

Development of Tool for Work Simplification in Kitchen

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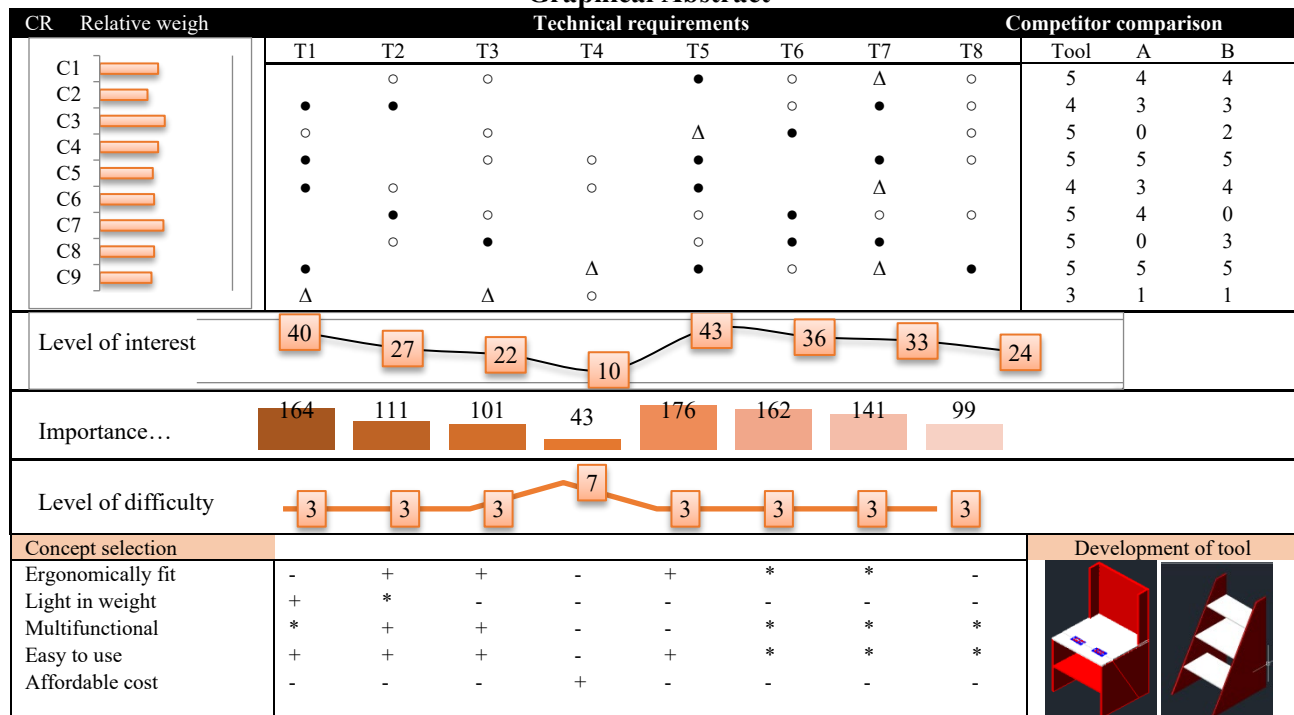
Abstract

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 T₅, T₁, and T₆, and a low relative importance weight was found for T₄ (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



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).

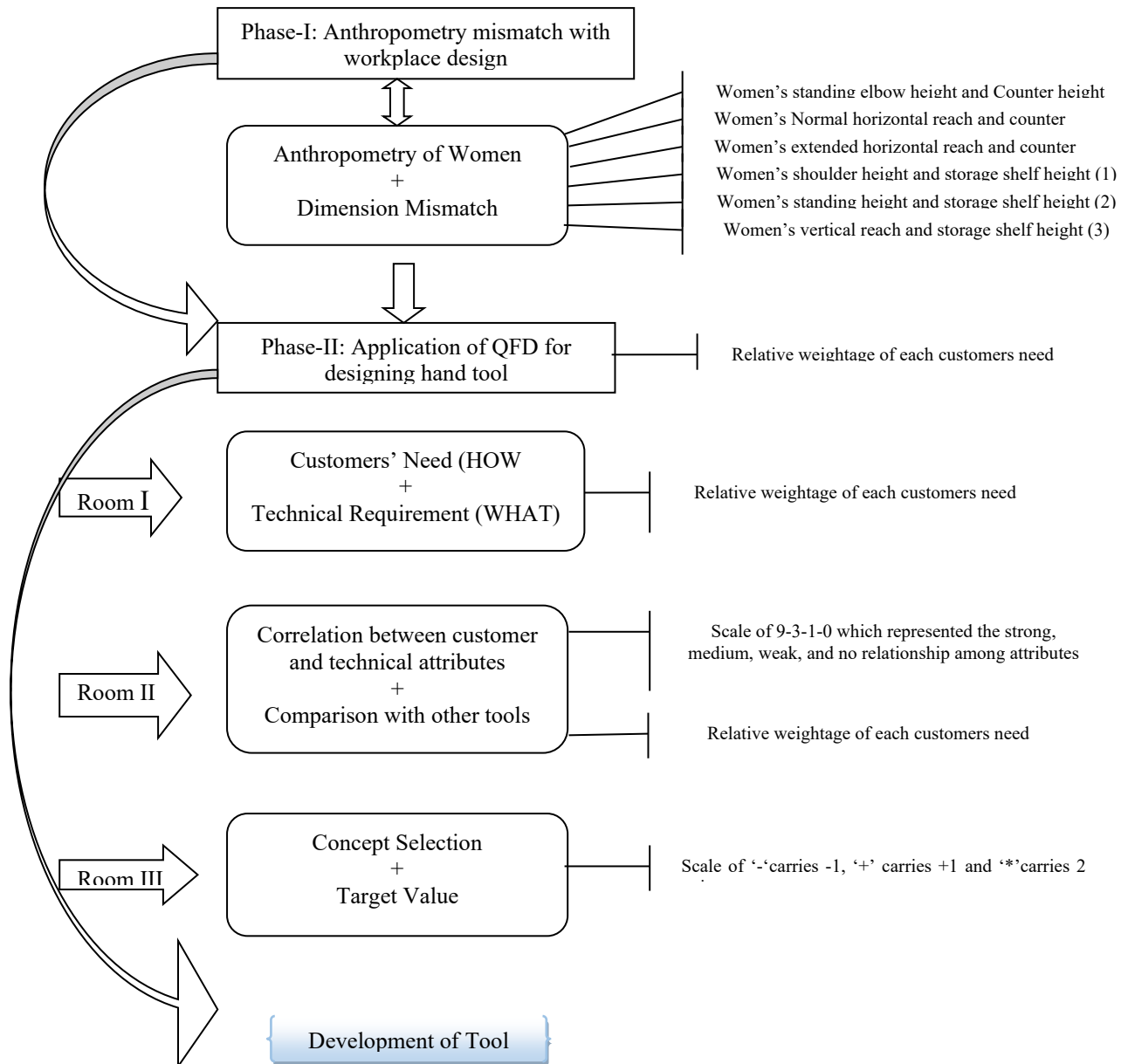


Figure 1. Graphical presentation of methodology which was followed during study

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
10 th percentile	124.1	121.9	152.6	162.8	176.3	225.9
50 th 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 (C₁-C₉) 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	T ₄
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	T ₈
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 T₅, T₁, and T₆. 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 T₅ (Strength/ load bearable material) followed by T₁ (material; wood $\bar{x} = 164$), followed by T₆ (Convertible / easy to fix) got the score of $\bar{x} = 162$. Low relative importance weightage was found in T₄ (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

	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	
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	<u>164</u>	111	101	43	<u>176</u>	<u>162</u>	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.

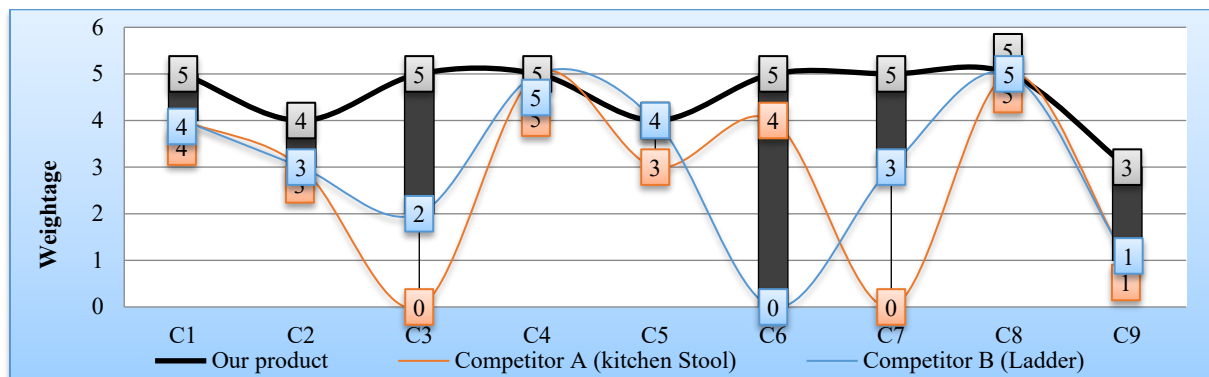


Fig. 2 Competitive analysis

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

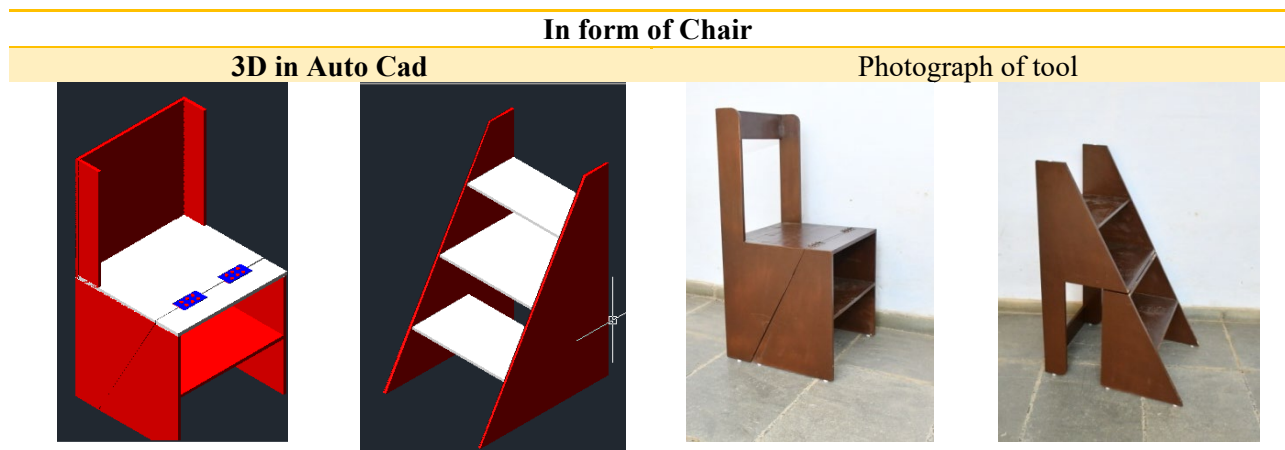
	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	Sum
Ergonomically fit	-	+	+	-	+	*	*	-	5
Light in weight	+	*	-	-	-	-	-	-	-3
Easily Convertible	*	+	+	-	-	*	*	*	8
Easy to use	+	+	+	-	+	*	*	*	9
Affordable cost	-	-	-	+	-	-	-	-	-6

'-' 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 height	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



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 (Castellucci 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)

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