OPTIMUM STOCK CONTROL MODEL FOR FARM TRACTOR SPARE PARTS IN NIGERIA

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Abstract

This paper examines the issue of developing an effective farm machinery maintenance management strategy in Nigeria. Investigative survey data on the inventory, type and condition of agricultural machinery in Nigeria were reviewed and additional information required was obtained from relevant establishments. Data on frequency of breakdown of farm tractors and the costs of purchasing various components' of the farm tractors were subjected to scientific analysis using some operational research techniques. Based on the result of the analysis, an inventory (stock level control) model was adapted for the supply and replacement of worn-out machinery parts and components, at recorded frequencies of farm tractor breakdown. Tentative projections on the optimum level of tractor spare parts required for ten states in Nigeria were made and the result are presented

1. Introduction
1.1 General
The application of maintenance management principles in agricultural mechanization is what may be referred to as farm machinery maintenance management. This involves the adequate supply and replacement of worn-out components and parts of machinery. No, doubt, the failure of many agro-based projects in Nigeria has been attributed to delays n the provision and utilization of spare parts for timely and proper maintenance of the farm tractor and associated machinery, The present efforts being made by the Federal Government to import spare parts are commendable. Unfortunately, the problem of lack of spare parts is still compounded by the fact that the needed spare parts are to be obtained from the equipment manufacturers which are overseas. These manufacturers usually supply spare parts according to the quantity or number of spares ordered. If the number of spare parts required by an equipment (e.g. the farm tractor) over a given period is known, then it may be possible to order the actual number or quantity and stock it over the period of use to avoid delays. The objective of this paper is therefore to present an adapted inventory (stock level control) model for the supply and replacement of worn-out machinery parts and components, at recorded frequencies of farm tractor breakdown. The model provides the most appropriate level of spare parts to be stocked for each tractor component system at the

minimum cost over a period of tractor use.

1.2 Farm, Tractor Component Systems and Replacement parts

For effective maintenance and repairs management, tractor parts are classified into major and minor components and parts:

1.21 Major components:

Major tractor components are those components which are subject to and are characterized by major breakdowns of farm tractors. Often times the repairs effected on such components are accomplished with difficulty.

In Nigeria, the standard farm tractor is typically a four wheeled tractor with 40 - 90 h.p, range and is considered to consist of the following eight main component systems: engine system, transmission system, fuel system, electrical system, cooling system, hydraulic control and steering system braking system and traction system.

1.22 Minor tractor parts

Minor parts or components of a tractor may be described as those parts which are subject to and are characterized by minor tractor breakdowns. The repairs carried out as a result of such breakdowns are easily accomplished, Example includes; electrical parts, like the fuses and connecting wires, and worn-out nuts, bolts and studs.

2.   Investigative Surveys for Data Collection on Frequency of Breakdown

An analytical method was employed in this research work. This method involves conducting an investigative survey by use of questionnaires and information request forms designed for selected categories of agro-industrial establishments which include machinery dealers and machinery users. The purpose was to obtain and collect appropriate data on farm machinery use and performance as well as other vital technical information on the acquisition, cost and supply and maintenance of agricultural machinery and equipment.

The data obtained were used to supplement published research data on Agricultural machinery inventory, type and condition in Nigeria[1,2]. The importance· of using questionnaires in collecting relevant data for effective maintenance management was also emphasized by Biller· and ·Olfe[3] They concluded that an improved knowledge of the use of tractors in agriculture can be obtained through the investigative survey approach.

3 Inventory Models and Application.

3.1 Definition of the inventory problem:

An Inventory problem exists when it is necessary to stock physical materials (e.g. spare parts) for the purpose of satisfying demand over a specified period. Almost every agricultural production business must stock a certain level of spare parts to ensure smooth and efficient running of its operation. The required demand for spare parts may be satisfied by stocking once for the entire period of demand or by stocking separately for every time unit during the period.

The two cases may be regarded as overerstocking (with respect to one time unit) or under stocking (with respect to the entire period of demand). An overstocking would require higher invested capital per unit time bat less frequent occurrences of shortages and placement of orders. An understock, on the otherhand, would decrease the invested capital per unit time, but would increase the frequency of ordering as well as the risk of running out of stock. The two extremes are costly, Decisions regarding the quantity ordered and time at which it is ordered may thus be based on the minimization of an appropriate cost function which balances the total costs resulting from overstocking and understocking. This is the major factor that has influenced the choice of the adapted model.

3.2 Adapted model Presentation

3.2.1 The probabilistic model

The probabilistic model adapted was developed as a special type of stock control model[4] that deals with the peculiar problems of stocking spare parts for a machine. This adapted model considers the decisions on spare parts holding at the time of placing orders for the purchase of new tractors in an establishment. The spares involved are those whose failure cannot be foreseen and lead to a tractor breakdown. This same category of spare parts cannot be easily procured at the time of breakdown of tractor, because they are not manufactured in the establishment. If the spare part is not available when required there is a high cost incurred in down-time of the tractor. On the other hand this category of spare parts is made up of major parts, which are expensive as compared to minor tractor parts; and can only be used with the particular size of tractor. The situation is such that, if the part is never needed, its value may be written off as scrap and the interest rate will also be a cost incurred by the stock holder. Therefore, to obtain the optimum stock level, the expected cost of overstocking these spares must balance the expected cost of stock run-out.

After considering records on the frequency of breakdown of farm tractors in each year over a five year period of tractor use, the optimum stock level of major tractor spare parts can then be determined based on the calculated results from the mathematical model

The cost associated with holding N unit s of spare parts, if the actual number of spares required by the tractor is r, should be:
either $(N - r)$ $C1$ $prob$ (r) if r $\leq$ N
or $(r - N)C2$ $prob$ (r) if $r > N$
where:

N is the number of spares to be stocked, r is the actual number of spares required, C_1 is the cost for overstocking one spare part, C_2 is the cost for being short of one spare part, and prob(r) is the estimated probability of indicated number o spares required.

Therefore, the total expected cost for all r, of holding N units of spares is given as:

$$C(N) = c_1 \sum_{R=0}^{N} (N - r) prob\,(r)$$

$$+ C_2 \sum_{r=N+1}^{r} (r - N) prob(r) \qquad (1)$$

Where; C(N) is the total expected cost of holding N units, for all r.

Note:

It is important to note here that, based on preliminary calculation, the results showed that when N = O, the total expected cost will reduce to the value of the following equation:

$$C(N = 0) = C_2 \sum_{r=N-1}^{r} (N - r) prob\,(r) \quad (2)$$

3.2.2 Identified Variables

Although a real situation may involve a substantial number of variables, generally a small fraction of these variables truly dominate the behaviour of the system. Thus, the simplification of the real system in terms of a model concentrates primarily on identifying the dominant variables and the relationships governing them. In order to determine the most effective level of spare parts to be stocked for the farm tractor, the following variable factors have to the be examined

i.   Date of purchase of tractor and purchase price.
ii. The model, size and capacity of tractor.
iii. Experience and skill of the operator
iv. Type of soil condition and farm operation.
v.   Nature and frequency of breakdown.
vi. Cost of spare part replacement.
vii. Cost of being short of one spare part when it is needed.

From the above consideration, only three

variables namely; nature and frequency of breakdown, cost of spare part replacement and cost of being short of one spare part, constitute the dominant variables which directly determine the maximum level of spare part to be stocked over a given period of tractor use. The other variable are less dominant and merely contribute to the dominant and merely contribute to the dominant factors. Therefore, the variable considered in the model are; frequency of breakdown, cost of spare part and cost of being short of spare parts.

3.2.3 Illustrative application of model

Optimum stock level for engine component. Spare part to be stocked is piston.

For a tractor spare part (piston), the unit replacement cost (i.e a set of four)

Is ₦8,500.00.if a major spare part is needed, because of a failure of the part in use and the major spare is not available at the time of need; the down-time cost of the tractor is ₦17,500.00[5].

Records of frequency of replacements of similar component in other tractors yield the information presented in Table.1

Table 1: Frequency of replacements for the Engine component in Ten tractors (Tt)

No of spare parts required in 5years	No of tractors requiring indicated no. of spares	Estimated probability of indicated no. of spares required
(r)	(Tn)	Prob(r)
0	0	0.0
1	8	0.8
2	1	0.1
3	1	0.1
4 or more	0	0.0

Detail are found in ikiriko[5]

$$Estimated\ probability = \frac{Tn}{Tt} = prob(r)$$

Where: Tn is the number of tractors requiring indicated parts, and Tt is the number of tractors.

From equation (1)

$$c(N) = C_1 \sum_{r=0}^{N} (N - r)prob(r)$$

$$+C_2 \sum_{r=N+1}^{r} (r - N)prob(r)$$

$$Given\ that; C_1 = ₦8,500; C_2 = ₦17,500$$

$$C(N = 0) = C_2 \sum_{r=N=1}^{r} (r - N)prob(r)$$

$$= 17500[(1 - 0)0.8 + (2 - 0)0.1 + (3 - 0)0.1]$$

$$C(N = 0) = ₦22,750.$$

$$C(N = 1) = ₦8,500[(1 - 0)0.0 + (1 - 1)0.8]$$

$$+17500[(2 - 1)0.1 + (3 - 1)0.1]$$

$$C(N = 1) = ₦5,250$$
$$C(N = 2) = ₦8,500[(2 - 0)0.0$$
$$+(2 - 1)0.8 + (2 - 2)0.1$$
$$+17500[(3 - 2)0.1]$$
$$C(N = 2) = ₦8,500$$
$$C(N = 3) = ₦85500[(3 - 0)0.0$$
$$+ (3 - 1)0.8$$

$$+(3 - 2)0.1 + (3 - 3)0.1$$

$$C(N = 3) = ₦14,450.$$

From the above calculation the lowest value of C (N) is: $C(N = 1) = ₦5,250$

Therefore the optimum level of spares to be stocked for the engine component is one (1) part.

Note: Determination of optimum stock level of spare parts for tractor principally involves cost minimization. This implies that for every other subsequent case involving other tractor spare parts, the principles remain the same, that is the lowest value of the expected costs calculated will always correspond to the optimum stock level for that particular tractor part considered.

4.Projected Farm Tractor Spare Parts Requirements in Nigeria

Having determined the optimum stock levels of major tractor spare parts for the conventional tractor using data from Anambra State, it is safe to project tentatively from the obtained results the

spare part requirement of other states whose records are also available.

The tentative projections are based on the available information on the percentage frequency of breakdown of farm tractor components, for ten states, including Anambra and Rivers states[1,2,6]. The results of the projections are presented in Table 2 and in Figs. 1-3.

Further details are reported in Reference 5.

5. Conclusion

This study has emphasized the need for the determination of the most appropriate stock level of tractor spare parts for timely repair and replacement of worn, out or damaged parts of the different tractor component systems.

From results obtained, it is established that overstocking of tractor spare parts and the risk stock run-outs can both be avoided by maintaining an optimum stock level.

The results also showed that about 22% of tractor Cost (purchased price) should be set aside for repair and replacement of worn-out or damaged tractor parts throughout the entire life-period of tractor use, in Nigeria. The percentage is justified, when compared with similar percentage values of other developing countries.

Table2: *Estimation of the Optimum Stock Level of Tractor Spare Parts for Ten States in Nigeria

Tractor spare part	Optimum stock level of spare parts by states										
	Anambra	Bauchi	Benue	Kaduna	Kwara	Imo	Ogun	Oyo	Plateau	Rivers	National average
Piston(a set)	2	2	2	2	2	4	0	4	8	1	4
Clutch	3	6	6	6	6	6	18	9	6	3	6
Kickstarter	8	8	8	4	4	4	8	8	8	8	8
Brakes(a set)	4	16	4	0	8	4	4	4	4	4	4
Hydraulic pump	6	6	6	3	6	3	3	12	6	3	6
Radiator	2	0	2	0	4	0	0	2	4	4	2
Rear tyre	1	1	4	9	3	2	3	1	2	5	2
Fuel injection pump	6	6	3	3	0	6	3	3	3	3	3

Estimation are made from optimum stock level of spares for Anambra state, and based on the recorded percentage frequency of breakdown on farm tractor component systems of the ten states.
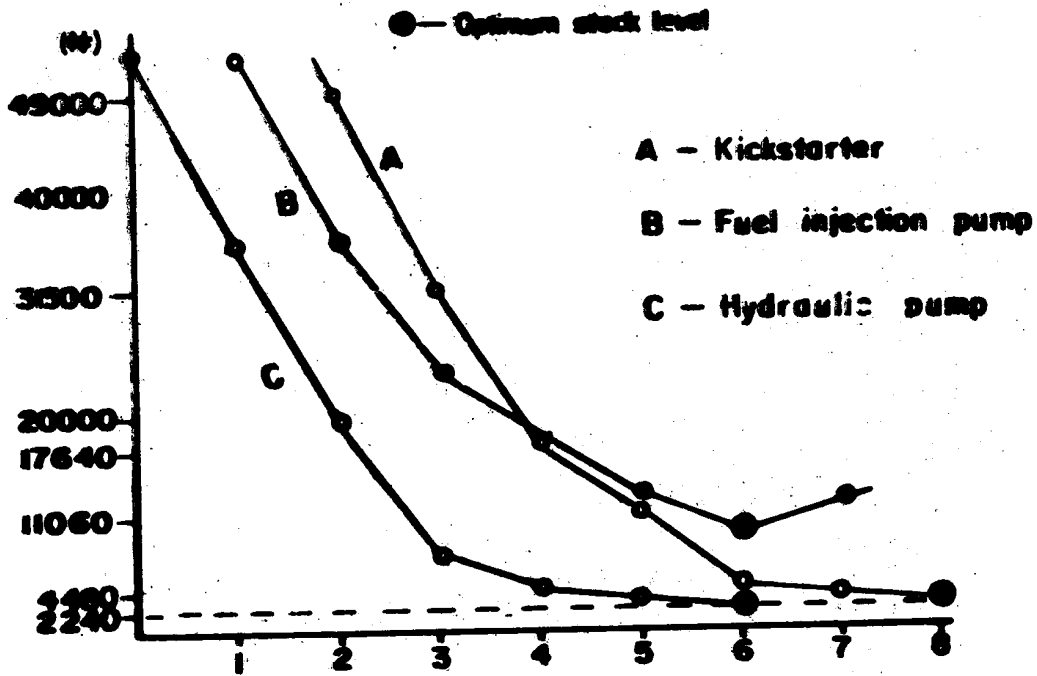
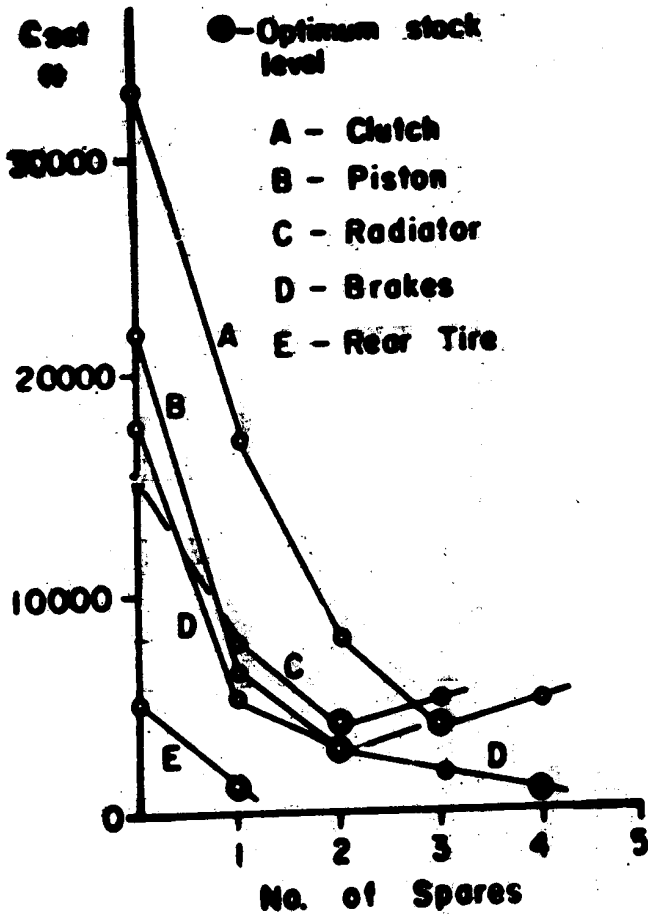Figure 1:   Component Spares to be Stocked and the Total Expected Costs
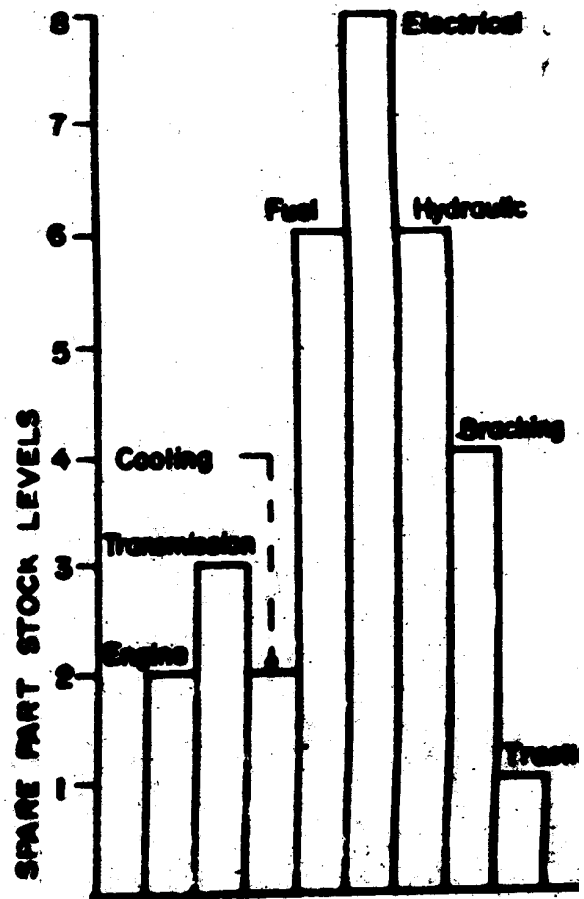

Figure 2:   Component Spares and Costs

Figure 3:   Tractor Component Systems and Optimum Stock Levels of Spare Parts

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