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COMPUTER MODEL FOR SUPPORTING FARM MACHINERY REPLACEMENT DECISION

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ABSTRACT

A computer model was developed to aid farm machinery decision makers in deciding the optimum replacement time for an individual machine. The model based on solving a set of mathematical equations via Microsoft Visual Basic® to resolve the appropriate decision. The mainly input data composed of machines purchased price, date and age when purchased, the annual inflation and interest rates, the yearly repair and maintenance costs and operating hours over the machine's life. The major criterion to keep equipment in service or replace it was the values of calculated average accumulated costs over a period of years. To run the model, realistic costs data of Kubota combine (35.79 kW), collected from the Agricultural Engineering Station in Elsadeen – Sharkia governorate, were utilized to proof its capability of making decisions. The results showed that it might be better to replace the Kubota combine at the end of year eighth years old or after 6000 operating hours. With high confidence one can assume that the current model would be helpful in assisting the mangers of farm machinery in building a clear strategy for machinery replacement.
Keywords: Computer Model; Replacement; decision makers; Farm Machinery.

INTRODUCTION

There is a growing demand to replace the older machines with a new one when mechanization of agriculture spreads widely in a given economy. The purchase of a new machine results from a need to replace older, or inadequate machines. This replacement decision is one of the most important decisions a machinery manager must take Hunt (2001).

Edwards (2008) mentioned that, a number of reasons to replace a given machine, which are costs minimization, new technology, reliability, tax exception, accident, and needs for different capacity. ASABE (2006) and Srivastava et al. (2006) also indicated that a machine should be replaced when it is anticipated that cost of repairs will began to increase the average unit accumulated cost above the minimum.

A number of available approaches were developed to determine an optimal time for farm machinery replacement; these approaches vary from one to another according to their nature for solving this issue (Hunt, 2001; Soliman, 2007; Taha, 2007).

Hunt (2001) developed two models for calculating optimum replacement time of farm machinery. The concept of the first model fundamentally relies upon an accounting approach. That is, the time of replacement decision can be resolved by calculating a machine accumulated costs over a period of years. The machinery manager can quantify accumulated costs of any given implement from the machinery cost records. Hence, keeping systematic cost records for each machine is the primary key for the current model in order to be valid. Nevertheless, the second one depends upon an analytical approach to predict the best time of making a replacement decision.

Soliman (2007) developed a model similar to the two preceding models, but a new concept, machinery downtime cost, was presented and added to the assessment of machinery accumulated costs, which was also considered a main criterion for determining an optimum replacement in this model. For the purpose of this study, it is not easy to use this model because the data required to calculate the element of machinery downtime cost are not available.

Taha (2007) formulated a mathematical model, being radically different from the previous models, where a deterministic dynamic programming (DP) technique was utilized to develop a model predicting the most economical replacement year for different machines over a span of years. Computations in DP are done recursively, so that the optimum solution of the sub-problem is used as an input to the next sub-problem. By the time the last sub-problem is solved, the optimum solution for the entire problem is at hand. Moreover, the author illustrated that in order to apply this model you need numerous data which are not easy to access under the current study.

The objective of the current study is to present a computer model. This model was primarily developed to assist the managers of farm machinery in supporting and making a decision on the optimal time of farm machinery replacement.

MODEL DESCRIPTION

The computer model was developed in Microsoft Visual Basic© programming language version (6.0) service pack 6 and based on the concept of first model of Hunt's two models (2001) mentioned in the Introduction Section and then demonstrated in the Model Development Section. The current study selected this model rather than other replacement models because the approach of this model for calculating the optimum replacement time per a machine relies on realistic costs data. Such data certainly represent the real image for each implement. Furthermore, Field and Solie (2007) indicated that decisions, made on actual costs data, are the best for the farm mangers. On the other hand, the other replacement models depend on the prediction of the machine's costs data that may not reflect the real fact.

Two primary assumptions are considered: (1) the machine life is assumed to be greater than or equal to 2 years and less than or equal to 10 years in order to set up the replacement analysis; and (2) fuel and oil, and labor costs are assumed to be independent of the time of replacement.

The input parameters for the computerized replacement analysis model could also be outlined as follows:

1. Basic machine information (code, type, model name, model number, horse power (kW), purchased date, and age when purchased).
2. The purchase price of a new machine at year n was priced according to its list price at farm machinery dealers at year n, but the purchase price of a

used machine (P_n) at year n was priced by using equation (1) developed by Bowers (1994).

$$P_n = clp_n \times RVP_n \quad \text{... (1)}$$

$$clp_n = clp_m \times (1 + IFR_n)^{n-m} \text{ ‘ } RVP_n = dep_1 \times dep_2^{\,n-m} \quad \text{If } n > m$$

Where:
P_n = the purchase price of the used machine at year n (LE);
clp_n = current list price of the used machine at year n (LE);
RVP_n = remaining value percentage at year n (%);
n = number representing the year which the machine is used;
m = number representing the year which the machine is new;
clp_m = current list price of the new machine at year m (LE);
IFR_n = inflation rate for year n, decimal;
dep_1, dep_2 = constant depreciation factors. dep_1 equals 0.67 and 0.65 for tractors and combines respectively, and dep_2 equals 0.94 and 0.93 for tractors and combines respectively.
3. Inflation rate (IFR %) for each year. It was used to convert the remaining values, annual ISTI, and R&M expenditures to constant prices, and consequently the distortions caused by inflation were avoided throughout the analysis.
4. Interest rate (IR %) for each year.
5. Yearly repair and maintenance costs (LE/yr); and
6. Total operating hours (OH) for each year (hr/yr) or total executed area (EA) for each year (fed/yr).

MODEL DEVELOPMENT

All computations were annually performed for each implement at the end of each assigned year. Hence, before starting the computations according to the mathematical equations below, the model firstly calculates the date at the start and end of each year respectively to be able to determine which date a machine should be replaced. Moreover, the equations used in the model are as follows:

1- The annual depreciation cost (d_n) in current prices was calculated according to the declining-balance method (Witney, 1988) and via equation (2). The ratio of depreciation rate (x) in the equation (2) equals to 1.

$$d_n = P\left(\left(1-\frac{x}{L}\right)^{n-1} - \left(1-\frac{x}{L}\right)^{n}\right) \quad \text{... (2)}$$

Where:
d_n = amount of depreciation charged for year n (LE/yr);
P = purchase price (LE);
n = number representing age of the machine (yr.);

L = machine life (yr.); and
x = ratio of deprecation rate (x may have any value between 1 and 1.5).
2- The remaining value (RV_n) was determined at the end of each year n in the current prices as shown in the following equation:

$$RV_n = RV_{n-1} - d_n \qquad ...(3)$$

Where:
n = number representing machine age and starting from 1, 2, 3 … n (yr.);
RV_n = remaining value for year n (LE/yr);
RV_{n-1} = remaining value for year n-1 (LE/yr): when n = 1, RV_0 = purchase price; and
d_n = depreciation cost for year n (LE/yr).
3- The inflation factor (INF_n) was compounded yearly and calculated by equation (4):

$$INF_n = INF_{n-1} \times \left(1 + \frac{IFR_n}{100}\right) \qquad ... (4)$$

Where:
INF_n = inflation factor for year n;
INF_{n-1} = inflation factor for year n-1: when n = 1, INF_0 = 1; and
IFR_n = inflation rate for year n (%).
4- The deflated remaining value (DRV_n) was assessed via equation (5):

$$DRV_n = \frac{RV_n}{INF_n} \qquad ...(5)$$

Where:
DRV_n = deflated remaining value for year n (LE/yr).
5- The depreciation cost in constant prices ($d^\backslash_n$) was calculated as in equation (6):

$$d^\backslash_n = DRV_{n-1} - DRV_n \qquad .... (6)$$

Where:
($d^\backslash_n$) = depreciation cost in constant prices for year n (LE/yr); and
DRV_{n-1} = deflated remaining value for year n-1 (LE/yr); when n = 1, DRV_0 = purchase price (P).
6- The interest rate on investment, shelter, taxes, and insurance costs ($ISTI_n$) were estimated via equation (7):

$$ISTI_n = \left(\frac{IR_n}{100} + 0.055\right) \times RV_n \qquad ... (7)$$

Where:
$ISTI_n$ = interest on investment, shelter, taxes, and insurance costs for year n (LE/yr);
IR_n = interest rate for year n (%); and
0.055 estimates the cost of shelter, taxes, and insurance.

7- The total fixed costs of the machine in current prices (FC_n) were calculated as shown in equation (8):

$$FC_n = d_n + ISTI_n \qquad \text{... (8)}$$

Where:
FC_n = total fixed costs for year n (LE/yr).
8- The total costs of the machine in constant prices ($TC^{\backslash}_n$) were calculated as in equation (9):

$$TC^{\backslash}_n = \left(\frac{ISTI_n + R\,\&\,M_n}{INF_n} \right) + d^{\backslash}_n \qquad \text{... (9)}$$

Where:
$TC^{\backslash}_n$ = total machine costs in constant prices for year n (LE/yr); and
$R\ \&\ M_n$ = repair and maintenance costs for year n (LE/yr).
9- The accumulated cost (AC_n) was calculated in constant prices via equation (10):

$$AC_n = \sum_{n=1}^{n} TC^{\backslash}_n \qquad \text{...(10)}$$

Where:
AC_n = accumulated cost for year n (LE/yr).
10- The accumulated operating hours (AOH_n) were calculated via equation (11):

$$AOH_n = \sum_{n=1}^{n} OH_n \qquad \text{...(11)}$$

Where:
AOH_n = accumulated operating hours for year n (hr/yr); and
OH_n = total operating hours for year n (hr/yr).
11- The average accumulated cost ($Ave.AC_n$) was calculated in constant prices via equation (12). Furthermore, the average accumulated cost can also be calculated by dividing the value of AC_n over the accumulated executed area (AEA_n).

$$Ave.\,AC_n = \frac{AC_n}{AOH_n} \qquad \text{...(12)}$$

Where:
$Ave.AC_n$ = average accumulated cost for year n (LE/yr).

Finally, the computer model was encoded and written via the Visual Basic Programming Language, and the model flowchart is depicted in Figure 1. The replacement decision was made on an individual machine whether to keep it in service or to replace it according to the values of average accumulated costs over a period of years. As long as these values diminish each year n until reaching their lowest value in a certain year, the machine should be retained in service. After that year, if these values begin to increase, the machine should be replaced.

Hunt (2001) and Soliman (2007) also reported that the time of replacement per a machine can be graphically resolved when the average yearly costs are more than the average accumulated costs.

MODEL VERIFICATION

In order to verify machinery replacement decision obtained from running the developed model, Randomized Number Tables technique was used to collect the actual data. Therefore, data, collected for a self-propelled combine at Agricultural Engineering Station in Elsadeen – Sharkia governorate, are demonstrated in Table (1). Additionally, the data included the yearly repair and maintenance costs (LE/yr) and the annual operation hours (hr/yr) for the period (2005 – 2013). The inflation and interest rates, posted by Central Bank of Egypt between the period 2005 – 2013, were gathered.

Table (1): Specifications of combine investigated in the replacement analysis.

Model Name	Model Number	Mechanical power kW (hp)	Purchased year	Age when purchased (yr.)	Purchase price (LE)	Current age[1] (yr.)
Kubota	R2-381	35.79 (48)	2005	0	130,000	9

[1]Current age or machine life for Kubota combine was calculated as a difference between the year of performing the present study (2013) and the purchased year.

MODEL RESULTS

Figure (2) depicts the replacement analysis report for the Kubota combine, obtained from running the model. The produced report consists of equipment' data and a number of items calculated annually over the age of the machine. The most important item in this report is in the last row, average accumulated costs, which is utilized to resolve the problem of the current study.

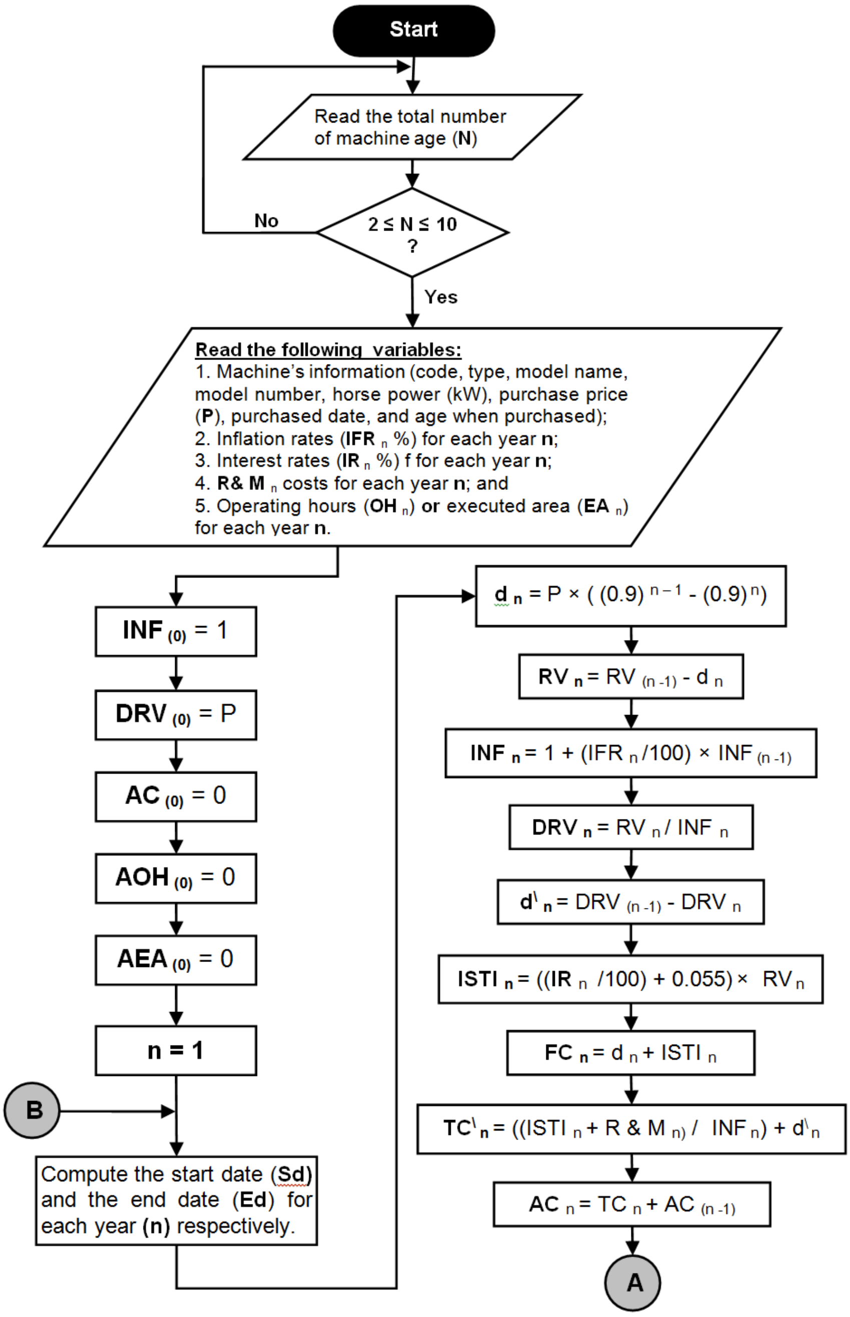
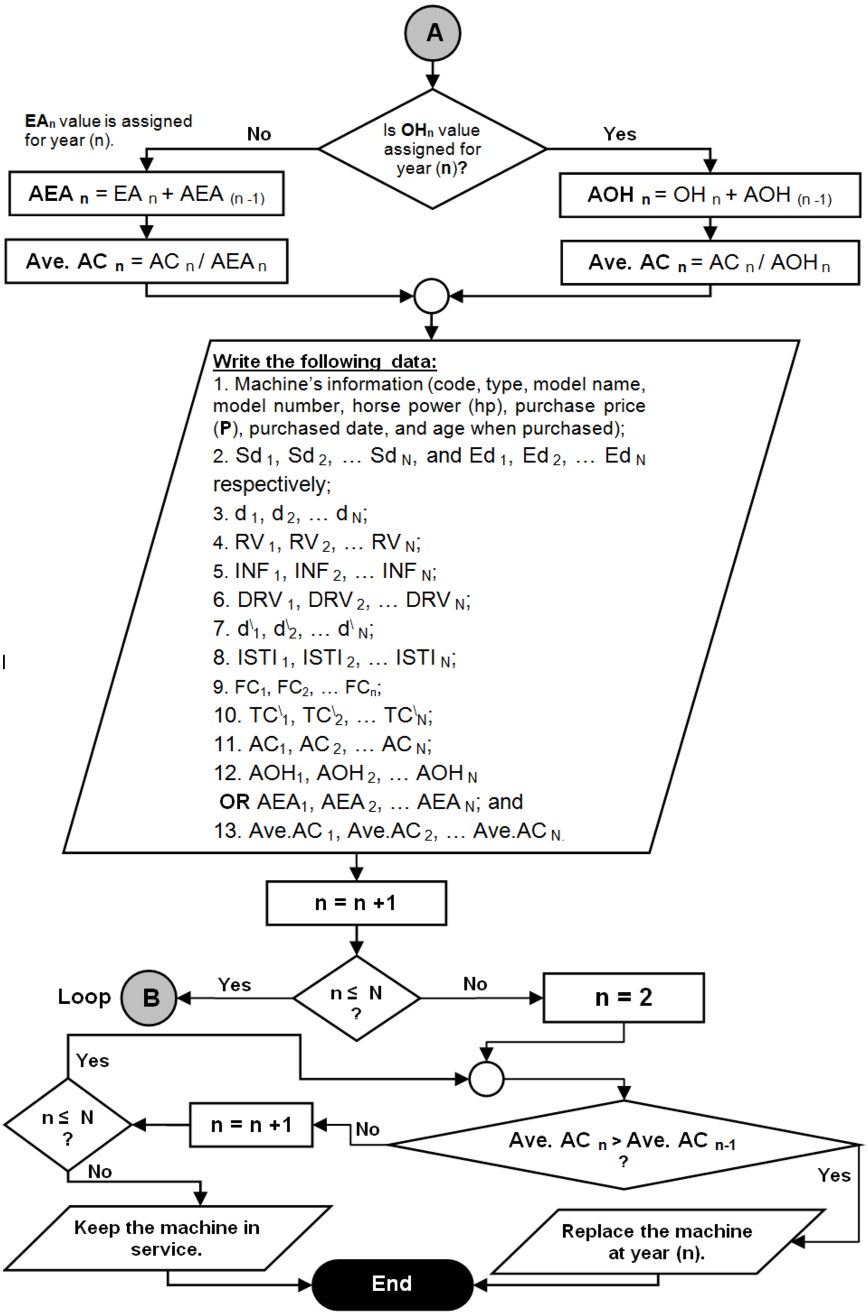
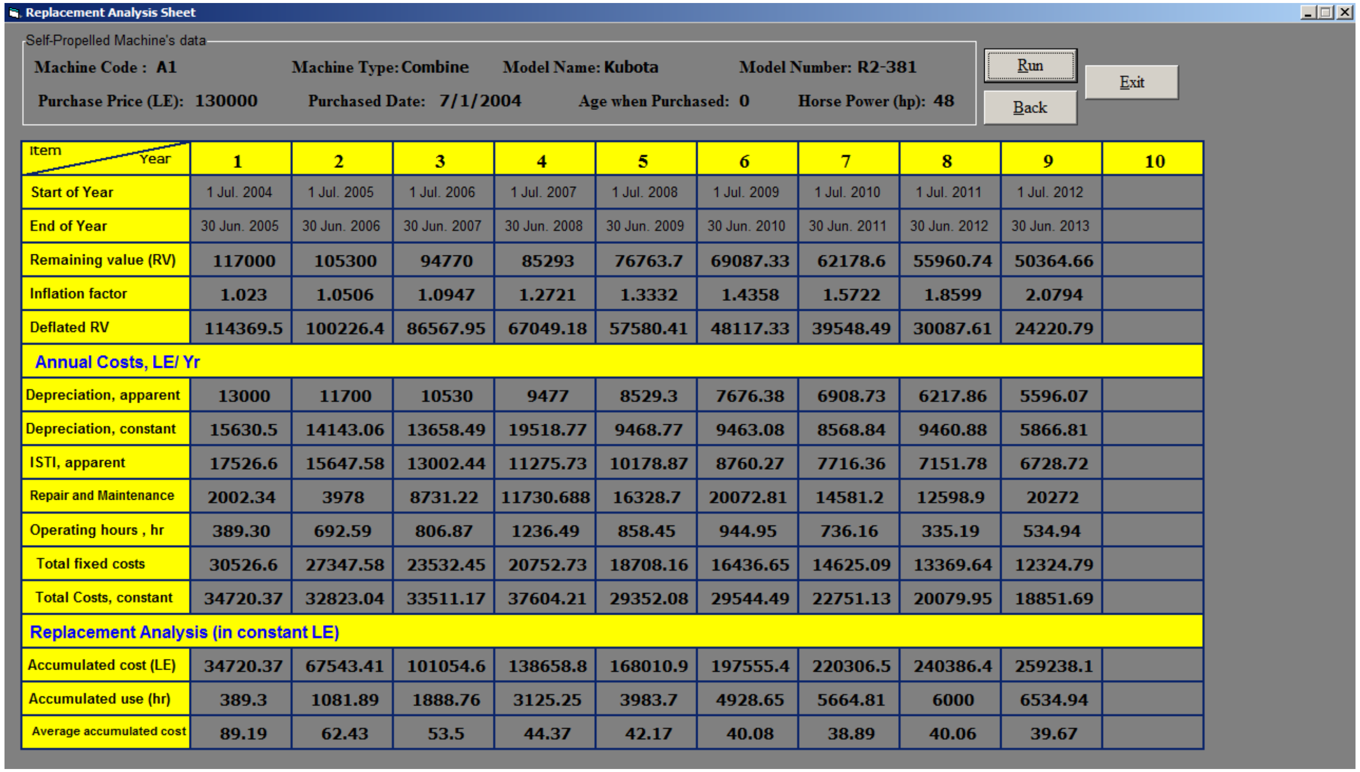


Figure (1): Flowchart of the developed computer model.



Cont. Figure (1): Flowchart of the developed computer model.



Item / Year	1	2	3	4	5	6	7	8	9	10
Start of Year	1 Jul. 2004	1 Jul. 2005	1 Jul. 2006	1 Jul. 2007	1 Jul. 2008	1 Jul. 2009	1 Jul. 2010	1 Jul. 2011	1 Jul. 2012	
End of Year	30 Jun. 2005	30 Jun. 2006	30 Jun. 2007	30 Jun. 2008	30 Jun. 2009	30 Jun. 2010	30 Jun. 2011	30 Jun. 2012	30 Jun. 2013	
Remaining value (RV)	117000	105300	94770	85293	76763.7	69087.33	62178.6	55960.74	50364.66	
Inflation factor	1.023	1.0506	1.0947	1.2721	1.3332	1.4358	1.5722	1.8599	2.0794	
Deflated RV	114369.5	100226.4	86567.95	67049.18	57580.41	48117.33	39548.49	30087.61	24220.79	
Annual Costs, LE/ Yr										
Depreciation, apparent	13000	11700	10530	9477	8529.3	7676.38	6908.73	6217.86	5596.07	
Depreciation, constant	15630.5	14143.06	13658.49	19518.77	9468.77	9463.08	8568.84	9460.88	5866.81	
ISTI, apparent	17526.6	15647.58	13002.44	11275.73	10178.87	8760.27	7716.36	7151.78	6728.72	
Repair and Maintenance	2002.34	3978	8731.22	11730.688	16328.7	20072.81	14581.2	12598.9	20272	
Operating hours , hr	389.30	692.59	806.87	1236.49	858.45	944.95	736.16	335.19	534.94	
Total fixed costs	30526.6	27347.58	23532.45	20752.73	18708.16	16436.65	14625.09	13369.64	12324.79	
Total Costs, constant	34720.37	32823.04	33511.17	37604.21	29352.08	29544.49	22751.13	20079.95	18851.69	
Replacement Analysis (in constant LE)										
Accumulated cost (LE)	34720.37	67543.41	101054.6	138658.8	168010.9	197555.4	220306.5	240386.4	259238.1	
Accumulated use (hr)	389.3	1081.89	1888.76	3125.25	3983.7	4928.65	5664.81	6000	6534.94	
Average accumulated cost	89.19	62.43	53.5	44.37	42.17	40.08	38.89	40.06	39.67	

Figure 2: The outcomes of running the replacement analysis model for the investigated equipment.

Total fixed costs

Total fixed costs (FC_n) were annually calculated for Kubota combine over a period of years. Figure (3) demonstrates the results of estimated fixed costs which were 23.48, 8.81, 7.04, 7.19, 7.83, 8.54, 9.39, 10.56, and 11.52% of their purchase prices over the machine’s life (9 years).

It can be noticed from Figure (3) that the value of total fixed costs is different for each year of the machine’s life and annually decreases until the year of 2007. After that year, the costs slightly increase with the passage of time. The greatest value occurs during the first year of life because the depreciation is highest in that year and declines in succeeding years.

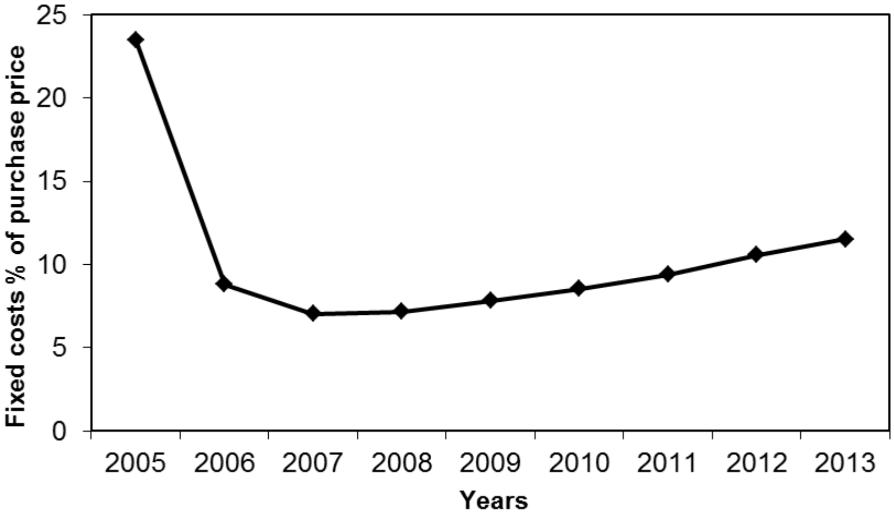


Figure (3): Yearly fixed costs as a percentage of purchase price.

Average Accumulated costs

As previously demonstrated, the current model was developed to calculate annually the average accumulated costs employed to determine the optimal time of replacement for an individual machine. Hence, the last row in Figures (2) represents the yearly values for the average accumulated costs for the investigated machine. Furthermore, the average accumulated costs curve was compared with the curve of average yearly costs to verify the decision made by the developed model.

According to the replacement analysis report of Kubota combine, illustrated in Figure 2, the analysis shows that the average accumulated costs for each year of the machine’s age (9 years) were 89.19, 62.43, 53.5, 44.37, 42.17, 40.08, 38.89, 40.06, and 39.67 LE/hr. As noticed from these values, the accumulated value in year 8 is up slightly compared with the previous year. As a result, the best decision was to replace machine after year 8 (i.e. after 6000 operating hours).

This replacement decision was emphasized in Figure 4 where the value of yearly charges is equal to the value of accumulated costs at the end of year 8.

It may be concluded that the Kubota combine at Elsadeen station may be uneconomic to keep in service because the cost of depreciation and repair and maintenance will be high in the future.

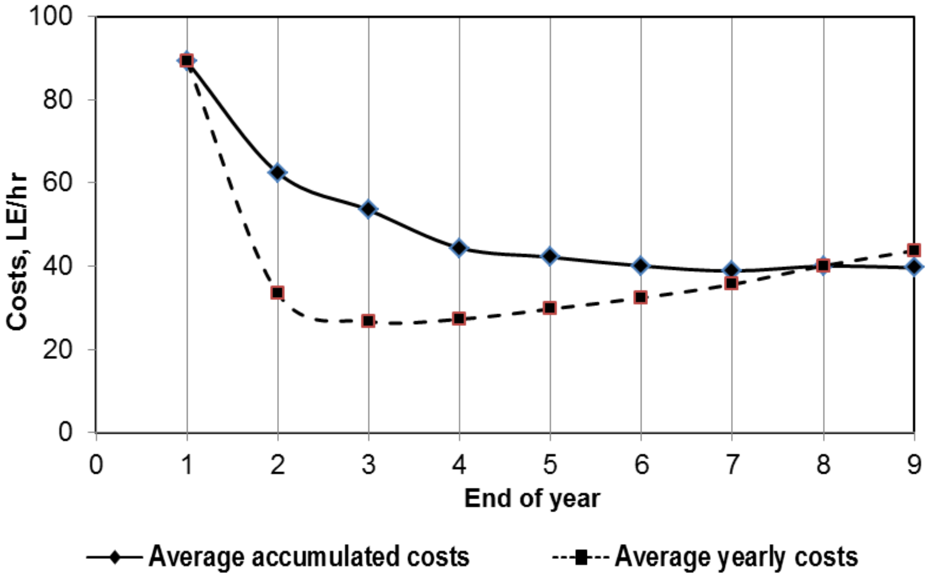


Figure (4): A verage annual and accumulated costs for the studied Kubota combine.

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نموذج حاسب آلى لدعم إتخاذ قرار إحلال المعده الزراعيه

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تهدف الدراسه إلى تطوير نموذج حاسب آلى يساعد المالكين للمعدات الزراعيه فى الحصول على أفضل ميعاد لإحلال المعده الزراعيه بعد عدد ساعات تشغيل معينه خلال عمر الآله. وقد اعتمد النموذج فى بناؤه على حل مجموعة من المعادلات الرياضيه باستخدام لغة الفيجوال بيزك المرئيه للوصول إلى القرار الأنسب. وشملت المدخلات الرئيسيه للنموذج على تاريخ شراء الآله، وسعر شراؤها، وعمرها عند الشراء، والتكاليف السنويه للإصلاح والصيانه، وعدد ساعات التشغيل السنويه، والمعدلات السنويه للتضخم والفائده خلال عمر الألـه. ويقوم النموذج بتحديد قرار احلال المعده من خلال القيم المحسوبه لمتوسط التكاليف المتراكمه سنويا خلال عمر الآله. وبإدخال البيانات الخاصه بكومباين كوبوتا قدرته 48 حصان (والتى تم الحصول عليها من محطة السعديين بمحافظة الشرقيه) إلى النموذج؛ تبين أنه كان من الأجدى اقتصاديا احلال الكومباين فى نهاية العام الثامن من دخوله الخدمه بالمحطه، وبعد 6000 ساعه تشغيل. ويمكن القول بأن هذا النموذج قد يساعد القائمين على إدارة النظم الآليه فى الحصول على مواعيد احلال المعدات الزراعيه.