REPAIR AND MAINTENANCE COST ANALYSIS OF FARM MACHINERY AND TRACTORS

BY

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B.Sc. (Agric. Mech.), Cairo University, 1982

THESIS

Submitted to the Graduate Division in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

IN

AGRICULTURAL MECHANIZATION

DEPARTMENT OF AGRICULTURAL MECHANIZATION
FACULTY OF AGRICULTURE
KAFR EL-SHEIKH
TANTA UNIVERSITY

1993

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ACKNOWLEDGEMENT

The author wishes to express his deep thanks and appreciation to **Prof. Dr. Metwalli Metwalli Mohamed**, professor and head of Agricultural Mechanization Department, Faculty of Agriculture, Kafr El-Sheikh, Tanta University for his generous encouragement and hepling.

The auther also would like to express his deep thanks to **Dr. Mamdouh Abbas Helmy**, associate prof. in Agric. Mech. Dept., Faculty of Agriculture, Kafr El-Sheikh, Tanta University, for his supervision and helpful comments.

Many thanks to Dr. **Samir Mahmoud Gomaa**, Assist. porf. in Agric. Mech. Dept., Faculty of Agric., Tanta University, for his supervision and helpful comments.

Special thanks and great indebted to **Dr. Ismail Ahmed Abdelmotaleb,** Assist. prof. in Agric. Mech. Dept., Faculty of Agric; Tanta University, for his Scientific help, supervision, excellent guidance, too much effort, continuous encouragement, helpful criticism, and providing effective research materials.

Very deep thanks to my parents, my brothers, my sister and my wife for their encouragement during my studying for M.Sc.

Special thanks for my lovely son **Essam** who is the light of my life .

CONTENTS

INTRODUCTION

It is known that total machinery costs include two main parts, fixed costs and variable costs. Fixed costs include depreciatoin, interest on investment, insurance, taxes and housing. Variable costs include repair and maintenance, fuel and oil, lubricant and labor. The distinction between fixed and operating costs is clear for all items except depreciation and repairs .

Repair and maintenance costs of farm machinery and tractors are important components of total costs. This is because one of the most important point of a modern machinery management system is an accurate cost estimate for each machine. This cost must be estimated accurately for a specific machine of any initial cost for any annual use and at any given age .

Abdelmotaleb (1993) conducted a study on repair and maintenance cost analysis of farm machinery under Egypt's conditions. He developed a survey to collect current repair cost data from a sample of Kafr El-Sheikh. These data were used to test the American Society of Agricultural Engineers (ASAE) repair cost formulas under Egypt's conditions. The analysis of the data indicated that, the ASAE repair cost formulas were not completely accurate under Egypt's conditions.

Reasonable estimates of repair costs are very important in the context of farm machinery selection, replacement decisions and for general farm management accounting purposes.

This study may help the people who are working on tractor and machinery service stations to keep good records for repair and maintenance costs for tractors and farm machinery .

<u>The objectives of this study were as follows :</u>

1- To obtain current repair and maintenance cost accurately and to use it for estimating the actual value of total costs for any machine .

2- To develop models for repair and maintenance cost so that it can be used for predicting repair costs under Egyptian conditions .

REVIEW OF LITERATURE

Total Costs :

Hunt (1983) mentioned that machiney costs have a great influence on profit. For farmers who don't have control over product prices, the revenue is well fixed, then, the size of an operation can be limited by machinery costs. Machinery costs are divided into two main categories, fixed costs and variable costs. Fixed costs are independent of use and it is depending more on how long a machine is owned rather than how much it is used. Fixed costs are including the following items:

a - Depreciation
b - Taxes
c - shelter
d - Insurance
e - Interest

Variable costs are those varying in proportion to the amount of machine use. It is including the following items :

a - Fuel and lubricant
b - Labor
c - Repair and maintenance

Repair and maintenance costs are considered as an important part of machinery costs. That costs involve those expenditures necessary to restore or to maintain the technical soundness and reliability of the machine following wear and tear, random failure, and accidents. There are many factors affecting rerpair and maintenance costs of farm machinery such as hours of working, machine age (years), made and model, and farm size.

Bainer et al. (1982) claimed that the greates single factor affecting the unit cost of operation of a machine was annual use.

1- **Repair and Maintenance Costs of Trctors :**

Boyce et al. (1960) carried out a study on agricultural machinery cost in the Eastern counties of England. They indicated that farm machinery costs may constitute about 30% of the fixed costs. Also, the repair and maintenance costs reach 60% of the initial cost. They estimated repair costs from the following formula :

$$Y = 3.00 + 0.005\ X$$

Where :

Y = Repair rate as % of initial price .

X = Accumulated annual use (hours).

Bowers and Hunt (1970) presented mathematical formulas for repair costs by surveying about 900 farmers at Illinois and Indiana. The farmers were asked to estimate age, annual use, initial cost, and repair costs for tractors. They ploted curves to indicate the relationship between repair rate and accumulated use. By integrating the repair rate curves, they obtained the following formula :

$$TAR = 0.1564\ X^2 - 0.000143\ X^3$$

Where :

TAR= Total accumulated repair cost .

X = Accumulated use in 100's of hours .

Fairbanks et al . (1971) conducted a study on cost of using farm machinery. They used the Kansas survey data to produce a repair cost formula for Diesel engine tractors as follows :

$$Y = 1.4\ (X / 1000)^{2.19}$$

Where Y is the accumulated repair cost in percent of initial list price and X is the accumulated operating hours as a percent of the wear - out life in hours .

Rahmoo et al. (1979) carried out a study on cost of owning and operating tractors in Pakistan. They surveyed 256 tractors which have power ranged from 50 to 55 HP. The costs are divided into two groups, fixed costs and variable costs. The variable costs include repair and maintenance costs. They found that repair costs showed a high rate during the fourth to sixth years of use, then decreased directly after the period of overhauls, then increased again with the age of the tractors.

Culpin (1975) mentioned that repair and maintenance costs of tractors were 25% of the total costs after 2500 hours of use .

According to ASAE (1980) repair cost equations for predicting repair and maintenance costs can be formulated as follows :

$TAR = 0.9168\ X^{1.4856}$ (For Tractors)

$TAR = 1.6146\ X^{1.7325}$ (For Combines)

$TAR = 55.24\ X^{1.05}$ (For Planters)

Where :

TAR = Total accumulated repair costs .

X = Accumulated hours .

Wiliam et al. (1981) obtained a new method for estimating farm machiery costs. They said that repair cost is one of the most important component of total costs. Also, they found that repair cost was 15% of the total costs .

Henderson and Fanash (1984) conducted a survey in Jordan to compare costs and use of governmental tractors with costs of operating privately-owned ones. The survey include 96 tractors of various makes. The private sample represented 16% of all the tractors. They found that tractor repair cost of privately-owned was 16% of total costs and it was 21% for governmental owned. Also, they mentioned that repair and maintenance costs after 636hours of use were 2.443JD/h(7.9$/h)

Rotz (1985) proposed a standard model for repair costs of agricultural machinery. He mentioned that, the model structure which best describes the typical trend in repair and maintenance costs was that described by ASAE (1966) as follows :

$$TAR = RC_1 (X)^{RC_2}$$ Where :

TAR = Total accumulated repairs as % of initial list price.

X = Accumulated hours as % of lifetime hours .

RC_1 , RC_2= Model parameters, function of machine type .

He modified a new model as follows :

$$TAR = LIP (RC_1) (USE)^{RC_2}$$

$$TAR = LIP (RC') [(USE)(S)]^{RC_2}$$

Where :

LIP = List price of new machine, $. USE = Accumulated hours

$RC' = RC_1 / (AS).RC_2$

AS = Average or typical field speed, Km/h

S = Field speed of machine, Km/h

He mentioned that a problem can occur by using that model if machine speed is considered because a machine which is operated at a faster speed will be used less hours and, therefore, have a lower cost .

According to ASAE (1986) accumulated repair and maintenance costs at a typical field speed can be determined using the following equation :

$$ARM = P\ [\ RF1\ (X) RF2\ ]$$

Where :

ARM = Accumulated repair and maintenance costs, % of initial list price .

X = Accumulated use of machine (X = accumulated hours/1000).

P = List price in current dollars .

RF1,RF2 = Repair and maintenance factors .

For Tractors :

RF1 = 0.012 (For 2WD)

= 0.010 (For 4WD)

RF2 = 2.00 (For 2WD and 4WD) .

Ward et al. (1985) conducted a study on repair costs of 2 and 4 WD tractors. They obtained data from the governmental department which was included 42 tractors (2WD) and 21 tractors (4WD) over the ten years period (1972 - 1982). They found that the repair cost for 4WD tractors is higher than 2WD tractors. They obtained the following equations :

- For two - wheel drive tractors :

$$TAR = 0.042\ (TAUH)^{1.895}$$

- For four - wheel drive tractors :

$$TAR = 0.04055\ (TAUH)^{1.923}$$

Where :

TAR = Total accumulated repairs as % of initial list price .

TAUH = Total accumulated hours of tractor use .

Abdelmotaleb and Marely (1987) developed a survey to collect current data on the costs of repair and maintenance of tractors and combines from a sample of Iowa farmers. They used these data to examine the previous formulas, which have been recommended by the ASAE, and to test their degree of accuracy. The analysis of the data showed that the previous formulas were not completely accurate in predicting repair costs of tractors and combines used in centeral Iowa.

Hanna and Younis (1987) conducted a study on repair and maintenance costs of farm machinery in Egypt using field data for 67 tractors. They found that repair and maintenance costs under Egyptian conditions were varied widely comparing with the previous data in various countries of the world. They reported that, tractors under investigation supposed to have a whole service life of 10,000 hours. The rate of repair and maintenance costs was 27.789% of the initial list price for the first 1000 hours, 30.043% of the initial list price for the 2000 hours and 46.278% of the initial list price after 1/4 of service life. They also investigated 50 turning mouldboard ploughs and 41 reciprocating mowers. They formulated the relationship between repair and maintenance costs as a percentage of initial list price (Y) and the accumulated hours of use (X) as follows :

$Y = 19.78e^{0.00034X}$ For Tractors.

$Y = 18.20\ e^{0.00169X}$ For Mowers.

$Y = 7.60\ e^{0.00128X}$ For Ploughs.

Hardesty and Carman (1988) reported that repair and maintenance cost per hour for a wheel tractor with an average use of 1200 hours year increased from $4.19 (during the first year) to $16.44 (during the tenth year). Also, they found that repair costs per hour of operation for medium crawler tractors was $6.58 and $11.07 for wheel tractors .

El-Banna (1988) obtained a standard model for tractor repair and maintenance costs as follows :

$$C_{(R\&M)} = a_r (X)^{br}$$

Where :

$C_{(R\&M)}$= Accumulated repair and maintenance cost, as a percentage of initial list price .

X = Accumulated use hours, in thouthand hours.

a_r and b_r = Model parameters that depend on machine type .

He also mentioned that ar and br are as follows :

	a_r	br
For Tractors :	0.0146	1.8290
For Combines:	0.0455	2.0960
For Rotaries :	0.1240	2.1150
For Drills :	0.0929	1.8730
For Pumps :	0.0326	1.7540
For Transplanters :	0.0925	2.0090

Gliem et al. (1988) conducted a study on variable costs of operating farm machinery in Ohio . They mentioned that the average total annual repair and maintenace costs for all tractors was $ 9.74per acre .

Morris (1988) carried out a study on tractor repair costs. Fifty tractors with complete records were selected for analysis. Those tractors were purchased between 1972 and 1983 with ranged total hours per tractor from 2500 and 7000 hours. He mentioned that repair costs can be estimated from the following formula :

$$Y = [0.0996 (X)^{1.4755}] / 1000$$

Where :

Y = total cumulative repair cost as a percentage of list price (%p)

X = Cumulative hours of use (hrs)

Witney (1988) mentioned that, accumulated repair and maintenance costs can be estimated from the following equation:

$$AR / PP = K [U. (V_1/V_0)]^m$$

Where :

AR = Accumulated repair and maintenance costs .

PP = Initial list price .

K = Repair constant.

U = Accumulated use hours.(hrs)

V_1 = Actual operating speed, (Km/h).

V_0 = Theoretical operating speed, (Km/h).

m = Repair exponent.

The value of repair constant and repair exponent for the tractors are 0.012 and 2.0(for 2WD) and 0.010 and 2.0(for 4WD) respectively .

Abdelmotaleb (1989) conducted two questionnaire surveys to collect current repair cost data for tractors and combines from a sample of Iowa farmers. He found that the factors affecting repair and maintenance costs for tractors and combines included make and model, age, annual use, and farm size. Also, he developed two formulas for predicting yearly repair cost for tractors and combines as follows:

$Y = 0.072\,TAH + 0.0096P + 0.066H + 78.00$ For Tractors

$Y = 241.70N + 0.016P + 2.27H + 1.07A - 1894.9$ For combines

Where :

Y = Repair and maintenance costs ($/year) .

TAH= Total accumulated hours of use at end of year (hrs).

P = List price ($) .

H = Annual hours of use (hrs) .

A = Annual harvested acres.

N = Age of combine (yrs).

Weiershaeuser (1989) carried out a study on repair costs for farm machinery in cost calculations. He collected the data from repair workshops. He found that, the best function for repair costs as follows :

$$Y = 28.78\,X^{0.75} - 13.9323\,X^{1.00} + 1.946353\,X^{1.25}$$

Y = Accumulated repair costs (DM).

X = Accumulated hours of use (hrs).

Zaidi et al. (1992) developed a mathematical model for repair and maintenance cost of agricultural machinery and tractors. A survey was conducted to collect the data from 24 villages (120 farmers). The data were recorded for 93 tractors. Their model was similar to Rotz's model (1985) and it was described by the following formula :

$TAR = A(TAUH)^B$

Where :

TAR = Total accumulated repairs as % of the initial price.

TAUH = Total accumulated use in hours as % of wear-out life.

A , B = Model parameters.

Parameter B describes the distribution of repair and manitenance costs throughout the machine life while parameter A describes the magnitude of the costs .

		A	B
For Tractors	:	0.0669	1.592
For Thresher	:	0.0936	1.465
For Trailer	:	0.0927	1.488
For Cultivator	:	0.3840	1.164

Abdelmotaleb (1993) conducted a study on repair and maintenance cost analysis of farm machinery under Egypt's conditions. Using the STEPWISE regression procedure to fit the best model for predicting total accumulated repair costs for tractors leads to the following equation :

$TARC = 1680A + 68.3P + 0.133\ ILP - 8824$

Where :

TARC = Total accumulated repair cost (L.E).

A = Age of the tractor (years) .

L.E = Egyptian pound .

P = Tractor Power (HP) .

ILP = Initial list price in current (L.E).

2- Repair and Maintenance Costs of Farm Machinery :

Boyce et al. (1960) found that there was a relationship between accumulated repairs and maintenance costs (Y) and accuumulated use (X) as follows :

For Chisel plough : $Y = 2.00 + 0.060X$

For Rotary plough : $Y = 2.00 + 0.050X$

For Disc harrow : $Y = 1.50 + 0.040X$

For Drills : $Y = 1.50 + 0.040X$

For Spiked Rotor : $Y = 1.75 + 0.045X$

In 1966, Huber conducted a study by personal interviews to determine the effect of type of crop harvested upon the depreciation and repair costs of relatively new self-propelled combines. He asked each farmer to provide information on machine make and model, purchase date, initial list price and acres of various crops harvested. He obtained an equation as follows :

Total repair cost in % of new cost = $4.53 - 0.034G - 0.022C$

Where :

G = Precent use in small grain.

C = Percent use in corn.

The analysis of the repair cost data indicated that soybeans were the cause of more repairs than corn and small grains.

According to the Agricultural Engineers Yearbook (1973), the accumulated repair and maintenance costs at any point in a machine's life can be estimated from the following equations :

- For Tractors 2WD :

$$TAR\ \% = 0.120(X)^{1.5}$$

- For Tractors 4 WD :

$$TAR\ \% = 0.100\ (X)^{1.5}$$

- For Scrapers :

$$TAR\ \% = 0.096\ (X)^{1.4}$$

- For Combines :

$$TAR\ \% = 0.096\ (X)^{1.4}$$

- For Rotaries :

$$TAR\ \% = 0.096\ (X)^{1.4}$$

- For Cornpickers :

$$TAR\ \% = 0.127\ (X)^{1.4}$$

- For Swather :

$$TAR\ \% = 0.159\ (X)^{1.4}$$

- For Fertilizer equip. :

$$TAR\ \% = 0.191\ (X)^{1.4}$$

- For Mowers :

$$TAR\ \% = 0.301\ (X)^{1.3}$$

Where :

TAR = Total accumulated repair cost to data divided by the list price, expressed as a percentage.

X = 100 times the ratio of the accumulated hours of use to the wear out life.

Hassan and Larson (1978) collected combine cost data through personal interviews of farmers and custom operators. They found that repair costs were 18% of the average total costs. Also, they stated that repair rates increased from 0.0116 to 0.1537 dollars per $ 1000 initial machine price from the first year to the tenth one.

Ward et al. (1985) developed a survey to collect data on repair costs and reliability of silage mechanization systems. The survey included 24 double chop forage harvesters, 44 trailed precision chop forage harvesters, 20 self-propelled precision chop forage harvesters and 57 rotary mowers. They obtained the following equations :

- For double chop forage harvesters :

$$TAR = 83.38\ (TAU)^{1.377}$$

- For trailed precision chop forage harvesters :

$$TAR = 74.87\ (TAU)^{1.640}$$

- For self-propelled precision chop forage harvesters :

$$TAR = 02.47\ (TAU)^{2.006}$$

- For rotary mowers :

$$TAR = 34.75\ (TAU)^{1.220}$$

Where :

TAR = Total accumulated repairs as percent of machine initial list price.

TAU = Total accumulated use (hours).

Abdel - Mageed (1988) obtained data on repair and maintenance costs of pumping sets in Egypt. He used the least square regression between total accumulated hours (X) and repair cost expressed as a percentage of initial list price (Y). He found that the best fit equations were the exponential form :

$$Y = a.e^{bx}$$

Where :

a and b are parameters depend on the type of the machine.

He mentioned that a = 0.015 and b = 0.297.

Abdelmotaleb (1993) obtained repair and maintenance cost formulas for the following machines :

- For Combines :

$$TARC = 2374.3A + 1.35TAH + 0.193\ ILP - 10599.$$

- For Transplanters :

$$TARC = 2.10TAH + 0.572\ ILP - 2532$$

Where :

TARC = Total accumulated repair costs (L.E).

A = Age of the machine (years).

TAH = Total accumulated use hours (hrs).

ILP = Initial list price in currentt (L.E).

MATERIALS AND METHODS

1- *Data Collection :*

The time period for collecting the data was from 1989 to 1992 during the working time . The data were collected from seven governorates. These governorates were Kafr EL-Sheikh, Dakahlya , Sharkiya, Beni-Swafe, EL-Fayoum , Alexandria and Beheira. The data were obtained from three main sources as follows :

a- Farm Machinery Service Stations .

b- Agricultural Rrsearch Centers .

c- Agricultural Engineering Research Institute .

a- **Farm Machinery Service Stations :**

The repair and maintenance cost data were collected from some farm machinery service stations such as Moubarak Center For Agricultural Machinery, Manzala and Dekerness (El-Dakahlya), Kafr Sakr (El-Sharkya), Sids (Beni-Swafe) and Kallein (Kafr El-Sheikh) service stations for farm machinery .

b- **Agricultunal Research Centers :**

The data also were collected from some research centers such as Sakha and Nobareia .

c- **Agricultural Engineering Research Institute :**

Many of the data were collected From Meet EL- Dyba (Rice Mechanization Center), Sabahiya , EL-Sheikh Ahmed, and Fayoum . All the previous centers are belong to Agricultural Engineering Research Institute .

1-1- Data collection Form :

The data were collected from seven governorates which keep machinery records as a part of large managemet accounting system. Repair and meintenance cost data for six kinds of machine were available. These machines were, tractors, combines, rice transplanters, seed-drills and rotary plows. All the previous machines are different sizes and powers. For each machine, separate records were kept for working of yearly hours and repair and maintenance costs.

The following form was used for collecting the repair and maintenance costs data :

SURVEY SHEET

* Machine Type :
* Make and Model :
* Specification :
* Technical Condition :
* Entry Date :
* Machine List Price

No.	Year	Yearly Operating Hours	Repair and Maintenance Costs (L.E.)	Notes
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
Total				

1-2- **Data Collection Difficulties :**

Data were collected (as mentioned before) from three main sources. On the other hand , collecting data from farmers were not available because many farmers did not have good records for their machines for repair and maintenance costs . Even sometimes one can read the hour meter, repair and maintenace costs were not available.

2- ***Data obtained :***

The repair and maintenance cost data included costs of repairing, oiling , greasing, cleaning , changing parts (such as filters, batteries , belts, knives, and so on), and mechanical inspection. These expenditures are necessary to keep a machine working due to wear, part failures , accidents , and natural deterioration according to (ASAE Standards 1989).

The following data were obtained :

1- Annual usage (hours).

2- Repair and maintenance costs.

3- Machine make and model.

4- Year of purchase.

5- Initial list price at purchasing year (L.E).

2-1- **Definition of Input Data :**

The computer program SAS (Statistical Analysis System), was used to analyse the input data for tractors, combine horvesters, rice transplanters, seed drills, scrapers and rotary plows. These input data were as follows :

a - Repair and maintenance costs :

They include all money spent for repairing machine in a service shope and for parts purchased form the installation on the farm.

b- Annual use hours :

They were collected annually, based on the records from the service stations or research centers.

c- Age, (years) :

It was the age of the machine since it was new until the year of estimation.

d- Initial list price :

It was obtained from the invoice of every machine which is suggested by manufacturers (Hunt 1970).

2-2- Correction For Inflation :

The costs of repair and maintenance have increased at a fairly constant rate according to the annual report of Egyptian Central Bank (1988 , 89 , 90), the inflation rate for farm machinery were as follows :

Year	84/85	85/86	86/87	87/88	88/89	89/90	90/91	Average
Inflation rate	5.6	14.7	14.7	29.3	16.5	20.9	19.1	17.26

All the costs and list prices in this study were corrected with the average inflation rate and multiplied by $(1+i)^n$ (ASAE Standards 1989).

Where :

i = The average inflation rate.

n = The age of the machine.

3- ***Data Analysis :***

Repair and manitenance cost data were examined and analysed using a compurter program (SAS). The computer is located at the Agricultural Research Center in Cairo.

3-1 **SAS Program (1985,88) :**

For selecting the best regression equations, it must include in the regression equations all the possible independent variables that may affect the dependent variable. However, according to this study, repair and maintenance cost was the dependent variable (Y), while, age (years), working hours (hrs) and initial list price (L.E.) were the independent variables (x_1, x_2, x_3) respectively.

There are several procedures for selecting the best regression equation.

The following three procedures were examined :

a- The Backward Elimination procedure :

The regression equation containing all variables is computed, regression parameters are estimated by the least squares method. The partial F-value is calculated for every independent variable in the regression equation and it is based on the partial mean square. The probability associated with the lowest partial F-value is compared with a pre-selected level of significance.

b- The Forward Selection Procedure :

The simple linear correlation of each one of the independent variables and the dependent variable is computed. The partial linear correlation for each of the remaining independent variables and dependent variable, adjusted for the variable(s) in the regression equation, is computed along with its associated probability.

c- **The Stepwise Procedure :**

The simple linear correlation of each one of the independent variables and the dependent variable is computed along with its associated probability. The partial linear correlation of each of the remaining independent variables and dependent variable, adjusted for the independent variable(s) in the regression equation, is computed along with its associated probability.

The STEPWISE procedure of SAS selects the best regression equation based on the above three methods as well as some other methods.

3-2 Data management Method :

For each machine, separate record was kept of yearly hour meter readings. The machines were classified by age (years), annual use (hrs), initial list price and accumulated repair and maintenance costs. The selected machines for analysis were purchased from 1980 and 1990. The machine age ranged from one to ten years. On the other hand, the operating hours ranged from 100 to 9500 hours during the ware out life.

The survey included 133 tractors, 100 combine harvesters, 120 rice transplanters, 142 local scrapers, 98 seed-drills and 99 rotary ploughs .

The survey data computed by two methods as follows :

1- The relationship between repair and maintenance costs (as a percentage of initial list price) and accumulated hours. Both initial purchase price and accumulated repair and maintenance costs were adjusted for inflation to a base year of 1991. The data were weighted according to the number of machines in each age group and entered into a least-square curve fitting program, then, the best fit equation was selected.

2- The relationship between repair and maintenance costs (L.E.) and all other variables such as age (years), accumulated hours and initial purchase price. The repair and maintenance costs and initial purchase prices were adjusted for inflation to a base year of 1991 .

The data entered into a Backward elimination procedure, Forward selection procedure and Stepwise procedure of a SAS program to select the best regression equation .

3-3 <u>SAS Computer Program :</u>

```
DATA; INPUT x1 x2 x3 Y ; CARDS;
                (data lines)
PROC PRINT ;
        TITLE 1 "forward selec., backward elim., and stepwise reg." ;
        TiTLE 2 "printout of the given data";
PROC STEPWISE; F B STEPWISE ;
        MODEL Y = x1 x2 x3 / F B STEPWISE ;
        TITLE  2 "Selecting the best regression equation" ;
RUN;
```

RESULTS AND DISCUSSIONS
1- TRACTORS

1-1 Characteristic of Tractors data :

The data obtained from this study were extracted from an analysis of 133 tractors (Table 1).

The percentage of Nasr tractors was 26.32%, and for Ursus tractors it was 18.80% of the total. The percentage of other 54.88% was Yanmar, Kubota, Ford, John-Deere and Hinomoto. Data in Table 2 shows the distribution of the tractors age. From these tractors, there were 20 tractors ten - years - old (15%) and 21 tractors nine-years-old (15.8%), while eight tractors were one - year - old (6%) and six tractors two years - old (4.51%) . The 58.64 % of the total were from three to eight - years - old .

Data in Table 3 shows the distribution of the tractors according to its power (kW). There are 50 tractors (37.59%) having a power ranging from 30 to 44 kW. The same percentage was obtained for the tractors having power ranging form 60 to 75 kW. The 24.82% of the total having power ranging from 45 to 59 kW. Data in Table 4 shows the statistical analysis for these tractors. The average (mean) of tractors age was 6.5 (yrs), 6072.7 (hrs) for accumulated hours , 27286.8 (L.E) for list price and 18172 (L.E) for accumulated repair and maintenance costs. Also, it was clear that 40.78% was for coefficient of variation of tractor age, 40.86% for accumulated hours, 26.78% for list price and 57.39% for accumulated repair and maintenance costs.

Table 1 : Tractor trade name for the survey :

Tractors	Number	Percent
Nasr	35	26.32
Ursis	25	18.80
Kubota	20	15.03
Yanmar	20	15.03
Ford	15	11.28
John-Deere	10	7.52
Hinomoto	8	6.02
Total	133	100

Table 2 : Number of tractors and its percentage of the total :

Age (years)	No. of tractors	% of each age group of the total tractor numbers.
1	8	6.02
2	6	4.51
3	6	4.51
4	6	4.51
5	20	15.04
6	19	14.29
7	13	9.77
8	14	10.52
9	21	15.79
10	20	15.04
Total	133	100.00

Table 3 : Number of tractors according to its power (kW) and the percentage of each group :

Power (kW)	No. of tractors surveyed	% of each group of the total
From 30.00 To 44.00	50	37.59
From 45.00 To 59.00	33	24.82
From 60.00 To 75.00	50	37.59
Total	133	100.00

Table 4 : Data statistical analysis for the tractors :

Measures	Age (years)	Accumulated Hours	List Price	Accumulated Repair & Maintenance costs
Mean	6.52632	6072.74	27286.8	18172
Median	7.00	6228	24000	17632
Mode	9.00	9600	24000	19704
Range	9.00	9280	22388	45543
Standard Diviation	2.66168	2481.09	7308.04	10428.4
Standard Error	0.230797	215.138	633.688	904.254
Coefficient of Variation	40.78	40.86	26.78	57.39

1-2 : Analysis of repair and maintenance costs for tractors :

Using SAS program , the following methods were used :

1 - Forward selection method .

2 - Backward elimination method .

3 - Stepwise regression method .

4 - Power method .

So, the obtained models were as follows :

Model (1) : $Y = a X^{b}$

Model (2) : $Y = a + b_1 X_1 + b_2 X_2$

Where :

Y = Repair and maintenance costs as a percentage of initial list price (%) .

X_1 = Age (years).

X, X_2 = Hours of working (use).

a, b, a_1, b_1 = Model parameters .

Table 5 shows the summary of tractor formula constants , R squared and degrees of freedom of the data for the two obtained formulas .

Table 5: The summary of tractor repair and maintenance cost formula constants :

	Constants				R2	d.f
	a	b	b1	b2		
Formula (1)	$Y = 0.0009 X^{1.2838}$					
	0.0009	1.2838	---------	---------	0.96	132
Formula (2)	Y = - 11.33 + 15.37 X1 - 0.004 X2					
	- 11.33	---------	15.37	- 0.004	0.89	131

These repair and maintenance cost models can be applied to any tractor .

Repair and maintenance costs tend to increase with the accumulated use as shown in Figure 1. In the first year of ownership, repair and maintenance costs are nearly zero becuase repairs are covered by the garranty.

Appendix (A.1) shows the summary of data analysis of forward selection, backward elimination and stepwise regression for selecting the best regression model for tractor repair and maintenance costs.

In addition, repair and maintenance costs reached about 123% of initial list price for the wear-out life of tractors (10000 hrs).

1-3 <u>Model verification</u> :

To verify the results obtained by the proposed model and its parameters, a comparison was made between the model and the other models which previously published by Ward et al (1985), ASAE (1987), and Hanna and Yonis (1987) for tractors . Table 6 shows a comparison between the models of previous studies and the model obtained by this study .

Table 6 indicates that repair and maintenance costs as a percentage of initial list price in Egypt is higher than the other countries except Ward model. That is due to the technical level of the workers and the type of working conditions.

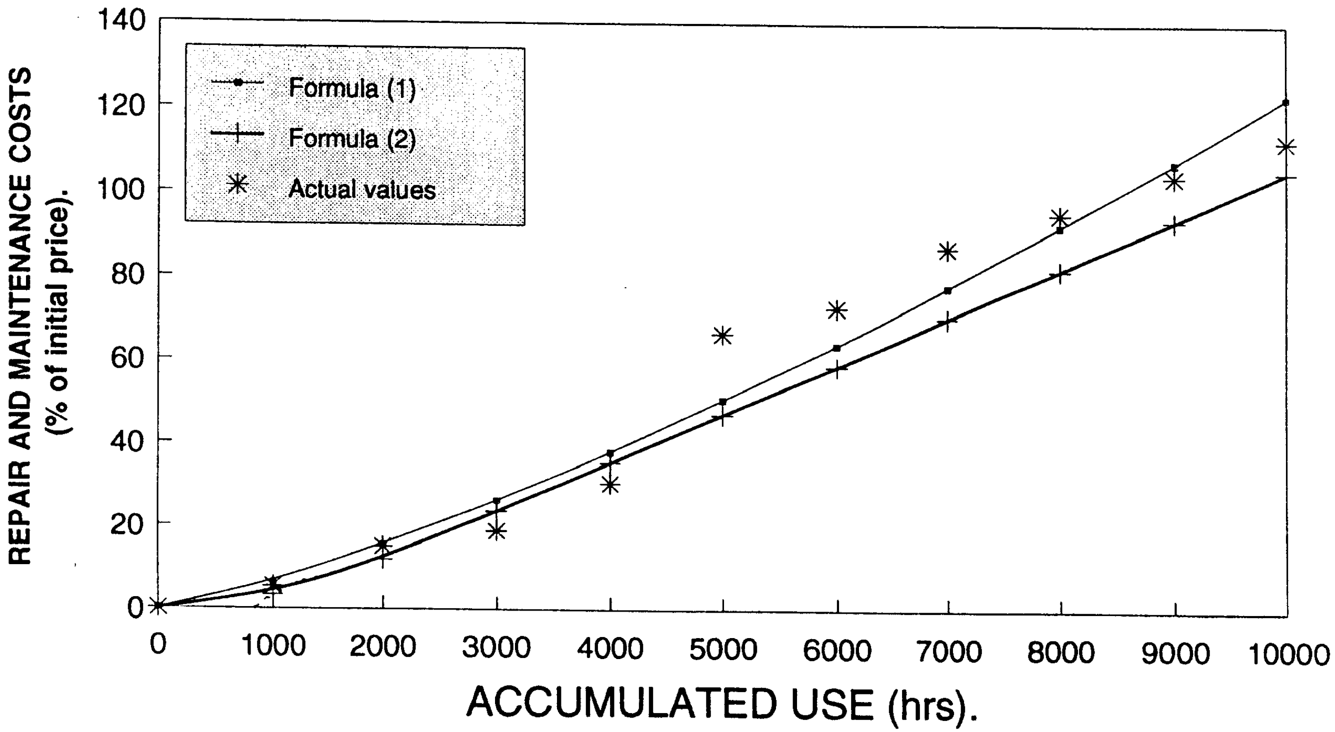

Fig.(1): The influence of accumulated use (hrs) on the repair and maintenance costs of tractors.

صفحة (٣١) ناقصة من المصدر

Table 6. Models obtained by previous studies of repair and maintenance costs for tractors:

No.	Source	Equation	Repair and maintenance costs % of list price at 10.000 hours.
1	Ward et al (1985)	$Y = 0.042(X/120)^{1.8950}$	183
2	ASAE (1987)	$Y = 1.2(X/1000)^{2.000}$	120
3	Hanna & Yonis (1987)	$Y = 19.78(e)^{0.00034X}$	593
4	The present work	$Y = 0.0009X^{1.2838}$	123

Where:

X = Hours of working (hrs).

Y = Repair and maintenance costs as a percentage of initial list price (%).

e = Base of natural logarithms (2.71828).

The repair and maintenance costs reached 49% of the initial list price after 5000 hours of working (ward et al 1985) and 183% of initial list price after 10.000 hours of use (fig .2). On the other hand it was found that ASAE (1987) repair and maintenance costs after 5000 hours of use reached to 30% of initial list price and 120% after 10,000 hours. Hanna and Yonis (1987) mentioned that repair and maintenance costs reached 108% of list price after 5000 hours of use and 593% of list price after 10,000 hours of use.

2- COMBINE HARVESTERS

2-1 Characterisitic of combine harvesters data :

The data obtained from this study were extracted from an analysis of 100 combine harvesters Table 7.

The main important factor for combine harvesters is the cutting width.

Table 7 shows the number of combines according to its cutting width. There were 12 units represent 12% of the total combine harvesters (90 cm cutting width), while most of the combines (48% of the total) had 120 cm cutting width, and 10% of the combines had 240 cm width. There were thirty combines (30%) their cutting width more than 240 cm. cutting width.

Table 8 shows the number of combine harvesters surveyed according to its age. This table shows that, the number of combines from one-year-old to four- year old were 49 units and representing 49% of total, while the other 51 units which represent 51% of the total, their age ranging from five to eight-years-old.

Table 9 shows the distribution of the combine harvesters according to its trade name. It was found that Yanmar combine harvester represented about 48% of total combines. Deutz make was 20%. On the other hand, 32% of the total were Kubota, John-Deere and others .

Table 7 : Number of combine harvesters according to its cutting width :

	Cutting width (cm)	No. of combines	Percent (%)
1	90	12	12.00
2	120	48	48.00
3	240	10	10.00
4	Morc than 240	30	30.00
	Total	100	100.00

Table 8 : Number of combine harvesters according to its age :

Age (years)	No. of Combines	Percent (%)
1	14	14.00
2	14	14.00
3	14	14.00
4	7	7.00
5	15	15.00
6	7	7.00
7	10	10.00
8	19	19.00
Total	100	100.00

Table 9 : Number of combine harvesters according to its trade name :

Combines	Number of combines	Percent (%)
Yanmar	48	48.00
Deutz	20	20.00
Kubota	12	12.00
John-Deere	10	10.00
Others	10	10.00
Total	100	100.00

Table 10 : Data statistical analysis for the combine harvesters :

Measures	Age (years)	Accumulated hours (hrs)	List price (L.E)	Accumulated R&M costs (L.E)
Mean	5.51	1260.17	87029.2	33051.1
Median	5	1275	76800	31393.5
Mode	8	1400	66000	46002
Range	7	2270	70485	104539
Standard diviation	2.47613	749.537	23612.6	25377.8
Standard error	0.247613	74.9537	2361.26	25377.8
Coefficient of variation	44.94	59.48	27.13	76.78

2-2 Statistical summary for combines data:

The statistical measures of combine's data are shown in Table 10. This Table includes the different measures of age, accumulated hours, list price and repair costs. The average of the combine ages was 5.51 (yrs), while the mean of acumulated hours was 1275(hrs). 76800(L.E) for list price and 31393.5(L.E) for repair costs. The standard diviation was also different from one measure to another. The standard diviation for combine ages was 2.5, 749.5 for accumulated hours, and 23612.6 for for initial list price. It was 25377.8 for repair and maintenance costs.

The coefficient of variation for all data ranging from 27% to 76.78%.

2-3 Analysis of repair and manitenance costs for combines:

Repair and Mantenance costs (R&M) for combine harvesters were found to be 109% of initial list price after 8 years (about 3000 hours of working). For the first year of working, R & M costs ranged from 2 to 5% of initial list price as in fig. 3.

From the data analysis, the following two equations were obtained :

Model (1) : $Y = a X^{b}$

Model (2) : $Y = a + b_1 X_1 + b_2 X_2$

Where : Y = Repair and Maintenance costs (R&M) as a percentage of initial list price.

X_1 = Machine age (years).

X, X2 = Hours of working .

The standard model for repair and maintenance costs must accurately predict the trend costs over the life of the machine (about 3000 hours). Repair and maintenance costs tend to increase with machine age. As the machine approaches the end of its life, repair costs tended to be constant annual value.

Figure 3 indcates that the first formula (exponential model) is very closed to the actual values comparing with the second formula.

The second formula can also applied, but from 500 hours or more. The number of working hours less than 484 hours gives a negative values.

Table 11 showes the constants, R squared and degrees of freedom of data analysis.

In addition, Appendix B.1 indicates the forward selection, backward elimination and stepwire regression for selecting the best regression equation.

Table 11. Constants of combine data analysis :

Models	Constant				R2	d.f
	a	b	b1	b2		
Model (1)	$Y = 0.0032 X^{1.3040}$					
	0.0032	1.3040	---------	---------	0.97	99
Model (2)	Y = - 11.47 + 7.12 X1 + 0.009 X2					
	- 11.47	---------	7.12	0.009	0.89	98

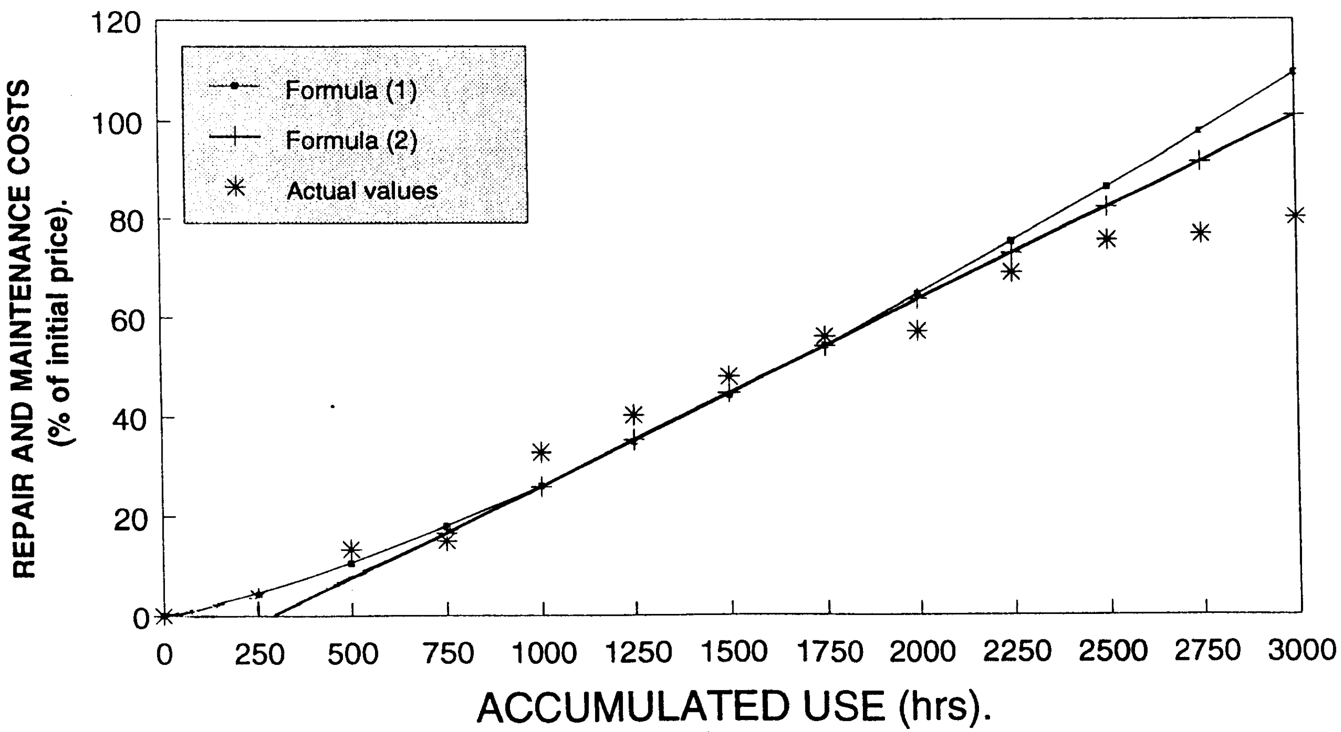

Fig.(3): The influence of accumulated use (hrs) on the repair and maintenance costs of combine harvesters.

2-4 Model verification :

To verify the results obtained by the proposed model, a comparison was made between this model and the models previously published by the standards year book (1973), ASAE (1980) and El-Banna (1988). Table 12 shows the previous studies and this study.

Table 12 shows that repair and maintenance costs as a percentage of list price reached 70.83% (Standards 1973) and 170.68% (ASAE 1980) after the end of combine's life (3000 hours). On the other hand, the repair costs in Egypt are different from other countries. For example, the repair cost reached 56.76% of list price after 3000 hours (El-Banna 1988) and reached 109.48% at the same working hours (this study). Generally, combine repair costs in Egypt are higher than other countries as shown in Figure 4.

Table 12. Models obtained by previous studies of repair and maintenance (R&M) costs for combines :

Source	Equation	R & M costs % of list price at 3000 hours
Standards (1973)	$Y = 0.00096\ X^{1.400}$	70.83
ASAE (1980)	$Y = 1.6146\ (X)^{1.7325} / 10000$	170.68
El-Banna (1988)	$Y = 0.0455\ (X / 100)^{2.0960}$	56.76
This study (1993)	$Y = 0.0032\ X^{1.3040}$	109.48

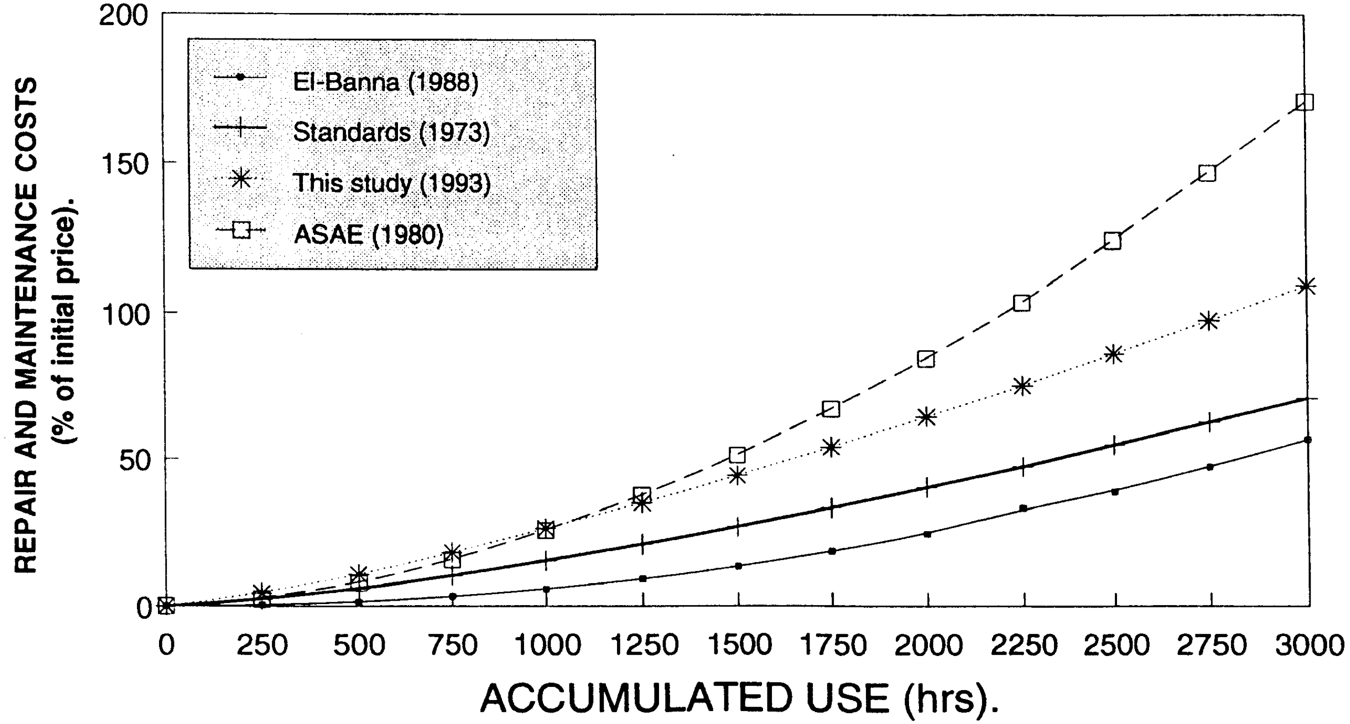

Fig.(4): Repair and maintenance costs as affected by accumulated use of combine harvesters (from various sources).

3- SCRAPERS

3-1 Characteristics of Scrapers data :

The data obtained from this study were extracted from an analysis of 142 local scrapers as shown in Table 13.

All of these scrapers were made in Egypt. The percentage distribution of the (6-feet) was 42.25%, 33.10% for (8-feet) and 24.65% for (12-feet). Data recorded in Table 14 shows the percentage distribution for the scrapers according to the age. It was 25.35% for one-year-old and 10.56% for two-years-old.

On the other hand, there were 40 units (28.17% of the total), their age ranged from three to five years. The others represented 51 units (35.92% of the total) their age ranged from six to eight-years-old.

Table 13 : Number of scrapers according to its trade name :

Model	No. of scrapers	Percent (%)
Local - 6 - feet	60	42.25
Local - 8 - feet	47	33.10
Local - 12 - feet	35	24.65
Total	142	100.00

3-2 Statistical summary for scrapers data :

Table 15 shows the average numbers obtained after analysing the data of scrapers statistically. These numbers were for average age (4.08) years, 1689.4 (hrs) for accumulated hours, 6347.39 (L.E) for list price and 1635.39 (L.E) for repair and maintenance costs. These numbers were 2.6 for standard diviation of ages, 1074 for hours, 1854.86 for list price and 132.9 for repair costs. The coefficient of variation for all data was ranged from 29.22% to 96.87%.

Table 14 : Number of scrapers according to its age :

Age (years)	No. of scrapers *	Percent (%)
1	36	25.35
2	15	10.56
3	20	14.09
4	10	7.04
5	10	7.04
6	12	8.45
7	21	14.79
8	18	12.68
Total	142	100.00

* All scrapers in this study were made in Egypt.

Table 15 : Data statistical analysis for the scrapers :

Measures	Age (years)	Accumulated Hours (hrs)	List price (L.E.)	Accumulated R&M costs (L.E.)
Mean	4.07746	1689.4	6347.39	1635.39
Median	3.5	1480	5952	1085
Mode	1	1300	6000	149
Range	7	3150	4620	5903
Standard diviation	2.54944	1074	1854.86	1584.27
Standard error	0.216462	90.1278	155.656	132.949
Coefficient of Variation	62.53	63.57	29.22	96.87

Table 16. Constant of scrapers data analysis :

Models	Constant				R2	d.f
	a	b	b1	b2		
Model (1)	$Y = 0.0012 X^{1.3248}$					
	0.0012	1.3248	---------	---------	0.98	141
Model (2)	$Y = -9.052 + 3.295 X1 + 0.013 X2$					
	- 9.052	---------	3.295	0.013	0.94	140

3-3 **Analysis of repair and maintenance costs for scrapers** :

Repair and maintenance costs (R&M) for scrapers were found to be ranged from 3 to 5% of the initial list price at the first year of working (about 400 hours). They were reached more than 20% of the intial list price at the half of the machine life (about 1500 hours). Then, it reached 68% of the initial list price at the end of the machine life (about 3500 hours) figure (5). The following two models were obtained from the data analysis :

Model (1) : $Y = a\,X^b$

Model (2) : $Y = a + b_1X_1 + b_2X_2$

where :

Y = Repair and maintenance costs (R&M) as a percentage of initial list price .

X_1 = Machine age (years)

X, X_2 = Hours of working

The formula which best describes the typical trend in repair and maintenance costs is formula (1) .

Table 16 shows the summary of repair and maintenance costs of scrapers .

In addition, appendix C.2 shows the forward selection, backward elimination, and stepwise regression methods for selecting the best regression equation.

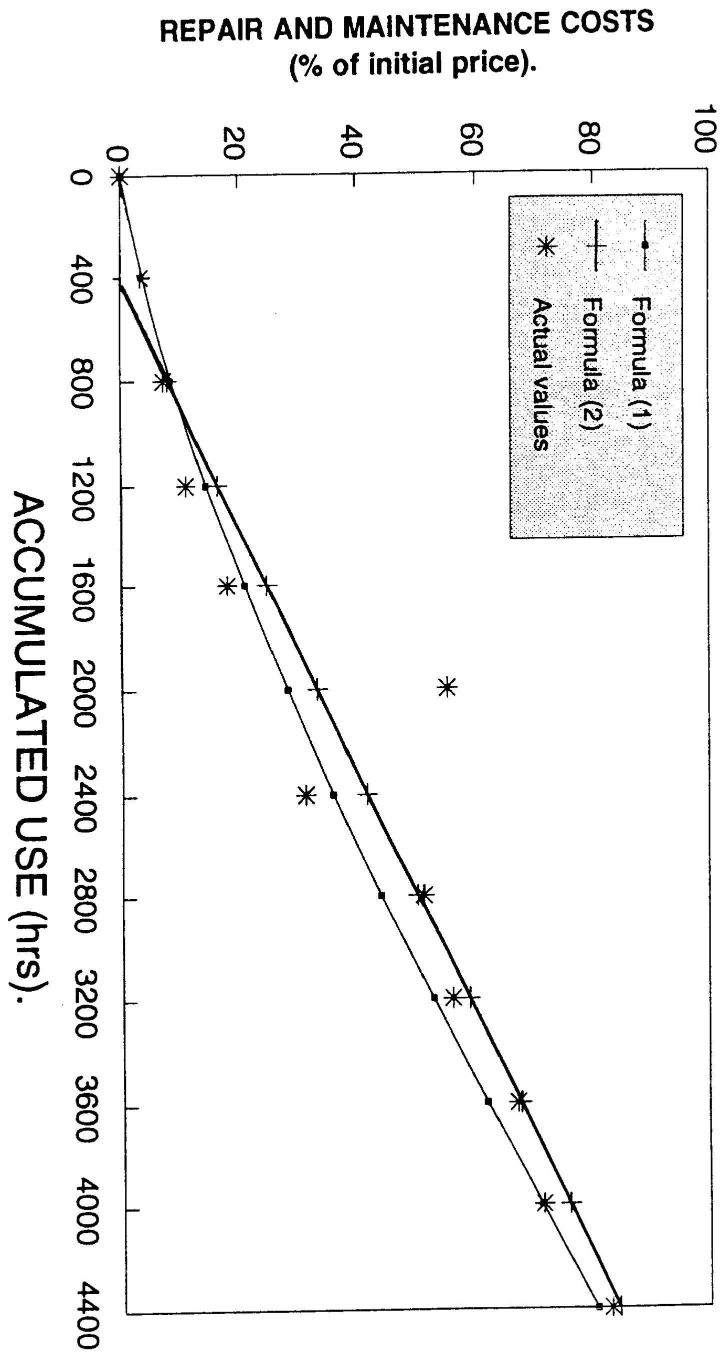

Fig.(5): The influence of accumulated use (hrs) on the repair and maintenance costs of scrapers.

4- ***SEED DRILLS***

4.1 **Characteristic of seed drills data :**

Table 17 shows the number of seed drills obtained from the survey.

Seed drill is considered as one of the most important farm machines. It depends on the number of seed tubes. The working width vary from 270cm to more than 340cm. The percentage distribution of studied seed drills was 15.3% for (270cm) and 66.33% for (315cm). Data in Table 18 showed the percentage distribution of seed-drills age .

On the other hand , most of surveyed seed drills were Tye trade name (66% of the total), as shown in Table 19 .

Table 17. Number of seed-drills surveyed based on working width :

Working width (cm)	No. of seed-drills	Percent (%)
270	15	15.30
315	65	66.33
340	15	15.31
More than 340	3	3.06
Total	98	100.00

4.2 Statistical summary for seed-dirlls data :

Table 20 indicates some measures of seed-drills. The average (mean) of the age was 4.7 years, 1775 (hrs) for accumulated hours, 28063.8 (L.E.) for initial list price and 8972.6 (L.E) for repair and maintenance costs. The standard diviation of the ages was 2.3, 988.1 (hrs) for accumulated hours, 5272(L.E) for list price and 6370.5 (L.E) for repair and maintenance costs. On the other hand, the coefficient of variation ranged from 18.79% to 70.99%.

In addition, appendix D.2 shows the forward selection, backward elimination and stepwise regression for selecting the best regression equation.

Table 18. Number of seed drills surveyed based on the age :

Age (years)	No. of seed drills	Percent (%)
1	12	12.25
2	12	12.25
3	10	10.20
4	10	10.20
5	15	15.31
6	11	10.48
7	15	15.31
8	13	14.00
Total	98	100.00

Table 19. Number of seed drills Surveyed based on the make of the machine :

Model	No. of the seed drills	Percent (%)
Tye	65	66.33
Sulky	15	15.30
Others	18	18.37
Total	98	100.00

Table 20 : Data statistical analysis for the seed-drills :

Measures	Age (years)	Accumulat Hours (hrs)	List price (L.E.)	Accumulat R&M costs (L.E.)
Mean	4.65306	1775.06	28063.8	8972.62
Median	5	1855	29555	8055
Mode	5	1880	30000	8044
Range	7	3200	17570	22941
Standard diviation	2.32912	988.135	5272.08	6370.47
Standard error	0.235276	99.8167	532.56	643.514
Coefficient of Variation	50.06	55.67	18.79	70.99

On the other hand, Table 21 shows the summary of repair and maintenance costs for seed-drills.

4.3 Analysis of repair and Maintenance costs for seed-drills:

Repair and maintenance costs (R&M) for seed-drills were found to be from 1.0 to 3.0% of initial list price at the first year of machine life (about 350 hours). It was found to increase with age during the first four years (25% of initial list price), then increased rapidly during the second four years(from 2000 to 3500 hours) of about 65% from initial list price as shown in Figure 6 .

The following two models were obtained from the data analysis :

Model (1) : $Y = a X^b$

Model (2) : $Y = a + b_1X_1 + b_2X_2$

where :

Y = Repair and maintenance costs (R&M) as a percentage of initial list price .

X_1 = Machine age (years)

X, X_2 = Hours of working

a, b, b_1, b_2 = Constant

Table 21. Constant of seed drills data analysis :

Models	Constant				R2	d.f
	a	b	b1	b2		
Model (1)	$Y = 0.0013 X^{1.3463}$					
	0.0013	1.3463	---------	---------	0.98	97
Model (2)	Y = - 7.309 + 2.919 X1 + 0.014 X2					
	- 7.309	---------	2.919	0.014	0.86	96

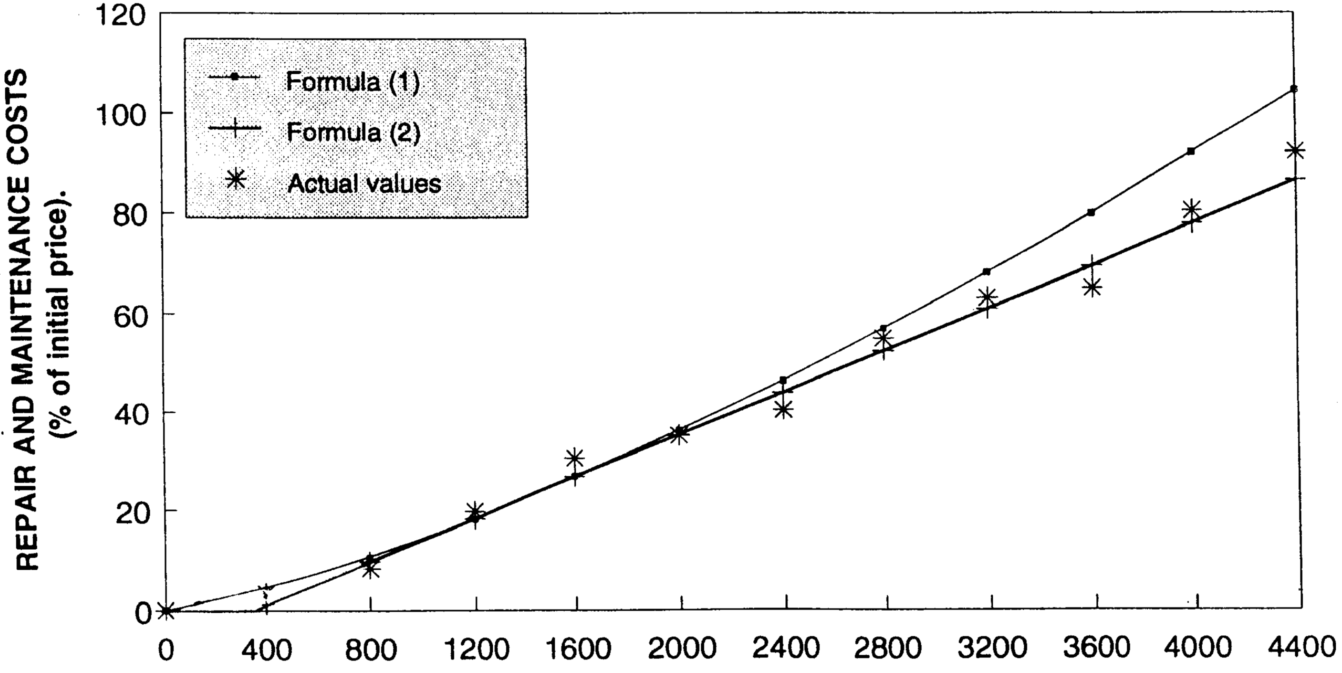

Fig.(6): The influence of accumulated use (hrs) on the repair and maintenance costs of seed drills.

5- *RICE TRANSPLAN TERS*

5-1 Characteristics of rice transplanters data :

Rice transplanters are not common in Egypt but in 1984 were popular in some areas such as kafr El-Sheikh. Table 22 shows the number of rice transplanters based on the age. Sixty units (50% of the total) are ranged from one to three-years-old. The rest of the total are ranged from four to Six-years-old. Table 23 shows the make of rice transplanters. All of the models are Japanese make such as Yanmar which represents 80 units (66.67% of the total). Fourty units (33.33% of the total) are Kubota.

Table 22. Rice transplanters surveyed based on the age :

Age (years)	No. of transplanters surveyed	Percent (%)
1	24	20.00
2	21	17.50
3	15	12.50
4	15	12.50
5	19	15.83
6	26	21.67
Total	120	100.00

Table 23. Rice transplanters surveyed based on the make of the machine :

Model	No. of transplanters surveyed	Percent (%)
Yanmar, 2- rows	10	8.34
Yanmar, 4- rows	30	25.00
Yanmar, 8- rows	40	33.33
Kubota, 8- rows	40	33.33
Total	120	100.00

Table 24 : Data statistical analysis for the transplanters :

Measures	Age (years)	Accumulate Hours (hrs)	List price (L.E.)	Accumulated R&M costs (L.E.)
Mean	3.51667	758.692	20084.5	7174.9
Median	3.5	690	18720	4814
Mode	6	1350	18600	2327
Range	5	1200	12580	20474
Standard diviation	1.8561	407.868	4259.68	6347.42
Standard error	0.169438	37.2331	388.854	579.437
Coefficient of Variation	52.04	53.76	21.21	88.47

5-2 Statistical summary for rice transplanters data :

The statistical analysis of rice transplanters are shown in Table 24. This table shows some measures of the data such as mean which was 3.5(yrs) for transplanters age. It was 758.7(hrs) for accumulated hours, 20084.5 (L.E) for list price and 7174.9 (L.E) for repair costs. The standard diviation was 1.9 for age, 407.9 for accumulated hours, 4259.7 for list price and 6347.4 for repair costs. The coefficient of variation was ranged from 21.21% to 88.47% for the data.

Table 25. Constant of rice transplanters data analysis :

Models	Constant				R2	d.f
	a	b	b1	b2		
Model (1)	$Y = 0.0003\ X^{1.7432}$					
	0.0003	1.7432	---------	---------	0.98	119
Model (2)	$Y = -17.41 + 4.22\ X1 + 0.05\ X2$					
	- 17.41	---------	4.22	0.05	0.93	118

5-3 Analysis of R&M costs for rice transplanters

Repair and maintenance costs (R&M) for transplanters ranged from 3 to 5% of the initial list price during the first year of machine life (about 200 hours). It increased from 14 to 19% of the initial list price at the half of the machine life (about 600 hours). The R&M costs reached to 79% of the initial list price after 1200 working hours figure 7.

From the data analysis (Table 25) the following two models were obtained :

Model (1) : $Y = a X^b$

Model (2) : $Y = a + b_1X_1 + b_2X_2$

Where :

Y = Repair and maintenance costs as a percentage of initial list price.

X_1 = Machine age (years)

X, X_2 = Hours of working

On the other hand appendix E.2 shows the forward selection, backward elimination and stepwise regression for selecting the best regression equation.

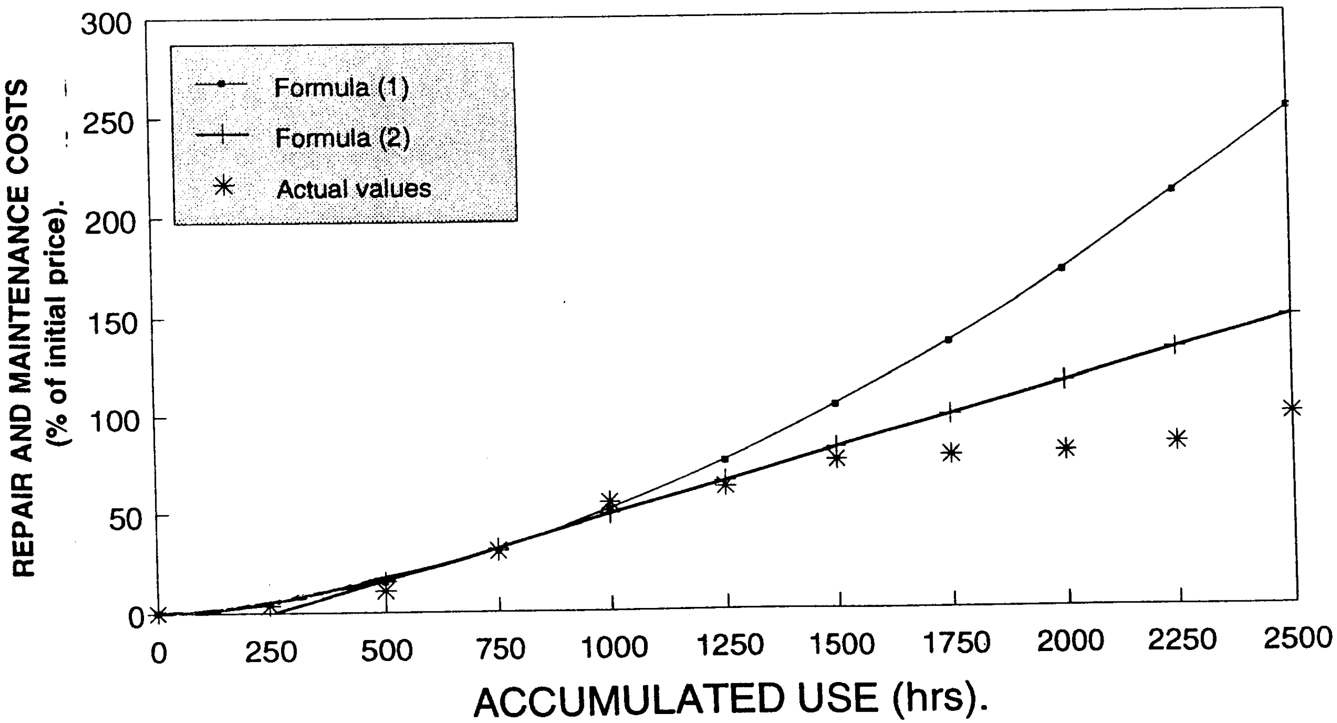

Fig.(7): The influence of accumulated use (hrs) on the repair and maintenance costs of rice transplanters.

6- ***ROTARY PLOWS***

6-1 **Characteristics of rotary plows data :**

Four models of rotary plows were surveyed. About half of the plows (52% of the total) were made in Japan (Table 26) and the rest from different countries. Some rotary plows have eight-years-old (20% of the total). The other units (80% of the total) have different ages (Table 27).

Table 26. Number of rotary - plows surveyed based on the make of the machine :

Model	No. of rotary surveyed	Percent (%)
Yanmar	29	29.29
Kubota	32	32.32
Dondi	21	21.21
Dutzi	17	17.18
Total	120	100.00

Table 27. Number of rotary plows surveyed based on the age :

Age (years)	No. of rotary surveyed	Percent (%)
1	12	12.12
2	8	8.08
3	15	15.16
4	10	10.10
5	10	10.10
6	10	10.10
7	14	14.14
8	20	20.20
Total	99	100.00

6-2 Statistical summary for rotary plows data :

Table 28 shows some measures of rotary plows. The average (mean) of the age was 4.9 (yrs), 2072 (hrs) for accumulated hours, 13153.5 (L.E) for initial list price and 4326.92 (L.E) for repair and maintenance costs. The standard diviation of the ages was 2.4 (yrs), 1031 (hrs) for accumulated hours, 1314.6 (L.E) for list price and 3008.5 (L.E) for repair and maintenance costs. On the other hand, the coefficient of variation ranged from 9.99% to 69.53.

Table 28 : Data statistical analysis for the rotary plows :

Measures	Age (years)	Accumulate Hours (hrs)	List price (L.E.)	Accumulate R&M costs (L.E.)
Mean	4.85859	2072.1	13153.5	4326.92
Median	5	2118	13277	4262
Mode	8	3400	13500	5819
Range	7	3140	4130	9380
Standard diviation	2.42861	1030.95	1314.56	3008.49
Standard error	0.244085	103.615	132.118	302.365
Coefficient of Variation	49.99	49.75	9.99	69.53

Table 29. Constant of rotary plows data analysis :

Models	Constant				R2	d.f
	a	b	b1	b2		
Model (1)	$Y = 0.0005 X^{1.4700}$					
	0.0005	1.7400	---------	---------	0.96	98
Model (2)	$Y = - 19.7 + 14.73 X1 - 0.01 X2$					
	- 19.7	---------	14.73	- 0.01	0.79	97

6-3 Analysis of R & M costs for rotary plows :

Repair and maintenance costs (R&M) for rotary plows ranged from 1% to 5% of initial list price during the first year of machine life (400 hours). The R & M costs increased from 20% to 24% at the half of machine life, then it increased again until reached to 64% of the initial list price at the end of the machine life (3000 hours) Fig.8. From data analysis (Table 29), the following two models were obtained :

Model (1) : $Y = a X^b$

Model (2) : $Y = a + b_1X_1 + b_2X_2$

Where :

Y = Repair and maintenance costs as a percentage of initial list price.

X_1 = Machine age (years)

X, X_2 = Hours of working

On the other hand appendix F.2 shows the forward selection, backward elimination, and stepwise regression for selecting the best regression equation.

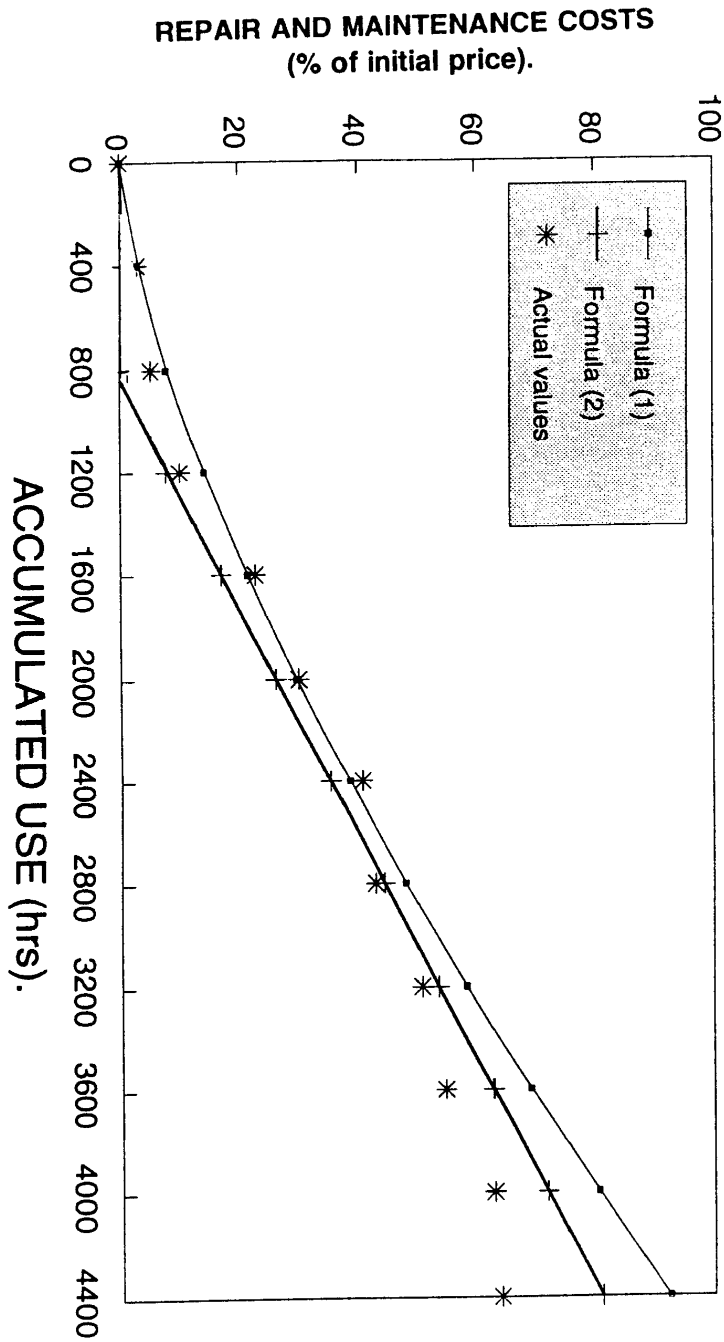

Fig.(8): The influence of accumulated use (hrs) on the repair and maintenance costs of rotary ploughs.

SUMMARY AND CONCLUSION

Total costs include two main parts, fixed costs and variable costs. Fixed costs include depreciation, interest on investment, insurance, taxes and housing. Variable costs include repair and maintenace, fuel and oil, lubricant and labor. The distinction between fixed and operating costs is clear for all items except depreciation and repairs. Repair costs of farm machinery are important component of total costs.

The objectives of this study were as follows :

1- To obtain current repair and maintenance costs accurately.

2- To develop Egyptian repair models for tractors and farm machinery.

Data obtained

Repair cost data were obtained from different places in Egypt. These places were Kafr El-Sheikh, Behira, Gharbia, Dakahlia, Alexandria, Fayoum and Beni-Swafe. The data were collected from farm machinery service stations and research centers. The data included 133 tractors, 100 combine harvesters, 142 scrapers, 98 seed drills, 120 rice transplanters and 99 rotary plows. For each tractor or form machine, the records were kept separately of working year hours, initial list price in current, make and model, machine age and yearly repair and maintenance costs.

Tractors were purchased in the period from 1982 to 1991 with total recorded accumulated hours per tractor ranged from 500 to 9500 hours.

The percentage distribution for the tractor was 26.32% for Nasr tractors, 18.8% for Ursus tractors and 54.88% for the other tractors such as yanmar, Kubota, Ford, John-Deere and Hinomoto. On the other hand, 20 tractors had ten-years-old (15% of the total), 21 tractors had nine-years-old (15.8% of the total) and 92 tractors had age ranged between One-year-old and eight-years-old .

Combine harvesters in this study had a cutting width ranged between 90 cm (such as yanmor and kubota) and more than 240cm (such as John-Deere and Deutz). These combines purchased in the period from 1984 to 1991 with total accumulated hours ranged from 200 to 3000 hours. The maximum age of the combine was eigh-year-old which represented 19% of the total combine harvesters surveyed. It was found that yanmar combine represented (48% of the total) and deutz (20% of the total).

All the scrapers were made in Egypt with different working width. The scrapers purchased in the period from 1984 to 1991 with total accumulated hours per unit ranged from 350 to 3500 hours. The age of scrapers were ranged from one-year-old (25.35% of the total) to eight-year-old (12.68% of the total).

The seed-drills were purchased in the period from 1983 to 1990 with working hours ranged from 200 to 3400 hours. Tye seed drills were represented 66% of the total. However, sulky were represented 18% of the total.

The seed-drills ages were ranged from one-year-old (12% of the total) to eight-year-old (14% of the total).

Rice transplanters in this study were yanmar (66.67% of the total) and Kobuta (33.33% of the total). The transplanters were purchased in the period from 1985 to 1990 with average accumulated working hours ranged from 180 to 1350 hours.

Rotary plows were purchased in the period from 1982 to 1989 with average accumulated working hours ranged from 360 to 3500 hours.

Analysis and results

The SAS program was used to analyse the data. Two formulas were obtained .

1- Exponetial model which in the form of : $Y = a X^b$

2- Linear function which in the form of $Y = a + b_1X_1 + b_2X_2$.

On the other hand three procedures for the selecting the best regression equations were used. These procedures were forward selection, backward elimination and stepwis regression.

The following formulas were obtained to estemate repair and maintenance costs :

1- For Tractors :

$$Y = 0.0009\ X^{1.2838}$$

$$Y = 15.37\ X_1 - 0.004\ X_2 - 11.33$$

2- For Combines :

$$Y = 0.0032\ X^{1.3040}$$

$$Y = 7.12X_1 + 0.009\ X_2 - 11.47$$

3- For Scrapers :

$$Y = 0.0012\ X^{1.3248}$$

$$Y = 3.295\ X_1 + 0.013\ X_2 - 9.052$$

4- For Seed-drills :

$$Y = 0.0013\ X^{1.3463}$$

$$Y = 2.919\ X_1 + 0.014\ X_2 - 7.309$$

5- For rice transplanters :

$$Y = 0.0003\ X^{1.7432}$$

$$Y = 4.22\ X_1 + 0.05\ X_2 - 17.41$$

6- For rotary plows :

$$Y = 0.0005\ X^{1.470}$$

$$Y = 14.73\ X_1 - 0.01\ X_2 - 19.7$$

Where :

Y = Accumulated repair and maintenance costs as percentage of initial list price (%) .

X, X_2 = Accumulated hours of use (hrs) .

X_1 = Age of machine (years) .

a, b, b_1, b_2 = Machine parameters .

Conclusion :

From this study, the following points can be concluded :

1- The power model ($Y = aX^b$) is much better than the linear model ($Y = a + b_1X_1 + b_2X_2$) for predicting repair and maintenance costs because :

a) The first model is very closed to the actual values comparing with the second model .

b) The linear model gives negative values of the costs when we substitute with more with more of 500 working hours. For this reason the second model can be used when :

1) X2 > 484 for combines .
2) X2 > 443 for scrapers .
3) X2 > 314 for seed drills .
4) X2 > 264 for rice transplanters .
5) X2 > 300 for rotary plows .

2- Repair and maintenance costs for tractors and combines were higher than rotary plows seed drills and , scrapers and rice transplanters as a percentage (%) of the initial list prices .

3- Tractor Repair costs reached to 123% and 102% of initial list price after 10,000 hours of use in case of utilization of power and linear function, respectively .

4- Combine repair costs reached to 109% and 87% after 3000 hours of use of utilization of power and linear function, respectively .

5- Repair and maintenance costs for scraper were 68% and 63% (after 3500 hours), 65% for seed-drill (after 35500 hours), 79% and 83% for rice transplanter (after 1500 hours), 64% and 68% for rotary plows (after 3000 h) of utilization of power and linear function, respectively .

6- Model parameters can be modified for other machines and other locations if care is taken .

7- Private owners of tractors and farm machinery in Egypt do not keep complete records for their machine's expenditures .

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APPENDIX A : STATISTICAL ANALYSIS FOR TRACTOR DATA

Table A.1. Statistical summary of exponential model for tractors :

Source	Sum of squares	D.F	Mean Square	F
Regression	15.2484	1	15.2484	2766.552
Residual	0.7220	131	0.0055	
Total	15.9704	132		
Variables	**Reg. Coefficient**	**Std. Error**	**T (d.f = 131)**	
X	1.2838	0.0244	52.598	
Constant	0.0009			

$$Y = 0.0009\, X^{1.2838}$$

Where :

X = Hours of working (hrs).

Y = Repair and maintenance costs as a percentage of initial list price (%).

Table A.2. Statistical summary of forward selection, backward elimination and stepwise regression for fitting the best regression equation of tractors.

	D.F	Sum of Squares	Mean Square	F	prob.>F
Regression	2	135231.347	67615.674	3526.9	0.0001
Error	130	2492.292	19.172		
Total	132	137723.639			

Variable	Parameter Estimate	Standard Error	Sum of Squares	F	prob>F
Intercep	-11.3271	1.0114	2404.6901	125.43	0.0001
X1	15.3647	0.8036	7008.3575	365.56	0.0001
X2	-0.0037	0.0009	345.0650	18.00	0.0001

$$Y = 15.3647 X1 - 0.0037 X2 - 11.3271$$

Where :

X1 = Machine age (years).

X2 = Hours of working (hrs).

Y = Repair and maintenance costs as a percentage of initial list price (%).

Table A.3. Average of obtained data for tractors

Year of manufacture	Age (years)	No. of tractors	Average of accumulated work use hours (hrs)	Average of accumulated inflated initial list price (L.E)	Average of accumulated inflated repair costs (L.E)	Average of accumulated inflated repair costs (%)
1991	1	8	852	27200	1657	05.56
1990	2	6	2000	29633	4348	14.39
1989	3	6	2867	29912	5547	18.44
1988	4	6	3815	29280	8587	29.12
1987	5	20	5073	26536	11459	42.90
1986	6	19	5116	27993	18953	67.32
1985	7	13	6824	25829	19542	75.40
1984	8	14	7063	25363	21017	82.46
1983	9	21	8180	27508	26729	96.75
1982	10	20	9535	27377	29691	107.82

APPENDIX B : STATISTICAL ANALYSIS FOR COMBINE HARVESTER DATA

Table B.1. Statistical summary of exponential model for combine harvesters.

Source	Sum of squares	D.F	Mean squares	F
Regression	17.8883	1	17.8883	2711.646
Residual	0.6465	98	0.0066	
Total	18.5348	99		

Variables	Reg.Coefficient	Std. Error	T (d.f = 98)
X	1.3040	0.250	52.073
Constant	0.0032		

$$Y = 0.0032\,X^{1.3040}$$

Where :

X = Hours of working (hrs).

Y = Repair and maintenance costs as a percentage of initial list price (%).

Table B.2. : Statistical summary of forward selection, backward elimination and stepwise regression for fitting the best regression equation of combine harvesters :

	D.F	Sum of Squares	Mean Square	F	Prob.> F
Regressio n	2	60769.338	20256.446	1845.1	0.0001
Error	96	1053.959	10.979		
Total	98	61823.297			
Variable	Parameter Estimate	Standard Error	Sum of Squares	F	Prob.> F
Intercep	- 11.4664	1.4261	709.7367	64.65	0.0001
X 1	7.1192	1.1911	392.2381	35.73	0.0001
X 2	0.0093	0.0039	60.5457	5.51	0.0209

$$Y = 7.1192\,X1 + 0.0092\,X2 - 11.4664$$

Where :

X1 = Machine age (years).

X2 = Hours of working (hrs).

Y = Repair and maintenance costs as a percentage of initial list price (%).

Table B.3. Average of obtained data for combine harvesters .

Year of manufacture	Age (years)	No. of combines	Average of accumulated work use hours (hrs)	Average of accumulated inflated initial list price (L.E)	Average of accumulated inflated repair costs (L.E)	Average of accumulated inflated repair costs (%)
1991	1	14	274	83500	3650	04.04
1990	2	14	448	83488	10340	12.05
1989	3	14	851	82493	16992	20.01
1988	4	7	1051	95543	32228	33.31
1987	5	15	1451	89698	39009	42.97
1986	6	7	1595	93419	49277	52.25
1985	7	10	1977	90850	53315	58.22
1984	8	19	2377	85974	63185	74.06

APPENDIX C : STATISTICAL ANALYSIS FOR SCRAPER DATA

Table C.1. Statistical summary of exponential model for scrapers .

Source	Sum of squares	D.F	Mean squares	F
Regression	29.7945	1	29.7945	4972.460
Residual	0.8389	140	0.0060	
Total	30.6333	141		
Variables	**Reg.Coefficient**	**Std. Error**	**T (d.f = 140)**	
X	1.3248	0.0188	70.516	
Constant	0.0012			

$$Y = 0.0012\,X^{1.3248}$$

Where:

X = Hours of working (hrs).

Y = Repair and maintenance costs as a percentage of initial list price (%).

Table C.2. Statistical summary of forward selection, backward elimination and stepwise regression for fitting the best regression equation of scrapers.

	D.F	Sum of squares	Mean square	F	Prob.>F
Regression	2	69064.6	34532.3	1131.95	0.0001
Error	139	4240.5	30.5		
Total	141	73305.1			
Variable	**Parameter estimate**	**Standard error**	**Sum of squares**	**F**	**Prob.>F**
Intercep	-9.0520	0.8692	3308.3044	108.44	0.0001
X1	3.2947	2.2804	63.6811	2.09	0.1508
X2	0.0127	0.0055	164.2846	5.39	0.0218

$$Y = 3.2947X1 + 0.0127X2 - 9.0520$$

Where:

X1 = Machine age (years).

X2 = Hours of working (hrs).

Y = Repair and maintenance costs as a percentage of initial list price (%).

Table C.3. Average of obtained data for scrapers.

Year of manufacture	Age (years)	No. of scrapers	Average of accumulated work use hours (hrs)	Average of accumulated inflated initial list price (L.E)	Average of accumulated inflated repair costs (L.E)	Average of accumulated inflated repair costs (%)
1991	1	36	403	6583	255	3.89
1990	2	15	823	6302	457	7.20
1989	3	20	1280	6151	758	12.19
1988	4	10	1687	6400	1169	18.27
1987	5	10	2016	5883	1624	27.83
1986	6	12	2447	6351	2236	34.41
1985	7	21	2922	6511	3493	53.45
1984	8	18	3316	6167	4051	65.46

APPENDIX D : STATISTICAL ANALYSIS FOR SEED - DRILL DATA

Table D.1. Statistical summary of exponential model for seed-drills

Source	Sum of squares	D.F	Mean squares	F
Regression	19.4424	1	19.4424	13205.09
Residual	0.1413	96	0.0015	
Total	19.5838	97		
Variables	**Reg. coefficient**	**Std.error**	**T (d.f = 96)**	
X	1.3463	0.0117	114.913	
Constant	0.0013			

$$Y = 0.0013\ X^{1.3463}$$

Where :

X = Hours of working (hrs).

Y = Repair and maintenance costs as a percentage of initial list price (%).

Table D.2. Statistical summary of forward selection, backward elimination and stepwise regression for fitting the best regression equation of seed-drills :

	D.F	Sum of squares	Mean square	F	Prob.>F
Regression	2	42307.6921	21153.8361	4836.74	0.0001
Error	95	415.4899	4.3736		
Total	97	42723.1820			
Variable	**Parameter Estimate**	**Standard error**	**Sum of squares**	**F**	**Prob.>F**
Intercep	- 7.3088	0.5682	723.6684	165.46	0.0001
X1	2.9191	0.7163	72.6351	16.61	0.0001
X2	0.0143	0.0017	313.4206	71.66	0.0001

$$Y = 2.9191\ X1 + 0.0143\ X2 - 7.3088$$

Where :

X1 = Machine age (years).

X2 = Hours of working (hrs).

Y = Repair and maintenance costs as a percentage of initial list price (%).

Table D.3. Average of obtained data for seed drills :

Year of Manufacture	Age (years)	No. of seed-drills	Average of accumulated work use hours (hrs)	Average of accumulated inflated initial list price (L.E)	Average of accumulated inflated repair costs (L.E)	Average of accumulated inflated repair costs (%)
1990	1	12	298	28083	781	02.68
1989	2	12	728	27905	2184	07.76
1988	3	10	1027	28496	4515	15.64
1987	4	10	1294	26800	5881	21.62
1986	5	15	1900	27826	9400	33.42
1985	6	11	2409	28629	12074	41.87
1984	7	15	2749	28356	15421	54.01
1983	8	13	3240	28292	18049	63.65

APPENDIX E : STATISTICAL ANALYSIS FOR RICE TRANSPLANTER DATA

Table E.1. Statistical summary of exponential model for rice transplanters :

Source	Sum of squares	D.F	Mean squares	F
Regression	27.7093	1	27.7093	5575.535
Residual	0.5864	118	0.0050	
Total	28.2957	119		
Variables	Reg. coefficient	Std.error	T (d.f = 118)	
X	1.7432	0.0233	74.670	
Constant	0.0003			

$$Y = 0.0003\ X^{1.7432}$$

Where :

X = Hours of working (hrs).

Y = Repair and maintenance costs as a percentage of initial list price (%).

Table E.2. Statistical summary of forward selection, backward elimination and stepwise regression for fitting the best regression equation of transplanters :

	D.F	Sum of squares	Mean square	F	Prob.>F
Regression	2	91816.7943	45908.397	1916.09	0.0001
Error	117	2803.2481	23.9594		
Total	119	94620.0424			
Variable	**Parameter Estimate**	**Standard error**	**Sum of squares**	**F**	**Prob.>F**
Intercep	- 17.4104	0.9607	7869.624	328.46	0.0001
X1	4.2214	1.4547	201.767	8.42	0.0044
X2	0.0491	0.0066	1317.297	54.98	0.0001

$$Y = 4.2214\ X1 + 0.0491\ X2 - 17.4104$$

Where :

X1 = Machine age (years).

X2 = Hours of working (hrs).

Y = Repair and maintenance costs as a percentage of initial list price (%).

Table E.3. Average of obtained data for rice transplanters :

Year of Manufacture	Age (years)	No. of rice transplanters	Average of accumulated work use hours (hrs)	Average of accumulated inflated initial list price (L.E)	Average of accumulated inflated repair costs (L.E)	Average of accumulated inflated repair costs (%)
1989	1	24	230	19275	768	03.89
1988	2	21	454	19611	1954	09.78
1987	3	15	618	20240	3552	17.09
1986	4	15	772	20480	7606	36.56
1985	5	19	1083	20152	11707	57.35
1984	6	26	1326	20847	15873	75.71

APPENDIX F : STATISTICAL ANALYSIS FOR ROTARY PLOW DATA

Table F.1. Statistical summary of exponential model for rotary plows :

Source	Sum of squares	D.F	Mean squares	F
Regression	17.8501	1	17.8501	2728.015
Residual	0.6282	96	0.0065	
Total	18.4782	97		
Variables	**Reg. coefficient**	**Std.error**	**T (d.f = 118)**	
X	1.4456	0.0277	52.230	
Constant	0.0005			

$$Y = 0.0005\,X^{1.4456}$$

Where :

X = Hours of working (hrs).

Y = Repair and maintenance costs as a percentage of initial list price (%).

Table F.2. Statistical summary of forward selection, backward elimination and stepwise regression for fitting the best regression equation of rotary plows :

	D.F	Sum of squares	Mean square	F	Prob.>F
Regression	2	47091.2360	15697.0787	1854.70	0.0001
Error	95	804.0216	8.4634		
Total	97	47895.2577			

Variable	Parameter Estimate	Standard error	Sum of squares	F	Prob.>F
Intercep	- 19.7032	2.7406	437.4359	51.69	0.0001
X1	14.7327	1.5431	489.2560	57.81	0.0001
X2	- 0.0064	0.0036	26.5769	3.14	0.0796

$$Y = 14.7327\, X1 - 0.0064\, X2 - 19.7032$$

Where :

X1 = Machine age (years).

X2 = Hours of working (hrs).

Y = Repair and maintenance costs as a percentage of initial list price (%).

Table F.3. Average of obtained data for rotary plows :

Year of Manufacture	Age (years)	No. of rotary plows	Average of accumulated work use hours (hrs)	Average of accumulated inflated initial list price (L.E)	Average of accumulated inflated repair costs (L.E)	Average of accumulated inflated repair costs (%)
1990	1	12	408	13250	494	3.64
1989	2	8	841	13148	830	6.26
1988	3	15	1338	13380	1661	12.29
1987	4	10	1672	12784	2884	22.49
1986	5	10	2126	12791	4186	32.59
1985	6	10	2550	12965	5510	42.37
1984	7	14	3081	12997	6694	51.39
1983	8	20	3341	13500	9568	63.46

١- مقدمة :

تكاليف أى آلة زراعية أو جرار زراعى ينقسم الى قسمين رئيسيين هما :-

١- التكاليف الثابتة ٢- التكاليف المتغيرة

والتكاليف الثابتة عبارة عن :

أ- استهلاك رأس المال ب- المأوى

حـ- الفائدة د- الضرائب

هـ- التأمين.

أما التكاليف المتغيرة فهى عبارة عن :

أ- الصيانة والاصلاح ب- الوقود والزيوت

حـ- العمالة

وتعتبر تكاليف الصيانة والاصلاح للجرارات والآلات الزراعية من أهم هذه التكاليف السابقة لما لها من أهمية كبرى عند حساب التكاليف الكلية لأى جرار أو آلة زراعية.

وتختلف التكاليف من دولة الى أخرى تبعاً لاختلاف الظروف الجوية والاجتماعية والاقتصادية وغيرها من الظروف المؤثرة على هذه التكاليف.

وفى مصر كانت هناك دراسات قليلة فى هذا المجال. لذلك فان هذه الدراسة تهدف الى الحصول على نماذج رياضية يمكن استخدامها فى حساب تكاليف الصيانة والاصلاح للآلات الزراعية والجرارات فى أى عام وعند أى عمر تشغيلى للآلة بمعرفة سعرها الأساسى وعدد ساعات التشغيل الكلية والسنوية. كما أن هذه الدراسة أيضاً تعطى فكرة للمهتمين فى هذا المجال لكى يتم وضع برنامجاً فعلياً للصيانة عن طريق سجلات واضحة مدون فيها كل ما يخص الآلة الزراعية أو الجرار من لحظة تشغيله حتى عند حساب التكاليف.

٢- تجميع البيانات :

تم تجميع البيانات من أماكن كثيرة أهمها :

أ - **محطات الخدمة الآلية** : مثل محطات سخا وقلين بكفر الشيخ ومحطة دكرنس بالدقهلية ومحطة سدس ببنى سويف ومحطة كفر صقر بالشرقية ومحطة قطور بالغربية ومحطة النوبارية للميكنة الزراعية بالبحيرة.

ب- **مراكز البحوث الزراعية**: مثل مركز بحوث سسخا بكفر الشيخ ومحطة اختبار الجرارات بالصباحية بالاسكندرية ومركز بحوث النوبارية بالبحيرة. وبعض المراكز البحثية ووحدات تكنولوجيا الزراعة الآلية التابعة لمعهد بحوث الهندسة الزراعية مثل مركز ميكنة الأرز بميت الديبة بكفر الشيخ ووحدة التكنولوجيا بالشيخ أحمد بالبحيرة.

٣- الأدوات المستخدمة :

تم حصر بعض الآلات الموجودة فى الأماكن السالفة الذكر وتم اختيار الشائع منها وكانت بياناتها كالآتى :

عدد **المواصفات**

١- ١٣٣ جرار زراعى مختلفة الطرز والقدرات .

٢- ١٠٠ ألة حصاد ودراس وتذرية (كومباين) مختلفة فى عرض تشغيلها والذى يبدأ من ٩٠سم حتى أكثر من ٢٤٠سم.

٣- ١٤٢ قصابية محلية الصنع بعرض تشغيل ٦ ، ٨ ، ١٢ قدم .

٤- ٩٨ سطارة حبوب مختلفة فى عرض تشغيلها حيث تبدأ من ٢٧٠سم وحتى أكثر من ٣٤٠سم .

٥- ١٢٠ شتالة أرز وجميعها يابانية الصنع تبدأ من صفين حتى ثمانية صفوفِ.

٦- ٩٩ محراث دورانى مختلفة فى عرضها التشغيلى (من ١٢٠ - ١٨٠سم)

وتم تسجيل البيانات الآتية عن كل آلة على حدة وكانت تشمل :

١- عدد ساعات التشغيل السنوية والكلية للآلة أو الجرار (ساعة) .

٢- تكاليف الصيانة والاصلاح فى العام (جنيه).

٣- سعر الآلة أو الجرار عند الشراء (جنيه) .

٤- سنة صنع الآلة أو الجرار وكذلك الطراز .

٥- بعض المواصفات الأخرى للمعدة الزراعية كالقدرة وعرض التشغيل .

٤- تحليل النتائج :

تم ادخال جميع البيانات السابقة عن كل آلة أو جرار زراعى على حدة. وقد استخدم فى ذلك البرنامج الاحصائى ساس (SAS) والموجودة بمركز الحاسب الآلى بمركز البحوث الزراعية بالقاهرة .

وتم الاخذ فى الاعتبار عند تحليل النتائج أن يكون سعر الآلة (بالجنيه) وتكاليف الصيانة والاصلاح (بالجنيه) مضروبة فى نسبة معامل التضخم فى مصر. وكان متوسط معامل التضخم فى مصر من عام ١٩٨٥ وحتى عام ١٩٩١ هو ١٧٪ (مأخوذة من البنك المركزى المصرى عن الجهاز المركزى للتعبئة العامة والاحصاء). وقد تم ادخال البيانات المتحصل عليها لمعرفة أيها أكثر تأثيراً على تكاليف الصيانة والاصلاح.

كما أنه تم ادخال تكاليف الصيانة والاصلاح كنسبة مئوية من سعر الآلة .

٥- الخلاصة والنتائج :

بعد تحليل النتائج تم الحصول على معادلتين لكل معدة أحدهما أسية والآخرى خطية كالآتى:

١- الجرارات :

ص = ,٠٠٠٩ س ^١,٢٨٣٨^

ص = ١٥,٣٧ س١ - ,٠٠٤ س٢ - ١١,٣٣

٢- آلات الحصاد والدراس والتذرية (الكومباين) :

ص = ,٠٠٣٢ س ^١,٣٠٤٠^

ص = ٧,١٢ س١ + ,٠٠٩ س٢ - ١١,٤٧

٣- القصابيات :

ص = ,٠٠١٢ س ^١,٣٢٤٨^

ص = ٣,٢٩٥ س١ + ,٠١٣ س٢ - ٩,٠٥٢

٤- السطارات :

ص = ,٠٠١٣ س ^١,٣٤٦٣^

ص = ٢,٩١٩ س١ + ,٠١٤ س٢ - ٧,٣٠٩

٥- آلات شتل الأرز :

ص = ,٠٠٠٣ س ^١,٧٤٣٢^

ص = ٤,٢٢ س١ + ,٠٥ س٢ - ١٧,٤١

٦- المحاريث الدورانية :

ص = ,٠٠٠٥ س ^١,٤٧٠^

ص = ١٤,٧٣ س١ - ,٠١ س٢ - ١٩,٧

حيث أن :

ص = تكاليف الصيانة والاصلاح كنسبة مئوية من سعر الآلة (٪) .

س ، س٢ = عدد ساعات التشغيل المتجمعة (ساعة) .

س١ = عمر الآلة (سنة).

وقد وجد أنه عند نهاية العمر التشغيلى للآلة فـان تكـاليف الصيانـة والاصـلاح عنـد استخدام معادلة القوى للجرارات وصلت الى ١٢٣٪ وفى حالة المعادلة الخطية وصلت الى ١٠٢٪ (بعد ١٠٠٠٠ ساعة تشغيل) .

وفى الآت الحصاد والدراس والتذرية (الكومباينات) وصلت الى ١٠٩٪ فى حالـة معادلـة القوى و ٨٧٪ فى حالة المعادلـة الخطيـة (بعـد ٣٠٠٠ سـاعة تشـغيل). وفـى القصابيـات وصلت الى ٦٨٪ فى حالة معادلة القوى و ٦٣٪ فى حالـة المعادلـة الخطيـة (بعـد ٣٥٠٠ ساعة تشغيل). وفى السطارات وصلت الى ٦٥٪ فى حالة المعـادلتين (بعـد ٣٥٠٠ سـاعة تشغيل) . وفى شتالات الأرز وصلت الى ٧٩٪ فى حالة معادلة القوى و ٨٣٪ فى حالـة المعادلة الخطية (بعد ١٥٠٠ ساعة تشغيل). وفى المحاريث الدورانية وصلـت الى ٦٤٪ فـى حالة معادلة القوى و ٦٨٪ فى المعادلة الخطية (بعد ٣٠٠٠ ساعة تشغيل). وكـانت هـذه النسبة المئوية من سعر الآلة .

ومن النتائج السابقة يتضح أن :

١- معادلة القوى والتى على صورة ص = أ س^ب هى الأنسـب تحـت الظـروف المصريـة وذلك لانه يمكن التنبؤ عن طريقها بتكاليف الصيانة والاصلاح بدقة أكثر حيـث انهـا دائماً تعطى قيماً موجبة حتى عند أقل عدد من ساعات التشغيل.

أما فى حالة المعادلة الخطيـة والتـى علـى صـورة ص = أ + ب١س١ + ب٢س٢ . لا تصلح الا عندما تستخدم فى عدد ساعات تشغيل أكثر من ٥٠٠ ساعة . أما أقل مـن ذلك فانها تعطى قيماً سالبة لتكاليف الصيانة والاصلاح لذا ينصح باستخدامها عندمـا تكون س٢ كالاتى :

٤٨٤ ساعة فأكثر فى حالة الآت الضم والدراس والتذرية (الكومباينات)

٤٤٣ ساعة فأكثر فى حالة القصابيات و ٣١٤ ساعة فـأكثر فـى حالـة السـطارات و ٢٦٤ ساعة فأكثر فى حالة الشتالات و ٣٠٠ ساعة فأكثر فى حالة المحاريث الدورانية (وعمر عامين فأكثر) .

٢- تكاليف الصيانة والاصلاح للجرارات وصلت لأكثر من ١٠٠٪ من ثمن الآلة عند انتهاء عمرها الافتراضى.

وعلى الجانب الآخر فان بعض الآلات الزراعية الأخرى كالمحاريث والقصابيات لم تتعدى فيها تكاليف الصيانة والاصلاح عن ٧٠٪ من سعر الآلة عند انتهاء عمرها الافتراضى وذلك يرجع الى قلة الأجزاء المتعرضة للتآكل والتى يتم فيها الاصلاح اذ ما قورنت بالجرارات أو الآت الضم و الدراس والتذرية (الكومباينات).

٣- تكاليف الصيانة والاصلاح للجرارات والآت الضم والدراس والتذرية فى مصر أعلى من نظيراتها فى بعض الدول الأخرى كالولايات المتحدة الأمريكية أو انجلترا وذلك يرجع الى اختلاف ظروف تشغيل المعدة كالطقس والتربة وكذلك الحالة الفنية للسائق والظروف الاقتصادية والاجتماعية.

٤- يؤخذ فى الاعتبار بعد ذلك وجود أو عدم وجود بيانات كافية عن تكاليف الصيانة والاصلاح من ملاك الآلات أنفسهم بمساعدة وكلاء بيع الآلات والمصانع المنتجة حتى تكتمل الصورة العامة لتكاليف الصيانة والاصلاح.

وفيما يلى ملخص لثوابت المعادلتين المتحصل عليهما بالاضافة الى معامل التقدير وتكاليف الصيانة والاصلاح كنسبة مئوية من ثمن الآلة .

م	نوع المعدة الزراعية		الثوابت				معامل التقدير	ص (٪)	العمر الافتراضى للمعدة (ساعة تشغيل)
			أ	ب١	ب٢	ب			
١	الجرارات	*	٠,٠٠٠٩	—	—	١,٢٨٣٨	٠,٩٦	١٢٣	١٠٠٠٠
		**	١١,٣٣-	١٥,٣٧	٠,٠٠٤-	—	٠,٨٩	١٠٢	١٠٠٠٠
٢	الكومباينات	*	٠,٠٠٣٢	—	—	١,٣٠٤	٠,٩٧	١٠٩	٣٠٠٠
		**	١١,٤٧-	٧,١٢	٠,٠٠٩	—	٠,٨٩	٨٧	٣٠٠٠
٣	القصابيات	*	٠,٠٠١٢	—	—	١,٣٢٤٨	٠,٩٨	٦٨	٣٥٠٠
		**	٩,٠٥٢-	٣,٢٩٥	٠,٠١٣	—	٠,٩٤	٦٣	٣٥٠٠
٤	السطارات	*	٠,٠٠١٣	—	—	١,٣٤٦٣	٠,٩٨	٦٥	٣٥٠٠
		**	٧,٣٠٩-	٢,٩١٩	٠,٠١٤	—	٠,٨٦	٦٥	٣٥٠٠
٥	شتالات الارز	*	٠,٠٠٠٣	—	—	١,٧٤٣٢	٠,٩٨	٧٩	١٥٠٠
		**	١٧,٤١-	٤,٢٢	٠,٠٥	—	٠,٩٣	٨٣	١٥٠٠
٦	المحاريث الدورانية	*	٠,٠٠٠٥	—	—	١,٤٧	٠,٩٦	٦٤	٣٠٠٠
		**	١٩,٧-	١٤,٧٣	٠,٠١-	—	٠,٧٩	٦٨	٣٠٠٠

عنوان الرسالة :

﴿ تحليل تكاليف الصيانة والاصلاحات للآلات الزراعية والجرارات ﴾

مقدمة من

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للحصول على درجة الماجستير فى الميكنة الزراعية

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﴿ لجنة الاشراف ﴾

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تحليل تكاليف الصيانة والاصلاحات للآلات الزراعية والجرارات

رسالة مقدمة من

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بكالوريوس زراعة – قسم الميكنة زراعية

جامعة القاهرة ١٩٨٢

للحصول على درجة الماجستير فى الميكنة الزراعية

من كلية الزراعة بكفر الشيخ – قسم الميكنة الزراعية

جامعة طنطا

– ١٩٩٣ –