RISK ANALYSIS OF DESIRED MINIMUM ANNUAL UTILIZATION

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Abstract

The paper presents the results of the risk analysis to achieve a minimum annual utilisation for the group of combine harvesters operated in services. For modelling, an appropriate economic model was created. The results of sensitivity analyses were used to determine the key factors within the risk analysis to achieve a minimum annual utilisation. The key factors were lilting within the range of ± 10%. The risk analysis was carried out using a stochastic simulation methods using a triangular distribution of these values. The risk to achieve minimum annual usage was evaluated for each harvester. The result of the analysis showed that the most frequent values of the minimum annual utilisation, i.e. 697 ha / year, will be achieved with a probability of 50.48%. The sub-profit of the enterprise arising from the operation of the combine harvesters is directly influenced by their accomplished annual utilisation.

Key words: harvester, economic model, key parameters, profit, business risk, machinery utilization.

INTRODUCTION

According to KAVKA (1997) the minimum annual usage is the turning point in the search for the purposefulness of purchasing your own machine in comparison with the use of mechanised services. This is one of the results of the so-called economic considerations relating to the development of strategies in the use of mechanical equipment. When searching for an appropriate strategy it is necessary to combine the operational parameters influencing the formation of profit, i.e. in particular: income from the operation of the machine; operation costs of the selected machine type (in relation to the purchase price, in the form of financing, the usage time and changing operating parameters in dependence on time).

From these variables the combination of the service prices of mechanised works in the market with duration of use, cost and annual utilisation of the machine can be emphasised. This combination of the operating parameters can determine operating spaces according to RATAJ (2005). The minimum annual usage is then the interface between the operating space of profit and a loss.

The annual performance of combine harvesters in agricultural enterprise must meet the security requirements of the harvest in agro-technical deadlines, to avoid generating losses by reducing crop yields. KAVKA ET AL. (1997) and KOLEK ET AL. (1997) dealt with the timeliness factor and its impact on the losses amount. ZACHARDA AND PEICH (2002) discovered in their research that the performance of combine harvesters operated in the services is up to 99% higher (834.8 hectares, while in agricultural enterprises it is only 419.4 hectares per year). SZUK AND BERBEKA (2014) reported on the basis of the analyses that for a business that doesn't reach the required minimum usage, it is more economical to buy a used combine harvester.

The unit costs of combine harvesters are directly affected by the achieved annual usage, when its growth means a decline in the proportion of fixed costs. KAVKA ET AL. (2010) states that the size of the fixed costs is also influenced by a machines usage time, when there is a decrease in fixed costs at the same annual performance with the extension of the machinery usage period.

MONTASER AND MOSELHI (2014) state that most forecasts concerning use of machines use deterministic or stochastic approaches, which are based on historical data. The disadvantage of this approach they see in the inaccuracy of the resulting simulations, since they don't take into account the unique characteristics of the machine operation. Therefore, they recommend the use data obtained through online monitoring of machines operation for modelling. From the data obtained it is possible to analyse the factors that increase the uncertainty of achieving the desired machine performance, such as e.g. the type of work carried out or the weather.

As the above review of the literature shows, the achieved annual performance of combine harvesters has a major impact on the economy of their operation.

Therefore, the main objective of this paper is to perform a risk analysis using stochastic simulation methods and to assess the impact of key parameters to achieve a minimum annual utilisation of combine harvesters.

MATERIALS AND METHODS

The key parameters are determined based on the results of the cost analysis. To determine the break-even point the analysis of the operational area is used. The results of these analyses carried out showed that the greatest impact on both the average annual partial gain from the combine harvesters operation as well as unit costs of combine harvesters, is a change in the price of services provided by threshing machine, the annual performance of threshing machine, purchase price of threshing machine and the fuel costs. For these key parameters there was a risk analysis carried out on the achievement of a minimum annual utilisation of combine harvesters. The equations 1–3 were used to calculate the minimum annual utilisation of combine harvesters according to Kavka (1997) and Rataj (2005).

$$aW\min = \frac{aCf}{Ph - uCv} \qquad [\text{ha/year}] \qquad (1)$$

where:

$$aCf = aCd + aCioc + aCibl + aCai + aCci + aCg \qquad [\text{Kč/year}] \qquad (2)$$

$$uCv = uCm + uCfl + uCp \quad [\text{Kč/year}] \qquad (3)$$

aWmin – minim annual performance [ha/year]
aCioc – annual costs on interest of own capital [CZK/year]
aCd – annual depreciation costs [CZK/year]
aCibl – annual costs on interest of bank loan [CZK/year]
aCci – annual cost of compulsory insurance [CZK/year]
aCai – annual cost of accident insurance [CZK/year]
uCfl – unit cost of fuel and lubricants[CZK/ha]
aCf – annual fixed costs [CZK/year]
uCv – unit variable costs [CZK/ha]
Ph – price of harvest [CZK/ha]
uCm – unit maintenance costs [CZK/ha]
aCg – annual cost of garaging [CZK/year]
uCp – unit personal costs [CZK/ha]

Gleissner and Berge (2004) have defined an algorithm of random numbers generation based on in advance determined conditions and statistical distribution in order to model the risky situation. Efficiency of the minimal annual utilisation of harvesters is effected by a large number of potential risk situations (key factors) and therefore Koenker et al. (1996) have used the method of quantilles allowing to resolve the distribution type. There were selected parameters by which can be expected the changes in order to provide modelling.

The paper is based on the principle of the neoclassical economic theory. It considers maximisation of the company's annual profit as the main criterion for enterprise decision making, which can be determined by the procedure set out in Kavka (1997). This criterion is extended to take account of the risks to the business. The parameter of annual utilisation of combine harvesters has the greatest impact on achieving annual profits and it shows how effectively the combine harvesters are used.

The risk analysis uses the stochastic Monte Carlo simulation method for generating random variables with the probability distribution of criterion variable using a triangular distribution at a significance level of 0.05. Random variables of the operating parameters are generated for one million high-risk situations. The key parameters are the lilting of ± 10% of the most common value. This defines the boundaries of the pessimistic and optimistic value of variables (annual usage, cost of mechanised labour, variable unit costs and fixed annual costs). Modelling is carried out in MS Excel.

Performance and operating parameters were monitored during the period 2009 to 2012 with a group of three combine harvesters, the John Deere model 9880i STS combine harvester (hereinafter referred to as 'JD 9880i STS'), John Deere model S 9660 WTS (hereinafter referred to as 'JD S 9660 WTS') and John Deere model S 690i (hereinafter referred to as; JD S 690i'). Data obtained from this monitoring is used in the analysis.

RESULTS AND DISCUSSION

Overlay chart in Fig. 1 shows the frequency distribution of a minimum annual utilisation for individual combine harvesters and generated random variables together with the probability of achieving them. The probability distribution of the output variable is interspersed with the most appropriate type of theoretical distributions – the best for all was binomial (the curve in the graph). As is apparent from the graph, the maximum value of the probability of achieving a minimum annual utilisation of 7.9% is performed by JD S 9660 WTS combine harvesters, which also has the lowest value of the minimum annual utilisation. The lowest value of the probability of achieving a minimum annual utilisation of combine harvesters, i.e. 5.2%, is achieved by the JD S 690i combine harvester, but it achieves the highest value of the minimum annual utilisation. The analysis of the sensitivity of the individual combine harvesters showed that the greatest impact on achieving minimum annual utilisation at the desired economical profit belongs to the cost of mechanised work (its influence ranged from 63.8 to 65.8%, followed by the unit variable costs (their influence ranged from 27.3 to 31.7%) and annual fixed costs (their effect ranged from 4.5 to 6.9%).

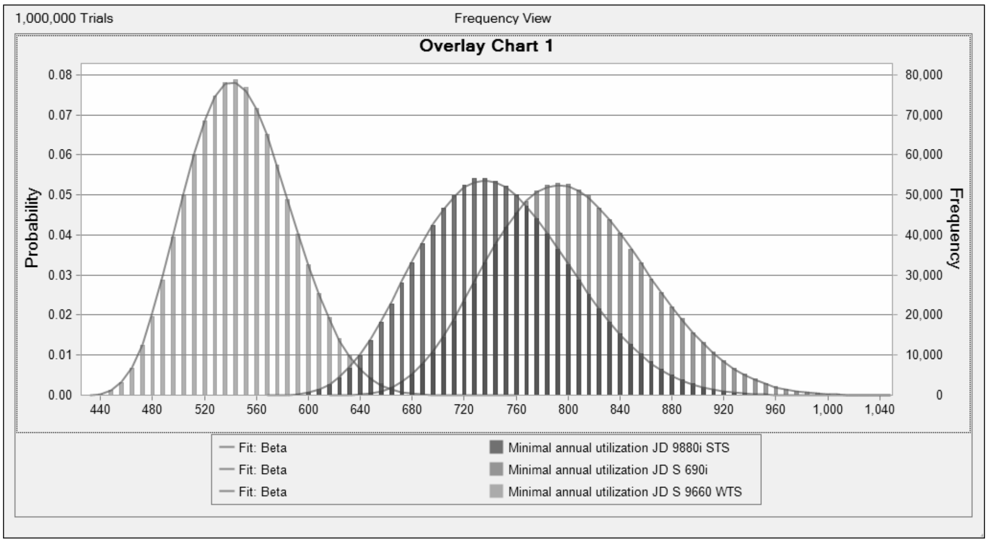

Fig. 1. – Distribution curve of probability minimum annual utilization of each combine harvesters, John Deere [ha/year]

As is evident from the values in Tab. 1, regarding the JD S 690i combine harvester the minimum annual utilisation is 799 ha/year, the maximum value of the minimum annual utilisation reaches 1,046 ha/year, the arithmetic average of 802 ha/year, the median, i.e. the value that after ranking the values from the smallest to the largest is found in the middle, is 799 ha/year and modus, i.e. the most frequently occurring reference value of 797 ha/year, which also indicates the most likely scenario. The value of the minimum annual utilisation of 799 ha/year will be achieved with a probability of 50.33%. Variance, i.e. the average of squared deviations of individual values from their arithmetic criteria averaging 3,454 ha/year. Standard deviation, i.e. the likelihood of diversion the resulting value of criteria from its expected value is 59 ha/year, coefficient of variation, i.e. variation of the criterion value in relation to the risk is 0.0733, skewness, i.e. value indicating whether the values selected around the mean value are symmetrical or are more focused on one side, is 0.22503. In this case, the average is greater than the median, which is larger than a mode, therefore it's a positive skewness of the distribution to the right. Kurtosis, that expresses how the values of the criteria are laid out around the middle, is 2.80. Kurtosis exceeds 1, so the probability is distributed around mean values in a thicker and steeper way, than it is outside the normal distribution. Graf is deflected slightly to the right, when the average value is higher than the median. The combine harvester should probably achieve a basic minimum annual utilisation even with negative development in risk factors within a defined range.

Regarding the JD 9880i STS combine harvester within the simulation the minimum annual utilisation is 570 ha/year, maximum annual usage is 988 ha/year, the arithmetic average of 746 ha/year, median of 743 ha/year and modus 729 ha/year. The value of the basic minimum annual utilization of 743 ha/year will be achieved with a probability of 50.07%. Scattering is 3329 ha/year, standard deviation of 58 ha/year, the variation coefficient of 0.0774, 0.2781 skewness and kurtosis 2.83. Kurtosis again exceeds 1, so the probability is distributed around mean values thicker and steeper than it is outside the normal distribution. The chart is again deflected slightly to the right, when the average value is higher than the median. The combine harvester should probably achieve a basic minimum annual utilisation even with negative development in risk factors within a defined range.

Regarding the JD S 9660 WTS combine harvester within the simulation the minimum annual utilisation of 428 ha/year, maximum of minimum annual utilisation of 716 ha/year, the arithmetic average of 547 ha/year, median of 545 ha/year and modus 535 ha/year. The combine harvester achieves about 46.62% lower average annual utilisation compared to the JD S 690i combine harvester. The value of the minimum annual utilisation of 545 ha/year will be achieved with a probability of 49.58%. Scattering is 1,550 ha/year and it is 122.84% lower than in the JD S 690i combine harvester. The standard deviation is 39 ha/year, the variation coefficient of 0.0719, 0.2427 skewness, kurtosis 2.80. Kurtosis here exceeds the value 1, so the probability is distributed around the mean values densely and steeply than it is in the normal distribution. Even this graph is deflected slightly to the right, although there is an average value higher than the median. The combine harvester should probably achieve a basic minimum annual utilisation even with negative development in risk factors within a defined range.

The combine harvesters can also be compared on the basis of the rules of mean value and variance. The highest mean value and smallest variance belongs to the JD S 9660 WTS combine harvester. Regarding the JD S 690i and JD 9880i STS combine harvesters it is not possible to clearly state that one dominates over the other on the basis of the rules of mean value and variance. The JD S 690i combine harvester, which has a higher average value, also has higher variance.

Tab. 1. – Statistical processing of high-risk situations a minimum annual utilization combines harvesters

Statistic	JD S 690i	JD 9880i STS	JD S 9660 WTS
Trials	1,000,000	1,000,000	1,000,000
Base Case	799	743	545
Mean	802	746	547
Median	799	743	545
Mode	797	729	535
Standard Deviation	59	58	39
Variance	3,454	3,329	1,550
Skewness	0.2503	0.2781	0.2427
Kurtosis	2.80	2.83	2.80
Coefficient of Variation	0.0733	0.0774	0.0719
Minimum	618	570	428
Maximum	1,046	988	716
Mean Std. Error	0	0	0

For the assessment of the combine harvesters we can therefore use the stochastic dominance rules, which evaluates the entire probability distribution of selected criteria, not just some of its features. According to the first rule of stochastic dominance, such a variant is preferred, in which the value of the distribution function at each point reaches higher values than the value of function for non-preferred option. Fig. 2 shows graphs of cumulative distribution function values and their mutual overlap. The graph shows that the distribution functions of the JD S 690i combine harvester is on the right of the cumulative frequency graph for distribution functions of the JD 9880i STS combine harvester, which lies to the right of the cumulative frequencies graph for the JD S 9660 WTS combine harvester. From this we can deduce that the distribution value of JD S 690i combine harvester is smaller for any value of the minimum annual utilisation, or equal, corresponding to the value of the distribution function of the JD 9880i STS combine harvester. The JD S 690i combine harvester stochastically dominates the JD 9880i STS combine harvester, regardless of risk. The 9880i STS combine harvester stochastically dominates the JD S 9660 WTS combine harvester JD S 9660 WTS. Therefore, for the above reasons, it is no longer necessary to access the application of the second rule of stochastic dominance. In terms of risk of reaching the required minimum annual utilisation, the best is the JD 690i combine harvester, followed by the JD 9880i STS combine harvester and in last place is the JD S 9660 WTS combine harvester, but which has the highest probability of achieving the average value of the minimum annual utilisation. However, it is necessary to closely monitor the development of individual risk factors, particularly the cost of mechanised labour and unit variable costs. In the event that their development would significantly deviate from the values used for this analysis, it will be necessary to re-analyse the risks based on changed conditions.

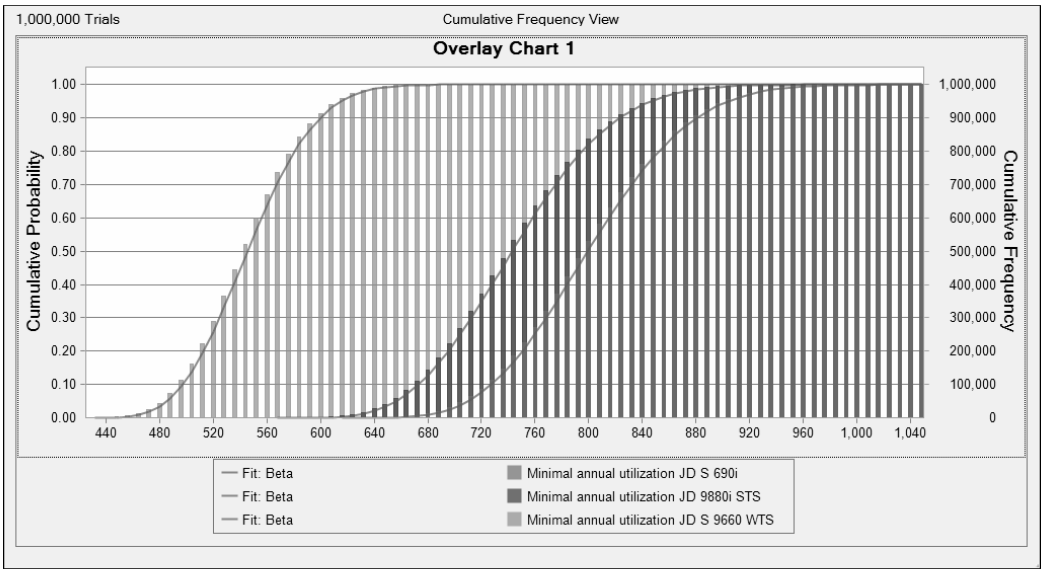

Fig. 2. – Graph the cumulative frequency distribution of the probability distribution function

Tab. 2 lists predicted values of achievement of a minimum annual utilisation for each combine harvester for different values of the probability in increments of 10%. From this table it can be determined on a specific degree of probability, which values of the minimum annual utilisation will be achieved in individual combine harvesters.

Tab.2. – The probability of achieving a specified range of a minimum annual utilization combines harvesters

Percentile	JD S 690i	JD 9880i STS	JD S 9660 WTS
100%	618	570	428
90%	728	673	497
80%	751	695	513
70%	768	713	525
60%	784	728	535
50%	799	743	545
40%	815	758	556
30%	832	775	567
20%	852	795	581
10%	881	823	600
0%	1,046	988	716

CONCLUSIONS

The risk is the probability of achieving or failing to achieve common values of annual performance. The minimum annual utilisation has essential impact on the achievement of positive economic results. Therefore, with the acquisition of combine harvester it is necessary to pay attention to those parameters that may affect it. The sensitivity analysis showed that the minimum annual utilisation at the desired economic result is mostly affected by price of mechanised labour, unit costs, variable and fixed costs. These parameters affecting revenues and costs, which stipulate the tipping point. Due to the seasonality of the deployment of combine harvesters it is necessary for an enterprise to try to maximize the annual utilisation. When creating a business strategy, it is important to decide how much risk is acceptable for the company, and how much risk is not acceptable. Agribusiness due to the biological nature and quantity of the factors influencing it, belongs to riskier sector. Based on the experience we can state that for a company it is acceptable to have the risk in the range of 0–60%.

Price of mechanised work is influenced by many factors, such as competition from other service providers in a given place and time, supplier-customer relationships, model of harvester, whether straw is crushed, the size and slope of the land, humidity and vegetation state, the type of crop being harvested etc. Major effect on the variable component of the cost is fuel consumption that is the reason why often the price is indicated without the diesel used, which is paid according to the actual consumption. The average market prices of mechanised labour in the years 2006–2015 found on a sample survey are given in Tab. 3. As Tab. 3 shows the average price of mechanised labour in the market is growing annually by about 0.8%. At the JD S 690i combine harvester there was an increase in price of the mechanised work in 2015 compared to 2008 by 5.76%. Regarding the JD W650 combine harvester the price increase of mechanised work in 2015 compared to 2007 amounted to 6.64%. This increase, however, due to high competition in the market, however, does not fully cover changes in inputs. Therefore, it is necessary to look for possible savings in cost items and increase the annual use of combine harvesters, to avoid generating negative partial profit.

Tab. 3. – Average market prices of mechanized work in the years 2006–2015

Year	Price of mechanized work in the services of JD 9880i STS / JD S690 [CZK/ha]	Annual change in the price of services [%]	Changing the price of services compared with 2006 [%]	Price of mechanized work in the services of JD WTS 9660/ JD W650 [CZK/ha]	Annual change in the price of services [CZK/ha]	Changing the price of services compared with 2006 [%]
2006	1,861			1,674*		
2007	1,876	0.81	0.81	1,688	0.84	0.84
2008	1,891	0.80	1.61	1,702	0.83	1.67
2009	1,906	0.79	2.42	1,715	0.76	2.45
2010	1,921	0.79	3.22	1,729	0.82	3.29
2011	1,937	0.83	4.08	1,743	0.81	4.12
2012	1,952	0.77	4.89	1,757	0.80	4.96
2013	1,968	0.82	5.75	1,771	0.80	5.79
2014	1,984	0.81	6.61	1,786	0.85	6.69
2015	2,000	0.81	7.47	1,800	0.78	7.53

The unit costs consist of variable and fixed components. Each component is influenced by many other factors, whose influence must be assessed individually. For example, fuel costs are influenced by development in oil prices on world markets, and it is almost impossible to influence the development of its price.

Costs for repairs and maintenance are very individual for each produced piece of machinery. CALCANTE ET AL. (2013) reports that the calculated costs for repairs and maintenance, adapted to the conditions in Italy for the combine harvester with a planned utilisation of 3,000 engine hours, amounted to 23.1% compared to 40.2% calculated according to the latest U.S. model. Usually, the cost of maintaining and repairing are for the first two years paid by the vendor of the technology within the warranty period. In the following years the costs then go to the operator. Based on the sample survey repair costs were monitored. The following Tab. 4 and Fig. 3 shows the average annual maintenance costs. As the table shows, the average cost of repairs and maintenance grow with the use of combine harvesters. Therefore, it is necessary to monitor their development and at the appropriate moment to carry out recovery of the techniques.

Tab. 4. – Average annual maintenance and repair costs for combine harvesters in the years 2006–2015

Year	Maintenance and repair costs for JD 9880i STS [CZK/year]	Annual change in maintenance and repair costs [%]	Changing the maintenance and repair costs compared with 2006 [%]	Maintenance and repair costs for JD 9660 WTS [CZK/year]	Annual change in maintenance and repair [%]	Changing the maintenance and repair costs compared with 2006 [%]
2006	162,583			77,864		
2007	160,973	-0.99	-0.99	79,453	2.04	2.04
2008	162,599	1.01	0.01	85,433	7.53	9.72
2009	189,069	16.28	16.29	90,887	6.38	16.72
2010	212,437	12.36	30.66	97,728	7.53	25.51
2011	241,406	13.64	48.48	107,393	9.89	37.92
2012	277,478	14.94	70.67	115,476	7.53	48.31
2013	311,773	12.36	91.76	124,168	7.53	59.47
2014	342,950	10.00	110.94	147,760	19.00	89.77
2015	390,963	14.00	140.47	189,133	28.00	142.90

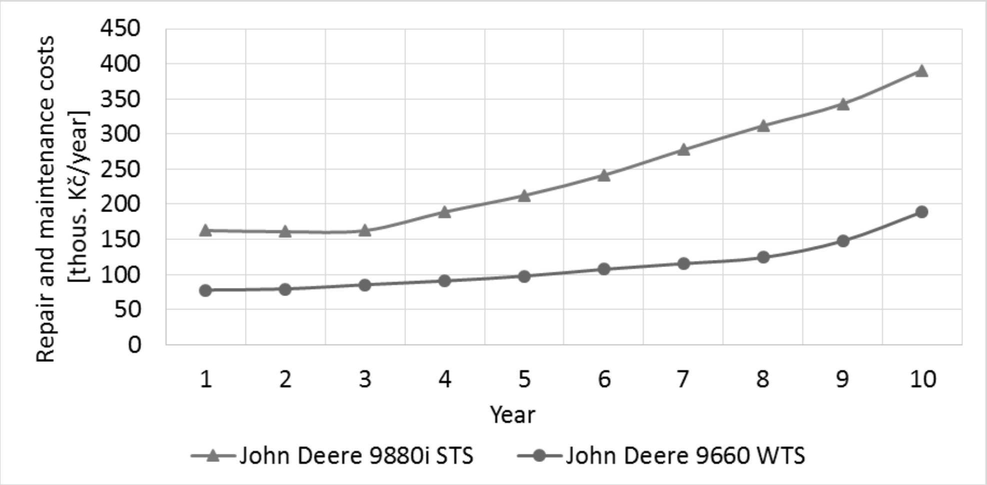

Fig. 3. – Course of costs for repairs and maintenance in time

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