Scientific Research and Essays Vol. 7(47), pp. 4047-4059, 3 December, 2012
Available online at http://www.academicjournals.org/SRE
DOI: 10.5897/SRE12.259
ISSN 1992-2248 ©2012 Academic Journals

Full Length Research Paper

Grain combine repair and maintenance costs as affected by machine width

Saleh A. Al-Suhaibani, Mohammed F. Wahby* and Ibrahim S. Tabash

Department of Agricultural Engineering, College of Food and Agriculture Sciences, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia.

Accepted 26 October, 2012

Work-job orders for 15 combines with different machine widths were studied in this research paper. Data for 352 work-job orders were recorded as repair or maintenance for nine items. These items included, header unit, threshing unit, separation unit, cleaning shoe unit, engine, pre-harvest jobs, general and fabrication works, electrical and tires. Total annual cost for each item was determined, and the ratio of total cost to purchase price was calculated. Total costs were divided into labor and parts according to each work job orders. Correlations between repair and maintenance costs and some factors (such as: separation hours, engine hours, combine age, labor cost and parts cost) were conducted. The relationship between repair and maintenance costs, combine age and machine width was investigated. Seventy-two percent of the work orders were structured as repair work while twenty-eight percent were seemed to be maintenance works. Repair mean total costs were significantly higher than that of maintenance costs. Furthermore, repair and maintenance mean total costs were directly related to grain combine working life (years) and some other factors.

Key words: Combine, farm machinery, repair, maintenance, cost.

INTRODUCTION

Machine costs are divided into time-related and use-related categories. Use-related costs are present only when a machine is used. They include fuel, lubrication, use-related repairs and labor. Time-related costs, also often referred to as overhead costs, accrue to the owner whether or not a machine is used (Lazarus, 2012). The prediction of repair and maintenance costs has significant impacts on proper economical decisions making of machinery managers such as machine's replacement and substitution (Rohani et al., 2011). Appraisal of repair and maintenance cost models for farm machinery is important to decide for replacement time and to decrease total costs (Bakht et al., 2008, 2010). The good estimation of operating costs of farm machinery is an important indicator of good machinery management (Al-Suhaibani and Wahby, 2008). The models of cost estimation should be developed on clearly justified bases. The degree of accuracy also depends on the accuracy of the inputs of accurate data, where there are no models better than that the data goes in it. The annual operating costs is usually estimated based on operating hours or per unit area according the system in the area of study.

The cost of repair and maintenance (R&M) for tractors in developing countries represents 53% of annual operating costs, in comparison to 8% in advanced countries (Inns, 1978). Several studies on R&M costs for combines had been worked out in different areas of the world. Most of the studies resulted with exponential models as a function of engine operating hours (Bowers and Hunt, 1970; Fairbanks et al., 1971; Rotz and Bowers, 1991; ASAE Standards, 1993). Frank (2003) estimated R&M coefficients for grain combines in Argentina. The study was depended on two representative machine; CASE axial flow 2188 and Deutz-Fahr Optima 550, for the coefficients estimation. A list of R&M means cost of

*Corresponding author. E-mail: wahby@ksu.edu.sa. Tel: + 966 14678470.

the two machines was used in the calculations of those values along with the regression analysis. Those costs were ranked according to the machine operating parts. A study done by Gliem et al. (1989) compared the R&M costs by using the standard equations adapted by ASAE Standard which is based on the cumulative area covered by the machine and the actual costs of some farms. It was found that the calculated costs were much higher than those of farm records and the variation between the actual and estimated reaches up to 700%. In another study by Abdelmotaleb (1993), R&M costs of the rice combine under the Egyptian conditions were calculated using a multi- linear model and they were higher estimation than those developed by ASAE (1993). R&M cost models as well as the other cost components of operating farm machinery need to be checked to assure their suitability for the area to be used for. However, more research studies needs to be carried out to estimate the percentage of each cost component in order to improve the cost models for better estimating. The components of R&M costs for any machine could be ranked according to the type of job performed for the machine. Analysis of tractors R&M records (Al-Suhaibani and Wahby, 1999) ranked data for more than 1670 work orders on R&M. Sixteen types of works (such as electrical, transmission, etc.) were defined as repair and twelve types (such as hour service, air system, etc.) were defined as maintenance. In their study, 51% of the work orders were identified as repair work; while 49% was identified as maintenance. The study concluded that the repair mean total costs were significantly higher than maintenance costs. It was also found that mean total costs were directly related to tractor working life and tractor power. Wahby (1995) developed a multi-linear model to estimate R&M costs for combines. The model included a relationship between the cumulative costs of combine R&M and machine power, price, and width of cut, cumulative engine working hours and separation hours. The comparison between the developed model and exponential model showed that the multi-linear model gave a very close estimate to the actual costs with difference up to 2%, while the exponential model had a difference up to 57%. Two exponential models were developed for R&M costs for combines by Wahby and Al-Suhaibani (1995). The first model estimated the costs when some or all machines moving parts were operating, which when compared with other similar models developed by other studies gave the least cost with an acceptable accuracy. The second model was developed to estimate the cost when all parts were operating. However, the study recommended that the use of R&M costs mathematical models for combines be used in the areas they developed for, or in conditions similar in cost of spare parts and labor.

In the light of the aforementioned, it is clear that there is a need for further investigation of the grain combine repair and maintenance cost components and identification of the frequency of each item. The objective of this research paper is to identify the types of repair and maintenance event and to study the effect of the combine age (working life) and machine width on repair and maintenance costs.

MATERIALS AND METHODS

Repair and maintenance of grain combines collected by HADCO (Hail Agricultural Development Company), Saudi Arabia, were studied in this research paper. The data of 15 combines out of 40 owned by the company were used. All data were listed in WJO (work-job orders) and stored in the company's computer. Each WJO included the following data: date of the job, combine serial number, machine power, type of work done, number and cost of the parts used, total labor requirement and the related cost, and the total cost of the WJO. Data for 352 WJO obtained from HADCO were sorted and identified as repair or maintenance according to the ASAE Standard (1993). The type of work was coded according to the description in the WJO. However, they were coded as follows: header, threshing unit, separation unit, cleaning shoe, engine, pre-harvest, general and fabrications works, electrical and tires.

RESULTS AND DISCUSSION

Analysis of the work-job orders

Analysis of the 15 grain combines WJO's showed that combines age ranged from 4 to 9 years, while the power varied from 71.3 to 202.5 kW and the power was directly related to machine width. Three combines groups were found in terms of model, machine width and power. Summary of grain combine's characteristics is listed in Table 1. Analysis of the WJO's from 1988 to 1993 showed that 253 (72%) WJO's were identified as repair work and 99 (28%) were identified as maintenance work. The total costs of all work jobs were consisted of 88.6% as parts cost and 11.4% as labor cost. Table 2 listed frequency and the distribution of WJO's of all grain combines for both repair and maintenance works during the period of the study. General repairs (routine check-up) came on the top of repair works to grain combines under study, while threshing unit and cleaning shoe repairs showed that the least repair works have been done to both units. This could be due to the effect of pre-harvest repairs (general check-up, fabrication of some parts, welding works, replace and rebuilt of parts: shafts, pulleys and crop lifters) which took care of all combines units before starting the harvesting season and therefore reducing the repairs of the above units to its lowest rate. Other repair works items could be directly related to the working hours of the combine during the harvesting season and were kept to a low values such as header, electrical and tires repairs. On the other hand, only five items of maintenance have been done to all grain combines. General maintenance (regular or complete service) came as the highest percentage of WJO's

Table 1. Grain combine's characteristics.

No. of combines	Model	Machine width [m (ft)]	Engine power (Kw)	Purchase date	Purchase price (US$*)	Mean working hours (h/year)	
						Engine	Separation unit
1	Gleaner N7	8.22 (27)	202.5	Feb. 83	106493	305.4	98.3
6	Gleaner N7	8.22 (27)	202.5	Apr. 84	104000	342.5	152.6
4	Gleaner N7	8.22(27)	202.5	May 84	101758	362.3	237.7
1	Gleaner F3	3.96 (13)	71.3	May 84	56000	177.7	101.9
1	Gleaner N7	3.96 (13)	71.3	Apr. 85	56000	188.4	106.1
1	Gleaner N7	3.96 (13)	71.3	May 84	57867	197.1	126.6
1	Gleaner M3	4.88 (16)	108.8	Apr. 85	69333	231.8	112.0

* 1US$ = 3.75 SR.

Table 2. Grain combines work orders and type of job.

Repair		Job type	Maintenance	
No. of work job	Percent (%)	Items	No. of work job	Percent (%)
5	1.97	Header	0	0
1	0.40	Threshing unit	0	0
0	0	Separation	0	0
1	0.40	Cleaning shoe	0	0
24	9.49	Engine	23	23.2
32	12.65	Pre-harvest	4	4.0
166	65.61	General	53	53.5
15	5.93	Electrical	13	13.1
9	3.55	Tires	6	6.2
253	100		99	100

followed by engine, electrical, tires and pre-harvest maintenance (routine checkup).

It was clearly shown in Table 2 that the company took a great care of the maintenance work of the major combines items, that is, header, threshing unit, separation unit and cleaning units, during the pre-harvest repairs in order to reduce the number of machine stopping during the harvesting season- because the weather gets very hot during the harvesting season and the pre-harvest grain losses increases. This action reduced the mean total cost of maintenance of those four units into zero cost, but added it to repair costs. It was also found that separation unit in all combines did not have any repair or maintenance costs, and it was the only unit that did not need any repair or maintenance works (Tables 2 and 3). The costs were listed in US$ and cost per purchase price of the combine (US$/price). It is shown from Table 3 that the highest mean repair costs was for pre-harvest which reached to US$1341, while the lowest mean total cost was for tires maintenance (US$ 38).

Effect of different parameters on R&M cost

Using the SAS package and PROC CORR and PROC REG which are statistical procedures, the relationships between R&M mean total costs and machine width; combine age (in years), engine working hours and some other parameters were tested. Pearson correlation coefficient between each of the two mentioned parameters was calculated, and the analysis results are depicted in Table 4. From the table, it is showed that a positive correlation (R = 0.67) existed between engine working hours and machine width. While a low correlation was seen between mean total cost and machine age (R = 0.212). Moderate correlation (R = 0.528) existed between engine working hours and separation unit hours. Figure 1 shows the annual repair and maintenance mean costs as affected by machine width and age. Figure 2 shows the relationship between machine width, machine age and the accumulated separating hours. It was also found that the number of work jobs and the repair and maintenance mean total costs per work job were directly related to the

Table 3. Grain combines repair and maintenance mean total cost*****.

Type	Code	Mean cost (US$)	Minimum cost (US$)	Maximum cost (US$)
Repair				
Header	1	743(0.0094)**	21	1707
Threshing unit	2	89(0.0008)	89	89
Separation unit	3	0	0	0
Cleaning shoe unit	4	108(0.003)	108	108
Engine	5	927(0.0089)	27	5705
Pre-harvest	6	1341(0.0131)	3	9172
General	7	1320(0.0134)	0	8850
Electrical	8	385(0.0038)	10	1005
Tires	9	147(0.0014)	0	1269
Total repair		1168(0.012)	0	9172
Maintenance				
Header	101	0	0	0
Threshing unit	102	0	0	0
Separation unit	103	0	0	0
Cleaning shoe unit	104	0	0	0
Engine	105	347(0.0034)	5	2318
Pre-harvest	106	156(0.0015)	3	273
General	107	199(0.0021)	0	329
Electrical	108	220(0.0021)	51	95
Tires	109	38(0.0004)	3	197
Total maintenance		225(0.002)	0	2318

***** 1US$ = 3.75 SR; ****** Cost/ price.

Table 4. Pearson correlation coefficients.

Parameters	Engine working hours	Separation unit hours	Machine width	Mean total cost	Machine age
Engine working hours	1.00				
Separation unit hours	0.528	1.00			
Machine width	0.670	0.465	1.00		
Mean total cost	0.192	0.110	0.139	1.00	
Machine age	0.573	0.323	0.168	0.212	1.00

machine width. As it was shown in Figure 1, the mean annual R&M cost increased as increasing the combine age and also by increasing the machine width. This could be the results of the intensive use of combines with wider machine width (that is, 8.22 m width) and as related to the mean engine working hours, as listed in Table 1. It was also shown in Figure 1 that the R&M mean total costs of the 8.22 m machine width was significantly higher than that of the 4.88 and 3.96 m machines. The same relationship was also existed between R&M mean total costs and combine age (years), as described previously. Regression analysis (PROC REG) showed a highly significant relation ($p<0.001$) between machine width and R&M mean total costs as listed in Table 5. Also, there was a linear relation between machine width and machine age. Identifying of repair costs and maintenance costs; separately, were made for each group of machines every two years in order to display the differences between costs of each code. Figures 3 to 8 show the effect of machine age and machine width on R&M annual costs, while, Figure 9 shows a comparison between the average R&M costs for different machine widths and machine ages.

Conclusions

Identifying of repair and maintenance in grain combines

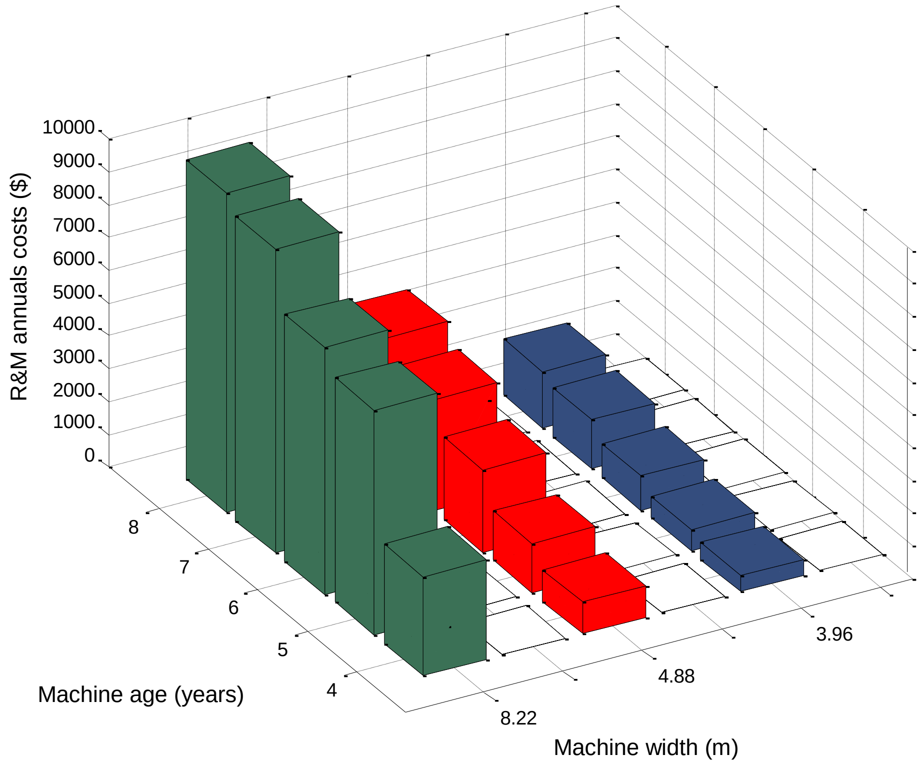


Figure 1. Repair and maintenance annual costs as affected by machine age and machine width.

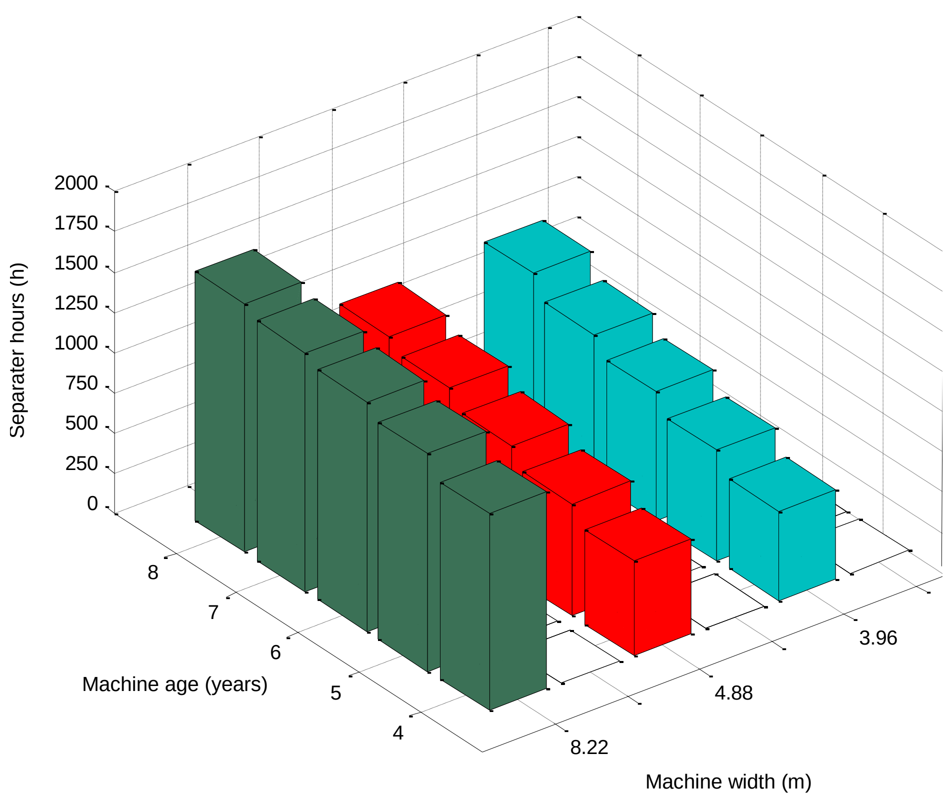
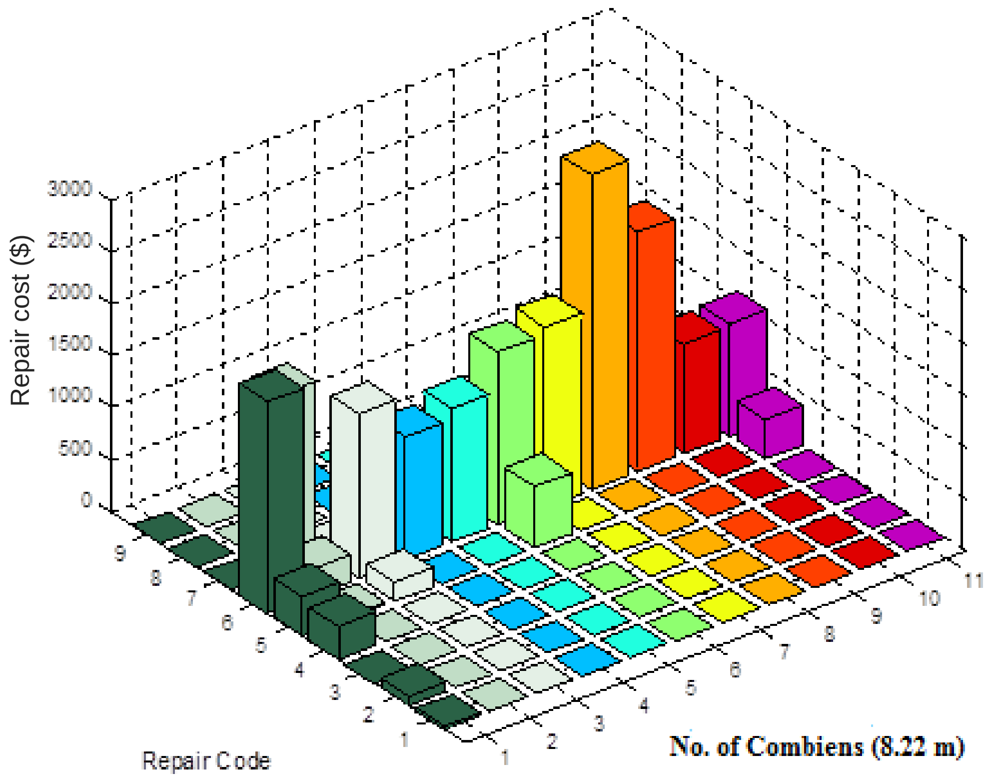
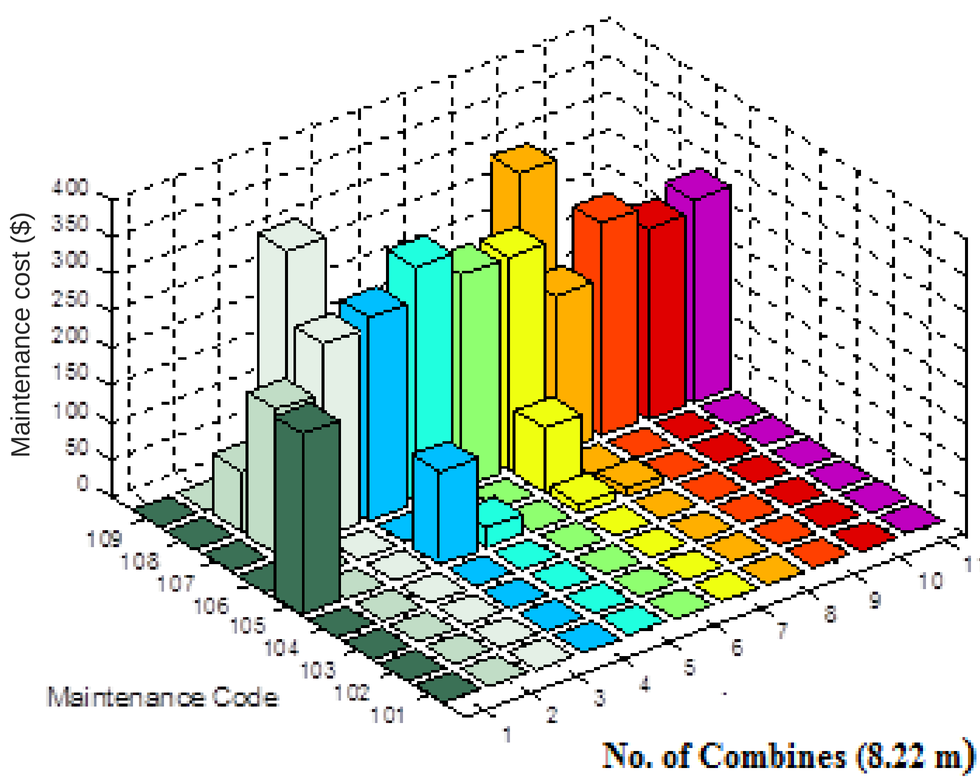


Figure 2. Accumulated separation unit hours affected by machine age and machine width.

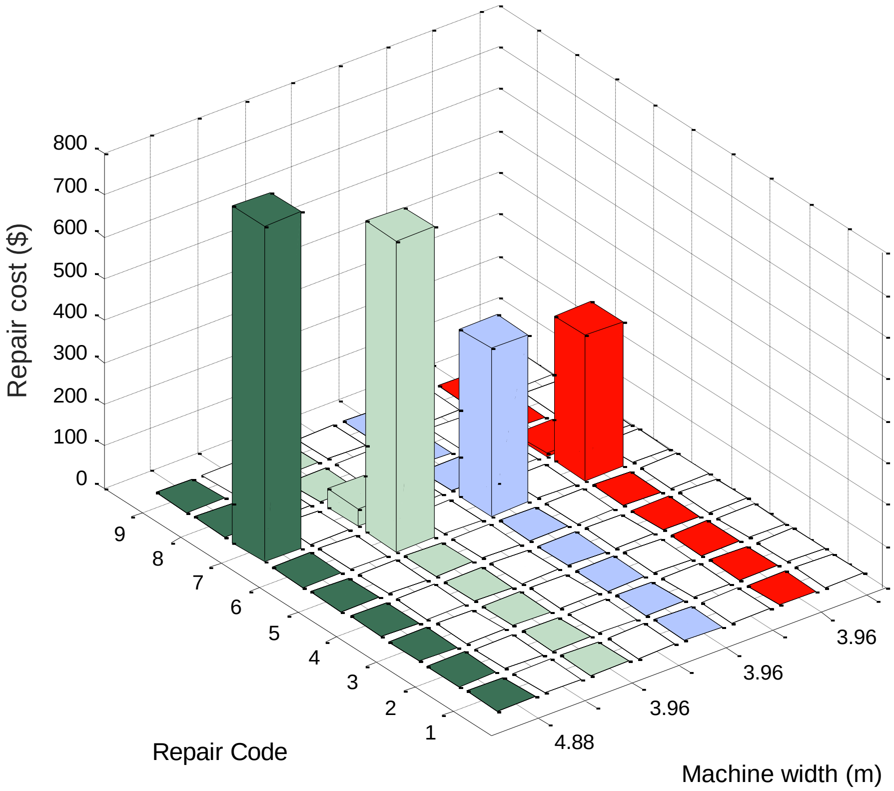


(a)

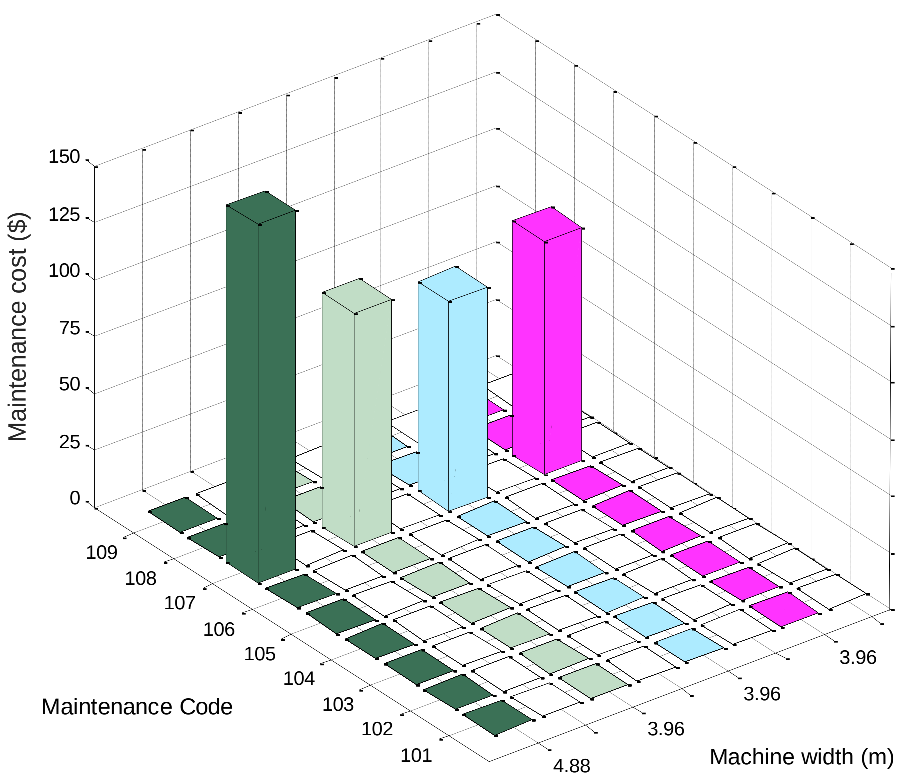


(b)

Figure 3. R&M costs of each items of each machine of 8.22 m width at year 4. a) Annual repair costs; b) Annual maintenance costs.



(a)



(b)

Figure 4. R&M costs of each item for machine of 3.96 m and 4.88 m width at year 4. a) Annual repair costs. b) Annual maintenance costs.

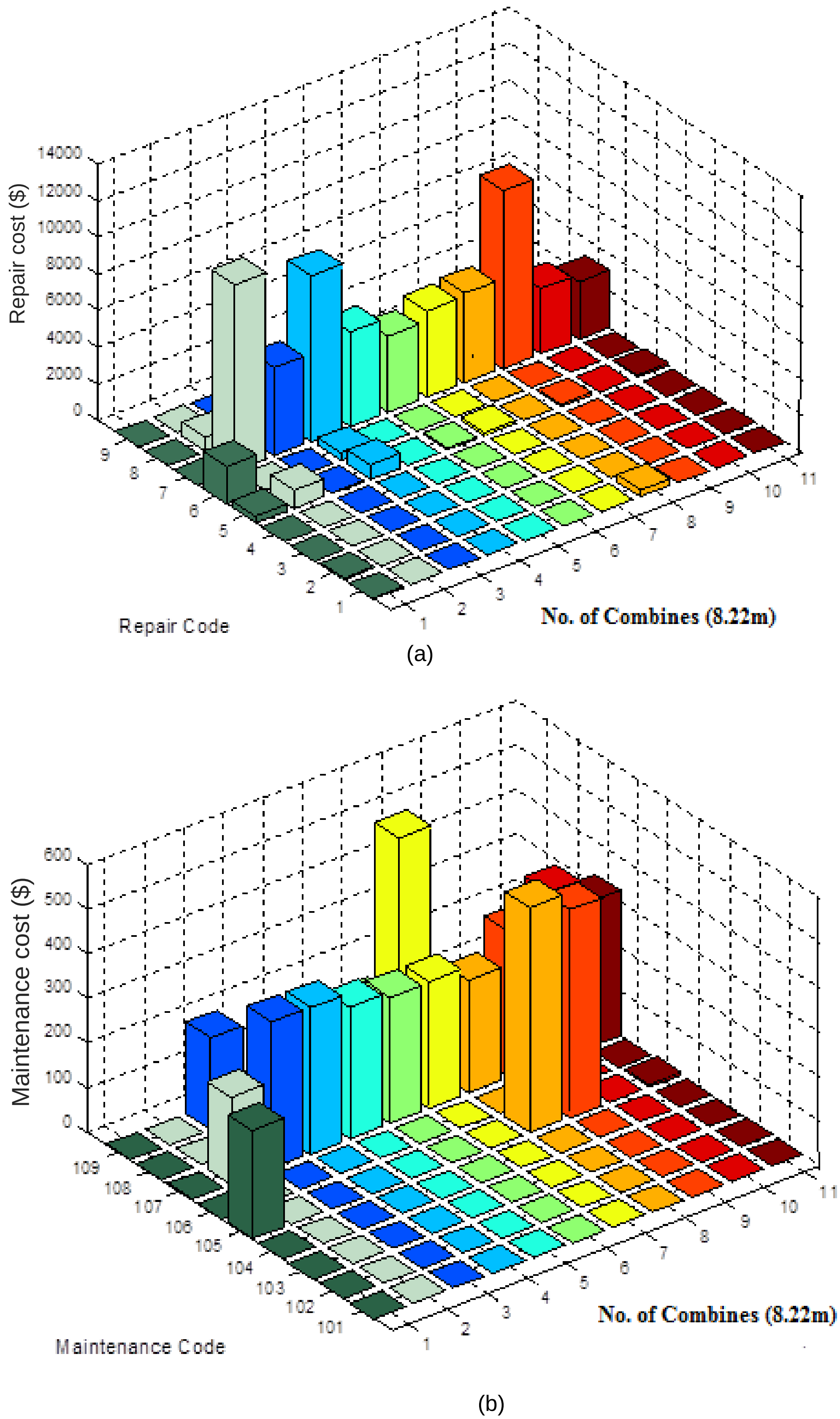
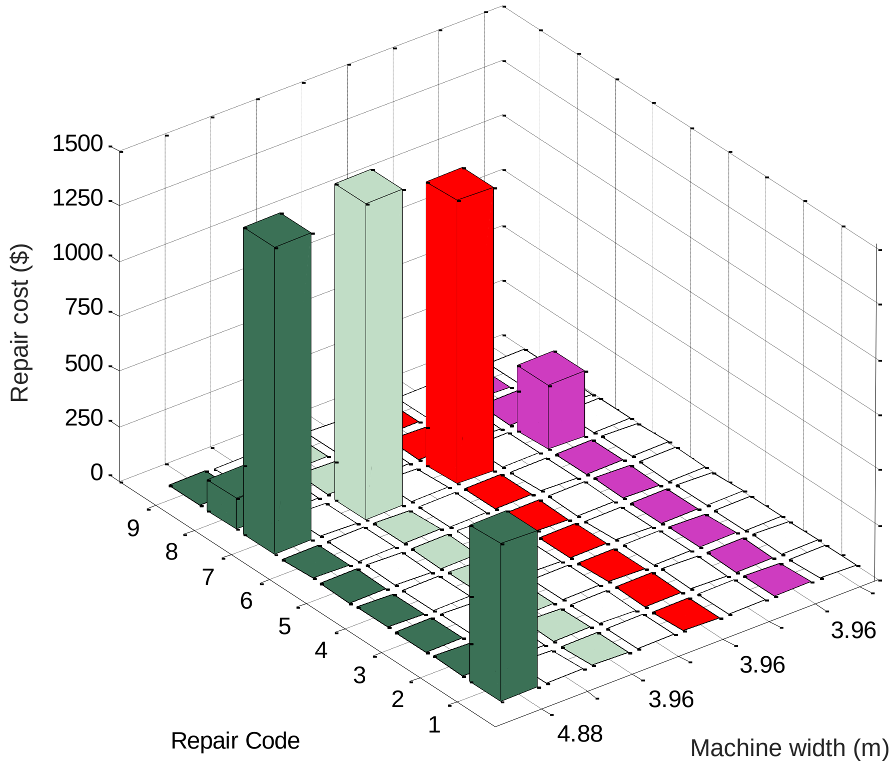
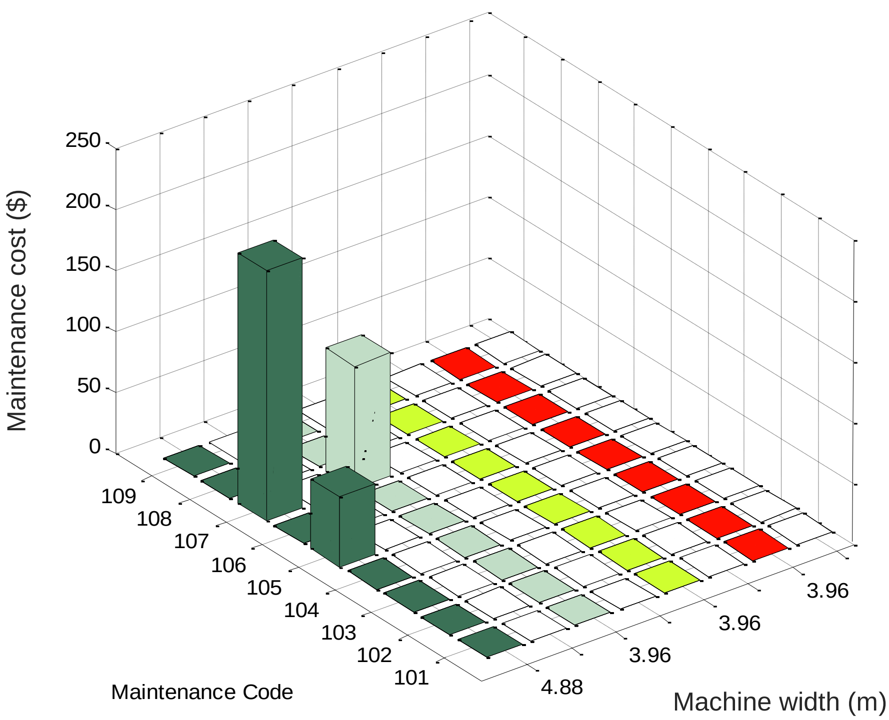


Figure 5. R&M costs of each items of each machine of 8.22 m width at year 6. (a) Annual repair costs; b) Annual maintenance costs.



(a)



(b)

Figure 6. R&M costs of each items of each machine of 3.96 and 4.88 m width at year 6. A) Annual repair costs; B) Annual maintenance costs.

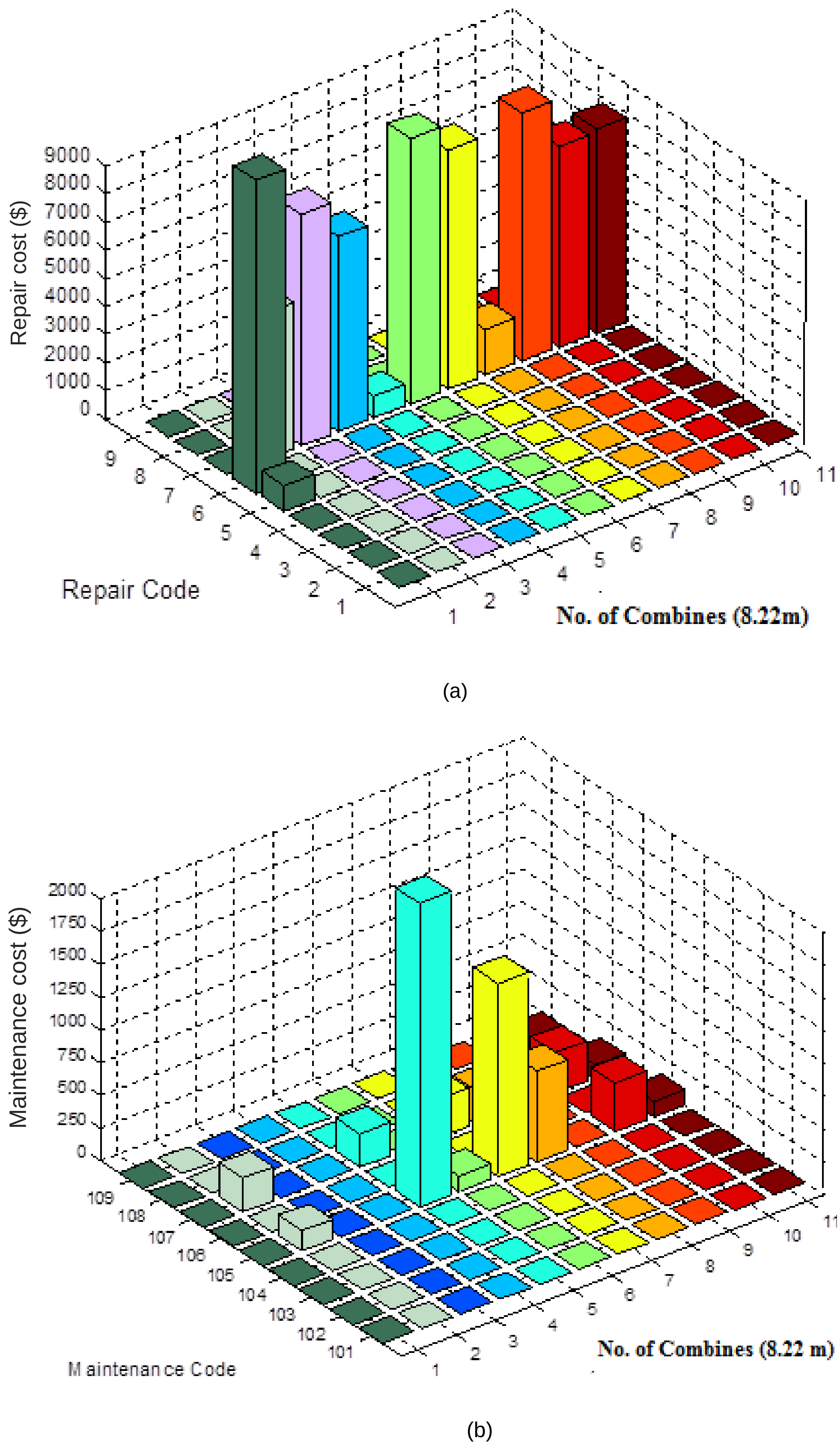
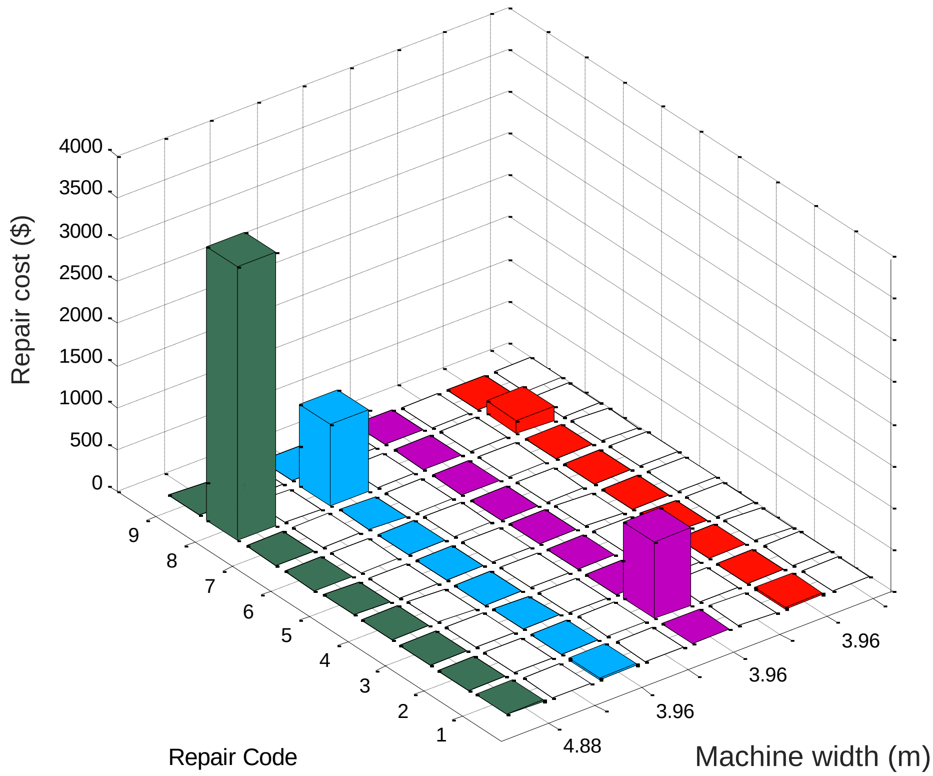
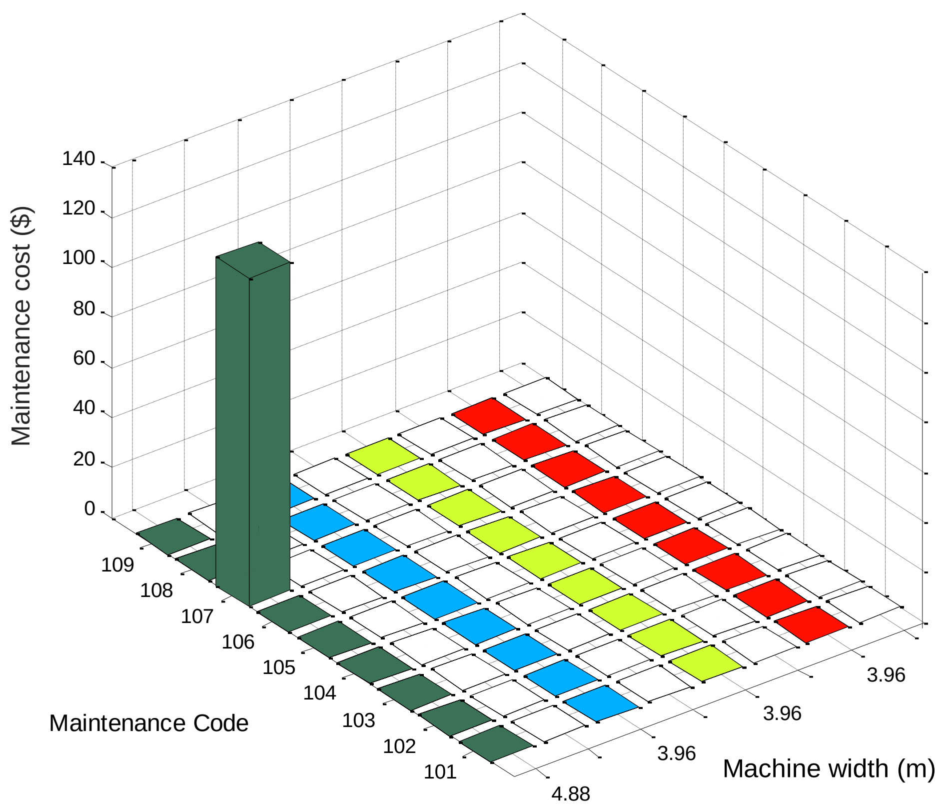


Figure 7. R&M costs of each items of each machine of 8.22 m width at year 8. a) Annual repair costs; b) Annual maintenance costs.

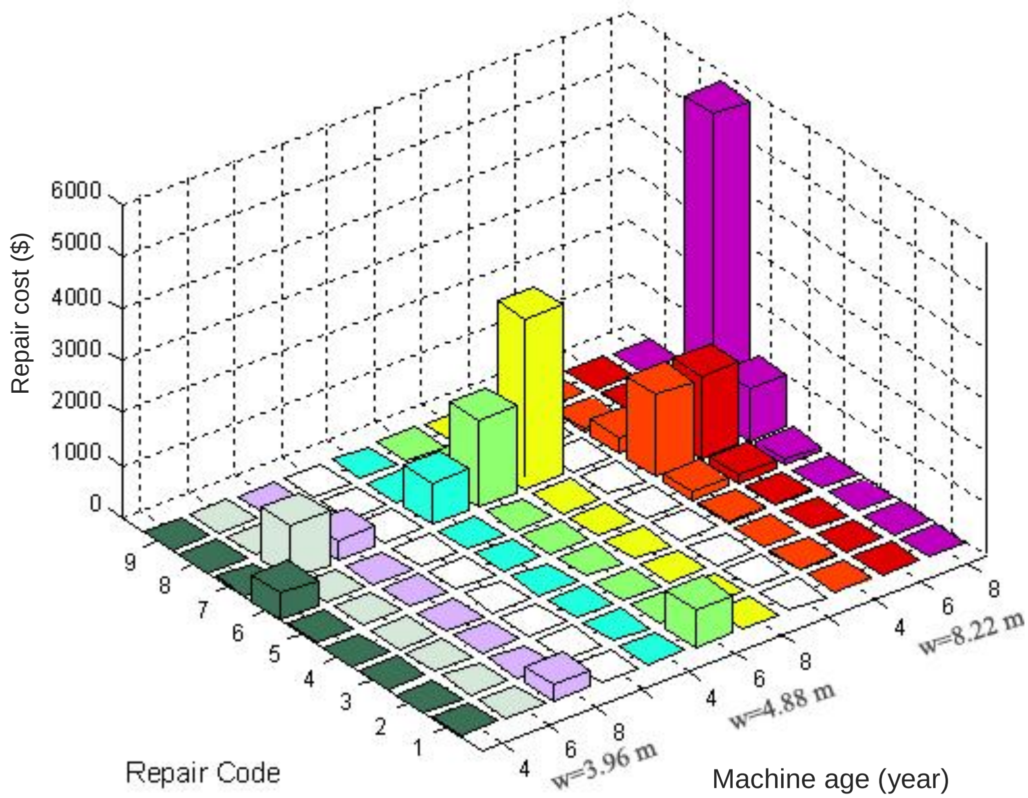


(a)

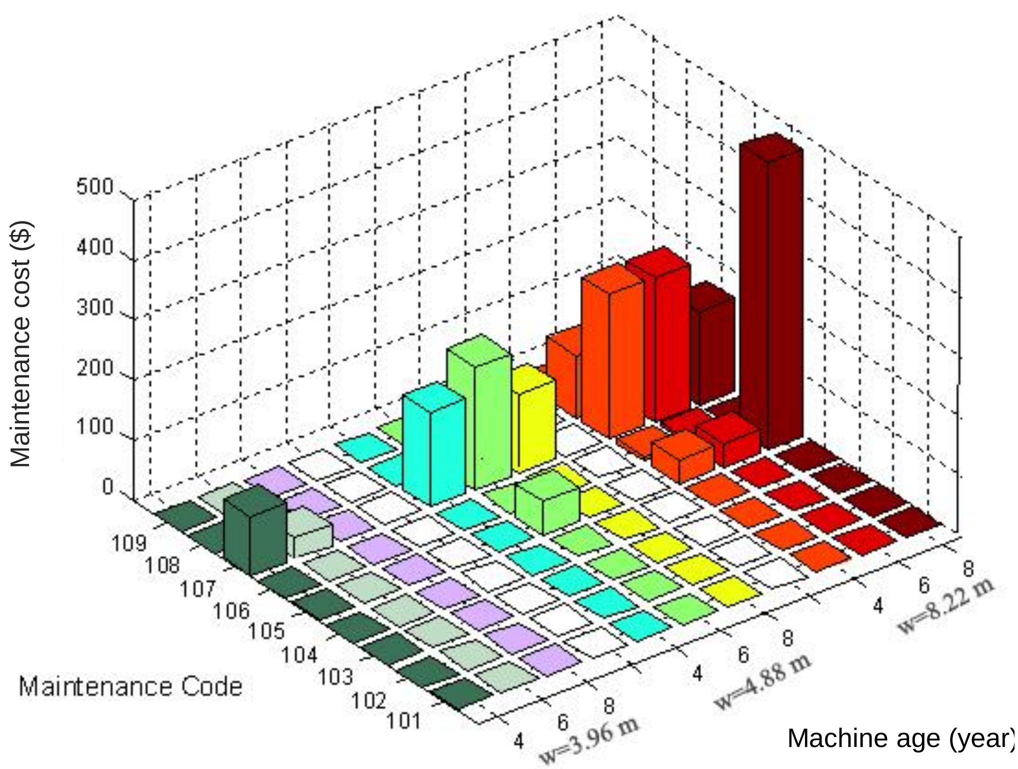


(b)

Figure 8. R&M costs of each items of each machine of 3.96 and 4.88 m width at year 8. a) Annual repair costs; b) Annual maintenance costs.



(a)



(b)

Figure 9. Effect of machine age and R&M codes on annual R&M costs of all machines. a) Mean annual repair costs. b) Mean annual maintenance costs.

Table 5. Results of regression analysis.

Dependent variables	F value	Pr > F	Independent variables
Machine width	6.90	0.009	Mean total cost
Engine hours	135.06	0.0001	Separation unit hours
Machine width	10.18	0.0015	Machine age
Engine hours	13.41	0.0003	Mean total cost
Separation unit hours	4.26	0.0399	Mean total cost
Machine width	10.18	0.0015	Machine age

is very important for recognizing the major causes of breakdowns. The results of this research paper led to the following conclusions:

1) Of all work job orders received, about 72% were for repairs and 28% for maintenance.
2) Repairs had the highest percentage of work orders, 72%, while the maintenance was 28%. Mean total costs were significantly higher than maintenance costs, and represented 83.8% of mean total costs. The most common repairs were pre-harvest followed by general and engine repairs. The most common maintenance costs were in the following order: engine, electrical, general and pre-harvest maintenance.
3) Pre-harvest repairs were usually executed every year before harvesting season. The pre-harvest repairs reduced costs of most other repair or maintenance jobs in the machines during the harvesting season.
4) R&M mean total costs were directly related to both machine width and combine age (in years). R&M mean total costs of the 8.22 m (27 ft) combines (60% of mean total costs) were significantly higher than that of both 4.88 m (16 ft) 15%; and 3.96 m (13 ft) 25%; machines.

ACKNOWLEDGMENTS

The authors wish to acknowledge HADCO (Hail Agricultural Development Company), Saudi Arabia for providing their accurate and useful data. Also, to the Deanship of Scientific Research and the Agricultural Research Center in the College of Food and Agricultural Sciences, King Saud University, Saudi Arabia for supporting this research effort.

REFERENCES

Abdelmotaleb IA (1993). Repair and maintenance cost analysis of farm machines under Egyptian conditions. Proceedings of the International Conference on Technological Techniques for Handling Agricultural Products, Misr Society of Agricultural Engineering, Egypt.

Al-Suhaibani SA, Wahby MF (2008). Grain harvester repair and maintenance costs. CSBE/SCGAB 2008 Annual Conference Vancouver, British Columbia.

Al-Suhaibani SA, Wahby MF (1999). Tractor Repair and maintenance in Saudi Arabia. Appl. Eng. Agric. 15(6):591-596.

ASAE Standards (1993). ASAE EP 496.1: Agricultural machinery management. St. Joseph, MI. USA.

Bakht GK, Ahmadi H, Akram A (2010). Determination of optimum life for MF285 tractor based on repair and maintenance costs: A case study in centre region of Iran. J. Agric. Technol. 6(4):673-686.

Bakht GMK, Ahmadi H, Akram A, Karimi M (2008). Repair and maintenance cost models for MF285 tractor: A case study in central region of Iran. American-Eurasian J. Agric. Environ. Sci. 4(1):76-80.

Bowers W, Hunt DR (1970). Application of mathematical formulas to repair cost data. Trans. ASAE 13(6):806-809.

Fairbanks GE, Larson GH, Chung OS (1971). Cost of using farm machinery. Trans. ASAE 14(I):98-101.

Frank L (2003). Coefficients of repair and maintenance costs for axial and trasverse combine combines in Argentina. Spanish J. Agric. Res. 1(3):81-97.

Gliem JA, Persinger KM, Carpenter TG, Holmes RG, Ozcan HE (1989). A comparison of ASAE estimated tractor and combine repair and maintenance costs to actual repair and maintenance costs of selected farmers. ASAE paper No. 89-1024 ASAE. St. Joseph. MI. USA.

Inns FM (1978).Operational aspects of tractor use in developing countries-A case for the small tractor. Agric. Engineer, Summ. 1978:52-54.

Lazarus WF (2012). Machinery Cost Estimates. faculty.apec.umn.edu/wlazarus/documents/machdata.pdf.

Rohani A, Hossein M, Fard A, Abdolahpour S (2011). Prediction of tractor repair and maintenance costs using artificial neural network. Expert Syst. Appl. 38(7):8999-9007.

Rotz CA, Bowers W (1991). Repair and maintenance cost data for agricultural equipment. ASAE paper No 91-1531 ASAE, St. Joseph, MI, USA.

Wahby MF (1995). Multi-linear models for repair and maintenance costs for combines in Saudi Arabia. Bull. Fac. Agric., Univ. Cairo 46(3):379-390.

Wahby MF, Al-Suhaibani SA (1995). Repair and maintenance cost models for combines in Saudi Arabia. Arab Univ. J. Agric. Sci. Ain Shams Univ. Cairo 3(2):59-69.