

# Estimation of Massey Ferguson tractors life and repair distribution functions and required number of repairmen

## Abstract

In order to reach suitable and effective performance of farm machines, on time agricultural operations is important. Also, using human resources productively and its productive enhancement needs appropriate planning. In the current study, the life and repair distribution functions of three tractors were estimated, and then, the necessary number of repairmen was determined in such a way that supplies the minimum waiting time to repair in one hand, and maximum human productivity is obtained in the other hand. Three tractors were under the study; i.e. two Massey Ferguson 285 and one Massey Ferguson 399. The tractors working data were gathered for 1100 hours. Then, the Monte-Carlo simulation method was applied to simulate tractors working conditions for around 3500 hours to have more reliable estimation of life and repair distribution functions. The results showed two functions for life and repair times; i.e. Exponential for life and 2-parameter Weibull for repair. Furthermore, two repairmen should be employed to have minimum waiting time to repair and maximum economic benefits from the view point of useful tractors working hours.

**Keywords:** life distribution function, farm management, maintenance engineering

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## Introduction

In order to obtain suitable and effective farm machinery performance besides higher crop yield, on time farm machinery field operations are essential. Farm tractors are important machines that used for soil tillage, crop planting and protection. It is even used for harvesting crops in some areas. Thus, any failure in farm tractors influences the series of field operations. Farm managers are usually looking for high reliable farm machineries to complete necessary operation in the pre-determined time Hunt.<sup>1</sup> However, farm tractors stop due to break downs and it is desired that they repaired on a minimum time and back to farms. Farm machinery costs are divided into two categories, i.e. owning or fixed costs and operating or variable costs Morris.<sup>2</sup> The cost of farm machinery repair and maintenance can contribute to most of farm machinery operational costs (after fuel) which can be reached to 15-60% of total crop production costs Mobley.<sup>3</sup> Having an effective repair and maintenance program, the costs of machinery maintenance and failures will be reduced to an optimum point Lips et al.,<sup>4</sup> by gathering machinery failures data on the farms, the failures distribution function can be estimated well and then some important issues such as machinery reliability and energy failures can be predicted as well Barabadi et al.,<sup>5</sup> Billinton et al.<sup>6</sup> In addition, the required number of repair-men can be predicted by simulation of data in such a way that farm machines imposes minimum waiting time for repair. The common life distribution functions for continuous data are Normal, Exponential, Logarithmic and Weibull Haj Shirmohammadi.<sup>7</sup> Weibull functions with wider applications can be descending, ascending or constant based on the function parameters Bartkute et al.<sup>8</sup>

In a study it has been found that the reliability function of failures data of tractors Massey Ferguson 285 can be estimated by an Exponential function Poozesh et al.<sup>9</sup> Another study showed that the failures of combine harvester John Deere 955 followed 2-parameter Weibull function Vafaei et al.<sup>10</sup> Liange<sup>11</sup> used Exponential function for estimation of farm machinery failures. Rotz<sup>12</sup> developed a model

based on equipment price and operating hours. Testing the model showed that the costs were more realistic when the area worked was considered instead of the operating hours.

After estimation of functions by using available life and repair data, a widely applied method namely Monte-Carlo simulation method was employed to simulate tractors life and repair characteristics for longer time. In other words, Monte-Carlo simulation produces distributions of possible outcome values based on an idea of using randomness to solve problems that might be deterministic in principle Salami.<sup>13</sup> Monte-Carlo simulation relies on repeated random sampling to obtain numerical results. A simple random sample is a subset of individuals (a sample) chosen from a larger set (a population). Each individual is chosen randomly and entirely by chance while each individual has the same probability of being chosen at any stage during the sampling process, and each subset of  $k$  individuals has the same probability of being chosen for the sample as any other subset of  $k$  individuals. Monte-Carlo simulation then calculates results over and over, each time using a different set of random values from the probability functions. A Monte Carlo simulation could involve thousands or tens of thousands of recalculations before it is complete.

The objective of this study was to estimate two distribution functions for tractors Massey Ferguson 285 (MF285) and 399 (MF399), the first function will estimate life distribution and the second one will be used for estimation of maintenance time. Then, the number of required repair-men was estimated considering minimum tractors waiting time for repair in one hand, and minimum cost of repair in another hand. The statistical methods were applied to determine distribution function and Monte-Carlo simulation method was used to determine required number of repairmen.

## Materials and methods

This study was conducted in 8 months from spring to autumn 2016

in Fars province, Iran. The data related to the life of three tractors were gathered. The tractors were MF285 and MF399 having a life of 5100hr at the time of study. The MF tractors were chosen since this tractor is most common tractor in Iran while MF285 is more available. Thus, we consider the condition of the study when two MF285 and one MF399 are available. The data of tractor repair times was gathered from a local repair center where the data was recorded. The life and repair data of around 1100hr were gathered representing that when and why each tractor was broken down and how much time was taken to be repaired.

### Life and repair distribution functions

Before estimating life and repair functions, homogeneity of data was analyzed using tendency test. The value of parameter U in this test was calculated as following Hall et al.<sup>14</sup>

$$U = 2 \sum_{i=1}^{k-1} \ln \left( \frac{T_k}{T_i} \right) \quad (1)$$

Where K is the k<sup>th</sup> failure,  $T_k$  is sum of tractor working hours,  $T_i$  is life of tractor. If the calculated parameter U is higher than the U from Chi square table (probability level=0.95 and degree of freedom=2(n-1)), the data is homogeneous.

Then, to find the best function, the fitting curve test using MATLAB was employed. Different fitting functions including Exponential, Normal, Weibull and Poisson were examined to find the best fitted model considering R<sup>2</sup> and RMSE. The examined Exponential and 2-parameter Weibull functions are given here as an example:

$$f(t) = \lambda e^{-\lambda t} \quad (2)$$

$$g(t) = \frac{\beta}{\alpha} \left( \frac{t}{\alpha} \right)^{\beta-1} e^{-\left( \frac{t}{\alpha} \right)^\beta} \quad (3)$$

Where  $\lambda$  is the rate of failures;  $t$  is the lifetime or repair time;  $\alpha$  and  $\beta$  are the Properties of distribution function.

### Using Monte-Carlo simulation by life and repair cumulative functions

As stated before, the data related to the 1100hr tractors working hour was gathered. Cumulative functions were used to simulate life and repair times of tractors in longer working hours. Thus, after estimation of life and repair distribution functions, corresponding cumulative functions were determined. For instance, the cumulative form for Exponential and 2-parameter Weibull functions are as following:

$$F(t) = 1 - e^{-\lambda t} \quad (4)$$

$$G(t) = 1 - e^{-t^\beta} \quad (5)$$

Where  $t$  is the life time or repair time;  $\lambda$  is the rate of failures;  $t$  is the life time or repair time;  $\beta$  is the properties of distribution function.

As the next step, using Monte-Carlo simulation and MATLAB software, the performance of tractors were simulated for 3500hours while it was determined that for any life span, how much time was spent for repair during all this 3500hours. The required number of repairmen to repair these three tractors were determined in such a way

that minimum waiting time to repair and minimum cost of repair were obtained. To meet this purpose, the result of three tractors simulations were drawn simultaneously in Excel software assuming the existence of one, two and three repairmen to clarify repair times besides waiting time to repair in a graph. Finally, the optimum number of repairman was determined with regard to the cost of repair and timeliness cost of tractors. The cost of repair was considered as high as an experienced repairman (above 5years experience) will be hired.

## Results and discussion

### Fitting model

The parameter U of tendency test was higher than that of chi-square for all the tractors meaning that the data related to the life and repair times were homogeneous Hall et al.<sup>14</sup> The fitting tests revealed that the best function for tractors' life and repair were Exponential and 2-parameter Weibull, respectively. The fitted Exponential function of tractor T1 has been shown in Figure 1. The parameter  $\lambda$  for tractors T1, T2 and T3 were 0.021, 0.017 and 0.023, respectively. Accordingly, the life function of tractors has been given in Table 1. The parameter  $\alpha$  and  $\beta$  and the predicted 2-parameter Weibull functions of tractors T1, T2 and T3 has been shown in Table 2. The magnitude of  $\beta$  for T3 shows that the tractor is near to the end of its economic life or the frequency of repairs are increased Najafi et al.<sup>15</sup> In other words, tractor T3 need more repair than tractors T1 and T2. After the prediction of distribution functions, the cumulative functions were estimated. The cumulative function of tractor T1, for instance, is as following: Cumulative Exponential function

$$F(t) = 1 - e^{(-0.021t)} \quad (6)$$

The Monte-Carlo simulation was applied to simulate life and repair times of tractors for 3500hours. Some part of the results has been shown in Table 3. For instance, the first random data from the simulation of T1 was 0.48 and the corresponding life was 31.3hr, and for the repair simulation, the first random data was 0.96 and the corresponding repair time was 4.75hr. the data for tractors T2 and T3 are also given as well.

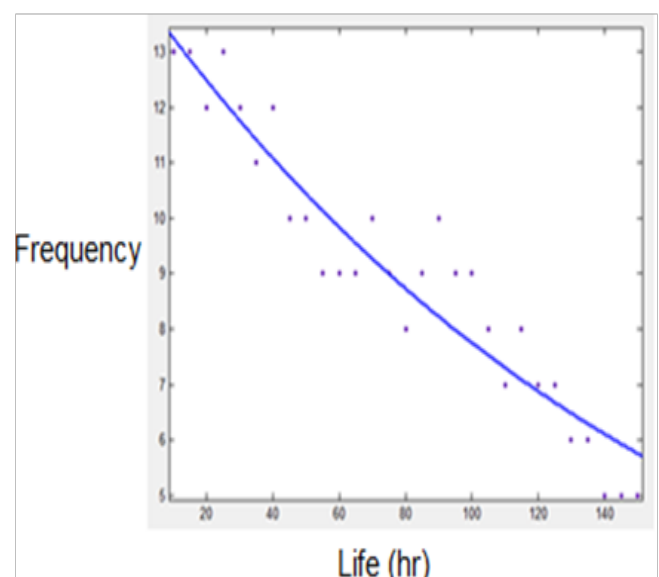


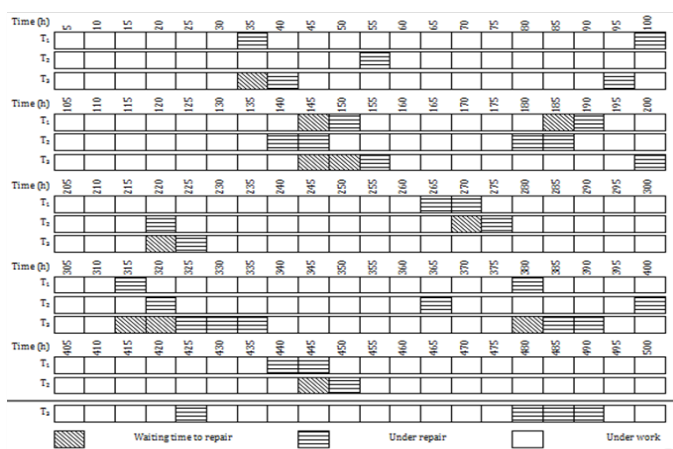
Figure 1 The fitted Exponential function of tractor T1 life.

**Table 1** Predicted life distribution functions for Massey Ferguson tractors T1, T2 and T3

Tractor type	Life distribution function $f(t)$	R2	RMSE
T1	$0.021e^{-0.021t}$	0.87	0.0018
T2	$0.017e^{-0.017t}$	0.89	0.001
T3	$0.023e^{-0.023t}$	0.87	0.0019

### The graph of tractors working hours

The data of simulation was used to draw the graph of tractors working hours besides times to repairs.<sup>16</sup> The drawing was completed in three mode: 1- employing only one repairman, 2- employing two repairmen and 3- employing three repairmen. The priority of repairs was from T1 to T3 meaning that when two tractors need to be repaired, the first tractor for repairing is T1, then T2 and finally T3. Another assumption is that each repairman works independently Figure 2 shows the simulation of three tractors for 500hr employing one repairman. Although the simulation was completed for 3500hr, the graph has been shown for 500hr due to limitation in space. Figure 3 shows the simulation of three tractors employing two repairmen (Figure 2) reveal that after 30hr working time, both the tractors T1 and T3 required to be repaired. Because of predetermined priority, tractor T1 is repaired first and meanwhile tractor T3 imposed 5hr waiting time. Then tractor T3 has been repaired. When we have two repairmen (Figure 3), two tractors (T1 and T3) have been repaired simultaneously and the waiting time of tractor T3 has been omitted.



**Figure 2** The graph of three tractors working hours when one repairman is employed.

Comparing (Figure 2) (Figure 3) reveal that waiting time is reduced when two repairmen are employed. The result of 3500hr simulation is tabulated in Table 4. The outputs clarify that in all the simulation modes, i.e. with one repairman, two and three repairmen, tractor T3 had the highest repairing time and waiting time to repair. The below calculations were done by using data given in Table 4 to investigate how many repairman is required in the repair and maintenance center in order to repair tractors with minimum waiting time and minimum cost.

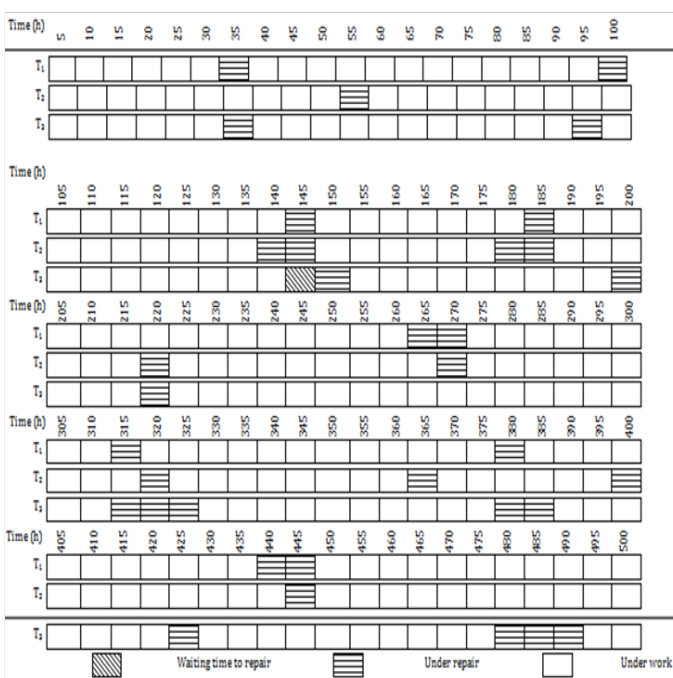
**If one repairman is employed:** In this condition, the repairman will be at the work for 3500hr, but there will be 1397.1hr down time (waiting time+time to repair). The sum of hours that the three tractors

are repaired is 1025.6hr. The cost of repairing is given in Table 5.

**If two repairmen are employed:** When there are two repairmen at the work, they will at work for 7000hr (Table 6). Accordingly, there will be 1106.7hr down time (waiting time+time to repair).

**If three repairmen are employed:** Three repairmen are available for a total of 10500hr while they work on the tractors for 1025.6 and the total down time (waiting time + time to repair) is 1025.6 (Table 7).

The result of (Tables 5-7) clarifies that the two repairmen should be employed to have minimum wait time to repair and minimum cost of repair. When there are two repairmen, the amount of waiting time to repair is reduced of 300hr, i.e. from 370hr to 70hr. The calculations revealed that the waiting time reduced even more (reach to zero) when there are three repairmen, but the cost of each tractors working hour is increased three times. Accordingly, for the current status, it is not reasonable to employ more than two repairmen.



**Figure 3** The graph of three tractors working hours when two repairmen are employed.

**Table 2** Predicted repair function for Massey Ferguson tractors T1, T2 and T3

Tractor type	Parameter	Parameter	Repair function $g(t)$
T1	7.28	0.78	$(0.78/7.28).t^{0.78} - 1. e^{-t(0.78/7.28)}$
T2	6.31	0.63	$(0.63/6.31).t^{0.78} - 1. e^{-t(0.63/6.31)}$
T3	5.83	0.55	$(0.55/5.83).t^{0.78} - 1. e^{-t(0.55/5.83)}$

**Table 3** Life time and repair time of Massey Ferguson tractors by Monte-Carlo simulation method

Tractor T1 (MF285)				Tractor T2(MF285)				Tractor T3(MF399)			
Random Number	Life (h)	Random number	Maintenance Time	Random number	Life (h)	Random number	Maintenance Time	Random number	Life (h)	Random Number	
0.96	31.3	0.48	4.75	0.62	53.41	0.94	4.54	0.81	34.32	0.56	
0.98	60.33	0.72	5.72	0.77	82.54	0.88	4.66	0.79	53.22	0.7	
0.71	43.91	0.64	3.15	0.38	27.62	0.9	5.32	0.92	45.44	0.61	

**Table 4** Sum of working, waiting and repair times for three tractors by Monte- Carlo simulation method

Number of maintenance labor		Time (h)	Tractor T1	Tractor T2	Tractor T3	Sum
One Repairman	working time		3169.5	3109.2	2824.2	9102.9
	Waiting time		55.3	80.7	235.5	371.5
	repair time		275.2	310.1	440.3	1025.6
	Sum		3500	3500	3500	10500
Two Repairmen	working time		3209.5	3164.6	3019.2	9393.3
	Waiting time		15.3	25.3	40.5	81.1
	repair time		275.2	310.1	440.3	1025.6
	Sum		3500	3500	3500	10500
Three Repairmen	working time		3224.8	3189.9	3059.7	9774.4
	Waiting time		0	0	0	0
	repair time		275.2	310.1	440.3	1025.6
	Sum		3500	3500	3500	10500

**Table 5** The cost of repairing when one repairman is employed

Costs	
350,000Rial/hr×1,397.1hr=488,985,000Rial	Down time
70,000Rial/hr×1,025.6hr=71,792,000Rial	Repair time
15,000Rial/hr×3,500hr=52,500,000Rial	Wage
613,277,000Rial	Sum
610,400,000 ÷ 9,102.9=6,7371.61Rial	The cost of each useful working hour

**Table 6** The cost of repairing when two repairmen are employed

Costs	
350,000Rial/hr×1,106.7hr=387,345,000Rial	Down time
70,000Rial/hr×1,025.6hr=71,792,000Rial	Repair time
15,000Rial/hr×7,000hr=105,000,000Rial	Wage
564,137,000Rial	Sum
564,137,000 ÷ 9,393.3=60057.38Rial	The cost of each useful working hour

**Table 7** The cost of repairing when three repairmen are employed

Costs	
350,000Rial/hr×1,025.6hr=358,960,000Rial	Down time
70,000Rial/hr×1,025.6hr=71,792,000Rial	Repair time
15,000Rial/hr×10,500hr=1,575,000,000Rial	Wage
2,005,752,000Rial	Sum
564,137,000 ÷ 9,474.4=211,702.27Rial	The cost of each useful working hour

## Conclusion

Most studies have focused on the estimation of tractors repair and maintenance costs, not estimation of required repairmen for tractors to minimize tractors down time. This is the first study on the investigation of required number of repairmen for Massey Ferguson tractors in Iran in order to minimize costs of repair and waiting time to repairs. The results showed that the best function for life and repair of tractors were Exponential and 2-parameter Weibull distribution function, respectively.

Monte-Carlo simulation suggested that two repairmen should be employed if minimum cost besides minimum waiting time is critical. Although only the calculations related to the costs have been shown here, the reduction on the waiting times lead to one time farm

operations which in turn increase crop yield which is not described more here. More investigation on this issue is suggested for future studies. Our observations revealed that around 80% of farmers are more satisfied with tractor MF285 than MF399. Seemingly, one of the reasons is that farmers are not so practically familiar with the new tractor MF399 and cannot work with it suitably.

Especially, some of regular daily and weekly services are important to mitigate emergency repairs and maintenances. The fitting of load with tractor power is also effective to reduce unwanted repairs. Currently, most farmers do not pass training periods in tractor regular services and work based on their experience. It is estimated that increasing farmers' knowledge especially to use MF399 (driving, regular services) is essential for 60% of farmers to improve machinery use efficiency.

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## Conflict of interest

The author declares no conflict of interest.

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