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The Effect of Usage and Storing Conditions on John Deere 3140 Tractor Failures in Khouzestan Province, Iran

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Abstract

The use of tractors to carry out agricultural work has played an important role in mechanizing the agricultural sector. A repairable mechanical system (such as an agricultural tractor) is subject to deterioration or failure. In this study, a regression model was used to predict the failure rate of a John Deere 3140 tractor. The machine failure pattern was carefully studied, and key factors affecting the failure rate were identified in five regions of the Khouzestan province. Through a questionnaire, data was obtained from farm records. This data was grouped into six sub-groups, according to the annual use hours (AUH) and the manner in which the tractors were stored. Results showed that AUH and storage policies affected failure rate slightly. With an increase in the age of the tractors, the failure rate in the tractors used for 1050–2000 hours annually and stored outdoors was higher than those used for 200–1000 hours annually and stored in sheds. When the tractors were of the same age, the slope of the curve in the 200–1000 annual use hours increased gradually and then rapidly, but failure rate in the 1050–2000 annual use hours was high from the beginning, and subsequent increase in this value was almost uniform. As a result, it can be said that with an increase in the annual use hours, the failure and breakdown rate in John Deere 3140 tractors rapidly increases, but maintenance conditions only slightly affect the failure and breakdown rate.

Keywords: Failure rate, John Deere 3140 tractor, Khouzestan., Machine availability

Introduction

One of the most important factors in obtaining high crop yield is timeliness, as an operation performed at an improper time may cause loss of potential yield (Say and Sumer, 2011). Farm machinery management determines the best combination and the most appropriate methods to apply when using agricultural machinery, by comparison and evaluation of items (Ashtiani et al., 2006).

Today, the tractor is one of the most important pieces of equipment in agriculture, and represents a major component of farm fixed costs. Its main use is found in planting, retaining and harvesting operations, followed by use in the mechanization sector (Sonekar and Jaju, 2011 and Asadi et al., 2011). Development of agricultural mechanization depends on amount of use and application methods of tractors.

The effect of tractors on agriculture is considerable, and attention must be paid to the frequency and cause of failures, and the time taken for repair. Assessment of the capacity and optimum number of machines, and their work program to determine the optimum time to replace them is important (Ruhani et al., 2009). The first time that the regression technique was applied to predict the repair and maintenance costs was around 1970, by the ASAE (Bowers and Hunt, 1970; Sabir et al., 1990). The repair and maintenance costs form important components of the cost of owning and operating the tractor. The cost of repair and maintenance is usually about 10 to 15% of the total cost (Vafaee et al., 2007; Khoub et al., 2010; Khodabakhshian and Shakeri, 2011). These costs can be

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decreased by up to 50%, by establishing effective repair and maintenance programs (Khodabakhshian et al., 2008). In this study, in order to predict the failure rate of the John Deere 3140 tractor in customary off-season storage conditions, failure rate versus tractor age was modeled in accordance with the exponential relationship of regression.

Materials and Methods

The experiment was conducted in the Khouzestan province in Iran, one of the most arid and semiarid agricultural regions in Southwest Iran. Khouzestan province is located between the latitudes of 29° 58′ and 33° 4′ N, and the longitudes of 47° 31′ and 50° 39′ S. Data for this study were collected in 2012, using field surveys and questionnaires. Five regions, including Andimeshk, Dezful, Shush, Ahvaz and Behbahan, were selected for this study. These locations were selected specifically to best represent the operation conditions experienced by most tractors in the Khouzestan province. One hundred tractors were sampled randomly, and data were collected by means of field visits. These data represented enough information for each given sub-group. It was widely accepted that the failure frequency of farm machinery was mainly affected by annual use hours (AUH), repair and maintenance policies, and the operating environment. This province is affected by the dust haze phenomenon (Effati Kalrami et al., 2012), which causes 47% of depreciation in machinery and 52% of their power consumption (Zarei Mahmoudabady and Dehghan Tezerjani, 2012). As the temperature reaches up to 50°C during summer, the storage places were also considered while creating sub-groups. The storage place of the tractor during the year, and the AUH were selected as the factors affecting the failure and breakdown rate, as all tractors were used in the same operating environment. The storage places were divided into three types, including sheds (typically a simple, single-story roofed structure in a back garden or on an allotment that is used for storage, hobbies, or as a workshop), porches (a construction usually external to the walls of a main building, which may be enclosed within latticework, broad windows, screens, or other light framed walls extending from the main structure) and outdoors (open air conditions). The relationship between failure rate and the age of the tractor was graphed and analyzed using a regression analysis, according to the following sub-groups:

1) 200 to 1000 AUH/shed (11 machines),
2) 200 to 1000 AUH/porch (8 machines) ,
3) 200 to 1000 AUH/outdoor (18 machines) ,
4) 1050 to 2000 AUH/shed (18 machines) ,
5) 1050 to 2000 AUH/porch (18 machines) ,
6)1050 to 2000 AUH/outdoor (27 machines).

Failure rate (λ) was equal to the reciprocal of the mean time between failures (MTBF), defined in hours, and its equation was as follows (Tufts, 1985):

$$\lambda = \frac{1}{MTBF} \qquad (1)$$

Where λ and MTBF are the failure rate and mean time between failures, respectively.

Exponential distribution is one of the most common methods used in the evaluation of failure rates (Kumar, 1977; Billinton and Allan, 1992). Therefore, this function was applied in this study.

Results and Discussion

Table 1 shows the failure types and their distribution in different mechanical systems of the John Deere 3140 tractor, including the motor, hydraulic, transmission, electrical components, brakes, steering, fuel, cooling systems, and miscellaneous components (e.g. tire, ring, ball bearing and operator seat), as a percentage of the

Table 1. Failure types and their distribution in John Deere 3140 tractors

System failure types	Number of failures						Total	%
	1	2	3	4	5	6		
Motor parts	6	9	5	18	16	46	100	11.61
Hydraulic	6	6	5	19	27	37	100	11.61
Transmission	6	12	7	15	19	38	97	11.26
Electrical	12	11	10	24	30	76	163	18.93
Brakes	2	1	0	9	6	13	31	3.6
Steering	2	2	2	10	12	21	49	5.69
Fuel	8	6	3	12	19	37	85	9.87
Cooling	16	12	8	30	27	56	149	17.3
Miscellaneous	8	2	5	19	17	36	87	10.1
Total	66	61	45	156	173	360	861	100

Table 2. Descriptive data related to AUH for different sub-groups

Sub group	Average annual hour used (h)	Average age (year)	Number of machines
1	590±94.6	8.82±1.91	11
2	708.75±115.88	8.5±2.57	8
3	656±70.86	7.25±2.06	18
Average/Total	644.74±54.5	8.26±1.2	37
4	1423.75±75.45	8.625±2.76	18
5	1507.5±116.67	7.375±1.78	18
6	1382.35±61.47	9.82±1.12	27
Average/Total	1422.72±45.58	8.94±0.96	53

Table 3. Descriptive statistics of some failures encountered in the given sub-groups

Sub-group	Number of failures			
	Min	Max	Average	Total
1	2	25	6±1.94	66
2	2	15	7.625±2.13	61
3	4	8	5.625±0.53	45
Average/Total	4	24	6.37±1	172
4	12	28	19.5±1.89	156
5	13	31	21.625±2.16	173
6	13	28	21.176±0.98	360
Average/Total	19	43.5	20.87±0.84	689

total failure data derived from farm records. It can be seen that the electrical and cooling systems caused the majority of recorded failures, 18.93% and 17.3%, respectively. Further, the reasons for electrical system failures were generally the short life span of the battery and dynamo in these types of tractors. For the cooling systems, the reason for failure was the rupture of the fan belt, and failure within the water pump and radiator.

The average AUH and average age are shown in Table 2. As can be seen, the average AUH for 200–1000 and 1050–2000 main groups was 644.74 and 1422.72 hours, respectively. The average age for all sub-groups was similar.

Some descriptive statistics of failure data in the given sub-groups are summarized in in Table 3. Average failure numbers calculated for the outdoor groups were higher than the shed and porch groups, and average failure rates for the 1050–2000 AUH groups were higher than the 200–1000 AUH groups. Failure numbers for the 1050–2000 outdoor sub-groups were the highest. The average failure rates calculated in Table 4 show the effects of the annual working hours and storage conditions. As can be seen, the

Table 4. Average failure rates and mean time between failures for sub-groups

Sub-group	Average failure rate	Mean between failures (h)
1	0.0092±0.0011	121.15±10.9
2	0.00959±0.0015	127.6±22.8
3	0.00962±0.0017	125.56±18.4
Average/ Total	0.0094±0.0008	124.37±9.35
4	0.0136±0.00112	76.58±6.04
5	0.0142±0.00068	71.3±3.19
6	0.015±0.00043	65.96±2.01
Average/ Total	0.0146±0.00039	69.83±2.03

average failure rate in the 1050–2000 AUH sub-groups was higher than the 200–1000 AUH sub-groups. Therefore, it seems that shed storage slightly decreases the frequency of failure of the tractor.

Failure rates versus tractor age was modeled according to the exponential regression relationship, because this model gave the highest R^2 of each sub-group when compared to other regression models. The relationship between the calculated failure rate and the age of tractor for each sub-group, along with their equations is shown in Figures 1, 2, 3, 4, 5 and 6. The predicted failure rate in the 1050–2000 AUH sub-groups was higher than that in 200–1000 AUH sub-groups. This shows the considerable effect of the AUH on John Deere 3140 tractor failure rate. The methods of storage, including shed, porch and outdoor, slightly affect the failure rate at the same AUH. Further, the estimated equations showed that the failure rate increased in the shed, porch and outdoor storage for each of AUH sub-groups, for the same age of the John Deere 3140 tractor. In the same storage conditions, the failure rate of the 1050–2000 AUH sub-groups was considerably different when compared to the 200–1000 AUH sub-groups. The curve of the 1050–2000 AUH sub-groups was nearly a straight line, and increase in the failure rate of the 200–1000 AUH groups was more gradual than for the 1050–2000 AUH sub-groups, but the given curves for the same AUH were similar to each other. At the age of 3 years, the slope of the curve in the Figures 1, 2, and 3 (200–1000 AUH) gradually and then rapidly increased, but failure rate in Figures 4, 5, and 6 (1050–2000 AUH) were high from the beginning and subsequent increase in this value was almost uniform. As a result, it can be said that with an increase in the AUH, the failure and breakdown rate of the John Deere 3140 rapidly

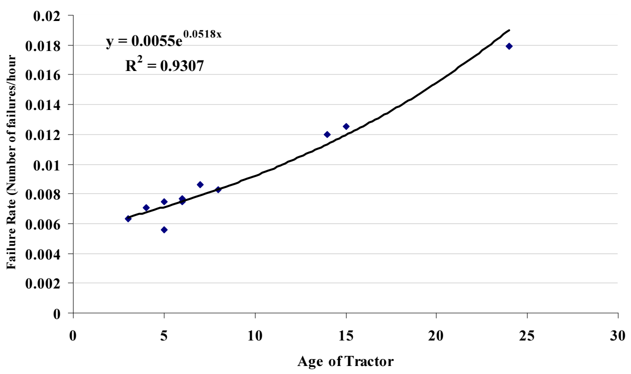

Figure 1. Calculated failure rate vs age of tractor for the 200–1000 AUH/shed sub-group.

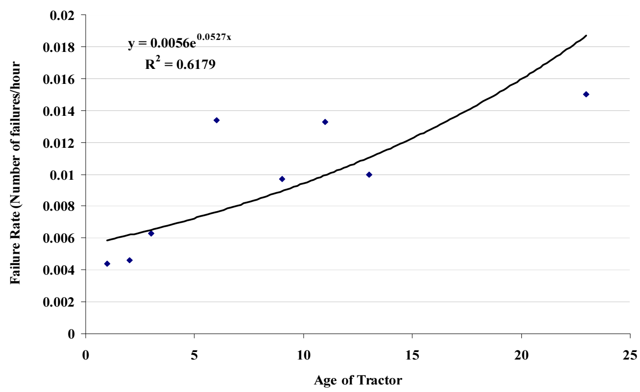

Figure 2. Calculated failure rate vs age of tractor for the 200–1000 AUH/porch sub-group.

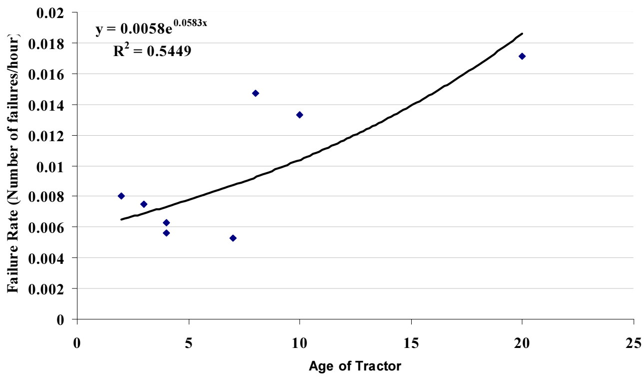

Figure 3. Calculated failure rate vs age of tractor for the 200–1000 AUH/outdoor sub-group.

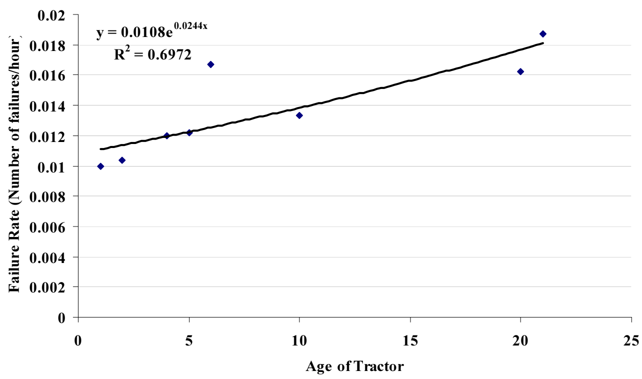

Figure 4. Calculated failure rate vs age of tractor for the 1050–2000 AUH/shed sub-group.

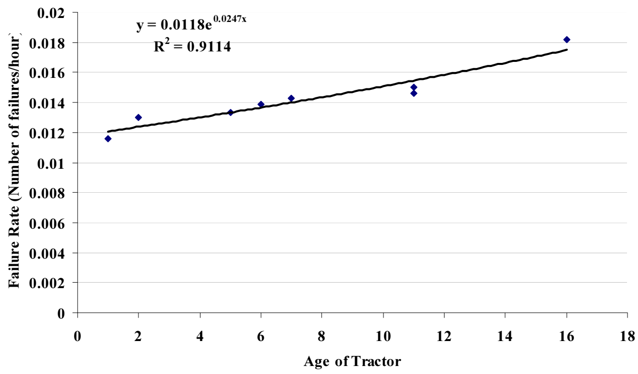

Figure 5. Calculated failure rate vs age of tractor for the 1050–2000 AUH/porch sub-group.

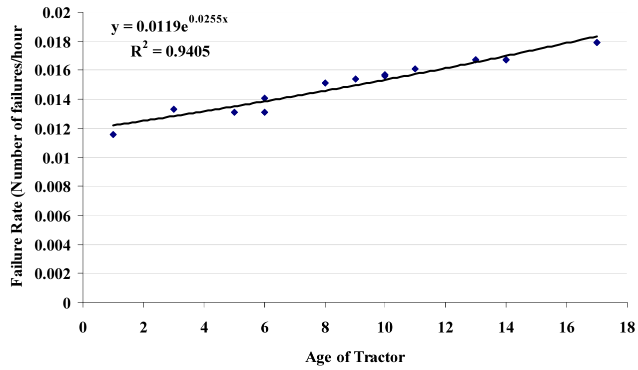

Figure 6. Calculated failure rate vs age of tractor for the 1050–2000 AUH/outdoor sub-group.

increased, but maintenance conditions only slightly affected the failure rate. Say and Sumer (2011) reported that open air storage conditions slightly increase the failure rate. Further, Grisso and Pitman (2009) found that shed storage reduces repair and shop time because parts such as belts, tires and hoses deteriorate rapidly when left unprotected.

Conclusions

The effective management of agricultural machinery (specifically tractors) is one of the most critical factors to reduce failure rates. The results of this study can help operators and farmers in decision-making concerning tractor storage methods. Appraisal of failure rate models for farm machinery is important for accurate estimation of the required spare parts, and to decrease extra repair and maintenance costs caused by delay during repair. In accordance with the data obtained from this study and the coefficients in the calculated equations, it can be seen that increase in the AUH increased the failure rate. Further, the effect of the storage methods on the failure rate values, especially in warm climates and in places affected by the dust haze phenomenon was significant. Therefore, the storage of tractors in sheds reduced failure rate and costs related to stochastic repairs.

Conflict of Interest

The authors have no conflicting financial or other interests.

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