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A REVIEW OF LITERATURE AND IDENTIFICATION OF TOTAL QUALITY MANAGEMENT (TQM) TOOLS FOR PRODUCT DEVELOPMENT AND DESIGN INTEGRATION; AND THE ERGONOMICS PRINCIPLES FOR CUSTOMER SATISFACTION

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ABSTRACT

Product design, Ergonomics and Total Quality Management (TQM) are three fields of engineering. They all aim for customer satisfaction, indigenously. Literature available entails that, mechanical engineers design products for the customers and realize that the inclusion of principles of ergonomics and TQM is there. The methodology of inclusion of these principles is limited to the particular designers, and there is no standard method for it. Ergonomists also talk about incorporating the principles of product design and quality characteristics in product, during the development stage. But, as ergonomics is a costly affair and designers do not want to change the design for the sake of ergonomics, it has to take a back seat many a times. The customers may not know about the principles of design or ergonomics, but good quality in the product decides the future of the product.

So, it can be said that, these three fields have a common goal of the customer satisfaction. At the same time, it is also realized that, there is need for uniting one field in other fields for the enhancement of customer satisfaction. In this paper, analysis is done to identify the total quality management tools, which can be used to incorporate the principles of product development and design and ergonomics for better customer satisfaction.

KEYWORDS: Product design, Ergonomics, Total Quality Management & Customer Satisfaction

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INTRODUCTION

A designer, designs the product for the customers use and satisfaction. An ergonomist also wants to satisfy and give the mental and physical comfort to the customers. Total Quality Management (TQM) also aims at giving the best quality in the products for maximum customers' satisfaction. These three fields of engineering indigenously focus on the satisfaction of the customers. If these three fields work together, the customer satisfaction will enhance further. To know more about it, the review of available literature is carried out, to find out the efforts of researchers for the integration of these three different fields of engineering to delight the customers.

Product Development and Design

When the literature in the field of Product development and design is reviewed; it is found that the engineers working in this field realize that product development and design will be better, if the opinions of people from different fields are also considered for the product development.

"Product Development is a sequence of design processes, that converts generally specified market needs or ideas into detailed information for satisfactory manufacturable products, through the application of scientific, technical and creative principles, acknowledging the requirements set by succeeding life cycle processes" (Remko W. Helm, 2002).

Industrial Designers Society of America (IDSA) defines product design as a skilled activity of developing and generating new ideas and possibilities, that adjust the function and add worth and aesthetics to the products for common benefit of both the customers and the manufacturers (Wayne C. Chung, Chun-Yen Wang, 2001).

Product Development Processes Requirements

The product development and design is an interdisciplinary activity, which needs to combine the ideas of all involved disciplines' creativity, opinions, concerns and suggestions to meet the expectations and benefits of users and manufacturers. The participation of all the departments in product development and design will ensure fewer problems during the process of production as well as after products are delivered to the customers.

Product development is an ingenious activity that changes the market opportunity and technological innovation into successful products. Product development is one of the major activities in the life of product-oriented enterprises. It is also essential for the economic success of the organization. Product development processes are structured in such a way that, they require participation by almost all the major functions within the organization, such as strategic planning, marketing, product design, manufacturing and financial planning and budgeting. It also includes participation of stakeholders such as customers, suppliers who are not the part of the organization directly (Bing Liu, 2003).

The thoughts expressed by Leslie Monplaisir says that, new product development is an ongoing activity that a corporation must keep on performing to develop, manufacture, and sell products. These activities are the result of a multidisciplinary effort that includes marketing, research, engineering design, quality assurance, manufacturing, and a whole chain of suppliers (Leslie Monplaisir and Sa'ed Salhieh, 2000).

For initiating the efforts to design and develop high quality products competently, designers should explore wide variety and sources of design knowledge and utilize them in design tasks. Following Figure 1 illustrates some of the areas of knowledge; designers must focus on during the design process (Paul A Rodgers and P John Clarkson, 1998).

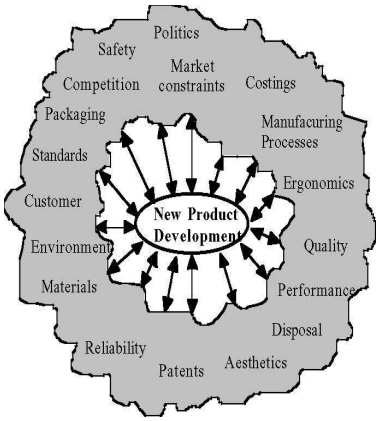

Figure 1: Areas of Knowledge

So, there is requirement of involvement of various fields for the success of product development and design activity. Now, let's see what the researchers say about the principles and procedure of product development.

Fifteen Principles of Good Product Development

The following fifteen principles provide a sound basis for good product development:

- Quality is a must - TQM approach
- A preference for cycle time reduction
- A bias for innovation
- Logical vision, strategy, plan and metrics
- A product-family oriented Business Unit
- Listening to the Voice of the Customer
- A clearly defined and well-organized development process
- Cross-functional product development teams
- Early supplier involvement in the development process
- A development methodology
- Highly skilled, well-trained people
- Computer Aided Design systems
- Digital product models controlled by Electronics Data Management (EDM) and Product Data Management (PDM) systems
- Simulation and rapid prototyping
- Best practice techniques (Johns Stark, 2000).

The role of professional designers is still not very influencing in almost 90% of the world's organizations (Emily Swanson, Vince LaConte). The industries take in the designers to achieve several objectives that they have in applying design theories and methods to their product development processes, which are:

- Reduction in the use of product development resources (time, money, etc.)
- Improvement in product functions
- Improvement in product reliability
- Reduction in product life-cycle costs (Derrick Tate, 1999).

To develop unique design concepts is a difficult task. The first part of the difficulty is that, there is no scientific or systematic technique for this activity. Some designers (Dr. Yoshiro Nakamastsu, inventor of the Floppy disk; holds ~2300 patents compared to 1093 held by Thomas Edison) indicate that conceptual design is an inspirational activity and not the systematic activity. Others (Prof Altshuller, founder of the TIPS, or the Theory of Inventive Problem-Solving system for design) assume it to be a systematic activity. For product development, there are essentially two cases: a completely new type of product (no comparison/benchmark is available) or a product refinement, where there are existing products, but

need to be improved, or their functions need to be extended (Otto, Wood). Identification of new customer needs leads to the development of new product (Paolo Rissone, Gaetano Cascini). A product development is said to be successful, if the product fulfills the needs and the requirements of the customers, generates profits to its shareholders and creates value to its stakeholders. Similarly, it can be said that, the two main characteristics of a product development project are its quality and profitability, where "quality" represents how well the product satisfies the customer needs, and "profitability" represents how much profit it can generate with limitation of budget and time schedule (Bing Liu, 2003).

So, for the principles of product development, it has been found out that there is no set procedure for product development and involvement of people from different walks of life is a must. Now, let's see how the product development gets affected by the opinion and experience of developers.

Product Development and Design: Previous Experience and Opinion of the Developers

Due to rapid change in technology and availability of software, almost all the designers develop the products with same technological features; it is difficult to differentiate between them. Therefore, the presentation of the product through advertisement aims to hit the emotional benefits of the customer and based on it they purchase the product (Pieter Desmet).

A well defined design process helps in developing the new products in minimum duration and minimum costing. Developing the product in minimum duration allows the manufacturer to push the product in market at a faster rate (8 Derrick Tate, 1999). For any organization, product development is a normal routine activity and it is taken as to be performed for large scale production (Charles Owen, 1998).

Researchers have realized that for traditional products, product design process is not a complicated process and can be achieved by any experienced design engineer using any design technique. Designer should have an exposure to shop floor to understand processing technology, understanding of performance of production equipment, skill for operating production equipment, and production process. Marketing experience will be an added advantage to understand the needs and expectations of the customers. Price of a product also affects the launching and success of the product in market, Therefore sufficient attention should be paid to optimize the cost during the development stage (Zhihai Zhang, 2000).

As success of the product brings advantages to the organizations; product design should be viewed from the point of view of promotions and selling for the customers instead of as an innovative thing (Maria Candi, 2005). To attract the customers, aesthetics is given more weightage then the design principles. Designers want their work to be appreciated. But, the same aesthetic aspect of the product may have a different appeal to different customers in different ways as the customers' social characteristics and personal experience varies. Designer should be able to justify the aesthetic requirements of the product by the manifestation of the product. The design elements such as shape, size colour, texture, unity, mass balance are some of the features for giving aesthetics to the product. These elements with composition and physical properties enhance aesthetic appreciation (Ernest J. J. Van Breemen, 1999). Designers themselves are not the users, and they design for an organization to manufacture. The manufacturers are also not the typical users as they are manufacturing it for the customers. The involvement of the customers in product development has never been given importance (Roger Hall, 1997).

Product designer should give priority to the basic functional requirements, expected in the product along with quality characteristics. Better quality gives an edge over the competitors, giving the overall advantage to the firm (Zhihai Zhang, 2000).

A well defined target group of the customers, for whom the product is designed, should be clearly targeted. The awareness for the same should also be created. Because the needs, wants and requirements are different for different age groups, genders and class. This would result in a successful product development policy (Jenny Janhager, 2005).

So, it can be said that the experience of the designer regarding a particular field has led him to make an opinion about the importance of the field during the product design. The involvement of customer has been realized. In the following section user/customer centered design approach is discussed.

User (Customer)-Centered Design

If the user is involved in the design and development process of the product before hand, their requirements can be easily included and the difficulties faced by the user in a manufactured product can be easily eliminated. There are so many studies, which support this concept.

In 1980s, the concept of user centered design was taken as a varied concept. There may be many different perspectives of user involvement in the design, which can better be defined by the the role of user in the design process. In the first type, user is a subject for whom the design is being done. In second case, user is contributing in designing. In third case, users are customizing local design to modify some features which will not change overall design (Roger Hall, 1997).

Figure 2: Three Forms of User Centered Design

The approach of the design process should be like design by the user, instead of designing for them (Roger Hall, 1997). According to S. Teeravarunyou the framework of user centered design should be as follow:

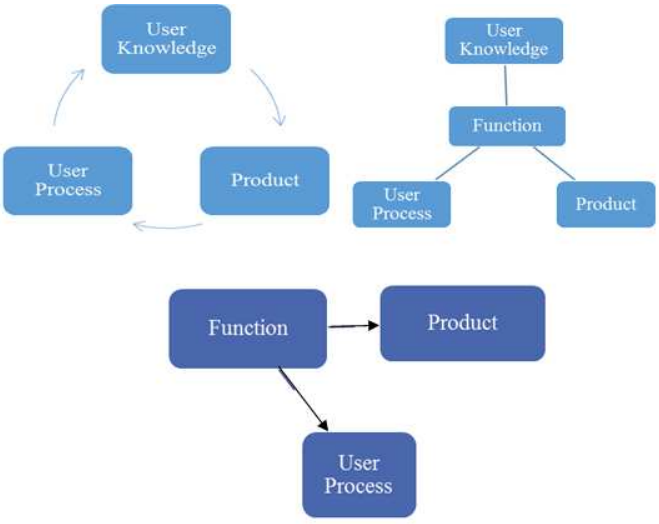

Figure 3: Design Process Framework (S. Teeravarunyou, K. Sato, 2001)

User centered design has many versions – all are equally usable, but cannot be combined to form a standard model. For instance Shackel refers to five types of design approaches each involving the user in a different way or role:

- Consider user and tasks since beginning
- Participation of user in design team
- User is involved for the trial run of prototype.
- Stringent norms of usability are defined in advance and trial runs are carried out till the satisfactory results are achieved.)
- User manuals or online support etc. are provided to assist the user (Rogger Hall, 1997).

Almost during the same time, when Shakel proposed the model of user involvement in product development and design, Gould also argued that for a good system design the four principles of system design should be followed

- Early - continual focus on users: This can be done by interviews, observations, participative design etc.
- Target group of customers are allowed to use the product and their reaction is observed
- Continuous assessment and improvement process to attain the set norms)
- All the aspects of usability of the product, as thought by the designer are developed simultaneously. Although there are many ways and approaches for product development, but still a standardized method is not available to integrate the various approaches suggested by different researchers (Jenny Jahangir, 2005).

Making a physical presentation of a thought is considered to be the most important, but difficult task in the creative process. Communication between designer and user is shown by reference to Figure 4, which shows the *design model* (the designer's conceptual model) and the *user's model* being linked through the *system image* (the visible interface of the product). If the system image does not make the design model clear and consistent, then the user will end up with the wrong mental model (Roger R Hall, 1997).) Therefore, a feedback is a must from the users, shown as feedback from the user.

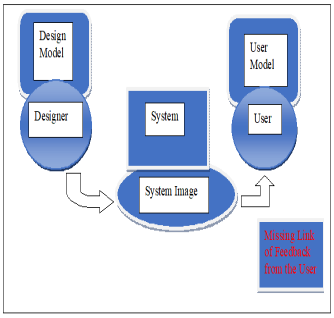

Figure 4: Designer - User Interface

If a user can interact with any product successfully, without ant interruption and understands how he has interacted with the product along with its consequences, then design is considered to be good (Maria Candi, 2005). The users accept or reject the product based on the usability aspect of the product. Usability features have higher effect on the customers for comparison of the products (Dr. Simo Säde, 2002).

So far, it has been found that the organizations approve the processes of product development and design, require the involvement of all involved disciplines. The process of product development is a subject matter of organizational policies and affected by the experience of the design engineers' experience. The involvement of user is important and methodologies about involving them are being developed. One of the ways to involve the users is by introducing principles of ergonomics in the product development and design. In the following section, the literature for product design in relation to ergonomics is discussed:

Ergonomics and Design

Ergonomics should be a part of Product design and designers should know about it. The product should not give any physical or mental stress to the user. Even if user initiates any wrong action, the product should not have any drastic effects on the user. The customer should be very comfortable and should have an intense internal desire to use the product (Otto and Wood). Ergonomics is dedicated to accommodate the people and product to improve their performance (Jan Dul, Harmen Willemse and Henk J. de Vries, 2003).

These days' ergonomics, designing and manufacturing are often separated from each other. Due to the advances in technology designing even a complex product has become an easy task. Although it requires inputs from several related areas of design (1 Remko W. Helms, 2002). It is the moral responsibility of the ergonomists to put a step forward and create a space for themselves in the field of product design (Jochim Vedder, 1999). If this space is not created then very soon ergonomics will be obsolete.

Big organizations have a trend, set for the routine engineering and manufacturing work. Although they find it difficult to move towards a new cohesive method which includes ergonomics even then they are now realizing the importance of the value added to the products due to good ergonomics (Hillary Carey et al., 2002).

According to Stanton and Young, more than 60 methods have been identified to integrate the ergonomics in product design. But these methods are indigenous and used by their developers only. There is a gap between designer and ergonomist also, because the suggestions of ergonomist are either not used by the designer or they are not communicated to him (Jenny Janhager, 2005).

If traditional principles of ergonomics are not followed, then new products may have some problems. One of the reasons is the deep down nature of technology itself. In a mechanical system, when one operates a system, the sound associated with the operation gives a feedback of competition of the job. For example, while operating the mechanical knob of the fan the sound associated with it gives unknowingly a feedback of the operation. This is a part of microergonomics. But, these days the feedback is unseen and mentle. Therefore, designers should develop some system for feedback.

To make the technology more usable, simple ergonomic principles like logical sequence of use, feedback of operation etc. should also be incorporated in new technology. Practicing and understanding of traditional ergonomic principles and applying them to the design of new technology will reduce the design flaws (Roger R Hall, 1997).

If the product is designed from the ergonomics point of view, then it is advantageous for Design for manufacturing. Similarly, ergonomically designed product will appeal to the end user as well. Hence, design and engineering both will be benefitted by the application of principles of ergonomics (J. Dula, W. P. Neumann, 2006).

If little extra is invested during the product development stage and ergonomics principle like Design for Assembly (DfA) or Design for Manufacturability (DfM) are included, then there will be less chances of corrections for assembly and manufacturing of the product. The cost associated with corrective ergonomics will also be eliminated.

As products are purchased on visible characteristics, ergonomics takes a back seat. Ward, a practicing industrial designer suggests that "Designers, engineers and others involved in the design process are largely unaware of the problems faced by users, and perceive user trials to be unnecessary or too costly". User trials during the development stage will provide hands on information about the users' experience. The designers should have user trials according to their proficiencies for better designs (Jan Dul Harmen Willemse and Henk J. de Vries).

Ergonomics is said to be an operational strategy for quality performance (J. Dula, W. P. Neumann, 2006). For good quality, ergonomics should be the functioning strategy. It should also be functioning strategy for producing the good quality product and services to the customers. In a study, it is found that good ergonomic jobs have multiple times better quality functions as compared to poor ergonomics jobs (Eklund J.)

So, it can be said that, ergonomics has to be part of product design and it will benefit the users. But, the ergonomists are still making efforts to get along with the designers to give the best quality products to the customers. In the following section, the literature on product development and design in relation to Total Quality Management is discussed.

Product Design and TQM

Now, the organizations are very much aware of the fact that for success quality is must. They use various TQM tools for product development, productivity and enhancing the customer satisfaction (Ross Chapman and Khleef Al-Khawaldeh). Quality should be imbibed in all functions, activities departments and people to make the organization effective. When all the stakeholders at every stage and interface strive for quality, then achieving the target of satisfied customers and better share in the market will be achieved easily.

If an organization promises for quality, then they should think from the point of view of customers, go for process orientation and always think for improvement. TQM requires an improvement in businesses operation strategies, and it should be reflected through actions and should be realized by the customers.

In a customer centered organization, attracting the customers from competitor will be easy, if the customers' ideas are given due importance. Many of the product designers incorporate the customers' ideas/suggestions in the product many a times. There are methods developed and available for aligning the design with customers' requirements. But, the customers are not the inventors. Therefore, it is difficult to find the right set of requirements. Also, the designers are made aware of the fact that incorporating the requirements of the customers may affect the market. When the customer needs are satisfied, then the customer becomes loyal to the company (Andreas Vollerthun, Eduard Igenbergs, 2000).

Therefore, it is one of the most important aspects of quality design to understand thoroughly what the requirements of the users are, what the constraints are and what the solution objectives are. The products' needs, requirements and specifications can be defined by a "user" only.

The literature elaborates the problem selected for the study that, if the product development and design is talked about, then the requirement of the involvement of all involved discipline and user is given importance. The literature for product design and ergonomics also shows that the users' involvement is mandatory as the products are for the users only.

Similarly, the literature for product development and design and TQM also talks about the involvement of all disciplines and the user for product development and design. Let's have a look at all those who are recognized as users or customers.

Who are the Users (Customers)?

The user/customers are lifeline of the business. They are not the barriers to work, but are the purpose of it. They are part of business and should not be considered as outsiders. The customer cannot be taken as a simple statistical terms who will be using product or services but they are human beings with flesh and blood who have feelings and emotions. They are the people who have needs and jobs. The customers have emotions, which are to be satisfied through the product. The customers need a product that's why he/she has come to you. If they do not turn up to you, loss will also be of yours. Any organization must know

- Who are my customers?
- What are their true needs and expectations? (dti)

CLOSURE

The crux of the problem lies in the fact that, those who know how to design give ergonomic features or quality products, do not come into direct contact with those who need something to be done. Designers understand the needs of Ergonomists in product development but incorporating them is not well defined. Even, it is found through the literature that a specific and standardized method is either not available or not being used by the designers. Therefore, they find it difficult to go for proactive ergonomics, which is the need of the hour.

Giving quality and winning the customers is the policy of many of the organizations. Through the literature, it is found that TQM provides with many tools which can be used for combining the principles of design and ergonomics. Some of them are Quality Function Deployment, Failure Modes and Effects Analysis, Concurrent Engineering, Reliability Analysis etc.

In the following section, a TQM tool House of Quality (HoQ) is developed for Air Conditioner. HoQ is a tool, which convert the requirements of the customers into the language understood by the manufacturers.

DEVELOPMENT OF HOUSE OF QUALITY (HOQ) FOR AIR CONDITIONER

Customers' Requirements

For the development of HoQ, the first step is to collect the opinion of the customers. To collect the qualitative Customers' Requirements, a questionnaire is developed for the customer survey to acknowledge the design ergonomic, and quality related requirements of the customers for the product i.e. Air Conditioner. For this, four attributes i.e. Aesthetics, Feel, Quality and Control are defined as primary customer requirement. Each attribute is subsequent by various characteristics, which are considered as secondary customer requirements. The questionnaire with the responses of hundred customers is given in Table 1.

Table 1: Questionnaire with Opinion of Hundred Customers

Attribute 1: Aesthetic Characteristics of AC					
	Very Bad (1)	**Bad (2)**	**Fair (3)**	**Good (4)**	**Excellent (5)**
Appearance		3	22	63	12
Shape	1	3	20	60	16
Size	1	6	31	50	12
Colour	1	4	16	57	22
Look	--	3	26	53	18
Attractiveness	3	3	32	48	14

Attribute 2: Feel Aspects Regarding AC					
	No (1)	**Less (2)**	**Somewhat (3)**	**Fairly (4)**	**Highly (5)**
Confidence	3	5	22	49	19
Pride	5	5	24	42	21
Reliability	2	2	16	48	29
Fun to Use	2	12	18	43	21
Simple to use	2	3	10	43	41
Gives good performance	2	3	15	46	34
Satisfaction of owning	3	3	16	42	36
Satisfaction with respect to Price	3	3	21	43	30

Attribute 3: Quality Characteristics of AC					
	Very Bad (1)	**Bad (2)**	**Fair (3)**	**Good (4)**	**Excellent (5)**
Performance		4	14	59	17
Reliability	Not Reliable (1)	Reliable (2)	Fairly Reliable (3)	Very Reliable (4)	Highly Reliable (5)
	4	12	24	47	13
Ease of use	Not Easy (1)	Less Easy (2)	Somewhat Easy (3)	Easy (4)	Very Easy (5)
	1	4	8	50	37
Safety	Not Safe (1)	Less Safe (2)	Somewhat Safe (3)	Safe (4)	Very Safe (5)
		2	7	66	25
Durability	Not Durable (1)	Less Durable (2)	Somewhat Durable (3)	Durable (4)	Very Durable (5)
	1	2	16	69	12
Stress while using the Product	Very Tiring (1)	Tiring (2)	Somewhat Tiring (3)	Less Tiring (4)	Not Tiring (5)
		7	6	34	52
Brochure and Documentation	Very Bad (1)	Bad (2)	Fairly Good (3)	Good (4)	Excellent (5)
	1	5	29	53	12
Noise while operating	Very Noisy (1)	Noisy (2)	Fairly (3)	Silent (4)	Very Silent (5)
		9	37	44	10
Vibrations while operating	Excessive (1)	More than Normal (2)	Normal (3)	Less than normal (4)	Very Little (5)
		6	34	22	35

Attribute 4: Control Features of Air Conditioner					
	Worse (1)	**Bad (2)**	**Fair (3)**	**Good (4)**	**Very Good (5)**
Appearance of remote	2	5	23	50	16
Shape of remote	2	8	22	53	12
Colour of Remote	3	5	20	60	8
Size of control buttons	1	6	27	46	15
Look of control buttons	2	7	29	42	16
Layout of control buttons	1	5	26	50	14
Labels marked on control buttons	2	5	20	52	16
Colour scheme used to distinguish control buttons		11	32	37	15
Adequacy of controls for different functions	2	6	32	50	6
Ease of operating controls	1	4	20	47	23

Manufacturers' "How"

To know the **Manufacturers "How",** the attributes are decided based on the requirement of integration of the principles of Design, Ergonomics and TQM. So, Design, Ergonomics and TQM are only used as the primary technical descriptors. Various tools of these primary technical descriptors are used as secondary technical descriptors. For example, for Design as primary technical descriptor; Design for assembly, Design for manufacturing etc. are taken as secondary technical descriptors.

Relationship Values

The relationship values are recognized as 9, 3 and 1, depending upon very strong, strong and feeble relationship for each secondary technical descriptor with every secondary customer requirement.

Customer Rating

In this study, the mean value obtained from the customer survey has been used as the requirement of the customers. An effort has been made to introduce a new group decision making approach. This approach takes into account multiple preference questionnaires and fuses different expressions into one uniform group decision. This value is used as the **Customer Rating.** The calculation is shown in table 2.

Table 2: Mean Value of Customer Rating for Appearance

Appearance				
Sr. No.	**Response Category**	**Total Score Group**		
		x	**f**	**f * x**
1	Excellent	5	12	60
2	Good	4	63	252
3	Fair	3	22	66
4	Bad	2	3	6
5	Very Bad	1	0	0
Total			**100**	**384**
x=S(f *x)/n			3.84	

Absolute Weight

The Absolute Weight is calculated for each secondary technical descriptor. It is the multiplication of customer

rating (calculated above), and the respective values of relationship matrix for the particular secondary customer requirement. Sample calculation is shown in table 3 a and 3 b.

Table 3 (a): Absolute Weight Calculation for Secondary Technical Descriptor Anthropometric Data

Customer Requirement		Technical Descriptors		Relationship Value	Mean value of Customer Requirement
Primary	**Secondary**	**Primary**	**Secondary**		
Aesthetic Characteristics	Shape	DESIGN	ANTHROPOMETRY	9	3.87
	Size			9	3.66
	Look			9	3.86
	Attractiveness			9	3.67
Feel	Confidence			9	3.78
	Pride			3	3.71
	Reliability			3	4.03
	Fun to use			9	3.72
	Simple to use			3	4.21
Quality	Reliability			9	3.64
	Ease of use			9	4.21
	Safety			9	4.14
	Durability			1	3.91
	Stress			9	4.32
	Appearance			3	3.76
	Shape			3	3.13
	Colour			1	3.71
	Size of control Buttons			9	3.72
	Look			3	3.68
	Layout			9	3.77
	Labels			9	3.79
	Colour Scheme			9	3.59
	Ease			9	3.92

Table 3(b): Absolute Weight Calculation for Secondary Technical Descriptor Anthropometric Data

Customer Requirement	Technical Descriptors	Relationship Value * Customer Requirement	Absolute Weight
Aesthetic Characteristics	Anthropometric Data	9 (3.87 + 3.66 + 3.86 + 3.67) =135.54	**594.12**
Feel		9 (3.78 + 3.72) +3 (3.71 + 4.03 + 4.21) = 103.35	
Quality		9 (3.64 + 4.21 + 4.14 + 4.32) + 1 (3.91) = 150.7	
Control Features		9(3.72+3.77+3.79+3.59+3.92)+3(3.76+3.13.3.68)+1(3.71)=204.53	

In the similar way, absolute weight for every secondary technical descriptor is calculated. The absolute weight for some technical descriptors is shown in the following table 4.

Table 4: Absolute Weight for Technical Descriptors

Sr. No.	Technical Descriptor	Absolute Weight
1	Design for Manufacturing	594.24
2	Anthropometric Data	594.12
3	Design for Assembly	557.05
4	User Friendly	481.08
5	Accuracy	437
6	Proportion	413
7	Creativity	402

Outcome of HoQ

Higher value of Absolute weight shows, the particular secondary descriptor should be addressed more for enhanced customer satisfaction. These values are highest for design for manufacturing, followed by anthropometric data and design for assembly. It means that a customer, who may not be aware of these terms have successfully put his demands for the features through a HoQ, a quality tool. The HoQ is shown in the following table 5.

Table 5: Hoq

		Primary Manufacturers' How																								
Secondary Manufacturers' How " Consumers' Requirements $		Design Tools													Quality								Ergonomics Tools				Customer Rating
		Design for Manu.	Design for Ass.	Creativity	Geometric Design	Form Variation	Visualization	Unity	Variety	Rhythm	Balance	Proportion	Contrast	Anthropometric Data	Efficient cooling	Silent operation	Safety	Minimum Maintenance	Material	After sales service	Absorb Current Fluctuation	User Friendly	Accuracy	Precision	Display output	
Primary Customer Requirement	Aesthetic																									
		Appearance	9	9	9	9	3	3	3	3	9	9	3	3				1		9			3			1	3.84
		Shape	3	3		9	3	3				3	9	3	9			3		1			3				3.87
		Size	3		9	3			3			3	9		9								9	3	3		3.66
		Colour			9		9		9	9	3	1		9						9				9			3.95
		Look	9	9	9	9	3	3	9	9	9	9	9	9	9			1		9							3.86
		Attractiveness	9	9	9	9	9	9	3	3	9	9	9	3	9			3		3			9	9	9	1	3.67
	Feel	Confidence	1												9	3	3	9	1	3	3		9	9	9	3	3.78
		Pride			9	3	9	9			3	3	3		3	9	3	3	3	3	3	1	3	9	9	3	3.71
		Reliablility	9	9											3	9	3	9	9	1	3	3	9	9	9	3	4.03
		Fun to Use			9		9		3	3	9			3	9	9	9	3	3	1	3	3	9	3	3	9	3.72
		Simplicity	3	3	9	9			3		9	3	9	1	3			1	9				9		1		4.21
		Gives good performance	3	3				3				1	1			9	3	3	9	3	1	3	9	9	9		4.02
		Satisfaction	9	9	3	3	1	9			9	3	9			9	9	9	9	1	3	3	9	9		3	4.05
		Satisfaction with respect to Price			9	9	3			1	1	1	1			9	9	3	3		9	3	3	3			3.94
	Quality	Performance	3	3				9				3				9	9	3	3		3	9	3	9	9	3	3.95
		Reliability	9	9				3						9	3	3	9	3	1	3	3		9	3	9	3	3.64
		Ease of use		3	3	1		1				3	9	3	9			3		1			9	3		9	4.21
		Safety	9	9	1	1		3				3	3	3	9			9						9	9		4.14
		Durability	9	9				3				9	3		1			9									3.91
		Stress while using the Product	3	3	1				3		9	3	3		9	1	9		1		1		3	1		3	4.32
		Noise while operating	9	9							3	9	9				9	3							3		3.55
		Vibrations while operating	9	9		1	1	1			1	9					9			3				3	3		3.89
	Control	Appearance of remote	9	9	3	9	9				1		3		3					3			3	3	3	3	3.76
		Shape of remote				3	3			1	1	1	3		3								1				3.13
		Colour of Remote						3							1					9							3.71
		Size of control buttons	9	9		3	3								9								3				3.72
		Look of control buttons	3	3		3	3			3	3	3	3		3												3.68
		Layout of control buttons	3	3		9	3				3	3	3		9			3					3	3	3		3.77
		Labels marked on control buttons	3		3		3								9			3					3	3	3		3.79
		Colour scheme used to distinguish control buttons										3	3	9	9					3					1		3.59
		Adequacy of controls for different operations	9	3																				3			3.87
		Ease of operating control buttons	9	9	9	3	9	9		9	9		3	9	9								3		3	3	3.92
		Absolute Weight	594.24	557.54	402	368.13	313.3	274.8	141	157	355	361	413	212	594.12	273.36	304.32	350	211.8	241	124.44	109.46	481.8	436.77	376	184	

CONCLUSIONS

TQM provides with many a tools, which can be used for incorporating the principles of ergonomics and product design. The HoQ is one of them, which has been used in the study for including the design and ergonomic demands of the customers for AC.

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