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RESEARCH ON STANDARD TIME FOR MILITARY AIRCRAFT WASHING OPERATIONS

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Abstract

Considering that military aircraft washing has a variety of requires and limitations, most of the works are completed in a manual way which costs more manpower and time. It is important and pressing to set up a reasonable standard time under the current downsizing of military personnel in different countries. This research studied a military aircraft washing operation at an air-force base in Hualien, Taiwan with stopwatch time study recording the time used in each section during the operation. Work sampling was adopted to develop the standard time of operations. With the establishment of the standard time, this research completed a sensitivity analysis of the number of washing teams' members, the number of hours worked per day, and the number of military aircraft in a different rate of operation completion in search of an optimal strategy. This research indeed proposed a latest and effective manpower allocation plan of military aircraft washing operations for the reference of practical manpower preparation. At the same time, a reasonable set of work measurement standards is established in order to improve working efficiency and achieve the goal of military aircraft washing.

Key words: military aircraft washing, standard time, work sampling, sensitivity analysis, working efficiency

Introduction

Taiwan is located in the subtropical area and has an island climate with high temperature and humidity. The air is filled with water and salt, which can easily rust metals (Chan, 2013). After the military aircraft takes off or land, adherence of salt and impurities to the aircraft might occur easily, which make aircraft washing particularly important. If the situation is not properly handled, corrosion and fatigue might occur in some aircraft parts that affect flight handling and safety.

In the technical documents of the military aircraft model discussed in this research (Air Force Command Headquarters, 2008), if aircrafts station within two kilometers of the saltwater area, water and chemical cleaning are necessary to carry on in every fifteen days. If the aircraft flies lower than three thousand feet high above the saltwater (Air Force Command Headquarters. Air force technical documents, 2006), it should be washed after the last flight on the day with soft water should be used throughout the operation. In the reason that the military base discussed in this research is a military-civilian dual-use airport, the operations of aircraft washing are subject to the Civil Aviation Law (Civil Aeronautics Administration Aircraft flight operation regulations, 2006) and the control tower. Therefore, aircraft towing is often influenced by the take-offs and landings of civil or military aircraft, resulting in up to 40 minutes or more time is need to finish towing. At present, every military aircraft washing operation is often performed by only five individuals, which takes more than two to three hours to complete the operation. In this situation, effectively allocating the manpower and time is important.

Common research methods used in general time researches are predetermined motion time system (PMTS),5 stopwatch time study (STS) (Ho, 2017; Liu et al., 2017), standard data system (SDS) (Ho and Wu, 2003), and work sampling (Chen and Ye, 1995; Chen and Ye, 2006; Brisley, 1952). Considering the characteristics of the studied military base, work sampling was used for the time study to establish the standard time for each work unit of the aircraft washing operation. In addition to the traditional method of stopwatch time study, this research also conducted work sampling on the predetermined unit actions by means of random sampling (Martinec et al., 2017). Finally, the standard time of aircraft washing each work unit was obtained by synthetic leveling.

Research Design

In this research, standard working time in every unit of the military aircraft washing operation was set up through six procedures by using work sampling method (Table 2).

Classify work units

The operation of military aircraft washing is divided into eight units,

namely equipment installation/ disassembly, towing, pharmaceutical preparations, wrapping, washing, wiping, anticorrosive and antiseptic treatment, and other. These eight work units are divided by reference to standard operating procedures and the noticeable end of the action.

Select an average skilled (normal) worker to perform each work unit and measure with stopwatch time study

Working time refers to the time required for the worker performing the prescribed standard action from the beginning to the end. An average skilled (normal) worker cannot be a senior or junior member since senior personnel already mastered the work, many actions can be performed at the same time while junior personnel might be unfamiliar with the work, which might cause respectively longer and shorter working time (Lin, 2007). Therefore, a member who has served at the base for six to eight years was selected as the average skilled worker and the stopwatch timing/record of each work units action time is performed afterward. The average value of the time data of each work unit under the operation of an average skilled (normal) worker is calculated by the end.

Schedule the pre-test and establish a work sampling form

This research spent ten working days as the pre-test, and filled in the work checklist (Table 1) according to the work unit and time, and filled the random time in as the same time.

Calculate the average time and standard deviation of each work unit

The daily observations are registered and tabulated (Table 2).

Calculate the total number of expected samplings per unit

The data of each unit in Table 2 was substituted into the observation data formula (1).

$$n_i = \frac{p_i(1-p_i)}{\sigma_{p_i}^2} \quad (1)$$

n_i : The number of checks based on the pre-test of the *i*-th unit.
p_i : The average occurrence rate of the *i*-th unit in the pre-test.
σ_{pi} : The standard deviation of the *i*-th unit in the pre-test.

After calculation, the maximum number of spot check is obtained, and the value is adopted as the number of formal sampling.

Result of pre-test

The pre-test of this research was carried out between November 2 and 13, 2016. A sergeant who has served for six years was selected as the average skilled (normal) worker. Through ten consecutive working days of observation, ten samples and 1,200 data (the number of occurrences) were obtained (Figure 1). The average occurrence rate and the

Table 1. Work sampling form

Operation：Military aircraft washing	
Spot check date：02/11/2015 (dd/mm/yyyy)	
Time	
Equipment installation/ disassembly	
Towing	
Pharmaceutical preparations	
Wrapping	
Washing	
Wiping	
Anti-corrosive and antiseptic treatment	
Other	

Table 2. Record form

Work unit	Frequency	Average occurrence rate	Standard deviation of occurrence rate	Number of spot check
Equipment installation/ disassembly				
Towing				
Pharmaceutical preparations				
Wrapping				
Washing				
Wiping				
Anti-corrosive and antiseptic treatment				
Other				
Total				

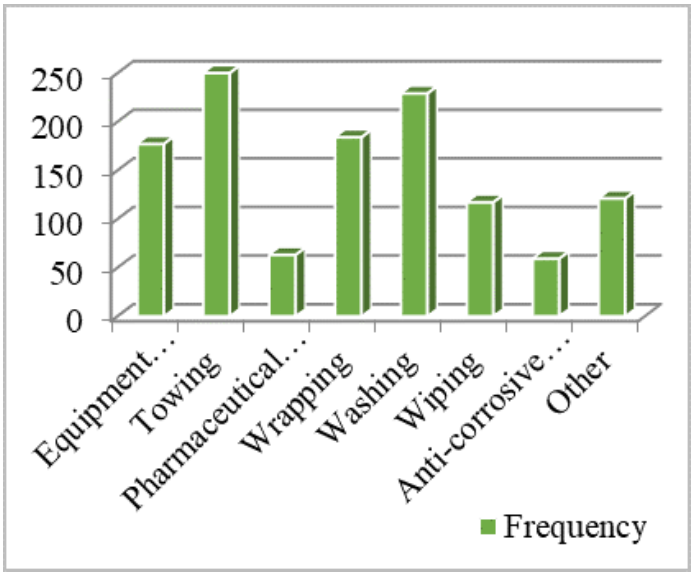

Figure 1. The number of occurrences of each unit in pre-test

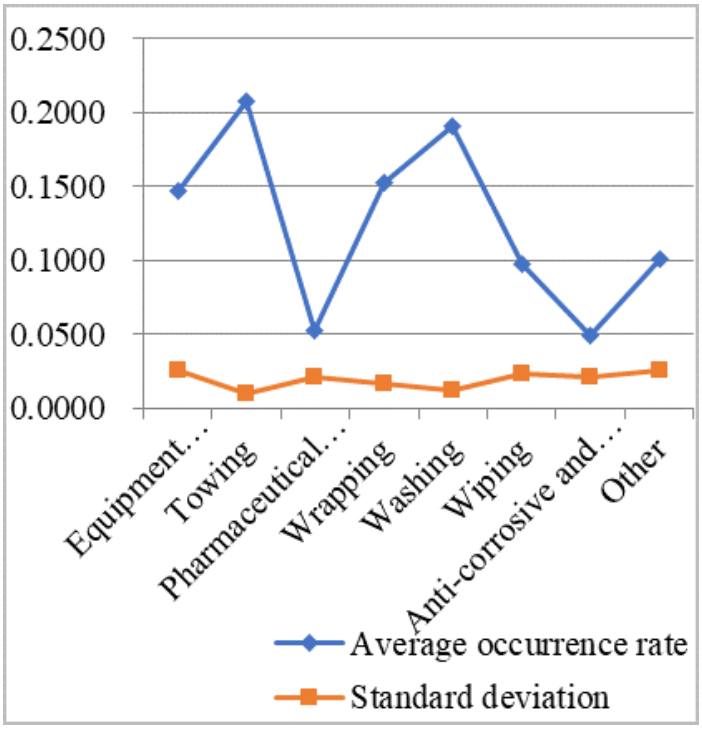

Figure 2. Average occurrence rate and standard deviation of each unit

standard deviation were calculated afterward according to the data (Figure 2).

After the data observation was completed, the data of the occurrence rate and the standard deviation were filled in Table 2, and substituted into the formula (1) to calculate the number of spot check in pre-tests (Table 3).

According to Table 3, the maximum number of spot checks is 1,602 times in aircraft towing unit. As a consequence, this research performed work sampling 1,700 times in twenty workdays within four weeks, eighty-five times per day.

Data Collection

In order to find out the average used time of every work unit (observation time, *Oi*), twenty times of stopwatch timing were completed in each work unit for each working team (5 workers in each team). Meanwhile, the selected average skilled (normal) worker was required to carry out the work normally at a general speed for the stopwatch timing.

The work units "Equipment installation/disassembly" and "Anti-corrosive and antiseptic treatment" were selected for timing since: 1. The required working time of these two units is shorter than the other units. 2. The work distribution of team members and the content of these two units are similar. 3. The time of work completion of these two units is identical. For the reasons above, these two work units were selected to be operated by an average skilled (normal) worker and timed for twenty times, and the average time was calculated as the measured average time (*Ni*). The synthetic leveling was applied to obtain the synthetic performance factor, which was placed in each work unit afterward (Table 4).

During the twenty-day observation, apart from recording the total number of occurrences of each work unit, the work output of the sampling target was collected. According to the results of work sampling, the normal time ($T_n(i)$) of each unit was calculated from equation (2).

$$T_n(i) = \frac{n_i \times T \times \overline{P}}{P_a \times N} \quad (2)$$

$T_n(i)$: The normal time of the *i*-th work unit
n_i : The number of times the *i*-th unit appeared during the spot check
T : The total time of spot check
$\overline{P}$: The synthetic performance factor
P_a : The number of output during the spot check
N : The total number of spot checks

The total time for performing spot checks is $T = 20 \times 8 \times 60 = 9{,}600$ minutes, the synthetic performance factor is $\overline{P} = 1.0583$ (Table 4), the number of output during the spot check is 62, and the total number of spot checks is 1,700. After substituting the calculation results of formula (2) and the number of occurrences of each unit during the spot checks (n_i) into formula (1), the normal time of each unit was obtained. The total normal time required to complete the operation of aircraft washing is 163.87 minutes (Table 5). The standard time of aircraft washing operation is obtained

Table 3. Data of pre-test

Work unit	Frequency	Average occurrence rate	Standard deviation of occurrence rate	Number of spot check
Equipment installation/ disassembly	177	0.1471	0.0254	194
Towing	250	0.2082	0.0101	1,602
Pharmaceutical preparations	63	0.0529	0.0211	112
Wrapping	174	0.1529	0.0172	436
Washing	229	0.1906	0.0125	990
Wiping	117	0.0976	0.0233	162
Anti-corrosive and antiseptic treatment	59	0.0494	0.0214	103
Other	121	0.1012	0.0260	135
Total	1,200	1.0000	--	--

Table 4. Observation time, measured average time, and performance factor of each work unit

Work unit	Observation time (*Oi*)	Measured average time (*Ni*)	Performance factor (*Oi* / *Ni*)	Synthetic performance factor
Equipment installation/ disassembly	10.05	9.65	1.042	1.0583
Towing	20.12	--	--	1.0583
Pharmaceutical preparations	10.54	--	--	1.0583
Wrapping	14.33	--	--	1.0583
Washing	28.85	--	--	1.0583
Wiping	20.98	--	--	1.0583
Anti-corrosive and antiseptic treatment	15.21	14.15	1.075	1.0583
Other	--	--	--	--

Table 5. Observation time, measured average time, and performance factor of each work unit

Work unit	Number of occurrences of each unit (n_i)	Normal time of each work unit ($T_n(i)$)	Standard time of each unit (+10% allowance)
Equipment installation/ disassembly	253	24.39	26.83
Towing	352	33.93	37.32
Pharmaceutical preparations	83	8.00	8.80
Wrapping	268	25.83	28.42
Washing	342	32.97	36.26
Wiping	155	14.94	16.43
Anti-corrosive and antiseptic treatment	78	7.52	8.27
Other	169	16.29	17.92
Total	1,700	163.87 minutes	180.25 minutes

after adding 10% of the normal time in each work unit as allowance and calculating the sum of each the standard time of each work unit, resulting in 180.25 minutes.

Sensitivity Analysis

Group size

There are five members in the washing team at the base at present. In this research, the number of aircraft and the number of working hours per day were immutable, and the sensitivity analysis was performed by the number of workers. The data were analyzed by 5 to 10 workers (Table 6).

According to Table 6, if there are seven members in a team, the standard time of a team washing one aircraft can be reduced to 128.75 minutes and the achieving rate can reach 108.06%. As the result, this research suggests that the military aircraft washing team size should be increased by seven workers, in that the work target (100% completion of washing) can be achieved without reducing the number of aircraft or increasing working hours.

Daily working hours

In some cases, achieving the goal of 100% completion of washing by increasing manpower may not be easy, it can be considered to increase the working hours. sensitivity analysis of daily working hours (Table 7).

Since the standard time cannot be changed when the number of workers in a washing team is only 5, extending the

daily working hours can make it possible to reach 100% completion rate of washing. Achieving rate can reach 100% of the working hours extend for three more hours (Table 9). However, eleven hours of work per day is not practical. It is not recommended to extend the working hours to achieve the work target (100% completion of washing).

Number of military aircraft

Downsizing the number of military aircraft should also be considered as an alternative to achieve a 100% completion rate of washing. It can be seen from Table 8 that the number of military aircraft in the military base is gradually reduced from 69 to 53. On the contrary, the aircraft washing completion rate increases with the reduction of the number of aircraft. When the number of aircraft is reduced to 53, the completion rate of washing will be 100%. However, there are certain rules and conditions for the deployment of military power, it is impossible to reduce the number of military aircraft in the reason of insufficient manpower.

Results and Suggestions

Based on the above analysis and discussion, this research suggests extending the daily working hours from eight to nine. With nine working hours per day and the change in the number of workers, the completion rate of washing can reach 100% (Table 9).

The standard time for washing one aircraft is 180.25 minutes when there are five workers in a team. Based on the rule of proportionality, the standard time for washing an aircraft under different numbers of team members is listed in Table 10. Different configurations of different team size and number of aircraft in 9,600 minutes as monthly working hours are listed in Table 11. Table 12 shows the configurations of different team size and number of aircraft when daily working hours extended to nine hours. A valid reference for the allocation of the number of workers in different numbers of aircraft is provided through the results shown.

Conclusions

Within the research, work sampling was used to establish the standard time of each work unit of the military washing operation and an average skilled (normal) worker was selected to perform the stopwatch time measurement for each work unit. Further, the standard time of each work unit, including the allowance, was calculated using the results of work sampling and stopwatch time measurement.

In the case that the number of military aircraft, equipment preparation and various flight training tasks have not been reduced, and the financial, and material resources for repairing and replenishing resources are limited, this study established a standard time for military aircraft washing operations, and for the number of teams members. The sensitivity analysis of the completion rate of washing was carried out based on the number of workers, the number of working hours per day, and the number of military aircraft. Finally, a feasible suggestion was proposed, and an effective reference basis for the number of work-

ers and number of aircraft was also proposed.

The research results show that, taking the current Hualien military base in Taiwan as an example, in a washing team of six members, nine hours of work per day, and twenty days of work per month, 104.20% completion rate of washing can be achieved. This does provide a reference for practical manpower arrangements and increasing the operational efficiency. Through the establishment of standard time, not only a new, effective and optimum configuration of the number of workers and working hours is proposed, but also the research method can be extended to related industries with manpower needs to improve work performance and competitiveness of the industry.

Table 6. Sensitivity analysis of the number of team members

Control variable	Number of aircraft	Number of days per month	Daily working hours			
Item	69	20	8			
Number of workers	5	6	7	8	9	10
Standard time	180.25	150.21	128.75	112.66	110.14	90.13
Achieving rate	77.19 %	92.62 %	108.06 %	123.50 %	138.94 %	154.37 %

Table 7. Sensitivity analysis of daily working hours

Control variable	Standard time	Number of workers	Number of days per month	Number of aircraft	
Item	180.25	5	20	69	
Daily working hours	8	9	10	11	12
Achieving rate	77.19%	86.84%	96.48%	106.13%	115.78%

Table 8. Sensitivity analysis of the number of military aircraft

Control variable	Standard time	Number of workers	Number of days per month	Daily working hours	
Item	180.25	5	20	8	

Number of aircraft	69	68	67	66	65
Achieving rate	77.19%	78.32%	79.49%	80.70%	81.94%
Number of aircraft	64	63	62	61	60
Achieving rate	83.22%	84.54%	85.90%	87.31%	88.77%
Number of aircraft	59	58	57	56	55
Achieving rate	90.27%	91.83%	93.44%	95.11%	96.84%
Number of aircraft	54	53			
Achieving rate	98.63%	100.49%			

Table 9. Sensitivity analysis of the number of workers with nine working hours per day

Control variable	Number of aircraft	Number of days per month	Daily working hours			
Item	69	20	9			
Number of workers	5	6	7	8	9	10
Standard time	180.25	150.21	128.75	112.66	110.14	90.13
Achieving rate	86.84%	104.20%	121.57%	138.94 %	156.30 %	173.67 %

Table 10. Standard time of washing an aircraft under different numbers of workers

Number of workers	Standard time (minute/per aircraft)
2	450.63
3	300.42
4	225.31
5	180.25
6	150.21
7	128.75
8	112.66
9	100.14
10	90.13
11	81.93

12	75.10
13	69.33
14	64.38

Table 11. Configurations of different team size and number of aircraft (eight working hours)

Monthly working hours	9600				
Number of aircraft	Standard time	Number of workers	Number of aircraft	Standard time	Number of workers
100	96.00	10	59	162.71	6
99	96.97	10	58	165.52	6
98	97.96	10	57	168.42	6
97	98.97	10	56	171.43	6
96	100.00	10	55	174.55	6
95	101.05	9	54	177.78	6
94	102.13	9	53	181.13	5
93	103.23	9	52	184.62	5
92	104.35	9	51	188.24	5
91	105.49	9	50	192.00	5
90	106.67	9	49	195.92	5
89	107.87	9	48	200.00	5
88	109.09	9	47	204.26	5
87	110.36	9	46	208.70	5
86	111.63	9	45	213.33	5
85	112.94	8	44	218.18	5
84	114.29	8	43	223.26	5
83	115.66	8	42	228.57	4
82	117.07	8	41	234.15	4
81	118.52	8	40	240.00	4
80	120.00	8	39	246.15	4
79	121.52	8	38	252.63	4
78	123.08	8	37	259.46	4
77	124.68	8	36	266.67	4

76	126.32	8	35	274.29	4
75	128.00	8	34	282.35	4
74	129.73	7	33	290.91	4
73	131.51	7	32	300.00	4
72	133.33	7	31	309.68	3
71	135.21	7	30	320.00	3
70	137.14	7	29	331.03	3
69	139.13	7	28	342.86	3
68	141.18	7	27	355.56	3
67	143.28	7	26	369.23	3
66	145.45	7	25	384.00	3
65	147.69	7	24	400.00	3
64	150.00	7	23	417.39	3
63	152.38	6	22	436.36	3
62	154.84	6	21	457.14	2
61	157.38	6	20	480.00	2
60	160.00	6	19	505.26	2

Table 12. Configurations of different team size and number of aircraft (nine working hours)

Monthly working hours	10800				
Number of aircraft	Standard time	Number of workers	Number of aircraft	Standard time	Number of workers
100	108.00	9	59	183.05	5
99	109.09	9	58	186.21	5
98	110.20	9	57	189.47	5
97	111.34	9	56	192.86	5
96	112.50	9	55	196.36	5
95	113.68	8	54	200.00	5
94	114.89	8	53	203.77	5
93	116.13	8	52	207.69	5
92	117.39	8	51	211.76	5
91	118.68	8	50	216.00	5

90	120.00	8	49	220.41	5
89	121.35	8	48	225.00	5
88	122.73	8	47	229.79	4
87	124.14	8	46	234.78	4
86	125.58	8	45	240.00	4
85	127.06	8	44	245.45	4
84	128.57	8	43	251.16	4
83	130.12	7	42	257.14	4
82	131.71	7	41	263.41	4
81	133.33	7	40	270.00	4
80	135.00	7	39	276.92	4
79	136.71	7	38	284.21	4
78	138.46	7	37	291.89	4
77	140.26	7	36	300.00	4
76	142.11	7	35	308.57	3
75	144.00	7	34	317.65	3
74	145.95	7	33	327.27	3
73	147.95	7	32	337.50	3
72	150.00	7	31	348.39	3
71	152.11	6	30	360.00	3
70	154.29	6	29	372.41	3
69	156.52	6	28	385.71	3
68	158.82	6	27	400.00	3
67	161.19	6	26	415.38	3
66	163.64	6	25	432.00	3
65	166.15	6	24	450.00	3
64	168.75	6	23	469.57	2
63	171.43	6	22	490.91	2
62	174.19	6	21	514.29	2
61	177.05	6	20	540.00	2
60	180.00	6	19	568.42	2

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