Applied Energy, Volume 79, Issue 1, September 2004, Pages 97-107.

PETROCHEMICAL INDUSTRY IN NIGERIA: A PERFORMANCE APPRAISAL

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ABSTRACT.

For any country, having a large indigenous petrochemical-producing industry tends to lead to raised prosperity, improved average standard-of-living for the population and the introduction of associated modern-technology locally. However, such benefits in Nigeria have as yet not been forthcoming to significant extents. This project reviews what needs to be done in the industry to achieve these desired improvements.

ABBREVIATIONS AND NOMENCLATURE

ABC	Activity-based costing
BP	Base period
CP	Current period
EFQM	European Foundation for Quality Management
FEC	Focused equipment improvement
ISO	International Standards Organisation
JIT	Just-in-time
MANQA	Malcolm Aldridge national quality-award
P_D	Daily rated capacity
P_N	Annual production capacity
PP	Polypropylene
SMED	Single minute-exchange of die
SWOT	Strengths, weaknesses, opportunities and threats
t	Tonne
TPM	Total-productivity management
VAM	Value-added management
W.C.	Working capital

GLOSSARY

Utilities	Steam, water, electricity, compressed combustible gas, etc
Kaizen method	Strive for a continual improvement, involving the participation of all employees
Performance factor	A parameter used to indicate the effectiveness of the considered process

Performance index	Ratio of output to input for the stated process
Total productivity index	Sum of all the partial productivity-measures. This could be used to describe the productivity of a single organisation or even a nation
5s housekeeping procedures	The 5s stands for: s-1→ Sort, identify unnecessary items in the work-place and discard them i.e. declutter s-2→ Set, arrange items in logical order, so that they can be located easily when needed, i.e. have a 'proper place for everything'. s-3→ Shine, thoroughly clean your workplace, machines and/or other equipment. s-4→ Standardize: harmonise requirements and sizes of equipment throughout the workplace s-5→ Sustain: train people to follow good house-keeping thrift disciplines autonomously and automatically.

PROBLEMS AND PROSPECTIVE SOLUTIONS

It is insufficient for an industry only to be highly productive in order to succeed: an in-demand (and of the right quality) end-product or service, flexibility (e.g. scope or variety of product), and lean management are needed together with low unit costs, reliability, customer satisfaction, and rapid delivery. The present investigation focused on the poor economic and engineering performances of one aspect of the Nigerian petrochemical industry: these disappointing characteristics are usually attributed to inadequate management and unstable political circumstances in the country.

Even up to the late 1960s, there was little financial investment in petrochemical production in Nigeria. However, since 1976, there have been growing economic and political pressures to (i) harness the vast indigenous natural-reserves of crude oil and natural gas, as well as (ii) stop natural gas being flared. The development of the petrochemical industry in Nigeria has been highly dependent upon expatriate labour and know-how as well as imported equipment. The set-up of the industry is in the form of joint ventures: hence problems have arisen from cultural and ethnic differences thereby hindering joint decision-making. Thus, self-sufficient, politically astute, technically well-qualified Nigerian leaders are urgently needed in the industry. Relevant entrepreneurship should be more quickly recognised and better rewarded at all levels in the industry. When such personnel are appointed, they should be allowed greater freedom to innovate in all aspects of the business (i.e. with respect to technological processes, quality control, management, financial decision-making and marketing).

TARGETS AND AUDITS

Specific detailed goal-oriented activities tend to be more productive. A typical audit of these activities would include the measurement of effectiveness [i.e. the extent to which the objectives of the planned activities are realized and the desired results achieved

quickly, without undue wastefulness of resources (ISO 9000, 2000)], and a subsequent comparison of the outcomes of the process corresponding with the required goals. The process "owner", usually, undertakes such an assessment. The evaluation may be accomplished using formal, standardized procedures e.g. benchmarking and self-assessment (Karapetrovic and Willborn, 2002).

When what has been achieved is presented in the form of a well-documented standard model or procedure, the evaluation is referred to as an "audit against criteria": see ISO 9000 (Karapetrovic and Willborn, 2002). Every individual at the petrochemical plant should check frequently as to whether or not s/he is behaving as a conscientious or contentious worker (Tamini et al, 1995) by asking such questions as: Do I achieve what is expected in a professional and acceptable way? Can I make improvements to the design or process being employed? What can I learn from the 'best-in-class' competitors in nominally similar production plants/services? Have I given, today, value-for-money to the organisation? If the answer is 'negative' to some such basic questions, then improvements need to be introduced.

The primary objective of the self-audit is to evaluate and upgrade ones behaviour, by continually examining both the performance enablers and achieved results. (Business performance enablers can be grouped into three categories: goals (including strategy, policy and objectives), resources (people, materials, information and infrastructure) and processes (including leadership and realization of outputs) (Karapetrovic and Willborn, 2002)). The enablers should be assessed for their suitability and effectiveness to achieve set performance-targets. The results, which may include those related to employees, customers, society, and key financial and non-financial outputs are measured and compared with targets levels (EFQM, 1999). The performance levels should be assessed periodically for their current appropriateness and feasibility. The basic requirements for continual improvement are: identifying accurately the problem, and motivating yourself (and others) to solve it by taking effective actions (Forsha, 1992). Shirley and Gryna, (1998), emphasized that, in order to achieve self-control, process owners or controllers must know:

- What their actual performance has been.
- What they are supposed to do: i.e. set of clear aims
- How to regulate their performance.

Improving productivity usually requires a wiser use of both human and other resources as well as facilities. A performance appraisal or productivity measurement should reveal:-

- What in detail needs to be done if the targets are to be achieved?
- The problems facing both the management and the employees.
- The costs of not solving, as well as solving, the problems being faced.
- The necessary actions required to overcome the problem, and how to relate the output to these actions.

To achieve the objectives, the audit must check that the set targets are within the framework and remit of the strategic plan, and that the targets are predictable to within the accuracy required. The productivity measurement or performance audit will identify

the key changes needed in the employed systems, working methods, skills and attitudes. It should highlight the resources, assistance, training and developments required by those concerned in order to overcome each problem.

The audit of a system will help (i) determine the effectiveness of existing operations, (ii) highlight the strengths and weaknesses in the systems and processes, and (iii) devise an implementable plan and controls for the activities to achieve higher productivities. Also, it should provide a methodology for improving the operation and maintenance schedules continually by auditing the main subprocesses, such as maintenance management (Raouf and Ben-Daya, 1995, Duffuaa et al, 1999) and thereby reduce running costs. Because a self-audit includes the measurement and comparison of what has been achieved with desired levels of performance, it may be represented as a process with a negative-feedback loop (see Figure 1).

Each individual should try to identify their strengths, weaknesses, existing opportunities as well as present and likely future threats i.e. undertake a SWOT analysis, and then compare his/her performance with set requirements (e.g. as given in a job description), and the standards achieved by the best in the field (i.e. benchmarking)(Karapetrovic and Willborn, 2002). While process-quality audits, self-assessments and benchmarking are all used to evaluate achieved performances against set criteria (ISO 9000 Standards business-excellence models, Malcolm Aldridge National and European Quality Awards, and state-of-the-art approaches, respectively), each methodology has its own merits (and limitations). For example, a self-assessment usually outperforms an audit in terms of identifying strengths and opportunities for continual improvement, prevention of crises arising and the incorporation of assessment results into the rolling strategic and operational business plans.

SCOPE.

To accomplish its objectives, an audit has to:

- Check how the targets have been set within the framework of the strategic plan.
- Identify (i) key problems and difficulties that should be confronted if the targets are not achieved; (ii) notional costs of failing to solve such problems; (iii) key changes needed in presently-employed systems, as well as considering methods, skills, and attitudes applied elsewhere in nominally-similar plants to achieve improved performances; (iv) resources, assistance, training/retraining and system development required by those concerned in order to deal with each problem; and (v) the means to tackle the problem through data gathering, their analyses, problem solving, and discussions with concerned personnel.

RESEARCH METHODOLOGY

The quantity of output from the Nigerian petrochemical-industry has been examined, analyzed and found wanting. Data were collected from the Warri and Kaduna Petrochemical Companies -see Table 1. The study looked at the utilization of various

resources and categorized them into the major segments: - capital, labour, energy, feedstocks, chemicals, catalysts, materials and utilities.

TABLE 1. Petrochemical industry in Nigeria

	1997 $	1998 $	1999 $	2000 $	2001 $
Fixed Capital	26,600,000	26,580,000	39,900,000	42,560,000	42,560,000
Working Capital	3,990,000	3,788,000	5,985,000	6,384,000	6,384,000
Total Capital	30,590,000	30,368,000	45,885,000	48,944,000	48,944,000

The main cause of the perceived low-productivity was due to the frequent breakdowns and excessive downtime. Other, sometimes interrelated, causes included the irregular supplies of feedstocks from the refineries, lack of adequate operating capital, insufficient maintenance budgets, mistakes in the plant's original design, limitations imposed by the inadequately trained workforce, improper maintenance policies, ageing plants and poor management.

Total-quality management and lean (e.g. just-in-time, JIT) management processes have been proposed, but their implementation in the present cultural set-up will be difficult. Hence, after the full implementation of 5s house-keeping procedures, benchmarking was recommended. This, to some extent, is now being attempted

Whole organizations should try to comply with ISO 9000 standards, use quality awards and benchmarks, and perform self-audits of their business performances (Karapetrovic and Willborn, 2002). Self-assessments are cross-functional, less formal, and always intrinsically motivated (Van der Wiele et al, 2001). The audit is still superior with respect to the objectivity of the evaluation process, reliability and consistency of results, as well as the identification of systematic failures: it provides an unbiased view of the process being audited.

Benchmarking facilitates the achievement of a good understanding of superior pertinent-practices, helps in fact-based decision-making and clearly identifies weaknesses (Dale, 1998): it essentially amounts to being guided by somebody else's successful processes to reach worthwhile targets, but with the potential locally to innovate (Besterfield et al, 1999).

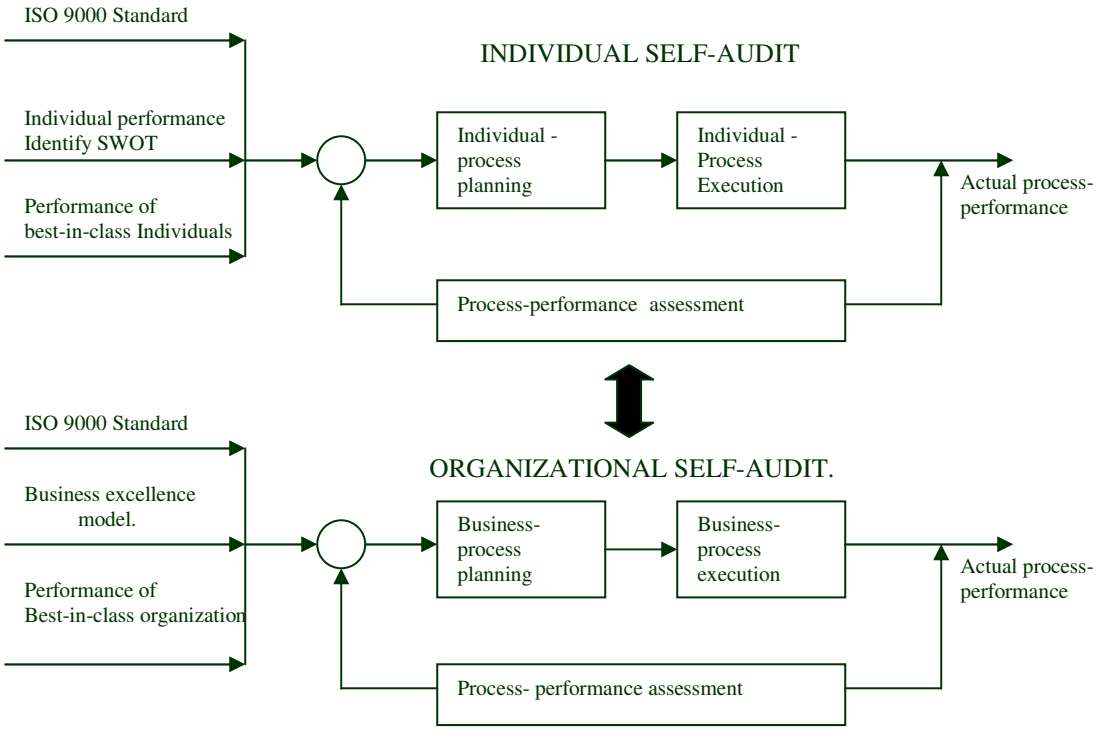

Figure.1 Self-audit procedure (Karapetrovic and Willborn, 2002)

Productivity

This is generally expressed as a ratio of an output to the corresponding input with a typical production model shown in Figure 2. Various productivity non-dimensional ratios are commonly used with respect to finance or energy (see Table 2).

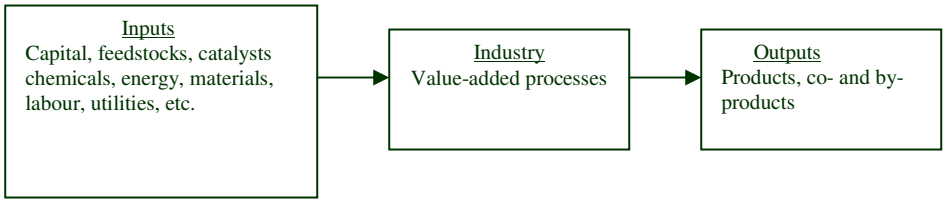

Figure 2. The production process.

Performance

A performance index PI (see Table 3), expressed as a percentage, has been defined by:

$$PI = \frac{100\ (\text{Annual Production})}{365\ (\text{Daily Rated Capacity})} = \frac{100\ P_N}{365\ P_D} \qquad (1)$$

Employing a quality-competitiveness index leads to an operational strategy whereby the considered firm's competitive position is compared with those of other firms in the same field. The considered parameters in this instance are unit price, quality, and flexibility of operation and delivery dependability.

Productivity Index. It is desirable to compare current results against the performance for a year that does not show an abnormally high or low value of productivity - see Table 4. It is apparent that during times of rapid inflation, comparing results for one period against those for a different period could lead to misleading values of the productivity index. The physical resources used may not increase, but their costs almost certainly will, thereby increasing the inputs and showing an apparent fall in productivity.

With this proviso being taken into account, the challenges of the productivity indices indicate trends with respect to how well resources are being utilized locally and act as signals for appropriate actions to be taken. They encourage one to "think harder rather than necessarily work harder".

VALIDITY OF THE MODEL

For the present investigation, 1997 was used as the reference year (i.e. base year period, BP). Polypropylene, PP, as intimated by Tables 2-4, was used as the considered product. The following were identified as the relevant input and output data:

(i) Input and output quantities produced during the period under consideration (Current Period ,CP).
(ii) Input and output quantities during the BP and CP
(iii) Mean unit selling prices during the BP and CP respectively
(iv) Individual input costs and output sales during the BP
(v) Costs of individual inputs and output sales during the BP

Data (see Tables 3-5) were collected for the Warri petrochemical plants. Unfortunately, too often, accurate pertinent records were either missing or not recorded correctly. The collected data are for the five-year period, i.e. 1997 to 2001 inclusive. All the inputs and outputs were translated into costs in US$. However, inflation was not taken into account, so each of the presented figures are the real cost for the stated year.

TABLE 2. Values of the Partial Productivity Non dimensional Ratios

Year	**1997**	**1998**	**1999**	**2000**	**2001**
Capital	0.083	0.099	0.042	0.06	0.046
Labour	88.5	62.6	39.1	52.1	19.5
Feedstock	2684.4	2256.6	1579.0	1973.7	1480.3
Catalysts/Chemical	63.8	53.1	40.2	46.9	31.3
Interest on W.C	265.6	265.6	213.1	260.4	195.3
Utilities	12.1	10.1	7.6	13.0	14.2

The ratios in Table 2 are useful in assessing the effectiveness of the industrial operation (i.e. financial output divided by cost for stated parameter), In the present calculations, it is assumed, for the evaluation of the indirect charges that 10%, 2% and 4% annually of the total capital will be allowed for depreciation, insurance and maintenance respectively.

TABLE 3 Performance index, PI (%) for polypropylene production in Nigeria

Year	1997	1998	1999	2000	2001	Average
PI	49	49	43	57	43	48.2

TABLE 4. Total Productivity Index for polypropylene output in Nigeria, using the value for 1997 for the normalisation

1997	1998	1999	2000	2001
1	1.119	0.58	0.74	0.55

TABLE 5 Warri Petrochemical Products

Year	Product	Annual Quantity produced (tonnes)	Approximate Unit Price (US$/tonne)
1997	Carbon Black	12,000	50
	Polypropylene	17,000	150
1998	Carbon Black	12,000	50
	Polypropylene	17,000	150
1999	Carbon Black	1,200	50
	Polypropylene	20,000	150
2000	Carbon Black	2,500	50
	Polypropylene	17,000	150
2001	Carbon Black	1,500	50
	Polypropylene	15,000	150

TABLE 6. Inputs for the production of polypropylene in Nigeria.

Inputs	1997 $	1998 $	1999 $	2000 $	2001 $
Capital expenditure	30,590,000	25,368,000	45,885,000	48,994,000	48,944,000
Labour	288,800	40,760	57,600	57,600	115,520
Utilities	210,192	252,284.4	294,268	231,522.04	158,932.8
Feedstocks	950	1,190	1,425	1,520	1,520
Catalyst/Chemicals	40,000	48,000	560,000	64,000	72,000
Interest on W.C	9,600	1,560	10,560	11,520	11,520
Indirect Charges	1,152	1,384.4	1,612.8	1,612.8	1,843.2
Total	31,150,684	25,723,062.8	46,704,588.8	49,298,754.84	49,303,016

Estimated Polypropylene (PP) Production-Cost versus Plant Performance Factor

From the observed patterns of behaviour of the petrochemical plant's polypropylene production in Nigeria, a wide variety of performance factors was observed. Thus four typical values of the performance factor namely 95%, 85%, 75%, and 48.2%, have been considered in this analysis, though with the exception of 95%, these values are below the average worldwide performance index for polypropylene production.

Using equation (1), the data of Table 7 have been deduced.

TABLE 7: Estimated annual gross-income versus plant-performance factor

Performance Factor %	Gross output (10^6t)	Sales $150/t $	Production Cost $ 136/t $	Income $
95	32,281.065	492,159.95	45,382.06	44,753.73
85	29,749.880	446,224.80	405,942.08	40,306.12
75	26,249.888	393,748.20	357,943.36	35,804.84
48.2	16,869.928	253,049.85	230,038.37	23,011.49

Annual imported supplement = 23, 9800 metric tonnes.
at production cost of $136.36/t = $32562768
at selling price of $150/t = $ 35820000
Cost in foreign exchange = $ 3257232

DISCUSSION

The results show that the input resources were ineffectively utilized. The installed capacity designed to be 35,000 metric tones/year of polypropylene, has never been reached, while the costs of capital, labour, interest on W.C, energy, and utilities have increased. Significant economics of scale and lower fuel costs per tonne of polypropylene produced should be achieved in Nigeria.

Nigeria's average performance factor during the period 1997 to 2001 was 48.2% whereas the worldwide average was 98%. This was partly due to insufficient feedstock being available and the low availability of functioning plant and equipment. The economic impact of a reduced indigenous performance resulted in the shortfall in polypropylene production to supply Nigeria's demand.

CONCLUSION.

There are many reasons for the poor performance of the Nigerian petrochemical-industry. Each manager, as well as the government, to a greater or lesser extent, bears some responsibility for it and this attitude should be integrated into each organisations. The industry needs more focus on (i) developing the skills of its workers, (ii) employing

higher-quality processes, (iii) achieving customer satisfaction and faster delivery, and (iv) appointing more entrepreneurial leaders.

Inappropriate government regulations, unwise employment contracts, lack of continual-improvement programmes (e.g. see Figure 4) have all led to poor performances. There is a need for benchmarking of performance against the 'best-in-class' worldwide. Sources of competitive benchmarking information include customers, visits to other companies, trade shows and journals, professional societies, standard committees, product brochures, outside consultants, and installation data.

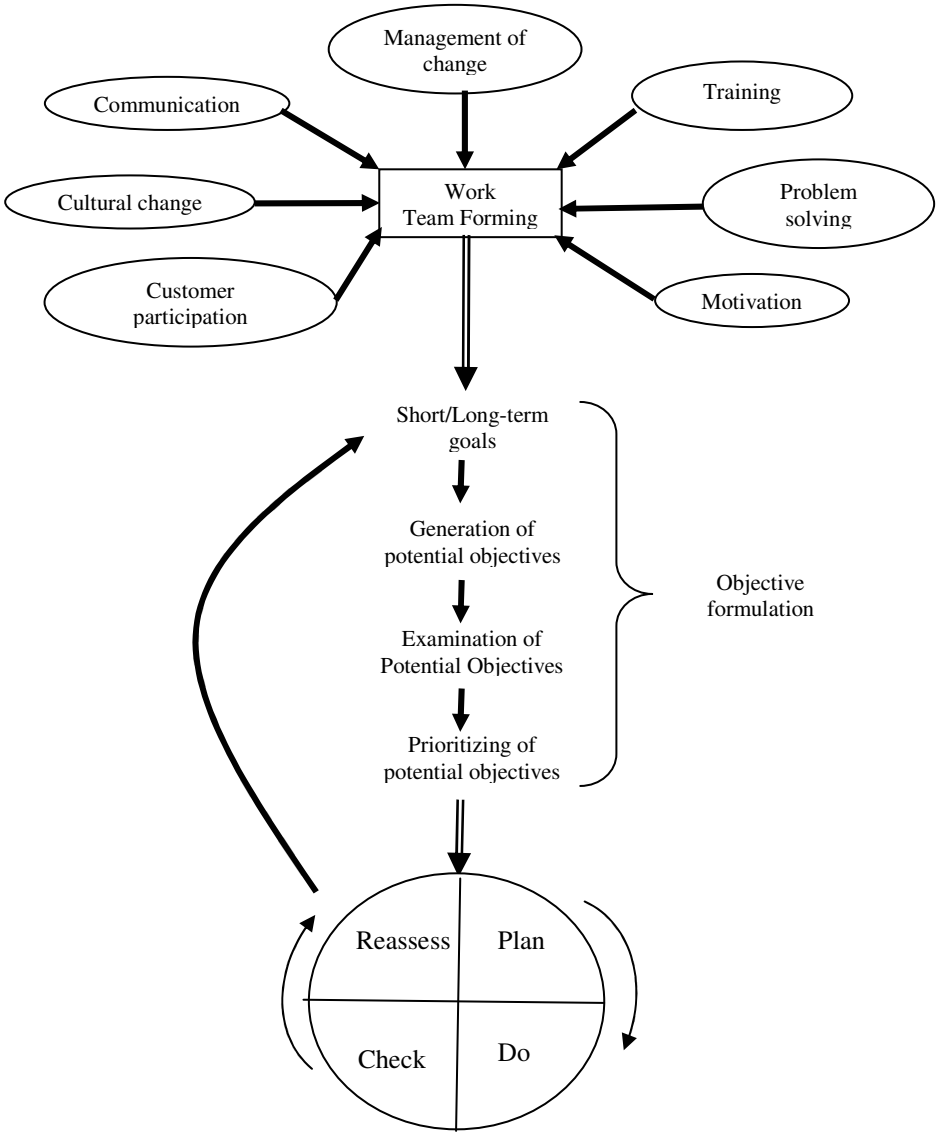

Figure 4. Continual-improvement procedures, which the Nigerian petrochemical industry needs to implement.

The present low productivities of Nigerian industries, such as the petrochemical industry, combined with rising wages and salaries are resulting in severe inflation, nationally. Nigerian society needs to break away from traditional but outmoded indigenous industrial and commercial policies and practices and be open to changes that would make the business more financially viable and sustainable.

REFERENCES.

1. Besterfield, D.H., at el, (1999), Total Quality Management, 2nd ed; Prentice-Hall, Englewood Cliffs, NJ.
2. Dale, B.G, (1998), Managing Quality, 3rd ed. Blackwell Publishers, Oxford.
3. Duffuaa, S.O, Raouf, A, and Campbell, J.D (1999), Planning and Control of Maintenance Systems: Modelling and Analysis, John Wiley, New York, USA.
4. EFQM, (1999), Assessing for Excellence: Practical Guide for self-Assessment, European Foundation for Quality Management, Brussels.
5. Forsha, H.I, (1992), "The pursuit of quality through personal change", Quality Progress, Volume.25, No.2, pp 61-4.
6. ISO 9000 (2000), Quality Management Systems: fundamentals and vocabulary, final draft International standard, International Organization for Standardization, Geneva.
7. Karapetrovic, S., and Willborn, W. (2001), "General audit of management systems: fundamentals". Managerial Auditing Journal, Volume. 15 No.6, pp.279-94.
8. Karapetrovic, S., and Willborn, W., (2002), "Self-audit of process performance", International Journal of Quality & Reliability Management, Volume.19 No.1 pp. 24-45
9. Raouf, A and Ben-Daya, M. (1995), Total maintenance management: systematic approach", Journal of Quality in Maintenance Engineering, Volume 1, No1, pp.6-14.
10. Shirley, B.M and Gryna, F.M. (1998), "Work design for self-control in financial services", Quality Progress, Volume 31, No. 5, pp 66-71.
11. Tamini N, Gershon, M. and Eurrall, S.C, (1995), Assessing the Psychometric properties of Deming's 14 principles", Quality Management Journal, Volume.2 No.3, pp.38-52.
12. Van der Wiele, T., Dale B. and William, R (2001), "Business improvement through quality-management systems", Management Decision, Volume 38, No.1 pp 1.19-23.