Work-Unit Time and Efficiency Index Of Repetitive Process Phases In Pasta Production

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***Abstract*—Time provides help in controlling the work done on day to day basis and for accurate advance assessment of potential output and production cost. This study investigates and summarizes the results of physical measurement of the industrial activity timing in a Pasta firm aimed at improving high productivity gains and entrepreneurial growth. This study determined the standard time and production efficiency index for productivity growth from the standpoint of the pasta production. To achieve this purpose, the study adopted a diligent and systematic process activity survey, measurements, and analyses, while following a workable project plan. A case study was conducted at one major pasta production firm which, for sake of confidentiality, is identified in this paper as GPC, operating sixteen elemental activities, in Nigeria. The learning curve concept was used to determine labour requirements for the process operations. The results of the study revealed that the combined unit standard time for pasta production is 0.02min/kg of pasta. This result favourably compares with literature statistic of 3 tons per hour. More so, at a zero production time loss, pasta production will not be earlier than seven hours. It was found that if the standard time is fully implemented, GPC stands the chance of increasing her average monthly production output by 6,000 cartons with an improved labour productivity of 467.5 kg of pasta per man-hour and would generate additional 75 man-hour jobs per shift. It was also, estimated that the average cost of electric power consumption at GPC is 405 million naira per annum at the rate of 0.173kWh of electric power per kg of pasta produced. The empirical results of this study stand in the gap for a competitive tool among concerned industries and, if implemented will have impact on job generation, which will greatly reduce unemployment level and make pasta business a viable one in Nigeria. Since time resource directly contributes to cost of production, these findings, if implemented, will enhance the corporate profitability and ensure economic growth in the nation.**

Keywords—work-unit, repetitive process, standard time, learning curve, activity cycle, pasta.

I. INTRODUCTION

The importance of time resource to all manufacturing processes cannot be overemphasized. The fact that in Nigeria today, many firms have closed shop and others are experiencing low productivity incidences creates the need for evaluation of plant management tools, especially time management in this study. However, there are challenges of not keeping time alright, particularly as it concerns pasta production. For example, long waits for pasta throughput has been identified in the process line of pasta production. A recent study has shown the effect of the aforementioned problem on productivity, and this is a great concern in view of the fact that more industries have entered the business and the Nigerian market for pasta is a huge one [1]. There seems to be a development where long process hours appear to be a substitute for efficiency contrary to set standards. This is a real decision problem and can be attributed to inaccurate measure of time required to accomplish the task. Although, it is essential to be able to make a decision, it is impossible to plan reliably without knowledge of the time likely to be taken to do the task. Since time is an essential parameter that affects product output and cost, a comparative work unit analysis has been done on the task of pasta production as a way of ensuring accurate planning and efficiency at different work-units. This study argues for prudent time management as it affects cost estimation, work effectiveness and productivity improvements in a repetitive process phases of pasta production in Nigerian work environment.

It has been reported in the literature how production engineers determine standard time and execute its management. Time management is essential for everyone as reported by Ojokuku and Obasan [2], although [3] stated it was initiated in industry. According to Cole [4], management of time is an issue which is fundamental to effective job performance. Hellesten and Rogers [3] and Claessens et. al, [5] reported that there is lack of agreement about the definition of time management. Arguably, personal or organizational effectiveness at work units can be said to be primarily a function of how time resource is managed. To support the preceding argument about influence of time resource on production efficacy, however, [6]; [7]; [2]; [8] [9] and [10] reported that application of time management to personal or organizational work-unit will lead to productivity growth and increase in efficiency. To put that in context, throughput and productivity gains are two performance variables influenced by time management. Here, the interest in time management as a means of measuring performance against set standards or goal-directed activity is a point of focus because of the importance of its control to productivity.

There are many aspects of time management including standard time, which is activity dependent and most critical to determination of elemental activity cost and completion period. It is an aspect of time management which specifies time including allowances for task accomplishment. Schmenner [11] and [12] reported that change in productivity rather than absolute levels of productivity is more regarded concept in a factory setting. In the opinion of the author, absolute level has to do with exact definition, while the former deals with its consistent measurement over time. This former definition is the approach adopted in this study while investigating the work-units of pasta production. Pasta is a popular food because of ease of preparation, sensory appeal, low cost and storage stability [13]. The term repetitive process phase has been used to refer to a combination of cycles of activities involved in pasta production with specific earned time. Since the normal run of work activity forms a company's regular production, it is possible to estimate the time taken within sufficient accuracy for planning purposes. For these characteristics, there is need for mutually agreed method and time measured consistently for pasta production in the sense of improving productivity. In this study, standard time refers to the earned time for a task using mutually agreed method and qualified personnel, while work unit refers to a team working together to accomplish a specific task.

Quite a few studies dealt with product standard time, for example, [14] and [15] as a strategic tool for optimization of productivity. Effective production operations require standard time that can help the concerned firms to determine labour content and efficiency of production. The justification for choosing a major pasta production firm, which for sake of confidentiality, is identified in this paper as GPC is because of her significant position as the first and largest pasta producing firm with 41 years of operation in the country. GPC therefore, can play a dominant role in the determination of pasta productivity indices in Nigeria. Also pasta market is growing rapidly, for example in 2009, the sale of pasta in the country grew by 19 per cent to reach ₦ 19.7 billion and 11 % of the growth was provided by GPC [16]. Notwithstanding the increasing product market and the prospect for huge job opportunities, there are issues with the corporate delivery and flexibility operation objectives as high product standardization is attained. These present a problem to GPC because of the expected emergence of large competitors in the pasta market, hence determining exact standard time of product is a necessity [17]. Also, it is a challenge to the firm in order to be competitive and increase its efficiency rather than pursue cost priorities exclusively as remedy for declining productivity, hence, time standards needs to be developed for the elemental activities in a repetitive work unit such as the pasta process. To the best knowledge of the authors, works have not been carried out in respect of work unit and efficiency index for pasta production.

The specific objectives of the study includes: to determine the standard time of pasta production at GPC, to determine the number of machines an operator can run at a given capacity, to estimate labour requirements and cost of pasta production at GPC used to ensuring continual increase in productivity of pasta production. The focus will be on different work-units accepted as having the necessary physical attributes to carry out the work in hand which may be manually executed or machine controlled to satisfactory standards of safety, quantity and quality.

2. Materials and Methods

Table 1 shows details of the elemental/stage-to-stage activities involved in the production of pasta from wheat milling to packaging. Measurements were taken during day and night shifts for 20 observations for the 16 elemental activities, A to P, that must be carried out in pasta production from wheat milling to packaging of the finished product and 6 production cycles or batches. There are 9 production lines at GPC; 6 of them are used in the production of spaghetti, namely: Fava long goods 1, 2, 3 and 4 as well as Pavan long goods 1 and 2. It is also important to note that the workers who operate in the production units have the required experience and familiarity with the material conversion process.

Data was collated and analysed, while all calculations were done per 8 kilograms of pasta or per stick of pasta. This is so because a measurement on per stick of pasta basis is a very important parameter in pasta production.

Table 1: Elements/activities in pasta production and their normal times

s/n	ELEMENTS	NORMAL TIMES (minutes)
A	WHEAT MILLING	0.094
B	DOUGH MAKING	0.125
C	DIVIDING AND CUTTING BY SPREADER KNIFE	0.441174
D	CONVEY PASTA TO TRIMMER	0.044023
E	TRIMMING	0.111604
F	TRANSPORT TRIMMED PASTA (SPAGHETTI) TO PRE-DRYER ENTRANCE	0.262338
G	PRE-DRYING AND MOVEMENT TO DRYER ENTRANCE	41
H	DRYING AND MOVEMENT TO	296

	COOLER ENTRANCE	
I	PASTA COOLING AND MOVEMENT TO FINISHED GOODS SILO	83
J	TRANSPORT PASTA FROM FINISHED GOODS SILO TO STRIPPER	0.05
K	CUTTING AT STRIPPER	0.14669
L	LOAD BUCKET	0.210777
M	CONVEY LOADED BUCKETS TO PACKING MACHINE	1.422339
N	TRANSWRAPPING	0.180733
O	CONVEY WRAPPED GOODS TO PACKERS	0.361333
P	PACKAGE WRAPPED GOODS (SPAGHETTI) INTO CARTONS BY PACKERS	0.193895

Since this production involves a repetitive process, an assumption is made that each repetition impacts a learning effect on the organization, which can be represented by a learning curve. The learning curve represents the relationship between experience and productivity [18]; [19]; [20] and it was used to determine the labour requirements in this study. The equation for the curve is expressed as:

$$Y_i = k i^{-b} \qquad (1)$$

Where Y_i = labour hours required to produce the i^{th} unit, k = labour hours required to produce the first unit (or initial productivity), i = ordinal number of unit (that is, 1^{st}, 2^{nd}, 3^{rd}, and so on). The labour hours required to produce the i^{th} unit is then plotted against cumulative output on arithmetic coordinates.

The standard was calculated as follows in equation (2)

$$\text{Standard time} = \text{Normal time} + \text{Allowances} \qquad (2)$$

The efficiency indicators can be expressed using the number of machines and labour requirements. The number of machines can be estimated in equation (3) thus:

$$Number\ of\ machines = \frac{Standard\ time}{plant\ rate} \qquad (3)$$

3.0 RESULTS AND DISCUSSIONS

3.1 Comparison between the normal times of the various elements or activities in pasta production

It can be deducted from table 1 that approximately 79.5 per cent of the time involved in pasta production is spent in the drying stage. This is so because it is at this stage that the integrity of the finished product can be secured with regards to microbiological and biochemical stability. Consequently, any form of machine breakdown, resulting from operator's idiosyncrasy or poor maintenance at this stage, will be a penalty on the entire system with respect to production time and product quality. Interestingly, about 19.6 per cent of the entire production time is spent in the cooling stage. This implies that 99.1 per cent of the production time is spent in both the drying and cooling stages while only 0.9 per cent is spent in other stages. This can be clearly seen from the pie chart in figure 1.

3.2 Comparison between the normal time curve and the mean normal time line in pasta production at GPC

The figure 2 indicate that production time of pasta at GPC will not be earlier than 420 minutes even at zero production time loss and that variation in the normal production time will only give values which will be evenly distributed above and below the mean normal time line. However, mean normal time for production is 423.6439 minutes.

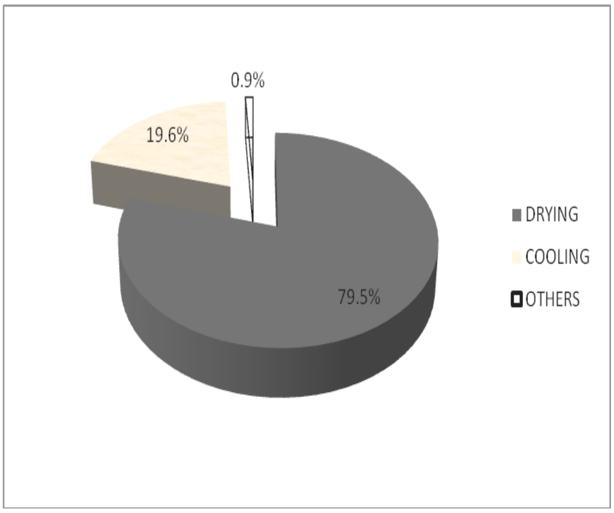

Figure 1: Percentage comparison of normal times for drying, cooling and other elements of pasta production at GPC

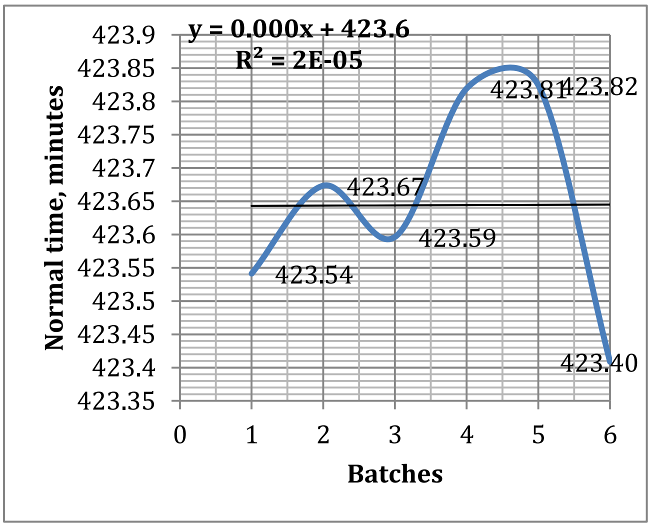

Figure 2: Graph of normal time versus batches of production, showing the mean normal timeline

The calculated standard time of pasta production is 0.02min per kg of pasta; it implies that about (24 x 60)/0.02 = 72,000kg of pasta will be produced per day by one of the production lines. This result compares favourably with literature statistic of 3 tons per hour.

At GPC, there are six production lines used in the production of spaghetti. Hence, an average of 432, 000kg of pasta will be the production output of the factory per day. Since 1 carton = 10kg of pasta, then estimated daily production output = 43200cartons. This follows that the average monthly pasta production output is (43 200 x 30) 129600 tons. Figure 3 shows the actual monthly production in cartons at Golden Pasta Company from the month of January to June 2013.

It can be clearly seen from the graph that output was highest in the month of June, followed by March in the first half of the year 2013.

We deduce from the above given information that the average actual production output per month is 1,290 tons. A critical investigation of the above figures shows that the output results from the research work and the actual production differ by 6 000cartons. This implies that if the standard time data is strictly employed, GPC stands the chance of increasing her average monthly pasta (spaghetti) production output by 6, 000cartons.

3.3 Consequences of the discrepancy between the output of pasta production using the calculated standard data, and the actual production output at GPC

It has been evaluated that by a circumspect use of standard data, GPC stands the chance of increasing her monthly production output by 6 000cartons. Whether this is feasible will depend on the current portfolio of the factory. Different options can be tried in order to attain the feasibility of the expected portfolio.

3.3.1 Estimation of the number of machine (production lines) requirements

From section 3.2, it can be clearly seen that by using standard data GPC would produce 432 000kg of pasta per day or 216 00kg per 12-hour shift. Recall that standard time of pasta production in referenced firm = 0.02min per kg. Given that available time per shift (12-hour shift) = 720minutes and downtime with zero delay allowance per shift of 60minutes and calculated plant rate of 0.003025 minutes per kg, 7 number machines are needed.

At present, there are only 6 production lines (machines) that produce spaghetti. From the foregoing results, it becomes evident that with the current portfolio of 6 machines, it is difficult for GPC to consistently reach an average monthly pasta production output of 1296 000cartons. This has consequences on profit profile.

Although 6 000cartons may seem negligible in order of millions of cartons per month. Yet if expressed in millions of naira for the whole year, will be a significant penalty on the overall profit of the company and hence on the financial/economic efficiency of the plant.

3. 3. 2. Estimation of labour productivity and labour requirements

There are at least 100 factory workers on ground, manned on the nine lines per shift. This suggests that at least 66 workers man the six spaghetti lines or 11 workers per line. The labour requirements impact on productivity can be examined in three phases (a) to (c) as follows:

$$(a)\, present\, case = \frac{output}{labour\, input}$$

$$= \frac{430000\ kg/day}{66 workers @ 12\ hours/day} = 542.9 kg/man - hour$$

To increase average output per day, one more production line is required which will definitely increase the number of workers in the factory per shift to say 77, from the aforestated argument. Therefore, the improved labour productivity will be

$$(b) improved\ case = \frac{output}{input\, labour}$$

$$\frac{432000\, kg/day}{77\ workers @ 12\ hours/day} = 467.5 kg/man - hours$$

Although the labour productivity is decreased with an increase in labour, the minimum average output level per day will be increased reasonably. This will also reduce the unemployment level in the society.

Moreso, if the workers are properly trained to perform at a performance level above 90% , this will imply that level of breakdown losses along the line will be reduced. Consequently, this will pacify the effect of the decrease in labour productivity.

However, if the number of labour is kept constant with an increase in average output per day, the labour productivity will be

$$(c) improved\ case = \frac{432000}{66 workers @ 12\ hours/day}$$

$$= 545.5\ kg/man - hour$$

From the above calculations, increase in labour productivity from 542.9kg to 545.5kg man-hour is quite interesting but this will be a penalty on the average production output per day which is not worth the increase. On annual basis, this is significant as can be observed from the effect a 90 % learning rate as illustrated in Fig. 4. Fig. 4 shows the learning curve with 90 % learning rate and an index of 0.1520.

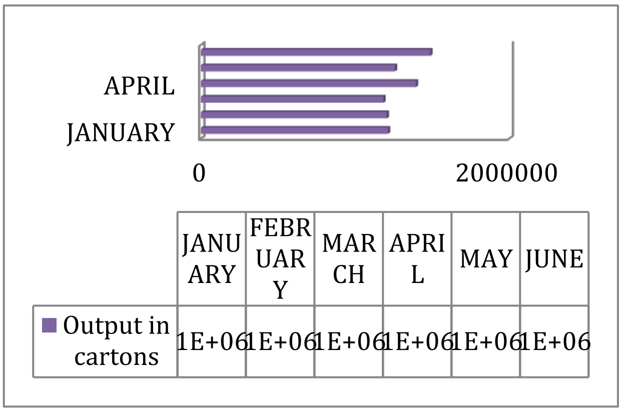

***Fig. 3:* Actual monthly production in cartons at Golden Pasta Company from the month of January to June 2013**

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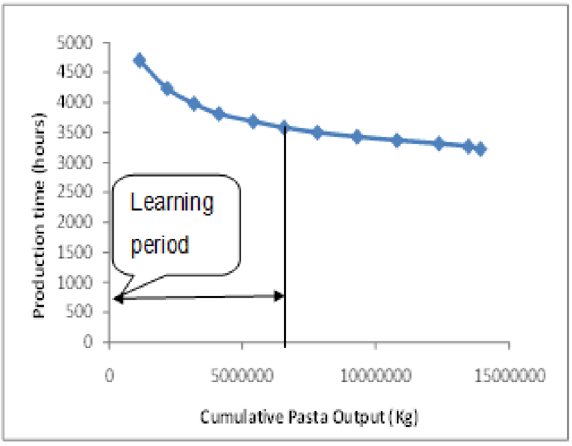

Figure 4: Learning curve with 90 % learning rate for pasta production

The implication of the gradual declining curve model of pasta production in figure 4 is that it has a slow learning rate, which accounts for value of experience and expectation for growth of capacity. The vertical line separating the curve is an indication of the difference between learning period and standard time for the product.

3.4: Estimation of Cost of Electric Power and implications per kilogram of pasta produced

The total power consumed and production output within the understudied period are 24,101,328 kW-hr and 13, 925,253 cartons of pasta, respectively. The tariff at the time study charged among industrial customers under Ikeja Distribution Company is N16.38 per kW-hr [21]. Therefore, 24,101,328kW-hr will cost N405 million per annum. Hence, the electric power consumed per carton of pasta produced is 1.73 kW-hr per carton. But 1 carton of pasta ≡ 10kg of pasta. Therefore, electric power consumed per kg of pasta will be 0.173kW-hr per kg of pasta produced. Therefore, the cost of pasta production on electric power is calculated thus N 2.83 per kg of pasta produced. Also, a sachet of spaghetti (pasta) is equivalent to 0.5kg of pasta. With this we can say that at GPC, the cost of production on electric power consumption is at the rate of N1.42 per sachet of spaghetti produced. Figure 5 shows the relationship between power consumption and production output

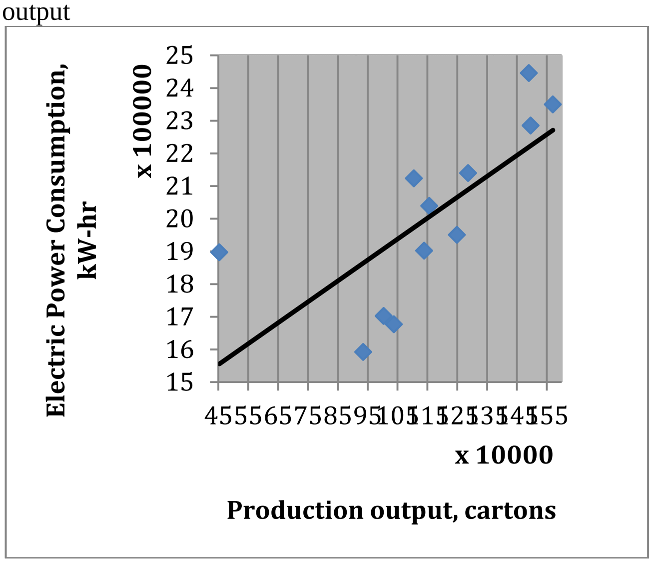

Figure 5: Graph of Electric power consumption versus production output

It is also noteworthy to comment that electric power consumption increases as production output increases as shown in figure 5. This implies that production time will increase while breakdown or downtime would have been reduced due to proper planning, maintenance and improvements of the various work-units involved in pasta production.

4. Conclusion

The comparative work-unit time analysis at a pasta production firm in Nigeria has been carried out in order to determine the standard time for pasta production. In achieving this purpose, the study adopted a diligent and systematic process analyses, measurements, calculations and synthesis, while following a workable project plan. The results of the study revealed that the combined units standard time for pasta production is 0.02min/kg of pasta. This result favourably compares with literature statistic of 3 tons per hour.

It becomes obvious from the measurements, calculations, analyses, results obtained and the discussions so far, that this research work validates the assertion that effective control in manufacturing process begins with accurate measurement. It validates also, the impact of product standard time on labour and machine requirements as production efficiency indices. This is in agreement with the assertion by [14] and [15] that accurate factory activity timing is a strategic tool for productivity improvement. The work validates the assertion that effective control in manufacturing process begins with accurate time measurement.

Acknowledgement:
The authors wish to acknowledge the assistance from the students who administered the questionnaire and staff of the firm for their response.

References

[1] Chukwu, C. D. (2013). Comparative work-unit time analysis of pasta production at Golden Pasta Company; of Nigeria Plc. Unpublished degree project, University of Nigeria, Nsukka.
[2] Ojokuku, R. M., K. A. Obasan (2011). Time management and organizational performance: a causal analysis. Pakistan journal of business and economic review, 2, 1, 60 – 75.
[3] Hellsten, L. M., W. T. Rogers (2005). Development and preliminary validation of the time management for exercise scale. Measurement in physical education and exercise science, 13, 13-33.
[4] Cole, G. A. (1993), Management Theory and Practice. 4th Edition, DP Publications limited, London.
[5] Claessens, B. J. C., W. Van Eerde, C. G. Rutte, R. A. Roe (2007). A review of the time management literature. Personnel Review, 36 (2), pp 255- 276.
[6] Hassanzabeh, R., A. G. Ebadi (2007). Measure the share of the effective factors and time management. World applied sciences journal, 2, 3, 168-174.
[7] Hellsten, L. M. (2012). What do we know about time management? A review of literature and a psychometric critique of instruments assessing time management. www.intechopen.com/download/pdf/33747 (accessed 9/12/2014)
[8] Nadinloyi, K. B., N. Hajloo, N. S. Garamaleki, H. Sadeghi (2013). The study efficacy of management training on increase academic time management of students. Procedia – Social and Behavioral Sciences, Vol. 84, pp134-138.
[9] Wigdor Tal (2014). Implementing Time Studies and the Development of Standard Times. St. Onge, Company 1400 Williams Road, York Pa 17402, 717-840-8181. Accessed on 7/7/2014 from www.stonge.com
[10] Jackson, V. P (2009). Time management: a realistic approach. Journal of American College of Radiology, Vol. 6 (6), pp434- 436, doi:10.1016/j.jacr.2008.11.018.
[11] Schmenner, R. W. (1987), Comparative Factory Productivity. Target, spring 1987, pp32 – 34.
[12] Haraldsson, Jorgen (2010). Development of a method for measuring pasta quality parameters. Unpublished doctoral dissertation, Linnaeus University, Kalmar, Sweden.
[13] Golden, L. (2012). The effects of working time on productivity and firm performance: a research synthesis paper. International labour organization (ILO), Conditions of work and employment series No. 33, Geneva
[14] Jamil, M., M. Gupta, A. Saxena, V. Agnihotri (2013). Optimization of productivity by work force management through ergonomics and standardization of process activities using M. O. S. T analysis – A case study. Global Journal of Researches in Engineering Mechanical and Mechanics Engineering, Vol. 13 (6), pp 44 – 55.
[15] Eraslan, E. (2009). The estimation of product standard time by artificial neural networks in the molding industry. Mathematical Problems in Engineering, Vol.2009, pp1- 12, doi:10.1155/2009/527452.
[16] Shosanya, M. (2010), Nigeria's Business Men are Mixing Pasta for GDP. Sunday Trust, Business News, 30 May, pp 25 -27.
[17] Freivalds, A., S. Konz, A. Yurgec, J.H. Goldberg (2000). Methods, work measurement and work design: are we satisfying customer needs? International J. Industrial Engineering, Vol. 7 (2), pp108 – 114.
[18] Abernathy, W. J., K. Wayne (1974), Limits of learning curve. Harvard Business Review, pp 109-119.
[19] Senge, M. Peter (1990), The leader's new work; Building learning organizations. The Sloan Management Review, p 7- 23.
[20] Sebrina, A. I., L. Diawati, A. Cakravastia (2011), Learning curves in Automobile assembly Line. Proceedings of 16th International on Industrial Engineering Theory, Applications and Practice, Stuttgart, Germany, September 20-23.
[21] Martin Ayankola, (2012) *New tariff: FG abolishes uniform pricing for electricity.* "The Punch", May 18, 2012.