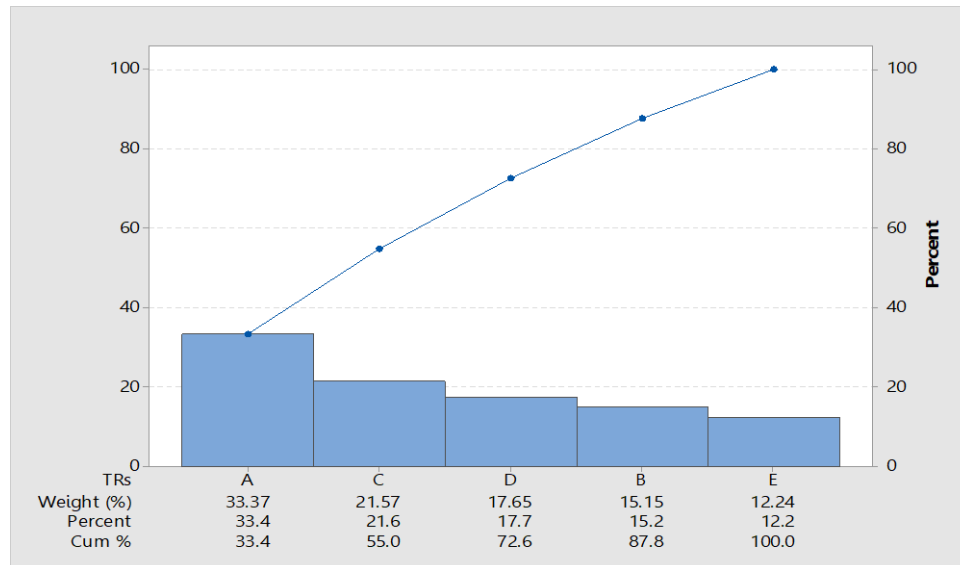


Figure 9 Priority ranking of technical requirements.

Table 7 Body proportions used in designing and developing work chairs. (Auesujaridwong *et al.*, 2011; Satieanrangsarith and Chaithanee, 2024)

Body Proportions	Application	Mean	5 th percentile	95 th percentile
1. Popliteal height	Chair height (cm.)	39.24	35.98	43.31
2. Buttock-knee length	Chair Depth (cm.)	44.54	39.20	50.22
3. Hip breadth	Chair width (cm.)	37.01	32.49	43.20
4. Elbow rest height	Armrest height (cm.)	21.80	17.46	27.50

4) Use the height from the floor to the elbow as data (elbow rest height) to determine the level of the armrest in order to reduce fatigue while working. The design principle will be based on using the lowest value, which is the 5th percentile, as data for designing, which is 18 centimeters, because this is a value that most people can use, as shown in Table 7

3.5 Using the obtained data to create a prototype work chair by creating 3 prototype work chairs, namely the 5th, 95th percentile, and mean values.

3.6 User satisfaction test by having a sample group of 30 people sit on the work chair before improvement and the prototype chair according to their body proportions.

Ten people with a height of approximately 162 centimeters sat on the work chair before improvement and the prototype chair at the 5th percentile. Ten people with a height of approximately 169 centimeters sat on the work chair before improvement and the prototype chair on the mean. Ten people with a height of 180 centimeters sat on the work chair before

improvement and the prototype chair at the 95th percentile. Then, the satisfaction was asked. It was found that before improvement, the satisfaction was 2.96 points. After improvement, the satisfaction of users increased to 4.04 points.

The results of the design and development of work chairs by applying the QFD technique together with the AHP technique and ergonomics principles led to guidelines for the design and development of work chairs that meet the needs of users and are of an appropriate size and proportion for users. To enhance the accuracy and completeness of the research, Finite Element Analysis (FEA), a computer simulation technique used to solve engineering problems, should be utilized in the future to support more efficient design. This reduces the risk factors of back pain due to work, which is consistent with the research of Boonla and Chaiklieng (2021) who systematically reviewed research on ergonomic management to reduce skeletal abnormalities of industrial production workers, namely, improving workstations to be suitable for work. Work chairs are part of the workstation and the research of Somupahard *et al.* (2024) who designed work

chairs for health by applying Kansei engineering and the Kano model. The results of the research study found that consumers' feelings towards work chairs for health have a total of 8 words: balance, comfort, ergonomics, work features, good quality, relaxation, simplicity, and strength. Including the research of Khanthusaeng *et al.* (2022) who improved the workstation to reduce ergonomic risks of microscope users by designing and developing chairs used in the work to be suitable for the body and nature of the work. By providing a backrest that supports the lumbar spine and allowing the chair to be adjusted high and low, including making the seat cushion softer, and the research of Auesujaridwong *et al.* (2011) who designed a chair for the fish blood scraping process by taking the height from the floor to the lower thigh to determine the height of the chair, taking the distance from the buttocks to the knee joint to determine the depth of the chair, and the width of the hips while sitting to determine the width of the chair. To enhance the accuracy and comprehensiveness of future research, it is advisable to utilize an electromyography (EMG) instrument for measuring muscle fatigue. Additionally, including images of the design and development results would be beneficial.

4. Conclusion

This research is the design and development of work chairs by applying the QFD technique together with the AHP and the principles of ergonomics. It starts with collecting the user requirements for the characteristics of the work chairs and then grouping the requirements into categories. After that, the user requirements are converted into technical requirements that need to be improved. The importance of the technical requirements is assessed using the AHP technique, the relationship between the technical requirements is assessed, the weight is calculated, the priority is ranked according to the importance of the technical requirements, and the ergonomics principle is applied. Body proportion is used as data in designing and developing work chairs. The results of the research study found that the most important user requirements are comfortable to sit, with a weight of 4.14, followed by strong and durable and not easily dirty, with a weight of 4.12, and good weight loading, easy to adjust, dose not slide when sit, appropriate size and proportion and easy to move, with weights of 4.08, 4.08, 4.06, 4.01, and 3.90 (respectively). It was found that the most important technical requirements are material selection accounting for 33.37 percent, adjustable height accounting for 21.57 percent, apply the principles of ergonomics accounting for 17.65 percent, appropriate size and shape accounting for 15.15 percent, and stable and strong structure accounting for 12.24 percent. The body proportions used in the design and development of office chairs include the height from the floor to the lower thigh, the distance from the buttocks to the knee joint, the width of the hips while sitting, and the armrests. After that, the obtained data was used to create 3 prototype

work chairs: the 5th percentile, the 95th percentile, and the average. Then, a sample of 30 people were asked to try the chair before the improvement and the prototype work chair that was created, with 10 people tested for each model and asked about their satisfaction. It was found that before the improvement, the users were satisfied with 2.96 points. After the improvement, the satisfaction increased to 4.04 points. The results of the research will use the obtained data to create an ergonomic work chair that can be adjusted in the range of 36-44 centimeters so that employees can adjust the level according to the size and proportion of their body.

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