ECONOMIC EVALUATION OF COMPUTED TOMOGRAPHY IN A TEACHING HOSPITAL

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ABSTRACT

Background: Computed tomography is very important for accurate diagnosis of some health conditions. However, the procurement and maintenance of CT equipment is expensive and the operating cost per study is high. Against the backdrop, that financial resources are scarce, prudent management and appropriate price fixing of CT scanning procedures is necessary for continuity in business.

Objectives: To evaluate the operations of a CT facility employing accounting, financial, and management principles to elucidate how to optimize economic gains in the operations of medical imaging facilities.

Method: Record of CT scans done at the University of Port Harcourt Teaching Hospital (UPTH) from May, 2007 to December, 2008 and the revenues generated from the studies were obtained and used for economic performance evaluation of the CT facility. The evaluation was done by analyzing the average variable, fixed, and total costs, as well as the average revenue.

Results: The operating cost per study for each of the studies was less than the billing per study thus, implying that profit was made per each study. Some studies contributed more to the profit per study than others e.g. sinuses, inner ear, and TMJ contributed ₦28,456.04 each to the profit/study while abdomen and chest contributed the least amounts of ₦17,792.01 and ₦17,818.24 respectively.

Conclusion and recommendation: CT facility can generate enough profit to sustain itself if the products are adequately priced. It was therefore, recommended that part of the profit generated should be used to raise capital via a sinking fund for equipment replacement as demonstrated in the study.

Keywords: Optimization, sinking fund, profit, variable cost, fixed cost, revenue, annuity.

INTRODUCTION

The value of Computed Tomography (CT) in modern day medicine cannot be overemphasized. It is invaluable for making accurate diagnosis in stroke as it distinguishes between ischemic (cerebral infarction) and hemorrhagic (primary intra-cerebral haemorrhage) strokes. Distinguishing infarcts from haemorrhages is a necessary condition for deciding what kind of treatment to be given as treatments for the two types of stroke differ and patients may suffer serious harm if the wrong therapy is administered.[1] CT scanning is also very useful in head injuries from road traffic accidents, in detecting space occupying lesions (SOL) and in the diagnosis of intra-thoracic and intra-abdominal lesions. However, CT equipments are very expensive and their maintenance is equally expensive. Even the operating cost per study is high. To that extent, prudent management and appropriate price fixing of CT scanning procedures is necessary if there must be continuity in business as experience has shown that procurement and replacement of these equipments does not come that easy especially, in Nigeria where budgetary allocation to health is relatively low (See the Nigerian national budget, 2000 - 2006). Hospital management must determine what pricing level or study volume will guarantee economic advantage for the facility considering the fact that funds must be made available for maintenance (routine servicing and repair) of the equipment, and replacement of the equipment someday.

Changes in government policies and regulations relative to healthcare reimbursement mechanisms, has brought about cost-restrictive measures within the healthcare system. Economic and financial considerations are now becoming very important in healthcare delivery. Profitability of investment in CT modality appears to be the most feasible option for continuity in the business. The trend is now shifting

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TABLE1: Number of CT scans and revenue from May, 2007 - December, 2008

Part of body	Adult (≥ 17years)	Children (≤ 16years)	Total	Billing/Study	Revenue
Brain	560	142	702	27,977.21	19,640,000
Abdomen	97	5	102	29,509.80	3,010,000
Pelvis	7	0	7	30,000.00	210,000
Chest	30	5	35	28,571.43	1,000,000
C-Spine	15	1	16	29,375.00	470,000
T-Spine	4	1	5	28,000.00	140,000
L-Spine	9	0	9	30,000.00	270,000
Neck	5	0	5	30,000.00	150,000
Orbit	8	0	8	30,000.00	240,000
P/N Sinuses	14	0	14	30,000.00	420,000
Inner ear	5	0	5	30,000.00	150,000
Nasopharynx	4	0	4	30,000.00	120,000
Face	2	0	2	30,000.00	60,000
TMJ	1	0	1	30,000.00	30,000
TOTAL	**761**	**154**	**915**		**25,910,000**

understanding of the cost and revenue structures of the CT suite.

MATERIALS AND METHOD

A record of CT scans done at the University of Port Harcourt Teaching Hospital (UPTH) from May, 2007 to December, 2008 and the revenues generated from the studies were obtained and used for the economic performance evaluation. This retrospective study included 915 patients grouped into two categories - adults and children. All the scans were done with GE HiSpeed NX/i dual slice helical CT scanner.

toward private sector ownership and government-private sector partnership in the healthcare industry.

It is desirable that CT scanning procedures be economically viable despite their health and social benefits. To that extent, the price of the CT scanning procedure should be objectively arrived at. It should be based on the actual direct and indirect costs incurred in the course of performing the scanning procedure. It is high time we made away with arbitrary pricing regime, and the so-called "going rate" pricing technique as this is unacceptable in the face of the present reality.

The purpose of this study was to determine whether CT imaging is economically viable, and whether the pricing policy of the hospital with respect to CT scanning procedures is adequate to ensure some profit margins in line with the demands of the new challenges as it relates to the daily operations of the CT suite. In the real business sense, it is expected that the hospital should be able to recoup its investment in a predetermined time horizon. A good analysis of the state of affairs requires an

Cost evaluations were done by analyzing the average fixed costs, average variable costs, and average total costs. Fixed costs are those costs required for operations that do not vary with changes in the radiographic procedure volume.[2] They include administrative salaries, equipment maintenance and service costs, and overhead costs. Variable costs are expense items that are required for each procedure, and they vary directly with workload. They include costs of contrast media, films, syringes, needles, request forms, film wallets, solutions, etc. The economic performance evaluation method used was a modified version of the one used by Bennington, James L. et al.[3]

TABLE 2: Variable costs per CT study (in Naira)

PART OF BODY	CONTRAST	MED. CONS.	PAPER GOODS	No. of FILMS	FILM	TOTAL
Brain	4,393.16	423.52	43.96	2	1,500	6,360.64
Abdomen	8,250.31	423.52	43.96	4	3,000	11,717.79
Pelvis	8,495.41	423.52	43.96	2	1,500	10,462.89
Chest	7,285.71	423.52	43.96	4	3,000	10,753.19
C–Spine	0	0	43.96	2	1,500	1,543.96
T-Spine	0	0	43.96	3	2,250	2,293.96
L–Spine	0	0	43.96	3	2,250	2,293.96
Neck	5,000	423.52	43.96	2	1,500	6,967.48
Orbit	5,000	423.52	43.96	2	1,500	6,967.48
P/N Sinuses	0	0	43.96	2	1,500	1,543.96
Inner ear	0	0	43.96	2	1,500	1,543.96
Nasopharynx	5,000	423.52	43.96	2	1,500	6,967.48
Face	5,000	423.52	43.96	2	1,500	6,967.48
TMJ	0	0	43.96	2	1,500	1,543.96

TABLE 3: Equipment tie-up time analysis

PART OF BODY	TOTAL No. oF SCANS	TIME PER SCAN (MINUTES)	TOTAL TIME (HOURS)
Brain	702	48	561.60
Abdomen	102	75	127.50
Pelvis	7	70	8.17
Chest	35	64	37.33
C – Spine	16	35	9.33
T - Spine	5	47	3.93
L – Spine	9	45	6.75
Neck	5	50	4.17
Orbit	8	70	9.33
P / N Sinuses	14	65	15.17
Inner ear	5	40	3.33
Nasopharynx	4	60	4.00
Face	2	56	1.87
TMJ	1	63	1.05
TOTAL	**915**		**793.53**

DATA ANALYSIS

The equipment tie-up time was computed as an average of the time taken for the scanning procedures - the time taken for each procedure being the duration when the patient entered, and left the CT room after the procedure.

The billing rate per study, the fixed and variable costs were determined by simple averages. The billing for a CT scanning procedure in the institution studied was ₦ 30,000.00 for adults and ₦ 20,000.00 for children (not older than 16years), with or without contrast medium, and irrespective of the body part scanned.

A. COMPUTATION OF VARIABLE COSTS
1. Medical Consumables
The expenses on medical consumables such as

TABLE 4: Average variable cost analysis

PART OF BODY	VARIABLE COSTS/STUDY	TOTAL VARIABLE COSTS
Brain	6,360.64	4,465,169 .28
Abdomen	11,717 .79	1,195,214 .58
Pelvis	10,462.89	73,240 .23
Chest	10,753 .19	376,361 .65
C – Spine	1,543 .96	24,703 .36
T - Spine	2,293 .96	11,469 .80
L – Spine	2,293 .96	20,645 .64
Neck	6,967 .48	34,837 .40
Orbit	6,967 .48	55,739 .84
P / N Sinuses	1,543 .96	21,615 .44
Inner ear	1,543 .96	7,719 .80
Nasopharynx	6,967 .48	27,869 .92
Face	6,967 .48	13,934 .96
TMJ	1,543 .96	1,543 .96
TOTAL		**6,330,065 .86**

contrast media, syringes, film, x-ray wallet, request form, report sheets payment vouchers, etc. used for each scanning procedure were calculated from the list of prices as charged by various vendors. For the purpose of this study, we assumed that all brain, orbit, paranasal sinuses, neck, abdomen, pelvis, chest, and all maxillofacial scans were contrast enhanced, as data were not available on the number of non-enhanced studies done.

Expenses on I. V. contrast media were estimated using the mathematical relation:

$$E = \{[(q_1 n_1 + q_2 n_2)\ q_0]\ ^*p_0\} (n_1 + n_2);$$

where , q_1 and q_2 = the mean quantity of contrast used for an adult and a child respectively, n_1 and n_2 = the number of adults and children scanned respectively, q_0 and p_0 = unit quantity and unit price respectively. There is an added expense for oral contrast charged for abdomino-pelvic scans.

Expenses on syringes, needles, I. V. cannula, gauze bandage, cotton wool, plaster, gloves, normal saline, etc. were computed from the relation,

Expenses = $[Q_i P_i] / Z$ where Q_i = quantity of each of the items used during the period under review, P_i = the unit price of each item, and Z = the number of contrast enhanced scans done during the period.

Expenses on each of the medical consumables including contrast media were then summed up to give the total variable costs per study.

B. COMPUTATION OF FIXED COSTS
1. Personnel Costs
The personnel salaries were computed as a function of the average time required for the CT scanning procedures. Salaries of personnel were computed from the consolidated harmonized tertiary institutions salary structure (CONTISS). The average values for Radiologists, Radiographers, and clerical staff directly involved with CT scanning were found to be ₦ 1,094.45 per hour, ₦ 697.35 per hour, and ₦154.32 per hour respectively. A working period of 160 hours per month (40 hours a week) was used for this analysis.

Available records show that the average time put in for each CT procedure by the reception clerk, and the typist, is 10minutes respectively while the file room clerk puts in 15minutes.

TABLE 5: Fixed costs (Personnel costs) analysis

PART OF BODY	TOTAL TIME (Hrs)	RADIO-LOGISTS	RADIO-GRAPHERS	RECEP-TION CLERK	TYPIST	FILE ROOM CLERK	TOTAL
Brain	561.60	614,643.12	391,631.76	18,055.44	18,055.44	27,083.16	1,069,468.92
Abdomen	127.50	139,542.38	88,912.13	2,623.44	2,623.44	3,935.16	237,636.55
Pelvis	8.17	8,941.66	5,697.35	180.04	180.04	270.06	15,269.15
Chest	37.33	40,855.82	26,032.08	900.20	900.20	1,350.30	70,038.60
C - Spine	9.33	10,211.22	6,506.28	411.52	411.52	617.28	18,157.82
T - Spine	3.93	4,301.19	2,740.59	128.60	128.60	192.90	7,491.88
L - Spine	6.75	7,387.54	4,707.11	231.48	231.48	347.22	12,904.83
Neck	4.17	4,563.86	2,907.95	128.60	128.60	192.90	7,921.91
Orbit	9.33	10,211.22	6,506.28	205.76	205.76	308.64	17,437.66
P / N Sinuses	15.17	16,602.81	10,578.80	360.08	360.08	540.12	28,441.89
Inner ear	3.33	3,644.52	2,322.18	128.60	128.60	192.90	6,416.80
Nasopharynx	4.00	4,377.80	2,789.40	102.88	102.88	154.32	7,527.28
Face	1.87	2,046.62	1,304.04	51.44	51.44	77.16	3,530.70
TMJ	1.05	1,149.17	732.22	25.67	25.67	38.58	1,971.31
TOTAL	793.53	868,478.93	553,368.17	23,533.75	23,533.75	35,300.70	1,504,215.30

TABLE 6.: Estimating gross profit or loss for computed tomography

	Equipment tie-up time (min.)	Total study time (hour)	Number of studies	Total revenue	Total variable costs	Fixed costs	Total costs	Gross profit (loss)	Billing rate per study	Variable cost/study	Contribution to profit per study
Brain	48	561.6	702	19640000	4465169.28	1069468.92	5534638.2	14105361.8	27977.21	6360.64	21616.57
Abdomen	75	127.5	102	3010000	1195214.58	237636.55	1432851.13	1577148.87	29509.8	11717.79	17792.01
Pelvis	70	8.17	7	210000	73240.23	15269.15	88509.38	121490.62	30000	10462.89	19537.11
Chest	64	37.33	35	1000000	376361.65	70038.6	446400.25	553599.75	28571.43	10753.19	17818.24
C-Spine	35	9.33	16	470000	24703.36	18157.82	42861.18	427138.82	29375	1543.96	27831.04
T-Spine	47	3.93	5	140000	11469.8	7491.88	18961.68	121038.32	28000	2293.96	25706.04
L-Spine	45	6.75	9	270000	20645.64	12904.83	33550.47	236449.53	30000	2293.96	27706.04
Neck	50	4.17	5	150000	34837.4	7921.91	42759.31	107240.69	30000	6967.48	23032.52
Orbit	70	9.33	8	240000	55739.84	17437.66	73177.5	166822.5	30000	6967.48	23032.52
P/N Sinuses	65	15.17	14	420000	21615.44	28441.89	50057.33	369942.67	30000	1543.96	28456.04
Inner Ear	40	3.33	5	150000	7719.8	6416.8	14136.6	135863.4	30000	1543.96	28456.04
Nasopharynx	60	4	4	120000	27869.92	7527.28	35397.2	84602.8	30000	6967.48	23032.52
Face	56	1.87	2	60000	13934.96	3530.7	17465.66	42534.34	30000	6967.48	23032.52
TMJ	63	1.05	1	30000	1543.96	1971.31	3515.27	26484.73	30000	1543.96	28456.04
TOTAL		793.53	915	25910000	6330065.86	1504215.3	7834281.16	18075718.84			

2. Overhead Costs
Data were not available for analysis of the overhead costs. This is due to the peculiar nature of the institution studied. Record on rates, rent, electricity bill, etc. were not easily accessible . In addition, the CT scanner is a VAMED project and still under warrantee hence, no record on service and maintenance cost, and depreciation charges were accessible.

RESULTS
The results are as shown in the tables below. Table 1 showed that the total number of CT scans done in the period under review was 915 and the total revenue from the studies was ₦25,910,000. It also showed the billing per study. Table 2 showed the cost of consumables for a single CT study for various parts of body. Abdomen, chest, and pelvis gulped the highest cost of consumables of ₦11,717.79, ₦10,753.19, and ₦10,462.89 respectively while cervical spine, paranasal sinuses, inner ear, and TMJ gulped the least cost consumables of ₦1,543.96 each. Equipment tie-up time (ie. time per scanning procedure) was shown in table 3. The average variable cost analysis is shown in table 4. The total variable cost is ₦6,330,065.86. The total fixed cost is ₦1,504,215.30 as shown in table 5. The estimation of gross profit or loss for computed tomography is shown in table 6. The estimation showed that profit was recorded for all the studies, as the total revenue for each study was more than the total cost. Some studies however, contributed more to the profit per study than others did. Sinuses, inner ear, and TMJ contributed ₦28,456.04 each to the profit per study while abdomen and chest contributed the least amounts of ₦17,792.01 and ₦17,818.24 respectively.

DISCUSSION
Analysis of cost and revenue enable operators of radiology facilities especially, CT facilities to efficiently provide services that enhance profitability. It provides the yardstick for comparing the contribution to the profit of each CT investigation and the cost associated with the performance of each investigation as shown by the results in table 6. It provides a means by which the prices of CT investigations and the pricing policy of the hospital can be evaluated. From our results, it is obvious that the charges for CT investigations at the UPTH are adequate as shown by the computed gross profit in table 6.

Unfortunately, this finding could not be compared with those of any previous studies in this same subject, as we have not seen any of such, reported in the literature. We only borrowed the ideas of Robert E. O'Mara (in Bennington, L. James et al[3]) in his work on the economic evaluation of imaging equipment in nuclear medicine.

It is important to note, here, that the total fixed cost was computed based only on the personnel costs owing to the reasons given earlier on the overhead cost. We are aware of the problems associated with electricity supply in Nigeria and the heavy cost of running electricity-generating set, which incidentally has become the main source of electric power supply for most businesses including hospitals. We could not lay hands on data concerning the cost of electricity (e.g. electric bills or any book entries) and the cost of running and maintaining the available power generating set in the facility we studied. We know that this and other overhead costs not considered in computing the total fixed cost would impact significantly on the gross profit shown in table 6.

An evaluation like this is better when done at specific intervals say, monthly, quarterly, or annually so that a trend can be established over time. This is necessary because at a glance one could tell when the fortune of the facility is dwindling so that actions could be taken to forestall the situation.

CONCLUSION AND RECOMMENDATION
The performance evaluation (table 6.) revealed that with the current price regime, the gross profit was quite substantial, with the non contrast studies contributing more to the gross profit than the contrast enhanced studies thus, suggesting that contrast enhanced studies should attract higher fees especially, abdomen, pelvic and chest scans. Generally, the gross profit was well over 65% of the revenue indicating that CT imaging is economically viable. Although our inability to analyze the fixed costs completely owing to non-availability of data would impact significantly on the gross profit, we are of the opinion that the impact would not reduce the gross profit to below 45 - 50% of the revenue, a margin that is still conducive.

As marketing experts would say, price is the only component of the marketing mix that generates revenue. In pricing medical imaging products therefore, there should be a well-defined objective for the pricing decision. "A pricing objective is a general goal that describes what an organization hopes to achieve through its pricing activities.[7]"

This study has shown that CT suites can be operated at a profit if the products are adequately priced. Given the fact that replacement of CT equipment does not come that easy especially, in public hospitals, we recommend that CT operators and indeed operators of medical imaging services should do economic

evaluation of their facilities periodically to ascertain whether they are operating at a profit or loss. A concerted effort should be made to save part of the profit for the replacement of the equipment in a sinking fund annually. This will go a long way in helping to build up enough funds for the replacement of the equipment.

Sinking fund has been defined as a sort of savings fund in which funds are systematically accumulated together with investment interest on the fund, so that they amount to a desired sum at a specified time in the future. Sinking funds are generally used for liquidation of bond issues at maturity, for the retirement of some long-term loans, for replacement of fixed assets or purchase of new equipment.[4]

The sinking fund is treated like ordinary annuities as equal amounts are paid into the fund at equal interval of time. To illustrate how the sinking fund can be used to accumulate financial resources for the replacement of a CT equipment, let us assume that 50% of the profit from the operation of the CT suite evaluated is put in a sinking fund annually and let the interest rate be 20% compounded annually then, the value of the fund in 10 years time can be computed from the relation:

$$S = R\{[(1+i)^n \ 1] / i\}; \quad \text{where}$$

S = future value or amount of the sinking fund,

R = the regular periodic payment,
i = interest rate per conversion interval, and
n = number of interest periods = number of payments.[5,6]

R = 50% of ₦18,075,718.84 = ₦9,037,859.42
i = 20% = 0.2
n = 10

$$S = ₦9,037,859.42\{[(1.2)^{10} \ 1] / 0.2\}$$
$$= ₦9,037,859.42 * 25.9587$$
$$= ₦234,611,081.30$$

This shows that over ₦—234Million would be accumulated over a period of ten years.

The above example presupposes a constant margin of profit over the ten-year period. However, this is not possible in reality hence, using the sinking fund method, a future amount needed is predetermined and then the amount of the regular periodic payment that will yield this desired amount over a given time period, in the future, is calculated using the formula: $R = S\{i / [(1 + i)^n - 1]\}$; where S, R, i, and n, have the same meaning as above.

Whereas we believe that a business approach to radiology operations would yield a better result, the best possible care for the patient should be our focus at all times as healthcare professionals.

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