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Estimation model of economically useful life of rice combine harvesters

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Abstract

The estimation model based on MATLAB/Simulink was estimated the economically useful life of rice combine harvesters. Result revealed systematically estimated the economically useful life using a sample of rice harvesters in the rice-growing region of Northeast Thailand. The findings revealed that the economically useful life of locally-made rice harvesters that was approximately for 10 years with 12,433 rai (7,460 hectares). The machines are still operated after 10 years, but it is costlier operated. The novelty of research proved the use of MATLAB/Simulink in the estimation model, as opposed to SPSS which is conventionally used to exist the estimation methods of other agricultural tools and machinery. The MATLAB/Simulink is compatible with a number of programing languages, and allowd for further development into web-based applications to use and greater user accessibility. Furthermore, the MATLAB/Simulink estimation model with minor modifications is applicable to other geographical areas, and rice combine harvesters.

Keywords: Economically useful life, Rice combine harvester, Ownership cost, Operating cost.

1. Introduction

Recent decades have witnessed rapid growth in the demand for agricultural machinery in rice-growing countries around the globe. The boom is attributable to high wage, labor scarcity, and low productivity [1-4]. The adoption of agricultural machinery involves large financial investment and recurring costs. As a result, efficient planning and management plays a key role in profitable investment in farm machinery [5].

In farm machinery management, the economically useful life of an asset is the age at which replacement of the asset is economically sensible [6]. In other words, an asset's economically useful life is the age at which the average total cost of the asset reaches the lowest point and reverses beyond the economically useful life.

By definition, the economically useful life of farm machinery is the expected period of time during which the machine remains useful to the owner. The asset could be operational beyond the economically useful life but may not be economically useful. Evidence shows that repair and maintenance (R&M) cost accounts for substantial proportions of agricultural farming [6-8], representing 35 – 50% of the total outlay (excluding land) [9-10].

Bowers & Hunt [11], Fairbanks et al. [12], Rotz [13], and Hunt [14], attempts have been made to establish universal R&M costs of farm machinery; however, the findings reveal that the R&M costs vary by agricultural area (area-specificity), time (machine age), and use (extent of operation). In (Hunt [14] and ASAE Standard EP496 [15], the optimal life of farm machinery is estimated based on fixed and variable costs of the machines. The economic life of farm tractors are determined using the ownership and operating costs of the assets [6, 7, 16-17]. In Pagare et al. [18], the researchers documented that the appropriate age for farm machine replacement is the point at which the average total cost is at the minimum.

Existing publications on Thai-manufactured rice combine harvesters have focused on production capacity [19], cost estimations and cost-benefit analysis [4]. There exists no research on estimation of economically useful life of locally-made rice combine harvesters, despite the prevalence of the rice harvesters in many rice-growing countries, especially in Southeast Asia. As a result, this research proposes a MATLAB/Simulink-based model to estimate the economically useful life of Thai-made rice combine harvesters. The ownership cost (depreciation and interest) and operating cost (R&M outlay) are the key components the estimation model. The study uses a sample of rice harvesters in the rice-growing region of Thailand's Northeast where the rice combine harvesters are commonly used. For other agricultural areas, the model execution requires different area-specific cost datasets.

Therefore, the objective of this study is to estimate models of economically useful life of rice combine harvesters.

2. Materials and methods

2.1 Study area and field data

The study area covers 11 major rice-growing provinces in Northeast of Thailand where locally-made rice combine harvesters are ubiquitous (Figure 1).

Field data were collected during October 2018 – June 2019. The data belong to 50 locally-made rice combining harvesters (excluding pre-owned harvesters). Data collection was carried out by interviewing owners of the combining harvesters. The key field data included the acquisition cost (i.e., purchase price), borrowing cost (interest rates), loan periods, annual R&M costs, and annual harvest areas.

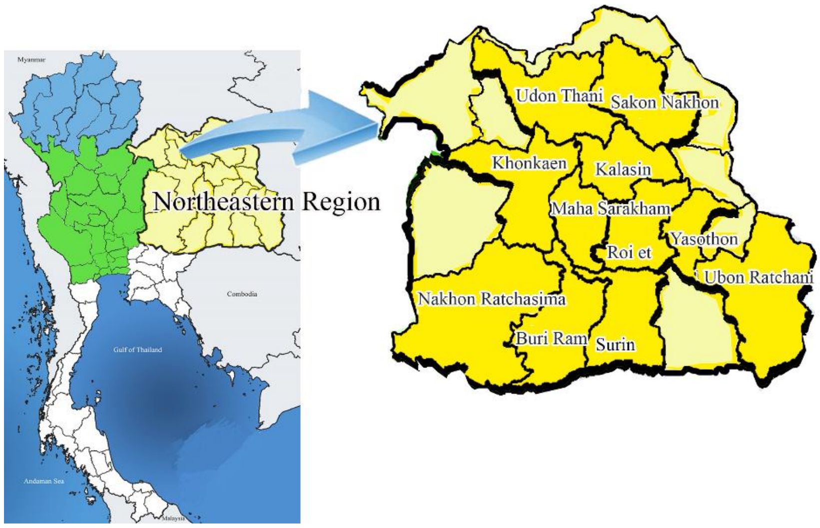

Figure 1 The map of Thailand and the Northeast regional map

2.2 Machinery cost and economically useful life estimation

Machinery cost consists of two cost categories: ownership cost (fixed cost) and operating cost (variable cost). The local made of rice combine harvester, the ownership cost consists of depreciation, interest, insurance, taxes, harvester hangar (to house the rice combine harvester). The operating cost includes fuel, lubricants, labor, repair and maintenance, location-to-location harvester transportation charge, administrative expense, and intermediary commission (in Thailand an intermediary acts as a business coordinator between harvester owners and farmers).

In Thailand, the owners of rice combining harvesters are not subjected to taxation, and most rice harvesters carry no insurance. Besides, the harvester hangars are of low-investment and low-maintenance structures. As a result, this research used depreciation and interest expenses for the ownership cost in the estimation of economically useful life of rice combining harvesters. The R&M cost is the only operating cost item in the estimation since R&M outlay is subjected to both time (machine age) and use (extent of operation) [8, 13]. Meanwhile, the rest (fuel, lubricants, labor, transportation charge, administration, and commission) are predominantly subjected to extent of operation.

Double declining balance method is calculated the annual depreciation expenses, whereby the value of rice combine harvester is depreciated at a faster rate in the early years of asset life than in the later years. The reason for using double declining balance depreciation is consistent combination of depreciation expense and R&M expense during the life of the asset. Specifically, in the early years of the asset's life, when the R&M expenses are low, the depreciation expense will be high. In the later years of the asset's life, when the R&M expenses are high, the depreciation expense will be low [6, 17]. The annual depreciation expenses are calculated by equation (1).

$$D = 2 \times C_a \times \text{Depreciation rate} \quad (1)$$

where D is the annual depreciation expense; C_a is the cost of rice combine harvester, which is the purchase price for the 1st year and the remaining values of the rice harvester for subsequent years; and Depreciation rate is the reciprocal of accounting-based useful life of the asset (i.e., 1/accounting-based useful life of the asset). The accounting-based useful life of an asset is an estimate of the number of years that the asset is likely to remain in service for the purpose of cost-effective revenue generation.

The accounting-based useful life of machinery and equipment is 5 years [20]. The cutting headers of rice combining harvesters commonly used in Southeast Asian countries, including Thailand, are 2.8 – 4 meters in the small widths, with an average initial price of 2.2 million Thai baht (THB 35/USD).

Annual interest payments are calculated using simple interest calculation, as shown in Equation (2). In Thailand, financial institutions apply the simple interest calculation to the farm machinery loans. The field survey data (by interviewing the rice harvester owners) indicate three sources of funding: the Bank for Agriculture and Agricultural Cooperatives (BAAC), commercial banks, and financial leasing companies. The average annual interest rates (i.e., borrowing cost) are 9%, 12%, and 14% for BAAC, commercial banks, and financial leasing companies, respectively.

$$I = \left(\frac{P_v}{PVIFA_{(i,n)}} \right) \div L \quad (2)$$

where I is the annual interest payment; P_v is the initial cost of rice combine harvester at the day of purchase; $PVIFA_{(i,n)}$ is the future value interest factor where i is the interest rate and n is the loan period (years), L is *Useful life of the asset* is the accounting-based estimate of the number of years that the asset is likely to remain in service for the purpose of cost-effective revenue generation. The accounting-based useful life of machinery and equipment is 5 years. Given the loan period (n) of 5 years, PVIFA at 9%, 12%, and 14% are 3.890, 3.605, and 3.433 [21].

The accumulative R&M cost is based on power function curve fitting (XX, YY) using MATLAB/Simulink, as expressed in Equation (3), where C_{RM} is the accumulative R&M cost; *a, b* are curve fitting coefficients; and *x* is the harvest area.

$$C_{RM} = ax^b \quad (3)$$

The average annual total cost of rice combine harvesters is estimated by equation (4), where Average total cost is the annual total cost of rice combine harvester per harvest area, Annual total cost is the summation of ownership (i.e., annual depreciation and interest) and operating cost (i.e., annual R&M cost), and Annual harvest area is the total area operated by the harvesters in a given year. The economically useful life is the age at which the average total cost of an asset is at the minimum [17-18]. Nonetheless, an asset can be in operational condition but may not be economically useful [6].

$$A_c = \frac{A_t}{A_h} \quad (4)$$

Figure 2 showed graphically summarizes the estimation model of economically useful life of rice combining harvesters based on the minimum average total cost. In this research, MATLAB/Simulink is utilized to estimate the economically useful life. Figure 3 illustrated the schematic of the economically useful life estimation model of locally-made rice combining harvesters.

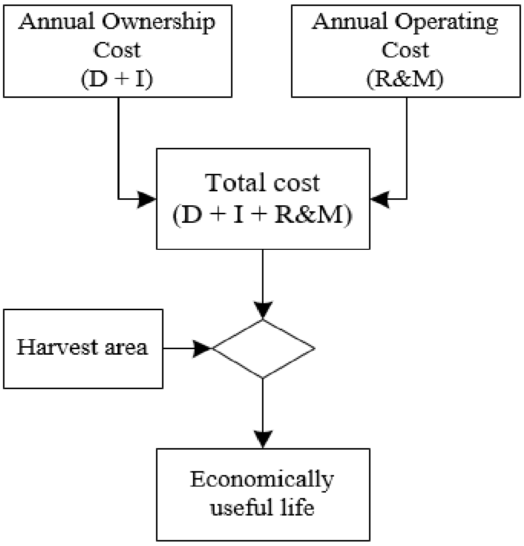

Figure 2 The estimation model of economically useful life of rice combine harvesters

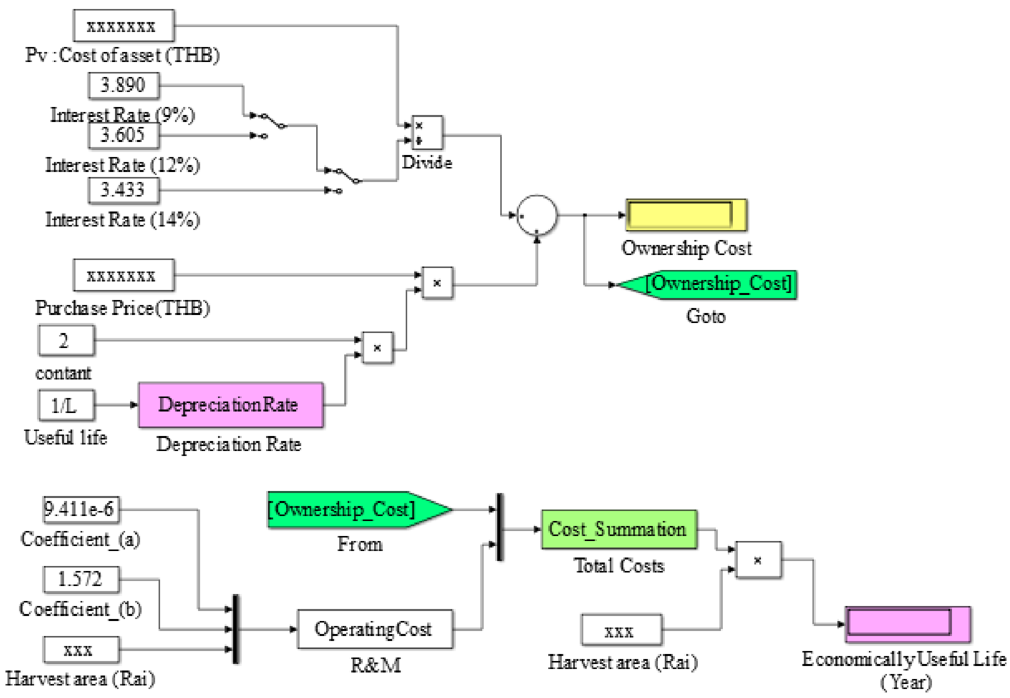

Figure 3 Schematic of the estimation model of economically useful life of rice combine harvesters

3. Results and Discussion

3.1 Repair and maintenance cost

The accumulative harvest area per harvester, annual R&M cost per harvester, per harvest area, and accumulative R&M cost per harvester are shown in Table 2. The data derived from 50 locally-made rice combining harvesters (excluding pre-owned vehicles), ranging from 2 – 12 years of age. The accumulative R&M cost per harvester was THB 694,800, accounting for 32.16% of the initial price, given the average purchase price of 2.2 million Thai baht. The exchange rate was THB 35/USD and 1 rai is 0.16 hectare. The small R&M outlays in the first two years are attributable to product warranty under which, except for consumables, the spare parts and labor are free-of-charge.

Table 1 Accumulative harvest areas and R&M outlays of locally-made rice combining harvesters

Age (Year)	Acc. harvest area / harvester	Annual R&M cost/ harvester	Annual R&M cost/ harvest area	Acc. R&M cost/harvester
	(rai)	(THB)	(THB/rai)	(THB)
1	1140	15060	13.21	15059.5
2	2442	27545	21.19	42604.5
3	3542	40890	37.17	83494.5
4	4742	43310	36.09	125804.5
5	6146	61893	44.06	188697.0
6	7446	49857	38.35	237554.1
7	8667	54391	44.58	292946.4
8	9867	80584	53.72	373529.0
9	**11240**	**104503**	**74.65**	**478032.4**
10	12433	87068	72.56	565100.0
11	13725	74700	57.46	639800.0
12	14550	55000	55.00	694800.0
Annual Avg.	1212.5	57900	45.67	-

The accumulative R&M outlay as a percentage of purchase price relative to accumulative harvest area is shown in Figure 4 and Table 2. The coefficient of determination (R^2) of power function fitting of 0.9984 indicated a strong relationship between the accumulative R&M cost and harvest area.

As previously stated, R&M cost is the operating cost item that is subjected to both time (age of machine) and use (extent of operation), whereas the other operating cost items (e.g., fuel, lubricants, etc.) are predominantly subjected to use. As a result, the accumulative R&M cost is used in estimation of the (time-related) economically useful life of locally-made rice combine harvesters. In addition, the accumulative R&M cost accounted for one-third (32.16%) of the purchase price.

Puzey & Hunt [22] reported that the accumulative R&M cost increased throughout the operating period, suggesting that the R&M cost is the key determinant of economically useful life of agricultural machinery.

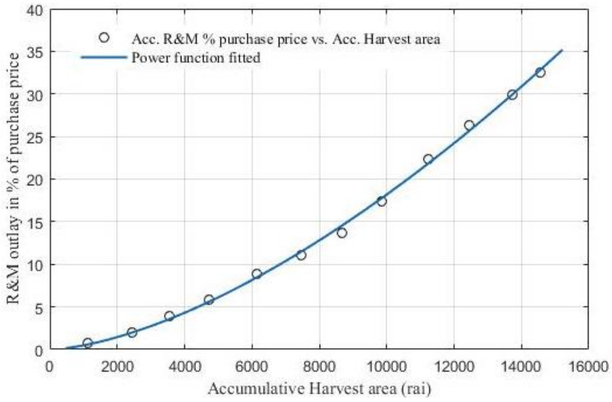

Figure 4 Accumulative R&M outlay as a percentage of purchase price relative to accumulative harvest area

The annual R&M cost per harvest area peaks in the year 9 (THB 74.65/*rai*) as a result of the major repairs and maintenance of the suspension system of locally-made rice combining harvesters are shown in Table 2. The major R&M of the suspension system is required after operation for approximately 10,000 *rai* due to wear and tear. The main components of the suspension system include the lower frame, drive chain, lead wheel, upper chain roller, lower chain roller, and tracks as shown in Figure 5.

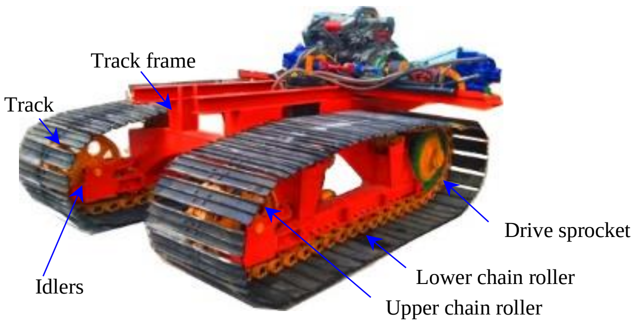

Figure 5 The suspension system of locally-made rice combine harvester

3.2 Economically useful life of locally-made rice combine harvesters

The operational life of locally-made rice combining harvesters as a function of average total cost is shown in Figure 6. The economically useful life of the rice harvesters is approximately 10 years or 12,433 *rai* (7,460 hectares), at which the average total cost was the lowest (THB 141.7/*rai*).

The accumulative ownership and operating costs, total cost, and average total cost of locally-made rice combine harvesters are shown in Table 2. The economically useful life of rice combine harvesters has approximately 10 years or 12,433 *rai* (7,460 hectares), with the lowest average total cost of THB 141.7/*rai*, corresponding to Figure 6. The operational life of the rice harvesters have gone beyond 10 years, suggesting that the machines were operational beyond the economically useful life. It was nevertheless operationally costlier, as evidenced by higher average total cost.

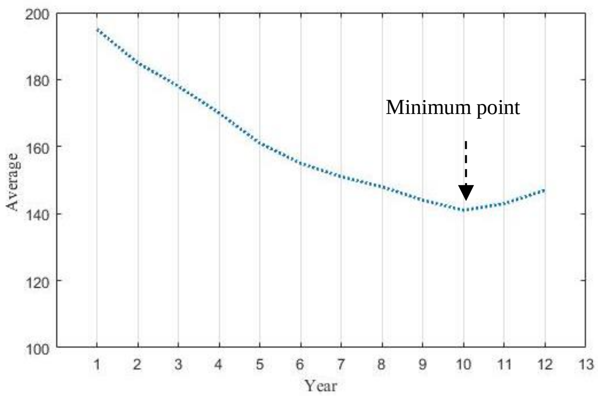

Figure 6 Operational life of locally-made rice combining harvester as a function of average total cost

Table 2 Total cost and average total cost of locally-made rice combine harvesters

Age (Year)	Acc. harvest area /Unit (rai)	Acc. Ownership cost/Unit (THB)*	Acc. Operating cost/Unit (THB)**	Total cost/Unit (THB)	Avg. Total cost/Unit (THB/rai)
1	1140	207269	15060	222328	195.02
2	2442	395749	42604	438354	185.00
3	3542	550428	83495	633922	178.00
4	4742	673866	125805	799671	170.00
5	6146	803582	188697	992279	161.44
6	7446	915420	237554	1152974	154.84
7	8667	1013349	292946	1306295	150.73
8	9867	1085686	373529	1459215	147.89
9	11240	1140323	478032	1618356	143.98
10	**12433**	**1196791**	**565100**	**1761891**	**141.71**
11	13725	1329308	639800	1969108	143.47
12	14550	1445147	694800	2139947	147.08

Note: * Ownership cost: depreciation and interest costs.
** Operating cost: the R&M cost

4. Conclusions

Despite the ubiquity of Thai-manufactured rice combining harvesters in many Southeast Asia countries and other rice-growing Asian countries there that exists no research on estimation of their economically useful life. As a result, this research proposed a MATLAB/Simulink-based model to estimate the economically useful life of the rice harvesters. The ownership and operating costs constitute the key cost components of the estimation model, and the economically useful life of rice combining harvesters is the age at which the average total cost was the lowest. The research finding used a sample of rice harvesters in the rice-growing region in Northeast Thailand where the rice combining harvesters are widely used. The results showed that the economically useful life of local made rice harvesters has been reached approximately 10 years or 12,433 rai (7,460 hectares), with the average total cost of THB 141.71/rai. The machines have been still operated beyond 10 years, but is operated costlier, and is evidenced by higher average total costs. The novelty of research work revealed in the utilization of MATLAB/Simulink in the estimation model, as opposed to SPSS which is conventionally used in existing estimation methods of other agricultural tools and machinery. In addition, MATLAB/Simulink is compatible with a number of programing languages, thereby enabling further development into web-based applications for greater user accessibility (i.e., machine owners are able to conveniently carry out the estimation). For other geographical areas, the model execution requires different area-specific cost datasets. Meanwhile, minor modifications to the estimation model are needed for rice combine harvesters of different countries of origin. In the subsequent work, the proposed MATLAB/Simulink estimation model is to be further developed into a web-based app that is applicable to different agricultural area types and rice combine harvesters.

5. Acknowledgements

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