ADVANCING INDUSTRIAL ENGINEERING IN NIGERIA THROUGH TEACHING, RESEARCH AND INNOVATION

A BOOK OF READING

Edited By
Ayodeji E. Oluleye
Victor O. Oladokun
Olusegun G. Akanbi

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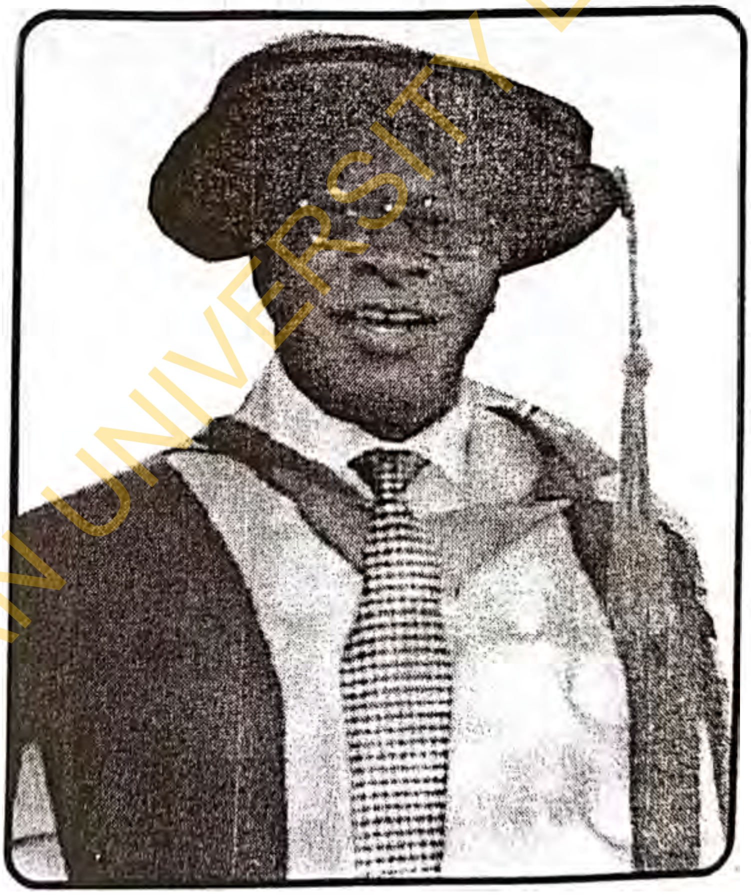
(A Festchrift in honour of Professor O. E Charles-Owaba)



Professor O. E. Charles-Owaba

Advancing Industrial Engineering in Nigeria through Teaching, Research and Innovation.

ISBN : 978-078-515-9

Published by

Department of Industrial and Production
Engineering
University of Ibadan.

Printed by:
Leading Edge Printers & Publisher
Ibadan

FOREWORD

It gives me great pleasure writing the foreword to this book. The book was written in recognition of the immense contributions of one of Nigeria's foremost industrial engineers, respected teacher, mentor, and lover of youth – Professor Oliver Charles-Owaba.

His commitment to the teaching and learning process, passionate pursuit of research and demonstration of excellence has prompted his colleagues and mentees to write this book titled – Advancing Industrial Engineering in Nigeria through Teaching, Research and Innovation (A Festschrift in honour of Professor O. E Charles-Owaba) as a mark of honour, respect and recognition for his personality and achievements.

Professor Charles-Owaba has written scores of articles and books while also consulting for a medley of organisations. He has served as external examiner to various programmes in the tertiary educational system. The topics presented in the book cover the areas of Production/Manufacturing Engineering, Ergonomics/Human Factors Engineering, Systems Engineering, Engineering Management, Operations Research and Policy. They present the review of the literature, extension of theories and real-life applications. These should find good use in the drive for national development.

Based on the above, and the collection of expertise in the various fields, the book is a fitting contribution to the corpus of knowledge in industrial engineering. It is indeed a befitting gift in honour of erudite Professor Charles-Owaba.

I strongly recommend this book to everyone who is interested in how work systems can be made more productive and profitable. It represents a resourceful compilation to honour a man who has spent the last forty years building up several generations of industrial engineers who are part of the process to put Nigeria in the rightful seat in the comity of nations. Congratulations to Professor Charles-Owaba, his colleagues and mentees for this festschrift.

Professor Godwin Ovuworie
Department of Production Engineering
University of Benin

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CHAPTER 14

Garment Sizing System: A Critical Review of the Past, Present and Future

Adepeju A. Opaleye[1] and A Kolawole[2]
[1,2] Department of Industrial and Production Engineering
University of Ibadan, Nigeria
[1]opaleye_adepeju@yahoo.com (corresponding author)
[2]kolawole_adekunle@yahoo.co.uk

1.0 Introduction

With the desire to remain competitive and customer driven, companies are fast adopting business models, programs and procedures to meet customer's volatile demand and shortened product lifecycle at efficient cost. Such business model includes mass customization and mass personalisation of products. They are fast becoming effective approach in many manufacturing sectors, such as the automobile, food, textile and garment, cosmetic industry because they offer opportunities for expanding the sphere of influence of a company, widening its customer base and production capacity.

Classically, mass customisation business model is described as the production of goods and services to meet needs of a defined market segment at a cost closer to that of the mass production system. It combines the economies of scale in mass production system with segmentation of market demand. Empowered by the internet, digital devices and social networks, customers are increasingly expressing interest in the design, and development of their product while powerful lever such as flexible computer-aided manufacturing system enable companies to customize or adapt standard products which meet many end users tastes and preference without inventory or purchasing delays. Thus, customers are not only treated as a market segment but as an individual entity. This process of personalizing requirements enhances prosumer's ability to determine their product specification but manufacturers are cumbered with challenges of reducing product life cycle, increased product complexity, and immense pressure from global competition.

The garment production industry is not an exception of such developments. The industry has one of the most complex and diverse products. For example, customers desire unique garment design and style specifications suitable to their unique body proportions, specific need, and personality. A report shows that Levi Straus and Co. offers women customised pants of about 49,000 different sizes in 30styles resulting in about one and a half million options available to consumer. In order to significantly impact and drive consumers' intentions in terms of willingness to repurchase, verbal referrals, commitment and loyalty, garment producers should adopt approach to meet customer's dynamically changing quality requirements without increasing shopping difficulty and confusion. Lamb and Kallal's (1992) proposed the Functional, Expressive, and Aesthetic (*FEA*) *Consumer Needs Model* which provide an overall conceptual framework for designing any type of garment. Consumer's f*unctional requirements include fit*, mobility, comfort, and protection; expressive requirements of a consumer provides an opportunity for the wearer to communicate his or her self-image while the aesthetic requirements are related to appeal of a clothing product in terms of style, colour, appearance, fashionability or attractiveness (Chae, 2017; Kasambala *et al*., 2016). Consumers are most likely attracted to garment items which satisfy all their intended requirements. However, according to various consumer and designer-mediated perspectives, inappropriate sizing and fitting system often result in return of the garment that they have been purchased (Connell, *et al*.,, 2006; Otieno, *et al*.,, 2016; Shin and Damhorst, 2018).

Almost every industrialized nation has home-based garment sizing system for each garment type. For instance, there are Canadian Standards, German sizing system, European, American, Japanese, Korean, Chinese, etc (Gupta, *et al*., 2006; Lee, 2014; McCulloch,*et al*., 1998; Tryfos 1986). Essentially, a sizing system takes garment-related anthropometric data from a sample of individuals in the nation's population as input to produce a number of garment sizes such that each size is for a subset of people who wear the same standard garment size. Thus, instead of dealing with fifty million (50,000,000) sizes for, presumably, fifty million (50,000,000) people in a nation; a tailoring industry may sew only twenty (20) standard sizes, for instance, to adequately cater for the millions (Mpampa, *et al*., 2010). Each size (a table of garment dimension values), may now have enough demand (2,500,000 potential customers in our case example). The goal of a sizing system is to provide the optimum number ready-to-wear (RTW) garment sizes for a given population with good fit for all individuals (McCulloch, *et al*., 1998). The literature is however sparse on the existence of garment sizing system for the Nigerian traditional clothing industry. Perhaps, this explains the slackened growth of the industry.

At the moment Nigeria is unable to reap from the afore-mentioned benefits from RTW or mass customisation enterprise because it operates a "bespoke" garment manufacturing system. Tailors produce garment patterns by measuring the body size of individual patrons of the firm, and the fitting process involve physical try-on of garment along some correction steps that reflect wearer's responses to obtain a desired fit. Unlike this production system, online customers do not have the luxury of physically trying-on a cloth and have to rely on the product image and the available size charts to select a product that fits well. As a result, they find it difficult to get garment of excellent fit. When such problem occurs in mass customised or personalised online orders, it can result in more problems than for ready-to-wear garment in mass production. While mass produced garment items can easily be sold to other customers, it may be difficult to sell personalised garment orders because it had been customized to the design, style and size of original orderer (Kim *et al*., 2019) . This may lead to increase in production costs and inventory management problems. Therefore, research on sizing and fit preferences is very necessary in order to deliver the bespoke customer experiences in the garment mass customisation and personalisation of Nigerian designs, thereby improve customer satisfaction percentage.

2.0 Overview of the Garment Sizing Problem

Garments are primarily worn to provide shelter, warmth against harsh weather change and it is secondarily worn to give beauty and a sense of expression to the wearer. The application of the principles of cutting, sewing with the nitty-gritty of fabrics and skill results in the accomplishment of garment manufacture. There are criteria that cannot be overlooked in designing and making a fabric that would perfectly suit a customer and they include the type of fabric used, colour of the fabric, the style to be sown, accessories/aesthetic used with the fabric and anthropometric measurement of the consumer. Psychological and social factors are also key factors that can be categorized under the significance of a garment. Garment has over time been used as a means of expressing oneself and a way of portraying social importance (Johnson, *et al*., 2014). According to Festinger (1954), human being get satisfied with the opinions made by other persons which can be consciously or unconsciously; Biolcati (2019) also highlighted that the approval of physical appearance of an individual by other persons most likely yields an increase in their self-esteem. Hence, effect of a garment fit on consumer's appearance and subsequent self-esteem may determine consumers' intent to repurchase a garment size.

Earliest garment sizing systems were dependent on the tailor's very own understanding and first showed up in pattern books before the end of the eighteenth century (Aldrich, 2000). These sizing systems utilized the corresponding scaling technique. The interest for armed force attire brought by wars during the nineteenth and twentieth hundreds of years quickened the production of ready-to-wear (RTW) dress and constrained the improvement in size structure. The proportional scaling technique did not precisely address the issues of the market. During the second half of the twentieth century, sizes started to be created from body estimations utilizing statistical strategies (Aldrich, 2000). From that point forward, anthropometric overviews have been led, and sizing standards have been published in various nations.

A sizing system can be characterized as a lot of pre-decided body sizes assigned in a standard way (Winks, 1997) which highly depends on the body measurements taken on a cross-area of the objective population. Winks (1997) implied that the system comprises of a scope of sizes from the smallest to the biggest with fixed interims between nearby sizes. The production of ready-to-wear garments categorized into various sizes has changed fashion from the era of tailor-fitted garments to mass-produced garments (Burns and Bryant, 2000). There are two major issues relating to garment sizing; the classification and measure of fit. Classification relates to identification of criteria required for distributing the target population into size groups. The classification procedure plays an essential role in assessing when a garment is wearable by a consumer or not. On the other hand, the fit is a measure of how well the consumer fit into the assigned group (Xia and Istook, 2017) . However, the latter remain the most important problem in the garment industry and a recurrent issue in the literature. It has been observed that fit problem is a difficult concept to research and analyse as the relationship between body and clothing is complex and often ambiguous (Loker *et al*., 2005).

2.1 Techniques for Garment Sizing

There are various approaches reported in literature that have been applied in solving garment sizing problem.

2.1.1 The Earliest Method

The general approach includes individual craftsmen perspective to solving clothing problems i.e. fitting to individual. It is also called 'haute couture" approach. This is common in the early 18th century, when all attire was handmade and fitted to each client. Professional tailors measured the body measurements of each client, and after that drew and cut the patterns for each piece of clothing and each client. After numerous unique designs were collected, tailors found relationships between body measurements, notwithstanding of individual differences. Tailors slowly created these patterns into a framework of attire production to make dress for individuals with comparable figure sorts (Hsu *et al*., 2007; McCulloch, *et al*., 1998).

The first sizing system reported in 1941 was based on bivariate classification of about 15000 women according to their hip and bust measurement. This was to ensure sizing uniformity in the garment making industry. Continuation of the work resulted in an empirical sizing system known as the Commercial Standard (CS) 215-58 reported in 1958. This modification of the initial system was based on various manufacturers' experience through trial-and-error. By the year 1970, another empirical sizing system known as the PS 42-70 Standard of the USA was developed using military anthropometrical data and a "trial-and-error" approach. CS215-58 and PS 42-70 sizing systems were based on out-of-date measurements taken at 1941 (Ashdown, 1998). ASTM D5585-94 is another system developed in 1994 by the American Society for Testing and Materials (ASTM) based on the experience of garment designers and available market information. The first national anthropometric study in Europe started in the twentieth century. The Polish cloth sizing table based on anthropometric measurement of about 180000 was first reported in 1982 and later republished in 1997 while that of the Czech Republic was based on anthropometric measurement of about 400000 persons. These serve as an anthropometric data source for many scientific and industrial researches.

However, as the living and medical condition of people begin to improve, there is a significant change in human growth and development in these countries and a significant change in the 21st (twenty-first) century human shape and silhouettes proportion.

2.1.2 Multivariate Statistical Technique

Roebuck (1995) and Beazley(2001) described steps involved in sizing systems to comprise among others, selecting appropriate body anthropometric data, select key dimensions and establish number of each size necessary to outfit the intended users' population. This procedure has been adopted in more contemporary study relating to garment sizing problems.

Perhaps, the first multivariate approach to garment sizing was achieved by Salusso-Deonier (1982) using the principal component analysis (PCA). The principal component analysis is a method used to discover the control variables in research; create a basis for classifying the population after identifying the key body measurements in the undertaken study. This approach is valuable in distinguishing the basic body or the fit affecting measurements that can frame the basis of size chart advancement. Salusso-Deonier (1982) considered anthropometric measurements of adult females over fifty five years old. The data analysis showed that there are two important variables; one represent body laterality such as body girth and width while the second represent body linearity such as heights and lengths. A similar study by Gupta and Gangadha (2004) shows that the bust and the hip measurement are key dimensions for the upper body and the lower body garment out of the twenty-one anthropometric data considered. The developed size charts accommodates 95% of the Indian adult females. The model was validated using aggregate loss of fit index. Also, Veitch, *et al*.,(2007) used PCA to consolidate twelve anthropometric measurements into the two primary central components for laterality (fullness) and linearity (length). The anthropometric data used consist of 54 measurements of 1265 Australia adult females. The classification results in 36 different size groups. This maximizes information pertinent to setting up a size and shape specification for the production of a bodice. Loker *et al*. (2005) applied both statistical and visual analysis methods to improve the garment fit of an existing sizing system of a garment company. In another study by Zakaria *et al*. (2008), multivariate statistical analysis technique was used to explore patterns in anthropometric data and develop a size system. The authors surveyed data of 629 schoolgirls aged between 7 to 12 years belonging to three different ethnic groups, namely, Malays, Chinese, and Indians. Mason *et al.*, (2008) considered sizing by identifying unique body shapes. The analysis of variance (ANOVA) and anthropometric data from female teachers in Africa was used. Esfandarani and Shahrabi (2012) also used principal component analysis to identify variables which partition a heterogeneous population into smaller homogeneous groups. The obtained size chart was evaluated using the aggregate loss of the fitness method. Xia and Istook (2017) considered integration of natural log-transformation, principle component analysis, multivariate linear regression, size range determination, and measurements calculation for developing the sizing system. Both the residual variance analysis and factor analysis are also multivariate techniques similar to the PCA.

According to Salusso-Deonier (1982), the effectiveness of body shape classification technique is highly dependent on the selection of the key body dimensions.

2.1.3 Optimisation Techniques

Generally, optimisation technique is a mathematical expression for the quantity to be maximised or minimised such as minimum number of size groups and maximum fit. The size optimisation method develops the optimum sizing system with the availability of anthropometry data and its framework is based on mathematical model of garment fit.

Gupta *et al*., (2006) applied three different solution approaches to the linear programming formulation in order to cluster a given population into homogenous body size groups. In the linear programming model, the constraints and the objectives are describeable by relationships which are straight line or linear type. The desired degree of fit is considered a basis for clustering individuals into size groups and exact number of people covered by the system can be determined. Tryfos (1986) in his work recommended the integer programming approach to optimize the number of sizes of a manufacturing clothing company or shoe company so as to maximize anticipated sales or minimize a record of aggregate distress. He partitions the space of body measurements artificially into a set of discrete conceivable sizes and specify a tolerance value for each critical dimension. For example, if a waist tolerance is± 1, a size of 30inches will accommodate customer having a waist girth between 29 and 30 inches. The problem was formulated as a "p median" or "Facility location" problem. Ashdown (1998) and McCulloch *et al*., (1998) focused on the developing a sizing system better than the ASTM D5585-94. The goodness of the fit experienced by a customer upon wearing a particular size is mathematically captured as a distance between the body measurements of the customer and the dimension of the prescribed size. The larger the variation, the worse the fit of the final garment. A non-linear optimisation technique, "aggregate loss of fit" and the PCSS method was considered as a solution procedure. The non-linear optimization strategies were utilized to infer a set of conceivable measuring systems from anthropometric information. Results appeared that measure assignment as well as the capacity to identify non-accommodated people leads to significant changes in fit over existing measuring frameworks. However, like any other mathematical optimisation problem, increase in the number of constraints may increase model complexity and compromise the performance of these sizing systems.

2.1.4 Data Mining

Increasing use of automatic data collection and storage system necessitates the use of data mining in many areas of science and engineering research domains. Specifically, the clustering methodology for garment sizing problems is a method of organising data based on their relative distances into clusters or natural groups. Clustering is also known as an unsupervised method of mining data which do not depend on any presumption common in statistical strategies.

Hsu *et al.*, (2007) integrated Ward's minimum variance method into the K-Mean technique to cluster eleven anthropometric data of 956 adult females in Taiwan. The Ward's minimum variance method was used for the first hierarchical clustering while the K-Mean was used for the second non-hierarchical clustering. In a similar study by Viktor *et al* .,(2009), the body scanned data was clustered into five clusters. The author stated that clustering technique must account for interrelationship between anthropometric data to obtain good clusters. Opaleye *et al.*, (2019) considered a fuzzy based clustering methodology for sizing adult male trousers. This clustering differs from the hard-clustering method by its nonlinear nature and the flexibility of gathering large data in a disciplined manner. It gives more precise and close-to-nature solutions for partitions and in this suggests more possibility of solutions for decision-making.

Simbolon (2014) deployed the principal component analysis and fuzzy c-means clustering to create a sizing system for Indonesia adults using anthropometric data of 912 adults. Hamad *et al*. (2017) defined an exhaustive methodology to obtain a clustering of human morphology shapes representative of a population and to extract the most significant morphotype of each class. The fuzzy clustering technique is applicable in sizing due to vagueness in classification of body types and imprecision in anthropometric measurement.

2.2 Issue of Garment Fit

The success of any scheme used in the process of sizing is dependent on the extent to which the scheme satisfies the intended function and fit requirements of the item. All consumers want the best fitting clothing item so they select a size close to their anthropometric measures, try it on and purchase or reject the item. A nice design or expensive fabric is of no use when the clothing item do not appropriately fit. In the study by McCulloch *et al*. (1998), the sizing system was formulated for the Misses subpopulation in USA. The researchers noted that the common practise of using one or two key body dimensions does not provide a good fit for populations with large variations in body proportions. Therefore, the non-linear optimization method was formulated as a multivariate sizing system and the fit defined as a measure of the proportional difference of an individual to a prototype (ideal) size. This approach provides a mathematical description of the goodness of fit. Individuals within a defined "cut off" for garment dimensions are automatically assigned into a size group. Ashdown (1998) defined the average of all discrepancies over the given garment dimensions from a specified size as the aggregate loss of fit. This represents how well the sizing system performs in fitting the population. The researchers found that optimized sizing systems better accommodate population with large variation in anthropometric measurement. Gupta *et al*., (2006) also defined a fit function within which certain proportion of the target population will be accommodated.

Similarly, the concept of grouping based on similarity of parts was adapted by Kolawole (2016). A customer pair-wise fit (CPF) model for quantifying degree of fit was formulated using garment sizing variables customer anthropometric dimensions and customers' tolerance for garment dimension. The fit is considered as a measure of the absolute difference of an individual to an ideal size and tolerance as the numerical value of space that a designer can add or subtract from the value of a particular dimension without hindering the fit of a garment to a set of customers. Given the tolerance, it was found that perfect transitive set of customers will be accommodated in the same size group. The cut-off, fit function and tolerance are synonymous to ease allowance as used in clothing and textile related research. The authors suggest quantitative frameworks for fit estimation; however, none of these researchers provide a clear rationale for quantitative estimation of ease allowance.

3.0 Quantification of Ease

Researchers have established that fit is a function of the interaction between body measurement, design/style parameters with the addition or subtraction of an extra dimension, which is commonly referred to as ease. Traditionally, ease estimation during pattern construction is based on practitioner experience without an explicit communication on how ease may be established, or what contributes to its determination. Without clear information and data on ease estimation, emerging CAD/CAM virtual fitting rooms required for online shopping of ready-to-wear, mass customisation or personalisation of clothing items will be practically impossible.

Theoretical description of ease is based on two definitions of radial ease allowance (REA) and girth ease allowance (GEA). REA is the distance between the body and the cloth surface measured from the same centre while GEA is the additional girth measurements in a garment that were in excess of the basic body dimensions. Ease can also be defined in terms of measured numerical difference between the garment dimension and wearer's anthropometric measurement at all points of their relationship. It accounts for other interdependent factors which in turn affect fit satisfaction. In practice, there are three types of ease; standard ease, dynamic ease and fabric ease. Standard ease is the difference between the maximal and minimal perimeters of the body while sitting or standing. Dynamic ease provide enough space for various body movement such as walking, running and jumping while fabric ease takes into account mechanical properties of the fabric used. As such, optimal quantification of ease is a trade-off between many factors which includes; wearer's body shape, style, fabric used, wearer's motional and aesthetic satisfaction (Y. Chen *et al*., 2009; Kim *et al*., 2019). Some research efforts towards the quantification of ease have been made.

Ashdown and DeLong (1995) investigate consumer's threshold of fit based on participant tactile responses to ease variation using sensory evaluation technique. Custom- fitted pants were made for the four participants as the control pant and fourteen other pants varied independently between ±0.5 and ±1.0 for the waist, ±0.5 and ±1.5 for the hip and ±0.5 and ±1.5 crotch were used as the test pants. The test pants were similar in style and fabric material to the control pant except that they were either smaller or larger at one of the identified dimensions. Statistical analysis of the experiment show that all the participants perceived variation at more than one dimension. However, further investigation shows that no consistent interactions exist between the actual and the perceived point of variation. The authors also noticed the operation of kinesthetic after-effects in their perception as participants were unable to recognise the control pants more than 42% of the time. The kinesthetic after-effects may also have effect whenever the difference between the test pants and the control was small. Frackiewicz-Kaczmarek *et al*., (2015) suggest a similar evaluation approach for tight, regular and loose shirt, jersey, undershirt and interlock undershirt. They used the factorial analysis of variance with Levene's test for homogeneity of variance to determine factors influencing the distribution of the air gap thickness and the contact area in selected garments, such as overall garment fit, garment style, body region, and fabric type. The author noted violation of model underlying assumptions. As a result, the statistical analysis conducted was not reported.

Chen *et al*., (2006) also propose a method of optimising ease allowance of a garment using a combination of fuzzy logic technique and sensory evaluation. Vertical body measurement and girth body measurement critical to garment design were selected using data sensitivity based criterion. These two features and the participants' sensory evaluations for comfort degree were used as inputs to the fuzzy methodology which permit automatic pattern generation to improve the wearer's fitting perception of a garment. An extension of the work proposed in (Yu Chen *et al*., 2008) and (Y. Chen *et al*., 2009) suggest an aggregated ease allowance using an ordered weighted averaging function. The OWA weights are based on garment design and designer's criteria on textile comfort and estimation of the ease allowance was based on some fuzzy rules extracted from the learning data.

Wang *et al*., (2006) and Kim (2008) proposed ease estimation by measuring difference between garment size and human body size separately at specified segment of the body circumference. Wang *et al*., (2006) further developed a mathematical model of ease distribution using surface fitting approach in order to predict ease of X-lined jackets at different point of measurements. Petrova and Ashdown (2008) proposed a body-location based estimation method. Garment ease at different dimension points was measured using the 3D scanned data. The authors observed a decrease in ease as body size increases but a statistical relationship was not suggested. Choi and Kim (2004) used a linear distance approach using the GEA for ease estimation in order to compare two different pattern making methods for women clothing. Subjects who have nearly the same body size were selected for the study. In the result of analysing the space between skin and clothing of each pattern by 3D Scanner, there exist significant differences in the chest and bust parts of the pattern considered. A similar method of ease allowance estimation was proposed by Wang *et al*., 2007; Kin *et al*., 2011 and Su *et al*., 2015.

Perhaps the most interesting approach is by Kim *et al*., (2019). They developed a linear regression model to estimate preferred ease allowance for a popular type of male jacket among male adults in South Korea as of

2014. Six different models were developed for preferred ease allowance on seven different parts measured on the jacket. Ranges of estimated ease allowance were obtained by inputting body size measurements of 62 male customers which showed the highest correlation with the preferred ease allowances. However, the complexity in the relationship between body and garment dimensions renders a straightforward estimation of ease inappropriate. Results of the statistical regression models may be inaccurate, most especially when there are difficulties in verifying distributional assumptions and relationship between the dependent and independent variables is vague.

4.0 Size system validation

Gupta and Zakaria (2014) highlight measures of evaluating a good sizing system which includes; cover factor, aggregate loss and size roll.

The cover factor is the percentage of sample accommodated under each assigned size within a sizing system. The researchers noted that the systems must accommodate between 65%–80%, of the target population. The higher the number accommodated by the system, the better for manufacturers. The aggregate loss is a measure commonly used by researchers for the validation of proposed sizing system (Gupta, and Gangadhar, 2004; McCulloch, *et al*., 1998). It is the Euclidian distance of the wearer's actual body dimensions to the assigned size. If the size fits the wearer well, then the distance from the assigned size to the actual size is said to be minimized. This an index of the absolute value of fit. According to Gupta and Zakaria (2014), the benchmark for an accurate sizing system is an ideal value of aggregate loss calculated as $2.54n^{1/2}$, (metric in centimetres) where 'n' is the number of key anthropometric dimensions used to segregate the target group. If the actual aggregate loss is less than the ideal, the system is considered good for the target population. The size roll on the other hand is simply the total number of sizes obtained for a sizing system, from the smallest to the largest, with fixed intervals between adjacent sizes. The more the number of sizes, the better the fit but the more customer's confusion in size selection.

Therefore, a trade-off between number of sizes and goodness of fit may be required for optimum size roll. Kolawole and Charles-Owaba (2018) proposed a percentage degree of fit index similar to the aggregate loss of fit. The proposed percentage degree of fit measures the degree (or percentage) to which a certain sizing system “satisfies” the target population. Evaluation of the percentage degree of fit for a sizing system ranges from zero which implies poor fit (no member of the group can wear same size) to 100 which implies perfect fit (all member of the group can wear same size). The measures of fit index enhance the process of individual and group validation of sizing system.

5.0 Conclusion and Future trends

The importance of an effective garment sizing and fitting mechanism to the mass production, mass customisation and personalisation system production systems has been emphasized. Conventional sizing system produce garments in sizes that can accommodate a majority of customers within a set of fixed sizes and it enhances the process of fitting garment to the consumer without which the overall objective of garment production cannot be met. The progressively evolving methods of producing a sizing system impact the efficiency of that sizing system. Methods ranging from simple bivariate classification, statistical techniques, multivariate techniques, mathematical programming techniques, data mining techniques and artificial intelligence techniques have been considered. This was made possible by the experience of more than 70 years of exploring and understanding how to develop sizing systems that are efficient for manufacturers, customers and retailers. Research shows that a good sizing system must be developed based on the knowledge of fit and cater for the actual body sizes and shapes of the target population. Gupta and Zakari (2014) and Kolawole and Charles-Owaba (2018) highlight measures of evaluating a good sizing system which include; cover factor, aggregate loss, size roll and percentage degree of fit.

Given the research discoveries and the weaknesses of different sizing systems, researchers are finding better ways of developing sizing systems and reduce fit problems by adopting advanced data mining, artificial intelligence methods and computer aided design technologies. It is anticipated that newer systems which integrates customers' preferences will produce better sizing systems resulting in a greater goodness of fit for clothing customers. Proper implementation of garment mass customisation and personalisation model will require determination of ease from customer's perceptive. Such model may not be generic as ease allowance is a function of design type and fabric. However, estimation of ease may be determined as a function of customer's willingness to pay for certain garment item with measurements slightly different from their anthropometric measurement of a particular design. An integration of fuzzy concept to account for imprecision in ease estimation and vagueness in body-garment relationship may also be a solution approach. This is very important to garment designers, manufacturers and retailers, as an effective system means that they can produce optimal sizes of garment which satisfy a larger percentage of customers and their fit requirements.

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