Development of Tool for Work Simplification in Kitchen

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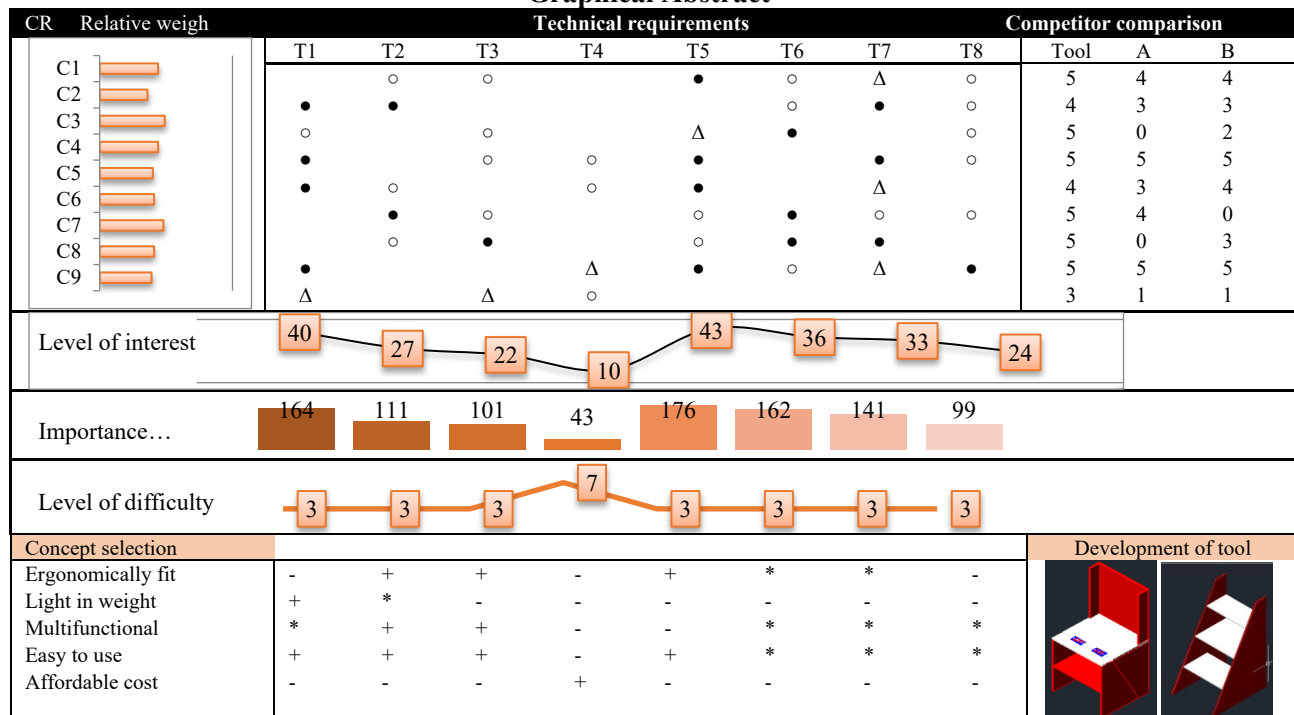promilakrishnachahal@hau.ac.in, mm1964@gmail.com

Abstract

The present study investigated the dimension mismatched between user's anthropometry and kitchen design and the implication of designing a tool for work simplification in kitchen activities. To find out the correlation between anthropometry measurements and kitchen design features 6 groups were created and the correlation among these was analyzed by using one-way ANOVA. Further, a handy step stool was developed by using Quality Function Deployment (QFD) methodology. Kitchen dimensions did not found to be matched with the majority of the women's physical responses. Women were found to be raising their heels, stretching their hands to perform the work, and adopting awkward postures which were simultaneously creating MSDs among women. For tool development, firstly customers determined the customer requirements and their relative weight along with technical requirements. The relationship matrix identified the technical requirements that satisfy most customer consequences. Maximum importance weight was received by T_5, T_1, and T_6, and a low relative importance weight was found for T_4 (Fixed cost). Regarding comparison with competitors, the handy step stool was found to be more suitable in ergonomically designed (5), easy to convert as peruse (5), strength (5), easy to sit and work(5), and easy to use as a step stool (5) parameters compared to other tools available in the market for same purposes. As per QFD, important criteria for handy step stool development were easy to use, followed by easily convertible and ergonomically fit.

Keywords
Quality function deployment, hand tool, work simplification, anthropometry.

Graphical Abstract

CR	Relative weigh	T1	T2	T3	T4	T5	T6	T7	T8	Tool	A	B
		Technical requirements								Competitor comparison		
C1			○	○		●	○	Δ	○	5	4	4
C2		●	●				○	●	○	4	3	3
C3		○		○		Δ	●		○	5	0	2
C4		●		○	○	●		●	○	5	5	5
C5		●	○		○	●		Δ		4	3	4
C6			●	○		○	●	○	○	5	4	0
C7			○	●		○	●	●		5	0	3
C8		●			Δ	●	○	Δ	●	5	5	5
C9		Δ		Δ	○					3	1	1
Level of interest		40	27	22	10	43	36	33	24			
Importance…		164	111	101	43	176	162	141	99			
Level of difficulty		3	3	3	7	3	3	3	3			

Concept selection	T1	T2	T3	T4	T5	T6	T7	T8	Development of tool
Ergonomically fit	-	+	+	-	+	*	*	-	
Light in weight	+	*	-	-	-	-	-	-	
Multifunctional	*	+	+	-	-	*	*	*	
Easy to use	+	+	+	-	+	*	*	*	
Affordable cost	-	-	-	+	-	-	-	-	

1. Introduction

Physical ergonomics regularly specializes in balancing place of business layout to maximize efficiency, with the desire to lessen the chance of harm to people. While occupational mission demands exceed joint power or muscle capability, employees can be predisposed to harm (Chimera et al. 2021). Most work-related musculoskeletal problems impact the top extremities (authorities of Canada, 2020). In Ontario, between the years 2011 and 2018, top extremity injuries accounted for 20% of all time-loss accidents. Anthropometry is crucial for product and place of job layout. (Castelluccia et al. 2021) From an ergonomics attitude, anthropometrics (Del Prado-Lu 2007) and energy demand (Kunelius et al. 2007) play an essential position in place of work layout for prevention of repetitive stress injuries, in particular for folks who carry out repetitive actions including obligations that contain gripping and wrist labor. Anthropometric exams recognition on duration, width, circumference, and power measures in addition to body weight, height, and body mass index (Chimera et al. 2021)

Quality Function Deployment (QFD) is a technique used by organizations to expect and prioritize consumer wishes and desires and to combine the needs and goals of purchasers in the services or products furnished to consumers (Mazur 2003). Using QFD inside the product layout technique will help the control to benefit an aggressive gain through the technique of creating the characteristics and attributes of high-quality services or products that can grow client delight. Quality Function Deployment methodology is proposed as a powerful design approach to combine ergonomics desires and luxury into hand tool layout as it explicitly addresses the translation of client needs into engineering traits (Kuijt-Evers et al. 2009).

The absence of ergonomists can result in undesirable product design (Marsot 2005). The ergonomic quality of hand-held products can be analyzed by means of several methods (Riedel 2009). In the course of that point, hand tool design centered on device capability as a way to enhance task performance and permit standardization. The device needs to perform the undertaking for which it turned into designed and corresponded to the traits of the greatest feasible variety of customers (Ginting et al. 2019, Marsot and Claudon, 2004). Hand equipment is widely utilized in a big quantity of occupations. Many workers ought to use hand tools to perform their responsibilities. The new ergonomically designed handles had been gave the impression to be more at ease in comparison to the traditional ones. Moreover, the findings of this have a look found that designing the hand tools' handles based totally on ergonomic principles and using anthropometric tables could enhance the hand posture, boom consolation, and reduce discomfort in the upper extremities. This indicates, a discount in paintings-associated UEMSDs is predicted (Veisia et al. 2019).

In ergonomics, one of the concepts that must continually be used is the principle of becoming the assignment/process to a person. This means that work ought to be adapted to the skills and boundaries of humans in order that the effects finished may be better. The existing looks aimed to decide layout alternatives primarily based on anthropometric dimensions of the women in standing and ergonomic ideas so that improvement can be done in the workplace (Veisia et al. 2019). Similarly, the implementation of the QFD method is also able to guarantee that information on client desires obtained inside the preliminary degrees of the making tool manner is carried out to all stages of the product cycle, from the layout concept, element planning, procedure, and manufacturing planning, to the product for consumers. The important thing to aggressive ability is the potential to respond to challenges in generating a product and/or carrier fast (Cohen 2007).

Hand tools are designed for the transformation of a concept into a product to satisfy customers' needs while ensuring respect for the environment, legislation, and corporate profitability. The initial stage of a tool design process, therefore, involves identifying and formalizing various expectations of farmers (users) about the product to be designed, among those relating to ergonomics features either explicitly or implicitly. The application of human factors has been shown in numerous studies to not only improve workers' well-being (such as reducing injuries and absenteeism and increasing job satisfaction) but also to increase productivity, improve customer service and reduce human error (Neumann and Dul 2010). This study addresses the issue of anthropometry and human factors involvement by engineers in the product design process to develop improved hand tools.

2. Methods

Phase-I: Study the dimension mismatches

Studies tested a large number of anthropometry and found mismatches between furniture and workplace design **(Castelluccia et al. 2021). For the** present study dimensions, the mismatch between women anthropometry and

kitchen counter and storage shelves are identified. Six groups were created based on dimensions and their association with design features and were observed as followed:

Group 1 = Relation between standing elbow height (cm) and counter height (cm);
Group 2 = Relation between normal horizontal reach (cm) and counter depth (cm);
Group 3 = Relation between extended horizontal reach (cm) and counter depth (cm);
Group 4 = Relation between standing shoulder height (cm) and storage shelf height (1) (cm);
Group 5 = Relation between standing height (cm) and storage shelf height (2) (cm);
Group 6 = Relation between vertical reach (cm) and storage shelf height (3) (cm);

After finalizing the concept that there was a huge difference between dimensions of women's and kitchen dimensions. Anthropometry data of women was further utilized for developing a prototype tool for work simplification in kitchen.

Phase-II: Application of QFD for designing hand tool

Hand tools are designed for the transformation of a concept into a product to satisfy customers' needs while ensuring respect for the environment, legislation, and corporate profitability (Chahal 2022). There are a number of well-established 'x-abilities' to improve aspects of design, such as design for quality (DFQ), design for manufacturing (DFM), design for assembly (DFA), design for sustainability, design for flexibility (DFF) and design for robustness (Riley and Dhuyvetter 2000). For the present investigation quality, function deployment methodology was taken for developing the concept of tool design (Akao 1960). A house of quality (HOQ) involves the collection and analysis of the 'voice of the consumer' which includes the customer needs for a product or service, customers' perceptions of the relative importance of these needs, and the relative performance of the producing company and its main competitors on the needs. Quality Function Deployment is proposed as an effective design method for integrating ergonomics needs and comfort into hand tool design because it explicitly addresses the translation of customer needs into engineering characteristics (Kuijt-Evers et al. 2009). Akbar et al (1999) define QFD as a quality-based method for increasing customers' satisfaction and value with products and services by translating the voice of customers into the design specification and implementation instructions, ensuring that the organization will carry them out and give customers what they will pay for.
For present investigation QFD was used under three rooms viz;

Room I: Contains customers' Needs (HOW) and technical requirements (WHAT)

This socio-technical systems approach to design is well documented in social studies (Helen et al. 2017). The customers' changing needs were difficult to assess, hence a QFD model was employed which summarized the vague and imprecise feedback from the customers. The design process is the preliminary design phase in which the design parameters/technical attributes and customers' needs and requirements are drawn up and analyzed (Marsot, 2005).

Room II: Correlation between the customer and technical attributes and comparison with other tools

After finalizing the customer needs and technical attributes, the analysis was done to draw a meaningful correlation among these attributes. So customers need to be met in end products and production engineers and workers' needs can meet the ever-changing demands for production. (Drury 2000). Human factors is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system to optimize human well-being, and overall system performance (Waechter et al 2018). For studying the interaction between attributes a scale of 9-3-1-0 was used which represented the strong, medium, weak, and no relationship among attributes. Within the QFD process, this stage corresponds to drawing up the ''Hows'' list, establishing ''Whats''/ ''Hows'' correlations, and seeking interactions between ''Hows''. (Marsot 2005). A comparison with other tools was also done based on relative weightage. Two hand tools viz; stool and ladder, which were found to be present in the market for similar use purposes, were taken for the analysis. Relative weightage was analyzed based on five categories: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree and 5 = Strongly agree.

Room III: Concept selection and target value

The application of biomechanical principles is important for preventing MSDs in order to improve working conditions and performance (Lee and Jung 2015). The present study tested a large no. of anthropometry data of women and found mismatches against kitchen design. The present study aimed to determine design based on anthropometric dimensions of the women respondents and ergonomic principles in order to develop the hand tool. The predictors of design features were assessed using the deployment methodology for tool designing (Veisia et al.

2019). The below Figure 1 represents the graphical presentation of the methodology which was followed during the study. This figure proposes a general design methodology to support effectively consciousness design of products (Sakao, 2007).
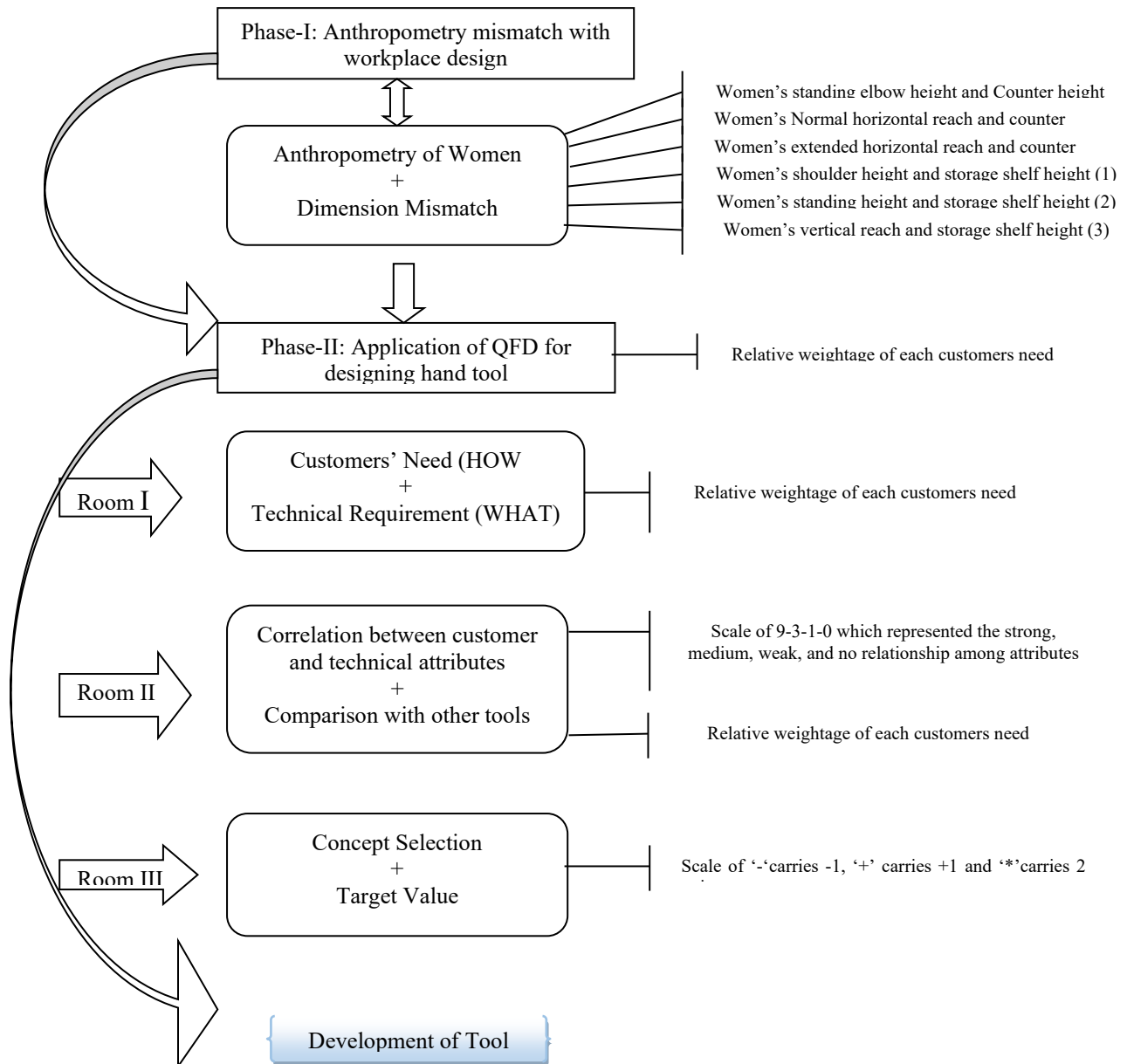

Figure with the following labeled boxes and annotations:

Phase-I: Anthropometry mismatch with workplace design

Anthropometry of Women + Dimension Mismatch
- Women's standing elbow height and Counter height
- Women's Normal horizontal reach and counter
- Women's extended horizontal reach and counter
- Women's shoulder height and storage shelf height (1)
- Women's standing height and storage shelf height (2)
- Women's vertical reach and storage shelf height (3)

Phase-II: Application of QFD for designing hand tool
- Relative weightage of each customers need

Room I — **Customers' Need (HOW + Technical Requirement (WHAT)**
- Relative weightage of each customers need

Room II — **Correlation between customer and technical attributes + Comparison with other tools**
- Scale of 9-3-1-0 which represented the strong, medium, weak, and no relationship among attributes
- Relative weightage of each customers need

Room III — **Concept Selection + Target Value**
- Scale of '-'carries -1, '+' carries +1 and '*'carries 2

Development of Tool

Figure 1. Graphical presentation of methodology which was followed during study

5. Results and Discussion

5.1 Study the dimension mismatches

Systematic results present a clear image of kitchen dimensions and women's physical responses (Castellucci et al. 2017). Results in Table 4 define the relation between anthropometric measurements of women and the dimension of counters in the kitchen. Report of result on one-way ANOVA gives a clear picture of findings as means, Minimum value, Maximum value, 10th percentile, 50th percentile, 95 percentile, F crit, F value, and P-value. As per ANOVA (analysis of variance) if the F value is less than the F crit, then the means of both groups are the same or significantly correlated. Otherwise, the means are significantly different from the p-value. Regarding the result of Table 1, in all the groups, p values were found to be less than 0.005 (5.82E-09, 2.3E-17, and 3.44E-10,) which represents that it is significantly different in means of each group (reflecting that kitchen counters' dimensions were not equal or matched with measurements of women). The same findings were reflected in data that F values were high (40.89, 107.7, and 49.02) than F crit (3.94), which reflected a significant difference in the means of each group. Dimensions of kitchen design features did not match the majority of the sample (Castelluccia et al. 2021). Women were found to be raising their heels, stretching their hands to perform the work, and adopting awkward postures which were simultaneously creating MSDs among women. The women were basically using their fingers with hand muscle groups and additionally they're lean to be a bad posture the body which consequential develops MSDs, weak points, aches, and discomfort (Nallusamy et al. 2020).

Table 1. Dimension mismatch between kitchen counter dimension and women anthropometry

	Group 1		Group 2		Group 3	
	SEH	CH	NHR	CD	EHR	CD
Mean value	99.5±.4	94.2±4.4	47.6±5.9	61.8±7.8	72.7±7.4	61.8±7.8
Minimum value	92.2	83.8	36.8	40.6	60.9	40.6
Maximum value	106.3	102.8	62.2	73.6	92.7	73.6
10th percentile	94.4	89.1	40.6	50.8	64.7	50.8
50th percentile	99.1	93.7	46.9	64.7	71.1	64.7
95 percentile	104.3	101.6	56.4	71.1	82.5	71.1
Fcrit	3.94		3.94		3.94	
F value	40.89		107.7		49.02	
P value	5.82E-09		2.3E-17		3.44E-10	

Group 1 = Relation between standing elbow height (cm) and counter height (cm); Group 2 = Relation between normal horizontal reach (cm) and counter depth (cm); Group 3 = Relation between extended horizontal reach (cm) and counter depth (cm); Significant at p-value of 0.05; Degree of freedom = 96.

Table 2. Dimension mismatch between height of shelves and women anthropometry

	Group 4		Group 5		Group 6	
	SSH	SSH(1)	SH	SSH (2)	VRH	SSH (3)
Mean	130.8±5.7	138.6±15.6	160.2±5.3	183.4±18.6	188.3±19.8	244.7±21.6
Minimum value	119.4	91.4	149.3	121.9	106.5	172.7
Maximum value	141.3	182.8	170.6	228.6	210	289.5
10th percentile	124.1	121.9	152.6	162.8	176.3	225.9
50th percentile	129.9	139.7	159.5	181.6	190.8	242.5
95 percentile	139.6	162.5	167.6	220.7	208.4	277.1
Fcrit		3.94	3.94		4.05	
F value		15.52	76.36		178.71	
P value		**<u>0.000154</u>**	7.6E-14		1.87E-17	

Group 4 = Relation between standing elbow height (cm) and counter height (cm); Group 5 = Relation between Normal horizontal reach (cm) and counter depth (cm); Group 6 = Relation between extended horizontal reach (cm) and counter depth (cm); Significant at p-value of 0.05; Degree of freedom = 96. Value in **bold** and *underline*: indicate the significant correlation among attributes

Results in Table 2 give a clear vision of the dimensions mismatch between women anthropometry and kitchen storage shelves design. As per findings height of the storage shelf (1) was found to be significantly correlated (p >0.000154) withstanding shoulder height of the women. Besides no correlation was observed between the standing height of women with storage shelf (2), and vertical reach of women with storage shelf (3). Similar results appeared when school furniture design was tested on students' performance. However, studying the effects of design and dimensions together produced an unclear positive effect (Castellucci et al 2017). A big range of research is posted worldwide wherein a clean mismatch among anthropometric traits and the dimensions of the furniture beneath examination has been identified (Batistão et al. 2012, Jayaratne 2012, Dianat et al. 2013 Van Niekerk et al. 2013). Most work-related musculoskeletal disorders impact the upper extremities. From an ergonomics perspective, anthropometrics (Del Prado-Lu, 2007) and strength capabilities (Del Prado-Lu, 2007; Kunelius et al. 2007) play an important role in workplace design for the prevention of repetitive strain injuries, especially for individuals who perform repetitive actions such as tasks that involve gripping and wrist exertions. Anthropometric assessments focus on length, width, circumference, and strength measures as well as body weight, height, and body mass index (Chimera et al. 2021)

5.2 Application of QFD (Quality Function Deployment) Methodology
5.2.1 Procedural steps help to quantify the customers' needs and technical attributes

Firstly study determined the customer requirements and their relative weight. The nine requirements (C_1-C_9) were mentioned by respondents regarding the tool they were asking for. Further, nine customer requirements (CRs) were mentioned and the weightage of each requirement was given by respondents from 1-to 5 and then the average value of each was calculated. The relative importance of the CRs was judged according to a priority scale developed as 1—not important, 2—important, 3—much more important, 4—very important, and 5—most important (Liker, 1992). Data in the Table 3 represent the requirement of technical attributes (TAs) for a handy step stool. A total of eight attributes were mentioned by the manufacturer which were wood as a material, standard size, finishing, fixed cost, load bearable material, convertible, and a fixed height of steps and chair.

Table 3. Procedural steps help to quantify the customers' needs and technical attributes

Customers' requirement	Code used	Weightage	Technical attributes	Code used
Ergonomically designed	C_1	3.9	Wood	T_1
Appropriate size	C_2	4.1	Standard size	T_2
Easy to convert as per use	C_3	4.8	Finishing	T_3
Strength	C_4	4.1	Fixed cost	T4
Standardized weight	C_5	4.0	Strength/ load bearable material	T_5
Easy to sit and work	C_6	4.4	Convertible / easy to fix	T_6
Easy to use as step stool	C_7	4.9	Fixed height of steps	T_7
Steady material	C_8	3.6	Fixed height of chair	T8
Low cost	C_9	4.4		

5.2.2 Relationship between customer requirements and technical attributes and comparison with other tools

To determine the relationship matrix of attributes, CRs were placed on the vertical edge on the left side, while the TAs were laid out in the horizontal section at the top edge. The relationship between customer requirements and technical requirements was determined based on an appropriate scale of 9-3-1-0 which represented the strong, medium, weak, and no relationship among attributes (Masui et al. 2003). Value for the importance was estimated by calculating the total weight for each relationship between product attributes and technical response. A high level of interest was noted in technical factors of T_5, T_1, and T_6. The table shows the relationship of each customer's attributes with technical requirements. Each correlation value in the table was multiplied by the weightage of customer importance and then all scores were added to find out the importance weightage of each technical point. Findings in the table revealed that maximum importance weightage ($\bar{x}$ =176) was received by T_5 (Strength/ load bearable material) followed by T_1 (material; wood $\bar{x}$ =164), followed by T_6 (Convertible / easy to fix) got the score of $\bar{x}$ =162. Low relative importance weightage was found in T_4 (Fixed cost). This matrix identifies the technical requirements that satisfy most customer consequences. The technical requirements that address the most customer

consequences should be a main priority in the design process to ensure a product or service that satisfies the stated customer expectations (Uppalanchi 2010).

Table 4. Relationship matrix between customer and technical attributes

		T₁	T₂	T₃	T₄	T₅	T₆	T₇	T₈
C1	3.9	-	3	3	-	9	3	1	3
C2	4.1	9	9	-	-	-	3	9	3
C3	4.8	3	-	3	-	1	9	-	3
C4	4.1	9	-	3	3	9	-	9	3
C5	4.0	9	3	-	3	9	-	1	-
C6	4.4	-	9	3	-	3	9	3	3
C7	4.9	-	3	9	-	3	9	9	-
LI		**40**	27	22	10	**43**	36	33	24
IW		*164*	111	101	43	*176*	*162*	141	99
LD		3	3	3	7	3	3	3	3

9-3-1-0 which represented the strong, medium, weak, and no relationship among attributes
T: technical attribute, C for customers' need, LI: level of Interest, IW: Importance weigh and LD: level of difficulty
BOLD: indicates high score for level of interest; italic and underlined score represent the attributes heaving high importance weigh; grey shaded cell reflects the high level of difficulty in attribute.

Technical difficulties were determined from the relationship of the technical response. The calculation was performed by translating all weight values of the relationship and dividing the weight of each technical response by the total weight (Chahal 2022). Furthermore, the level of difficulty (on a scale of 1 to 9) was given based on the range of percentage like; (a) 0 – 5 % level of difficulty = 1 (b) 6 – 11 % level of difficulty = 3, (c) 12 – 17 % level of difficulty = 5, (d) 18 – 23 % level of difficulty= 7, (e) >24 % level of difficulty= 9. Based on these scores, maximum difficulty was noticed in fixed cost (7), beside this all the parameters were having equal levels of difficulty. This matrix addresses the direction of improvement, target values, the final weights of service and quality characteristics, and the level of difficulty to reach the target values. The direction of improvement indicates the type of action needed to ensure that the service characteristics are sufficient to make the service competitive (Uppalanchi, 2010).

5.2.3 Comparison of developed handy step stool with similar products of market
The planning matrix defines how each customer consequence has been addressed by the competition. It provides market data, facilitates strategic goal setting for the new product, and permits comparison of the customer desires and needs. It also compares the service to its key competitors (Uppalanchi 2010). Handy step stool was compared with other similar products available in the market *i.e* kitchen stool and ladder. A comparison was made on the basis of customer requirements for the required tool. As per findings, the handy step stool was found to be fulfilling most of the requirements of women like ergonomically designed (5), Easy to convert as peruse (5), Strength (5), Easy to sit and work(5), and Easy to use as a step stool (5). Besides kitchen stool available in the market was found to be fulfilling only two criteria of women i. e. Strength (5) and Steady material (5). Similar findings were noted in the case of the ladder.
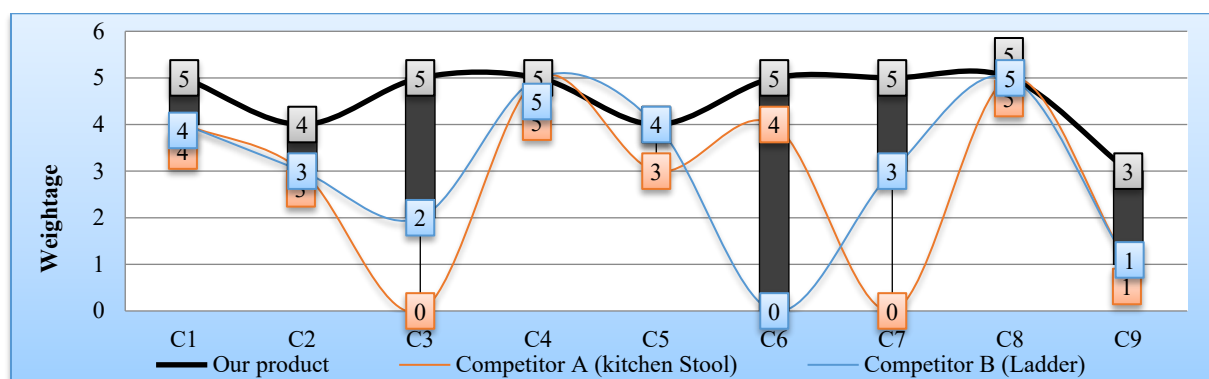

Fig. 2 Competitive analysis

For finalizing the concept; the five most point design features were taken and their relation with technical parameters were calculated based on three parameters viz; - means no relation, + means positive relation and * means strong relation. The score was assigned to each symbol (- having-1point, +having +1point, and * having 2 points). The findings in the below tables (Table 5, 6 and 7) reflect that the most important criteria for tool development were easy to use (9) followed by easily convertible (8) and ergonomically fit (5). On the basis of QFD methodology light in weight and affordable cost were the least preferable parameters in designing of the tool with scores -3 and -6.

5.2.4 Concept selection and target value for designing

Table 5. Concept selection

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Sum
Ergonomically fit	-	+	+	-	+	*	*	-	5
Light in weight	+	*	-	-	-	-	-	-	-3
Easily Convertible	*	+	+	-	-	*	*	*	8
Easy to use	+	+	+	-	+	*	*	*	9
Affordable cost	-	-	-	+	-	-	-	-	-6

'-'carries -1, '+' carries +1 and ''carries 2 points*

Table 6. Target value for designing multipurpose handy steps stool

Particulars	Dimension (inches)
Chair	
Height of chair	36
Sitting heght	18
Width of seat	18
Back rest	18x18
Steps stool	
Height of step	8.5'
Width of step	18
Depth	10±2.5
Maximum height of last step	27
Maximum height of tool	36
Weight	
Steady convertible point	Hinge joint

Table 7. Developed tool

In form of Chair	
3D in Auto Cad	Photograph of tool
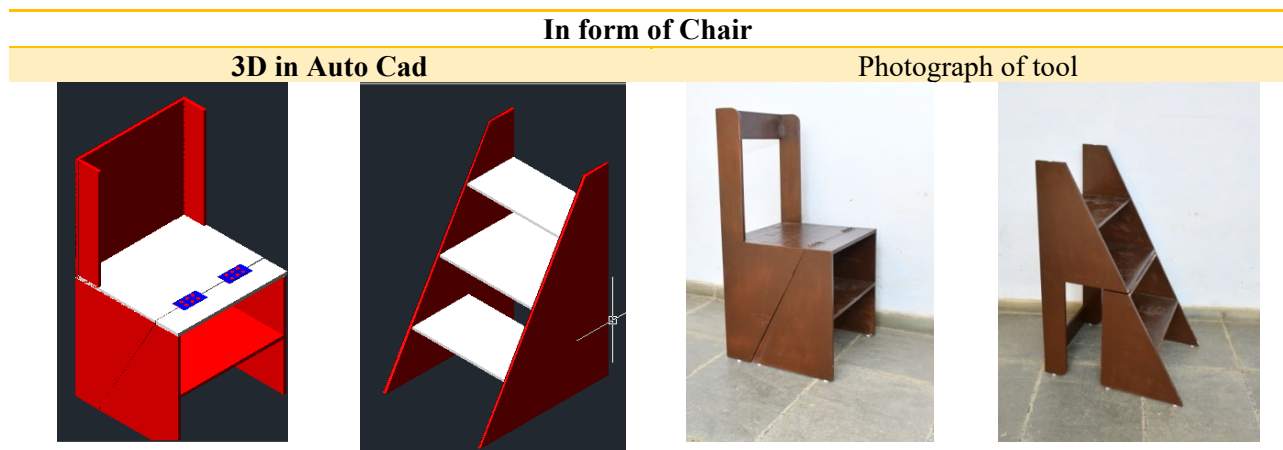
This matrix depicts the values assigned by the researchers for the direction of improvement and/or standard values of each technical requirement needed to be competitive in the industry. Oftentimes, if a numerical value cannot be absolutely determined, the researchers and/or industry experts use judgment based on expertise in the subject area to assign "targets." The direction of improvement indicates the type of action needed to ensure that the technical requirements are sufficient to make the service competitive for each entity evaluated. As mentioned, to define school furniture dimensions or quantify the level of mismatch, it is important to consider students' features. To avoid the mismatch problem, one of the best possible solutions is adjustability (Castellucc et al. 2014).

6. Conclusion

Ergonomically designed tools play an important role in accomplishing effectiveness and efficiency while providing comfort and ease to industrial workers to accomplish the required productivity. The quality function deployment tool played an important role in a handy step stool development. A systematic methodology (illustrated in fig-1) was adopted in designing ergonomically designed tools. The requirements were quantified as requirements of customers' technical requirements mentioned by the engineers. Workers' requirements were translated and accomplished in terms of 'WHATs' and 'HOWs' using QFD. The final concept was developed based on the target value of tool designing along with specific features. The changing taste of customers and mass customization demands greater research in the area of ergonomically designed tools for comfort and ease at work. Using QFD methodology, tool design incorporates the ideas, thoughts, and technical views of experts in product design, which are directly and indirectly related to the customers' requirements for products. Research may be taken up to incorporate such changes in order to accomplish effectiveness and efficiency (Akbar et al. 2010)

References

Akao, Y., *Quality Function Deployment: Integrating Customer Requirements into Product Design,* (ISBN: 0-915299-41-0) Publisher: Productivity Press, 1960.

Akbar, R., Noor, S. and Shah, W., Qfd as a Tool for Improvement of Car Dashboard, *J. Qual. Technol. Manag.*, vol. 6, pp. 1–22, 2010.

Batistão, M. V., Sentanin, A. C., Moriguchi, C. S., Hansson, G., Coury, H. J. C. and Sato. T., Furniture Dimensions and Postural Overload for Schoolchildren's Head, Upper Back and Upper Limbs, *Work: A Journal of Prevention, Assessment & Rehabilitation, vol.* 41, no.1, pp. 4817–4824, 2012.

Castellucci, H. I., Arezes, P. M. and Molenbroek, J. F. M., Applying Different Equations to Evaluate the Level of Mismatch between Students and School Furniture, *Applied Ergonomics, vol.* 45, no. 4, pp. 1123–1132, 2014.

Castellucci, H. I., Arezes, P. M., Molenbroek, J. F. M., de Bruin, R. & Viviani, C., The influence of school furniture on students' performance and physical responses: results of a systematic review, *Ergonomics*, vol. 60, no.1, pp. 93-110, 2017.

Castelluccia, H. I., Viviani, V. Arezes, P., Molenbroek, J., Martínez, M. and Aparici, V., Application of mismatch equations in dynamic seating designs. *Applied Ergonomics*, vol. 90, 103273, 2021.

Chahal, P., Quality Function Deployment:A Methodology for Testing Agriculture Sickle, N. K. Rana et al. (eds.), *Technology Enabled Ergonomic Design*, *Design Science and Innovation,* pp. 266-277, 2022.

Chimera, N., Holmes, M. and Gabriel, D., Anthropometrics and electromyography as predictors for maximal voluntary isometric wrist torque: Considerations for ergonomists, *Applied Ergonomics, vol.* 97, 103496, 2021.

Cohen, L., *Quality Function Deployment: How to Make QFD Works for You*, 1ˢᵗ edition, Michigan: Addison Wesley-Publishing Company, 2007.

Del Prado-Lu. J.L., Anthropometric measurement of Filipino manufacturing workers, *Int. J. Ind. Ergon., vol.* 37, pp. 497-503, 2007.

Dianat, I., Ali Karimib, M., Asl Hashemic, A. and Bahrampour. S., Classroom Furniture and Anthropometric Characteristics of Iranian High School Students: Proposed Dimensions Based on Anthropometric Data, *Applied Ergonomics, vol.* 44, no.1, pp. 101–108, 2013.

Drury, C. G., Human Factors and Quality: Integration and New Directions, *Human Factors and Ergonomics in Manufacturing*, vol.10, no. 1, pp. 45–59, 2000.

Ginting, R., Ginting, R., Tarigan, U. and Panjaitan, N., 2019. The Application of Quality Function Deployment and Ergonomics: A Case Study for A New Product Design of A Texon Cutting Tool. 11th Curtin University Technology, Science and Engineering (CUTSE) International Conference *IOP Conf. Ser.: Mater. Sci. Eng.* 26-28 November, 2018. Vol. 495, pp-1-9, 2019

Helen P. N., Hughes, Chris, W., Clegg, Lucy, E., Bolton, and Lauren, C. and Machon, Systems scenarios: a tool for facilitating the socio-technical design of work systems, *Ergonomics*, vol. 60, no. 10, pp. 1319-1335, 2017.

Jayaratne, K., Inculcating the Ergonomic Culture in Developing Countries: National Healthy Schoolbag Initiative in Sri Lanka, *Human Factors: The Journal of the Human Factors and Ergonomics Society*, vol. 54, no. 6, pp. 908–924, 2012.

Kunelius, S., Darzins, J., Cromie, J. and Oakman. Development of normative data for hand strength and anthropometric dimensions in a population of automotive workers, *Work,* vol. 28, pp. 267-278, 2007.

Lee, K. and Jung, M., Ergonomic Evaluation of Biomechanical Hand Function, *Safety and Health at Work, vol.* 6, no.1, pp. 9-17, 2015.

Likert, R., A technique for the measurement of attitudes, *Archives of Psychology*, vol. 22, no. 140, pp. 55, 1932.

Marsot, F., Claudon, L., Design and ergonomics: Methods for integrating ergonomics at hand tool design stage, *International Journal of Occupational Safety and Ergonomics, vol.*10, pp. 13–23, 2004.

Marsot, J., QFD: A methodological tool for integration of ergonomics at the design stage, *Appl. Ergon, vol.* 36, pp.185–92, 2005.

Masui, K., Sakao, T., Kobayashi, M., and Inaba, A., Applying Quality Function Deployment to Environmentally Conscious Design, *International Journal of Quality and Reliability Management,* vol. 20, pp. 90-106. 2003,

Mazur, G., Voice of the customer (define): QFD to define value, *Proceedings of 57th Am. Equal*, 2003.

Neumann, W. P., and Dul, J., Human Factors: Spanning the Gap between OM and HRM, *International Journal of Operations and Production Management*, vol. 30, no. 9, pp. 923–950, 2010.

Riedel, S., Einsatz Der Infrarot-Thermografie Bei Der Ergonomischen Griffgestaltung, *Zentralblatt Fur €
Arbeitsmedizin, Arbeitsschutz Un IOP Conf. Series: Materials Science and Engineering,* IOP Publishing, *pp* 495, 2009. doi:10.1088/1757-899X/495/1/012009,

Riley, M. W., and Dhuyvetter, R. L, Design Cost Savings and Ergonomics, *In Proceedings of the IEA 2000/HFES 2000 Congress, San Diego, California*, 30th July / 4th August, 2000.

Sakao, T, A., QFD-centred design methodology for environmentally conscious product design, *International Journal of Production Research*, vol. 45, no. 18-19, pp. 4143-4162, 2007.

Uppalanchi, A., Application of Quality Function Deployment in new product and service development, Masters Theses, 2010.

Van Niekerk, S., Louw, Q. A., Grimmer-Somers, K., Harvey, J. and Hendry, K. J., The Anthropometric Match between High School Learners of the Cape Metropole Area, Western Cape, South Africa and Their Computer Workstation at School, *Applied Ergonomics, vol.* 44, no. 3, pp. 366–37, 2013.

Veisia, H., Choobineh, A., Ghaem, H. and Shafiee, Z., The effect of hand tools' handle shape on upper extremity comfort and postural discomfort among hand-woven shoemaking workers, *International Journal of Industrial Ergonomics*, vol. 74, 102833, 2019. https://doi.org/10.1016/j.ergon.2019.102833

Kuijt-Ever, L. E., Morel, K. P. N., Eikelenberg, N. L. W. and Vinka, P. Application of the QFD as a design approach to ensure comfort in using hand tools: Can the design team complete the House of Quality appropriately?, *Applied Ergonomics* , vol. 40, no. 3, pp. 519-526, 2009. https://doi.org/10.1016/j.apergo.2008.09.009 May 2009

Waechter, Michael, Hoffmann, H. and Bullinger, A. A., Towards an Engineering Process to Design Usable Tangible Human-Machine Interfaces, *In Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018),* Advances in Intelligent Systems and Computing. Cham: Springer International Publishing, edited by Bagnara, S., Tartaglia, R., Sara Albolino, Alexander, T. and Fujita, Y, vol. 825, pp. 136–147, 2018.

Nallusamy S., Pankaj , Suraj, S., Kumar, National Hamid Reza M.D. Evaluation of human posture and ergonomics by appropriate assessment tool in a medium scale manufacturing industry, *International Journal of Mechanical and Production Engineering Research and Development*, vol. 10, no. 3, pp. 861 – 872, 2020.

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