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Risk analysis regarding a minimum annual utilization of combine harvesters in agricultural companies

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Abstract. This article presents the results of entrepreneurial risk analysis concerning a minimum annual utilization of harvesters in a company providing agricultural services where a group of combine harvesters is used. Furthermore, this article presents the following analysed key operating parameters with the greatest influence on reaching the minimum annual utilization and performance: the changing market price of mechanized work, the volatile purchase price of the machines, average maintenance costs).
Partial profit which an enterprise can reach through operating combine harvesters is directly affected by the level of their annual utilization. Not reaching the minimum annual utilization of combine harvesters would create losses that could result in termination of business activity in the specific field or even insolvency of the company. It is therefore necessary to monitor the key factors which influence the minimum annual usage and in case of negative developments to take timely corrective actions.

Key words: combine harvester, data modelling, key parameters, profit, business risk, agriculture, machinery utilization, business profitability.

INTRODUCTION

Accomplishment of minimum annual utilization of combine harvesters is always associated with some risk and uncertainty, which is caused by natural, biological, technological and technical parameters.

Based on the on-farm time motion studies Sørensen (2003) stated harvesting costs make up 30% of overall in-field machinery costs. The machinery performance (field efficiency) varies from 63 to 81% and is influenced by a number of technical and biological factors. These factors include the basic theoretical capacity as determined by the machinery size and the working speed, the shape and size of smaller fields, the traveling pattern in terms of subdivisions of the field, combine maneuverability, crop conditions, operator skill, etc. An increase in the field efficiency from, for example, 0.5 to 0.9 in terms of a combine with improved maneuverability, better reliability of the technical components, increased field size and more regular field shape, etc. implies a 30% reduction in costs, all other things being equal. Undercapacity is 50% more costly than overcapacity.

As mentioned by Edwards & Boehlje (1980) whatever the farm type, field machinery capacity should be large enough to complete operations on time not only under 'average weather conditions' but also in difficult seasons, without incurring excessive costs. However, establishing the 'appropriate' size of single machines in a machinery system is a difficult question as specific machinery costs are closely related to timeliness costs, which in turn are linked to available field workdays, the most uncontrolled and unpredictable variable affecting field operations.

Jánský et al. (2012) discovered that at the production of silage from perennial fodder plants the following factors account for the highest part regarding the average primary costs: employment of machinery operation (25.7%), labour costs (22.2%), overhead (17.7%) along with other direct costs and services (10.1%). Kavka et al. (2010) stated that the size of the fixed costs is also influenced by the service life of the machines. There is a decrease in fixed costs at the same annual performance (e.g. 1,000 ha per annum) when the period of usage of the machinery is extended (one machine is in operation for e.g. 10 years instead of 6 years only).

Gleissner & Berge (2004) defined an algorithm of random-numbers generation based on predetermined conditions and statistical distribution in order to model the risky situation. Montaser & Moselhi (2014) stated that most forecasts concerning use of machines use deterministic or stochastic approaches, which are based on historical data. Therefore, according to Koenker & Hallock (2001), it is necessary to establish 1) a pessimistic 2) an expected and 3) an optimistic estimate of the analysed situation. Only then can the data be used for modelling a triangular distribution. In view of the complexity of this issue, which is clear from the previous literature review, the main aim of this article is to perform a risk analysis using stochastic simulation methods and to assess the impact of key parameters to achieve a minimum annual utilization of combine harvesters.

MATERIALS AND METHODS

Key parameters are determined based on the results of the cost analysis. The analysis of the operational area is used in order to determine the break-even point. The results of these analyses carried out showed that the following factors had the greatest impact on both the average annual gain from the partial operation of combine harvesters and the unit costs of the combine harvesters:

– a change in the price of services provided by combine harvester,
– the annual performance of combine harvesters,
– combine harvesters purchase price, and
– the cost of fuel.

For these key parameters, a risk analysis was conducted focused on the achievement of a minimum annual utilization of combine harvesters. To calculate the minimum annual utilization of combine harvesters, calculations were done according to Kavka (1997) and Rataj (2005). The annual costs (see Eqs 2 and 3) reflect the change of the annual performance combine harvesters, purchase price and the cost of fuel and lubricants. Based on the above findings, an analysis of the risk of achieving minimum annual utilization of combine harvesters was carried out (see Eq. 1).

$$aWmin = \frac{aCf}{Ph - uCv} \text{ [ha year}^{-1}\text{]} \quad (1)$$

where

$$aCf = aCd + aCioc + aCibl + aCai + aCci + aCg \text{ [CZK year}^{-1}\text{]} \quad (2)$$

$$uCv = uCm + uCfl + uCp \text{ [CZK year}^{-1}\text{]} \quad (3)$$

$aWmin$ – minim annual performance [ha year^{-1}]; aCf – annual fixed costs [CZK year^{-1}]; Ph – price of harvest [CZK ha^{-1}]; uCv – unit variable costs [CZK ha^{-1}]; aCd – annual depreciation costs [CZK year^{-1}]; $aCioc$ – annual costs on interest of own capital [CZK year^{-1}]; $aCibl$ – annual costs on interest of bank loan [CZK year^{-1}]; $aCai$ – annual cost of accident insurance [CZK year^{-1}]; $aCci$ – annual cost of compulsory insurance [CZK year^{-1}]; aCg – annual cost of garaging [CZK year^{-1}]; uCm – unit maintenance costs [CZK ha^{-1}]; $uCfl$ – unit cost of fuel and lubricants[CZK ha^{-1}]; uCp – unit personal costs [CZK ha^{-1}].

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. This criterion is extended to take account of the risks to the business. 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 (with regard to the analysis for risk factors, the triangular distribution is utilized). 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: John Deere model 9880i STS (hereinafter referred to as 'JD 9880i STS'), John Deere model S 9660 WTS ('JD S 9660 WTS') and John Deere model S 690i ('JD S 690i'). Data obtained from this monitoring is used in the analysis.

RESULTS AND DISCUSSION

The analysis of the sensitivity of the individual combine harvesters showed that the greatest impact on achieving minimum annual utilization at the desired profit resulted from the cost of mechanized work (this factor ranged from 63.8 to 65.8%), followed by the unit variable costs (this factor ranged from 27.3 to 31.7%) and the annual fixed costs (the effect ranged from 4.5 to 6.9%).

Risk analysis with regard to achieving a minimum annual utilization of a group of combine harvesters

In the next step, the risk analysis for all three combine harvesters was carried out based on average risk parameters and the annual performance required for all three combine harvesters. In this case, the three combine harvesters made up one investment unit. Combine harvesters are used in the enterprise as individual units and in combination with machine lines.

Fig. 1 depicts a graph of the probability of distribution of frequencies necessary to reach a minimum annual utilization in connection with the generated random variable risk factors and the probability of achieving them. The probability distribution of the output variable is interspersed with the most appropriate type of theoretical distributions. Here we see the most effective binomial distribution (green curve in the graph). The parameters of theoretical probability distributions are given in the Table 1. The graph shows that the highest value regarding the probability of achieving a minimum annual utilization is 3.7%. Furthermore, the basic average annual utilization of 697 ha year^{-1} is achieved with a probability of 50.48%.

The results of the sensitivity analysis show conclusions similar to the results of analysis individual combine harvesters. That is, the greatest impact on achieving minimum annual utilization has mechanized labor costs of 64.6%, followed by the unit variable costs of 29.8% and fixed costs by 5.6%.

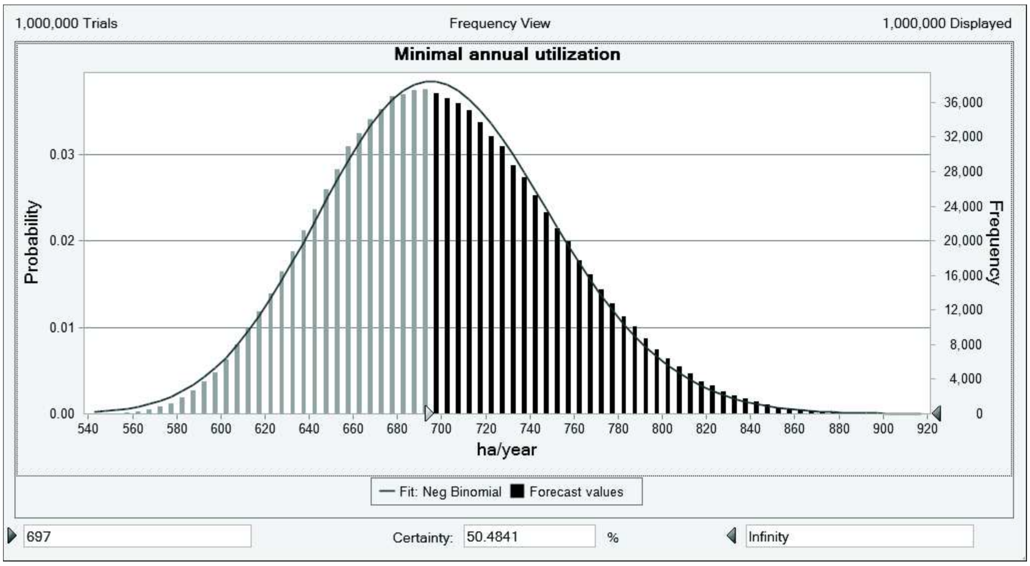

Figure 1. The distribution curve shows the risk probability with regard to achieving a minimum annual utilization for the John Deere group combines.

Table 1 presents basic statistical characteristics of theoretical binomial distribution. Further, the statistical characteristics of the simulated values are indicated. As can be seen from the values in table 1, the minimum annual utilization of combine harvesters is 540 ha year^{-1}, maximum 919 ha year^{-1}, the arithmetic average of 700 ha year^{-1}, median of 697 ha year^{-1} and modus 691 ha year^{-1}. Scattering is 2,695 ha year^{-1}, standard deviation of 52 ha year^{-1}, the variation coefficient of 0.0742, skewness 0.2573 and kurtosis 2.81. Kurtosis exceeds 1, so the probability is distributed around a mean value denser and steeper than it is outside the normal distribution. Graph is slightly deflected to the right when the average value is higher than the median. Harvester operated jointly as an investment unit should probably not achieve the required minimum annual usage even when there is a negative development of risk factors within a defined range.

Table 1. Statistical processing of risky situations concerning the average minimum annual utilization and parameters of theoretical probability distribution

Statistic	Fit: Neg Binomial	Forecast values
Trials	---	1,000,000
Base Case	---	697
Mean	700	700
Median	698	697
Mode	695	691
Standard Deviation	52	52
Variance	2,701	2,695
Skewness	0.1678	0.2573
Kurtosis	3.04	2.81
Coeff. of Variation	0.0743	0.0742
Minimum	144	540
Maximum	Infinity	919
Mean Std. Error	---	0

Fig. 2 shows a graph of cumulative frequency risks with regard to achieving minimum annual utilization. The graph shows that the value of the basic minimum annual utilization of 697 ha year^{-1} will be achieved with a probability of 50.48%. Group of combines should probably achieve a basic minimum annual utilization and negative developments in risk factors within a defined range.

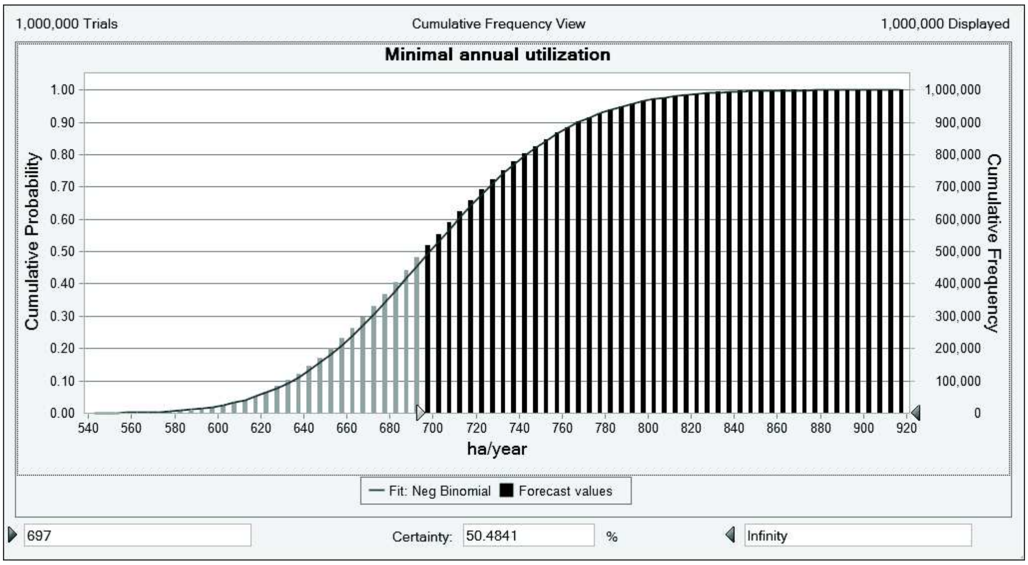

Figure 2. Graph depicts the cumulative frequency distribution of risk probability of achieving an average value of the minimum annual utilization of combine harvesters.

Table 2 presents the probabilities for different values in increments of 10% of the predicted extent of achievement of a minimum annual utilization for the whole group combines. From this table it can be determined with a specific degree of probability which values result when the minimum annual utilization is achieved by a group of combine harvesters.

Price of mechanized work is influenced by many factors, among others: competition from other service providers in a given place and time, supplier-customer relationships, weather conditions, type of combine harvesters, the size and slope of the land, humidity and vegetation, whether straw is crushed or not, as well as the type of crop being harvested. Therefore, it is necessary to look for possible savings in cost items and increase the annual use of combine harvesters in order to avoid generating negative partial profit.

Table 2. The probability of achieving annual minimum extent of utilization of the group combines

Percentile	Fit: Neg Binomial	Forecast values
100%	144	540
90%	634	634
80%	656	655
70%	672	670
60%	685	684
50%	698	697
40%	712	711
30%	726	726
20%	743	744
10%	767	769
0%	Infinity	919

Purchase prices of combines in the period 2006–2015 are based on the catalog prices that machinery dealers provided (in Table 3). The prices are affected by inflation, exchange rate, competition among manufacturers, technological advances and numerous other factors. The following table 6 shows the evolution of the purchase price of the combine harvester JD 9880i STS until 2007, when it ceased production. Subsequently, since 2008 harvester JD S 690i has been the successor model. The purchase price of the combine harvester JD 9660 WTS in 2006, when it ceased to produce, has been replaced by the price of the combine harvester JD W650, which became its successor since 2007. As table 6 shows, development of the purchase prices is quite variable. The largest annual decline occurred between the years 2012–2013 with JD S 690i by -6.44% (i.e. in total -570 thousand CZK), while the largest increase occurred between 2011–2012 by 18.16% (i.e. in absolute terms by 1,360,000 CZK). When comparing the change in the purchase price of the combine harvester JD S 690i between the years 2008–2015, we see a growth of 24.29%. Concerning the combine harvester JD W650, the purchase price in 2015 increased compared to 2007 by 27.31%. Therefore, every agricultural company must pay close attention to this parameter.

Table 3. The development of the purchase prices of combine harvesters in the years 2006–2015

Year	Purchase price of JD 9880i STS/ JD S 690i [mil. CZK^{-1}]	Annual change in purchase price [%]	Change in the purchase price compared with 2006 [%]	Purchase price of JD WTS 9660/ JD W650 [mil. CZK^{-1}]	Annual change in purchase price [%]	Change in the purchase price compared with 2006 [%]
2006	6.790			4.640		
2007	7.070	4.12	4.12	4.650	0.22	0.22
2008	7.370	4.24	8.54	4.560	-1.94	-1.72
2009	7.610	3.26	12.08	4.780	4.82	3.02
2010	7.800	2.50	14.87	5.610	17.36	20.91
2011	7.490	-3.97	10.31	5.580	-0.53	20.26
2012	8.850	18.16	30.34	5.330	-4.48	14.87
2013	8.280	-6.44	21.94	5.290	-0.75	14.01
2014	8.800	6.28	29.60	5.577	5.43	20.19
2015	9.160	4.09	34.90	5.920	6.15	27.59

Source: Catalog prices of dealers.

CONCLUSIONS

An economic model was created in order to emulate the minimum annual utilization of the combine harvesters using MS Excel. Based on the results of the sensitivity analysis, the key factors were determined. For these factors, the risk of not achieving the desired minimum annual utilization was subsequently determined. For the simulated situation, the key factors were activated within the range of ± 10% using a triangular distribution of these values. The result of this analysis showed that the most frequent value of the basic minimum annual utilization of 697 ha $year^{-1}$ is achieved with a probability of 50.48%. The overall outcome of the combine harvesters should be profitable.

There is a risk with regard to the probability of achieving or failing common values set for an annual performance. In order to avoid financial losses, it is important in advance to assess properly the risk of not reaching an annual performance and the planned income. Minimal annual utilization has serious effects on achieving positive economic results. Szuk & Berbeka (2014) reported on the basis of the analyses, that for a business which does not reach the required minimum usage, it is more economical to buy a used combine harvester.

Therefore, in acquiring combines, it is necessary to pay attention to those parameters that may affect it. As the sensitivity analysis showed, the price of mechanized work, variable unit costs and fixed unit costs had the greatest influence on the desired economic result. These parameters affect revenues and costs which determine the break-even point. Given the seasonality of the deployment of combine harvesters, it is necessary for the company to attempt to maximize the annual utilization. Zacharda and Pepich (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). In addition, it is necessary to seek further opportunities to increase the annual use of combine harvesters. When creating a business strategy, it is important to decide how much risk is acceptable for the company. Doing business in the agricultural sector is always associated with some risk and uncertainty. In view of its biological nature and the number of influential factors, agribusinesses are very risky. Based on our experience, we can state that the company can accept a risk in the range of 0–60%. The sub-profit of the enterprise arising from the operation of the combine harvesters is directly influenced by their accomplished annual utilization.

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