Improving the Quality of Medium Scale Enterprises in Nigeria Using Taguchi Method: The Fashion Industry

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ABSTRACT

This work involves the improvement of the quality of dressmaking in a medium-sized business in Nigeria. To investigate the quality characteristics of dresses in relation to the specific objectives, Taguchi's orthogonal array, signal-to-noise ratio, and analysis of variance (ANOVA) were used. Three factors were identified in the analysis: fabric type, drawing-cutting duration, and sewing speed. As a result, an appropriate L9 orthogonal array was chosen, and experiments were carried out. The results of the experiments revealed that fabric type has the highest signal to noise ratio of 77.7742 at level 3, drawing and cutting has the highest signal to noise ratio of 77.9484 at level 3, and sewing speed factor has the highest signal to noise ratio of 79.4155 at level 2. Furthermore, the highest mean signal to noise ratio of fabric type is 25.9242 at level 3, drawing and cutting duration is 25.9828, and sewing speed has the highest average signal to noise ratio of 26.4718 at level 2. The analysis of the results obtained by ANOVA shows that, sewing speed has the greatest influence on dress quality (38.7 percent). To improve the quality of the manufactured product, the parameter setting recommended in this study is A3B3C2 and the Taguchi model should be used both in the beginning and end of the dress production process.

Keywords: ANOVA analysis, Orthogonal Array, Production cost analysis, Signal to noise ratio, Taguchi Method.

1. INTRODUCTION

Organizations in today's world face growing challenges from global competition and more sophisticated customers in terms of what they want and changing needs. The ever-increasing global competitiveness of the business environment has compelled corporations to devise strategies for becoming low-cost producers while also differentiating their goods and services from their competitors. Quality reduces costs and becomes a powerful product differentiation to customers through customer-focused quality programs [1]. This paper is tailored along these lines,

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and it seeks to assess the level of awareness of quality management practices among Nigerian small and medium-sized enterprises (SMEs). Small and medium-sized enterprises (SMEs) are modern economies' lifeblood. In terms of job creation, income generation, and ensuring equitable distribution of limited resources, SMEs play a unique role in a country's industrial development. Unfortunately, despite the fact that SMEs account for the vast majority of Nigerian businesses, the performance of the SME sector has been dismal in terms of economic development, contributing to the poor performance of larger businesses as well [2]. One of the most important phases for improving product quality is parameter design, which can also be referred to as robust design studies, controllable and non-controllable factors are the two types of control factors. Taguchi's experimental design is the most effective method for determining the effect of these factors. The Taguchi method is a new engineering method that ensures the improvement of quality in products and processes while keeping costs and resources to a minimum [3].

Medium-sized businesses are critical to economic development and account for a sizable proportion of business enterprises in Nigeria. Medium-sized businesses are a viable way to create jobs, alleviate poverty, and develop entrepreneurship, including indigenous technology, at a low investment cost [4]. Failures of medium-sized businesses in Nigeria have eroded the value these businesses add to the nation's economic growth and development [5]. As a result, it is critical to investigate the strategies used by medium enterprise leaders to sustain their business enterprises and increase their value added to the nation's economic development. Once the fashion design industry understands where they stand in terms of quality standards in comparison to their foreign competitors, the process of improvement can begin. It will be easier to find solutions if the fashion industries understand the reasons for their current state. However, regardless of the size of the business, quality is critical to its success. Although there is much evidence in the literature of research being conducted in established economies, it is clear that there is a limited amount of research being conducted in developing countries concerning Quality management (QM). According to [6], "a number of gaps in the literature on quality management in developing countries have been identified, along with significant challenges such as differing perceptions of quality." Therefore, in other to tackle this problem, it is needful to study on the application of Taguchi method to improving medium scale enterprises in Nigeria, using tailoring and fashion designing factory as a case study. The aim of this research is to improve the quality of dress making in a small- medium scale enterprises in Nigeria using Taguchi method. The specific objectives of the study are to; Investigate the factors that affect the quality of dress making in the medium scale enterprises using Taguchi techniques, determine the signal to noise ratio (S/N) of the medium scale enterprises using Taguchi techniques, Improve on the factors that affects the quality of dress making production of the medium scale enterprises using Taguchi techniques, Improving production stability of products in the fashion industry (medium scale enterprises).

2. RESEARCH METHODOLOGY

Data were obtained from the study area, which is the fashion/tailoring industry, for this research, which included their past production activities, types of cloths produced, quantity of cloths produced, time of production, quality rate, and cost of materials for production. Based on the findings of this study, the Taguchi optimization method was used in this research project to improve the quality of garments in medium-sized businesses.

2.1 Orthogonal Array

The orthogonal array is a matrix of rows and columns filled orthogonally with factor levels.
This orthogonal arrangement ensures that each and every level of each and every factor interacts with each and every level of every other factor. The maximum number of factors that can be studied is indicated by the number of columns in an Orthogonal Array [7]. According to [8], using an orthogonal array allows for a more reliable estimation of the effect of factors with fewer experiments. [9] Emphasizes Taguchi's recommendation for using orthogonal arrays when designing experiments. The orthogonal array solves the problem of dealing with the ever-increasing number of variables that must be considered. The L^9 orthogonal array was considered for this study.

2.2 Taguchi Method used Signal to Noise ratio (S/N Ratio)

This is used to calculate the variance from a design experiment. The S/N ratio is the mean (signal) to standard deviation ratio (noise). At each run of the experiment, the method for calculating the S/N ratio defends itself. The Taguchi Method converts three (three) characteristic values in Signal to Noise Ratio (S/N Ratio). These three values described various quality characteristics based on the problem's purpose. The S/N Ratio characteristic values are "Nominal is best," "Larger is better," and "Smaller is better." S/N Ratio is calculated for each level of process parameters based on S/N analysis; larger is better [10].

For “Nominal is the best”

$$\eta = \frac{S}{N} = 10\log_{10}\frac{y}{s^2} \quad (1)$$

Larger is better;

$$\eta = \frac{S}{N} = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y^2}\right) \quad (2)$$

Smaller is better;

$$\eta = \frac{S}{N} = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n}y^2\right) \quad (3)$$

In this research the quality characteristic used was larger is the better, which is the larger the defect products the better the result [10].

2.3 The S/N Ratio for the Individual Control Factors

The S/N ratio for the individual control factors are calculated as given [10]:

$Ss_1=(\eta_1+\eta_2+\eta_3)$,$Ss_2=(\eta_4+\eta_5+\eta_6)$ and $Ss_3=(\eta_7+\eta_8+\eta_9)$ (4)

$S_{f1}=(\eta_1+\eta_4+\eta_7)$, $S_{f2}=(\eta_2+\eta_5+\eta_8)$ and $S_{f3}=(\eta_3+\eta_6+\eta_9)$ (5)

$St_1=(\eta_1+\eta_5+\eta_9)$,$St2=(\eta_2+\eta_6+\eta_7)andSt3=(\eta_3+\eta_4+\eta_8)$ (6)

η_k is the S/N ratio corresponding to Experiment k. Average S/N ratio corresponding to fabric type at level 1 = $Ss_1/3$ Average S/N ratio corresponding to fabric type at level 2 = $Ss_2/3$ Average S/N ratio corresponding to fabric at level 3 = $Ss_3/3$ j is the corresponding level each factor. Similarly, S_{fj} and S_{tj} are calculated for drawing duration and sewing speed

2.4Analysis of variance (ANOVA)

The following are the procedures that will be used in the experiment:

i. Determine the signification parameters (ANOVA)-Analysis of variance [11].

The ANOVA is used to investigate and identify which processes have had a significant impact on the quality of dress sewing.

The analysis was used to determine which factors are most important in terms of quality improvement. Similarly, the important factors identified must be properly monitored during the experimentation process in order to consistently gather high quality dress making.

ii. Perform a main effect plot analysis to determine the best level of control factors.

iii. Carry out a factor contribution rate analysis

iv. Confirm the experiment and make plans for future applications.

Sum of square (SS) = $\sum_i^n (y_i - \check{y})^2$ (7)

Mean sum of square (MS) = $\sum_i^n (y_i - \check{y})^2/N$ (8)

3. RESULTS AND DISCUSSION

3.1 Results for the Analysis of Control and Levels of the Experimental Design

Table 1 shows the result of control factors and different levels of the dress manufacturing process being monitored from a small-scale medium enterprise.

Table 1: Control factors and levels of the experimental design

Process Parameters	Symbol	Level 1 (Low)	2 (Medium)	3 (High)
Fabric type	A	Light	Intermediate	Strong
Drawing and	B	40	60	80

cutting duration (min)				
Sewing speed (min/sec)	C	70	90	120

Tables 1 shows the three control factors that can influence the quality of sewing/manufacturing of dress and their respective level of interference in a small- scale enterprise. These control factors are fabric type, drawing/cutting duration and sewing speed. From Table 1 it was seen that fabric type control factor increases as the level increases from light to strong, for the drawing/cutting duration it increases from level one 40min to level three 80mim. Also, the sewing speed increases from level one 70m/s to level three 120m/s.

3.2 Result of Analysis of Experimental Layout using Orthogonal Array

Table 2 and 3 shows L9 (3^3) OA as was selected for the controllable factors which was the most efficient orthogonal design to accommodate three factors at three levels.

Table 2: Experiment Layout Using L9 (3^3) Orthogonal Array

Experiment No.	Control Factors		
	1	2	3
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

From Table 2 it was seen that the L9 (3^3) array specifies nine experimental run that was performed. This means that nine experimental trials with different combinations of the factors was conducted in order to study the main effects. Three controllable factors were identified which could affect the quality of the dress manufacturing process. There are three parameters with three levels each. The three controllable factors parameters which selected are fabric type, drawing and cutting duration (min) sewing speed (min/sec). It is decided to test each controllable factor at three levels.

3.3 Result for the combination process variables for experiment

The Table 3 shows the combination of process variables for all nine experiments that have been run.

Table 3: Taguchi L9 (3^3) orthogonal array design

Experiment Trial	Parameters Fabric type	Drawing and cutting duration (min)	Sewing speed (min/sec)
1	Soft	40	70
2	Soft	60	90
3	Soft	80	120
4	Intermediate	40	90
5	Intermediate	60	120
6	Intermediate	80	70
7	Strong	40	120
8	Strong	60	70
9	Strong	80	90

Table 3 shows the application of Taguchi in the dress manufacturing small scale enterprises**.** From experiment one (1) to three (3) fabric type is soft and drawing and cutting duration increases from 40minute to 80minute and sewing speed increases 70m/s. to 120m/s. Also, for experiment 4 to 6 the fabric type are all intermediate, the drawing and cutting factor still increases from 40mins to 80mins and the sewing speed of experiment 4 is 90m/s 5 is 120m/s and experiment 6 is 70m/s. thus, for experiment 7 to 9 the fabric type factor are strong, the drawing and cutting duration increases from 40min to 80min and sewing speed reduces from 120m/s to 90m/s.

3.4 Analysis of Main Effect plot for signal-to-Noise Ratio

The result for the analysis of main effect for signal to noise ratio is shown in Figure 1, 2 and 3. The main effect plot is a plot of the mean response values at each level of design parameter or process variables. The sign of the main effect indicates the direction of the effect, whether the average response value was increases or decreases. The magnitude indicates the strength of the effect. If the effect of a design or process parameter was positive, it implies that the average response was

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higher at high level then at low level of the parameter setting. In contrast, if the effect was negative, it means that the average response at the low- level setting of the parameter was more than at the high level.

Table 5: Average S/N Ratios for each Factor

Level	Fabric type		Drawing duration &cutting		Sewing speed	
	Sum (Ssj)	Avg S/N ratio	Sum (Sfj)	Avg S/N ratio	Sum (Stj3)	Avg S/N ratio
1	68.5386	22.8464	68.5723	22.8574	59.5078	19.8359
2	60.2136	20.0712	59.9954	19.9984	79.4155	26.4718
3	77.7742	25.9247	77.9484	25.9828	67.6031	22.5343
Difference	17.56	5.83	17.95	5.98	19.90	6.63
Rank	3	3	2	2	1	1

Fig 1 shows the result for the analysis for main effect for the signal to noise ratio of the experiment for the different fabric type. Based on this graph, it reveals that the trend of the fabric type is less significant than other factors. For fabric type, the S/N ratio is smoothly decrease between soft type to intermediate type and approach to the minimum of S/N ratio which then followed by slightly increase of fabric type of intermediate to strong.

Figure 1: Main Effects Plot for Signal to Noise Ratio of Experiment for Fabric Type

Figure 2 shows the results for the analysis of main effect for signal to noise ratio for the drawing and cutting duration. For drawing and cutting duration, the graph trend begins with slightly decreases between 40 minute and 60 minute of dress manufacturing process.

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Figure 2: Main Effects Plot for Signal to Noise Ratio of Experiment for Drawing and Cutting

Figure 3 shows the results for the analysis of the main effect for signal to noise ratio of the experiment for sewing speed. The S/N ratio value between 60 minutes and 80 minutes was squally increase and approach to the minimum of the S/N ratio value. The S/N ratio was slightly increased from 70m/s setting to 90m/s setting, but the S/N ratio was slightly decreases and approach to the mean line for 120m/s sewing

Figure 3: Main Effects Plot for Signal to Noise Ratio of Experiment for Sewing Speed

Figures 1, 2 and 3 show S/N graphs for the dress manufactured experiment respectively. Basically, the larger the S/N ratio shows the better the quality. Based on the Figures 1, 2 and 3, it can be described that the sewing speed was the main factor that influenced the quality of the output of the

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dress manufacturing process. It shows that the fabric type is the control factor that has the most significant factor. The effect of the other factors (a and b) is of less significance.

Also, the ranking in Table 3 show that S/N ratio of sewing speed, which has ranking 1, has relatively strong impacts and influence on the quality of dress. S/N ratio of fabric type and drawing/cutting duration which has ranking 3 and 2 respectively have relatively weak impacts. So, S/N ratio of sewing speed should be strictly controlled for high quality of dress during the manufacturing process. The effect of the other factors (A and B) is of less significant. Since the objective of this study is to optimize the dress product process, the S/N ratio should be maximal in order to minimize variability. Thus, factor c should be to set at level 2 in order to get the maximum result.

3.5 Analysis of Main Effect Plot for Means

Figures 4, 5 and 6 show the average S/N ratio values for the experiment at three levels setting of each factor and the effect of each main effect on the S/N ratio in respectively.

Figure 4 Main Effects Plot for Data Means of Experiment Fabric Type

Figure 5 Main Effects Plot for Data Means of Experiment Drawing &Cutting

Figure 6 Main Effects Plot for Data Means of Experiment Sewing Speed

Figure 4, 5 and 6 shows the mean graphs for the dress manufactured experiment. Basically, the larger of the S/N ratio is as the better of quality. Figure 4 shows the best levels for each control factors to obtain the ideal accepted of the dress artifact. Based on the graph, it shows that the trend of the fabric type was less significant compared to other factors. The mean is slightly decreased from soft type to intermediate type, but then slightly increased by approaching the mean line for strong type of fabric type. For drawing and cutting duration, the graph trend begins with slightly decrease between 40 minute and 60 minute of production process. The mean value between 40 minutes and 60 minutes is squally increase by approaching the maximum of the S/N ratio value. For sewing speed, the mean is smoothly increased between 70m/s and 90m/s by approaching the maximum of mean and follow by slightly decrease for sewing speed of 90m/s to 120m/s. Also, from the Figure 4, 5, 6, it can be described that the sewing speed was the main factor that influence the quality of the output of the dress manufacturing process. It shows that the sewing speed is the control factor that has the most significant factor. The effect of the other factors (A and B) is of less significance. Table 2 shows the average mean values for the experiment respectively at three levels setting of each factor and the effect of each main effect on the mean. The mean of mean values for the fabric type at level 1, level 2 and level 3 is 22.8464, 20.0712 and 25.9207 in respectively. Clearly, the mean of fabric type at level 3 appears to be the best choice since it corresponds to the highest average mean. The mean of drawing and cutting duration is 22.8574, 19.9984 and 25.9828 at level 1, level 2 and level 3 in respectively. This is means that for the drawing and cutting duration, the parameter at level 3 is better than at level 1 and level 2. The mean of sewing speed is 19.8359, 26.4718 and 22.5343 at level 1, level 2 and level 3 in respectively. This is means that for the sewing speed, the parameter at level 2 is better than at level 1 and level 3. Based the analysis above, the best parameters selected to improve the quality of dress manufactured was$A_3B_3C_2$. Since the maximum-minimum value is equal to the range of mean variance due to the change in the level setting, the larger the range, the more powerful impact the control factor has on quality. The ranking in Table2 shows that the sewing speed has ranking 1 and relatively strong impacts and influence on the quality of dress. Thus, the fabric type and drawing and cutting duration are the ranking 3 and 2 where they are relatively given the weak impacts. Table 10 shows that the most significant factor for the output of the product is control factor c (sewing speed). The effect of the other factors (A and B) is of less significant. Since the objective of this project is to improve the dress invention process, what is required is to the maximum values in order to minimize variability. Thus, factor c should be to set to Level 2 in order to get the maximum result.

3.6 Analysis of Variance (ANOVA)

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Table 6 shows the result of ANOVA analysis and percentage contribution of control factors and different levels of the dress manufacturing process from small scale medium enterprises.

Table 6: Sum of all squares of all deviations

Factors	**DOF**	**SS**	**MS**	**SS% Contribution**
Fabric type	2	15.9978	7.9989	27.8
Drawing &cutting duration	2	17.9181	8.9590	31.1
Sewing speed	2	22.2734	11.136	38.7
Residual error	1	1.4064	1.4064	2.4
Total	8	**57.5957**		100

Based on the performed ANOVA analysis in Table 6, it can be seen that the greatest influence on dress quality is sewing speed 38.7%, followed by drawing and cutting duration 21.1 % and fabric type 27.8%. Factor which has a less contribution for reducing the variance of response can be neglected. It is clear that the effect of residual error (2.4%) on dress manufacturing process is very low as compared to the control factors.

4 CONCLUSION

The aim of this research is to improve the quality of dress-making in a small-medium scale enterprise (Fashion Industry) in Nigeria using Taguchi method.

The first objective was to investigate the factors that affect the quality of dress making in the medium scale enterprises using Taguchi techniques. This objective was achieved as the factors affecting the quality of dress making was identified and thoroughly investigated using the Taguchi technique .The factors that where pinpointed and investigated that influence the quality of dress making are the fabric type, drawing and cutting duration and sewing speed were discovered to be the parameter factors that affect the quality of dress manufacturing process. It was seen that fabric type, control factor increases as the level increases from light to strong, for the drawing/cutting

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duration it increases from level one 40min to level three 80mim. Also, the sewing speed increases from level one 70m/s to level three 120m/s.

The second objective which was to determine the signal to noise ratio (S/N) of the medium scale enterprises using Taguchi techniques was also achieved. The analysis using Taguchi‘s method shows that the optimal result achieved when the parameter setting of the process were $A_3B_3C_2$. This means that the fabric type should set to strong, drawing and cutting duration at 80 minutes and sewing speed at 90m/s. In this ideal process of controlled parameters situation, the sewing speed was identified as the most important factor because graphical inspection is used to determine the dress quality characteristic in this study.

The third objective which was to improve on the factors that affects the quality of dress making production of the medium scale enterprises using Taguchi techniques was achieved too. The effect of the other factors (A and B) is of less significant. Since the objective of this project is to improve the dress invention process, what is required is to the maximum values in order to minimize variability. Thus, factor c should be to set to Level 2 in order to get the maximum result. Based on Taguchi and ANOVA analysis, conclude that the greatest influence on dress making process is sewing speed 38.7%. The effect of residual error (2.4%) on dress manufacturing process is very low as compared to the control factors.

The last objective which was to improve production stability of products in the fashion industry (medium scale enterprises) was achieved. After putting into consideration different factors that affect the quality of dress making, the research aids to have a stable process of production that supports high quality output with minimal waste at the expected time frame.

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