Optimized manpower capacity planning model for aviation industry

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Abstract *— Aircraft Maintenance is a combination of complicated tasks that ensures the safety of the technicians, airworthiness of the aircraft as well as the safety of the passengers where the workload is subdivide as base and line maintenance. Traditionally, the prearrangement of the maintenance manpower supply in accordance with the scheduled maintenance tasks is been based on staff experience and been performed manually which is time-consuming as well as an ineffective criterion. Therefore, formulating an optimized framework with the purpose of allocating the right amount of workforce in the right combination of skills and experience levels to eradicate any shortfalls or surpluses is essential for the continuation of efficient and effective maintenance in any organization. Hence, this research mainly aims at devising of a manpower-planning model for the aircraft maintenance industry. Sri Lanka Air Force and Sri Lankan airlines that are the predominant aviation operators of the country reviewed as case studies in identifying the correlation between maintenance manpower requirement with respect to aircraft flying hour demands. In order to ascertain intended outcome, interdependency between an aircraft total maintenance deployment, its operational flying ratio would have identified, and subsequently the maintenance friendliness factor for the individual aircraft type would have determined. The ultimate result of this research would provide a solid framework to eradicate disparities between the current available and the actual required manpower quantities for maintenance events. Moreover, the proposed model would facilitate the aviation industry in solving capacity-planning issues related to manpower scheduling and requirement, and to find feasible roistering and task scheduling of shift workers that minimize peak fatigue while satisfying their days off demands.*

Keywords— Aircraft Maintenance, Maintenance development, Manpower planning, Capacity planning

I. INTRODUCTION

Manpower planning is a significant factor that is being considered currently by each and every organization in the world. This concept deliberates the benefits such as cost reduction and improved efficiency of workers together through planning of the manpower in a particular organization.

As this research is focused on identifying an appropriate maintenance manpower model for the aviation industry, basically two sub objectives are being defined to support the main point, determination of a correlation between flying hour ratio demand and aircraft maintenance manpower requirement;

1) Identifying a relationship between flying hour ratio and maintenance hour requirement
2) Identifying a link between maintenance hour requirement with man-hour allocations

The line maintenance tasks; arrival check, departure check, walk-around inspection and so forth, are being accomplished by the line maintenance technicians with relevant skill levels while the base maintenance activities which include A check, B check, C check and D check, are being performed on the aircraft by a group of well experienced base maintenance technicians. Performance of all these tasks according to the regulatory and designer configurations, in an accurate manner will ensure the continued airworthiness of the aircraft. Moreover, although the military and the commercial aviation applications selected perform under different regulatory frameworks and according to different working schedules, all concerns were being considered, to develop the manpower-planning model to match with such different environments.

II. STATEMENT OF THE PROBLEM

Aircraft maintenance activities has long identified as a major constraint in aircraft scheduling and flight operations. (Sriram & Haghani, 2001) Maintenance tasks must have done according to timely manner without any delays. Therefore, maintenance personals have huge task to finish the maintenance of particular aircraft before deadline and return it to the service to comply with the flight schedules.

Inability to calculate exact manpower requirement for individual maintenance task leads to two types of issues,

- Overutilization of Manpower: Assignment of excess number of technicians for a maintenance activity.
- Underutilization of manpower: Not allocating adequate number of technicians for maintenance activities.

Moreover, the inability to calculate the exact skill level requirement for individual maintenance task leads to following issues,

- Underutilization of technical skills: Assigning highly skilled technicians for minor maintenance (Line) activities.
- Competency mismatch: Assigning inadequately skilled technicians for major maintenance activities (Base).

III. METHODOLOGY

A. Data Collection

Since the research is focused on validating the formulated model to the Sri Lanka Air Force and the Sri Lankan Airlines, data gathering is being conducted through various means.

1. Monitoring of maintenance documentation including manpower planning and scheduling supports
2. Structured interviews with maintenance workforce
3. Direct questionnaires
4. Gather of expert opinions

In order to acquire quantitative data as well as the qualitative data, above mentioned strategies supported with the research.

B. Definition of Terms and Abbreviations

Line Maintenance (LM): Line Maintenance generally refers to minor, unscheduled or scheduled maintenance carried out on aircraft to ensure that the aircraft is airworthy to fly *(Swoboda, 2013)*

Base Maintenance (BM): Aircraft maintenance activity carried out once the aircraft has been removed from the operating environment for scheduled maintenance activity or for defect investigation and rectification activity *(SKYbrary, 2011)*

Base Maintenance Friendliness Factor (BMFF): *Ratio of total base maintenance carried out over total flying hours flown for a particular aircraft. The Factor determines the base maintenance performance approachability of that aircraft.*

Line Maintenance Friendliness Factor (LMFF): *Ratio between total line maintenance performances by the total flown hours for a certain aircraft that specifies the aircraft's line maintenance performance responsiveness*

Line Maintenance Technicians (LMT): *Technicians are assigned with the line maintenance task performance and are being certified in performance of relevant maintenance activities*

Base Maintenance Technicians (BMT): *Technicians capable of the performance of base maintenance tasks on an aircraft with the relevant competency and experience levels.*

C. Model Formation

The two sub objectives behind the model formation;

1. Correlation between the flying hour ratio demand and total maintenance requirement
2. Correlation between total maintenance requirement and actual maintenance man-hour requirement

Correlation between the flying hour ratio demand and total maintenance requirement.

In the consideration of a commercial or a military centered air transportation providing organization, the number of flights per day or flying hours that the aircraft can be flown would be increased to achieve more productivity with the available under reduced maintenance cost factors. However, the time allocations for the maintenance technicians to facilitate the maintenance requirements should also be reduced where the Aircraft on Ground (AOG) causes numerous losses to the specific organization.

Hence, for safe and more profitable flight operations, the below proportionate equation can be defined.

$$FH \propto TM$$

$$FH = (\frac{1}{K}) \times TM \quad (1)$$

Where, flying hours is denoting as FH and the total maintenance as TM. Although the flying hour efficiency of a particular aircraft or a fleet depends upon the characteristics such as the fuel quantity, weight and balance, maintenance and so forth, through the Theory of Constraints, the element that effects mostly the flying hour demand will be the maintenance performed on each aircraft separately. Hence, it has been taken into consideration in proceeding with the research.

For the research, the K is defined as the Total Maintenance Friendliness Factor (TMFF).

Then,

$$TMFF = \frac{Total\ maintenance\ hours}{Flying\ hours}$$

$$TMFF = \frac{TM}{FH} \quad (2)$$

"K" depicts regarding the maintenance friendliness of a particular aircraft with respect to its flying hour demand. As per the equation, for an aircraft to be relatively more friendly, the total maintenance tasks to be perform on it should be less compared to the number of flying hours. Therefore, an aircraft can be termed as more friendly if the K value is comparatively less. However, this friendliness factor of the aircraft might be dependent on a combination or individually of some other factors, such as, aircraft age, fuel, time intervals of periodic inspections, component life lengths, aircraft operating environment conditions and so forth.

As the total maintenance requirement is a combination of line maintenance and base maintenance, a Line Maintenance Friendliness Factor; K1 (LMFF) and a Base Maintenance Friendliness Factor; K2 (BMFF) can be verified separately.

$$LMFF = \frac{Total\ Line\ maintenance\ hours}{Flying\ hours}$$

$$LMFF = \frac{LM}{FH} \quad (3)$$

Low values of K1 and K2 represent that the specific aircraft's frequency of component failure where more line and base maintenance will be required, will be relatively less and vice versa.

$$BMFF = \frac{Total\ Base\ maintenance\ hours}{Flying\ hours}$$

$$BMFF = \frac{BM}{FH} \quad (4)$$

Ultimately,

$$TMFF = LMFF + BMFF \quad (5)$$

When separately the LMFF and the BMFF values are low, the overall maintenance performance of the aircraft will be at a lower level with respect to its life span.

D. Manpower productivity Analysis

*Man*power scheduling advocate using 100% of productive workforce every day. However, in real life scenario employees spend more than half of their scheduled working time to non-value added activities. The Real Maintenance Work Day" concept *(Folkard, 2002)* is described in figure 1.

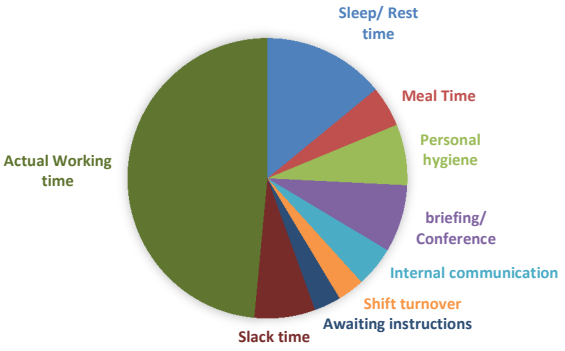

Figure 1 : Real maintenance working day

The Average Workforce Productivity hours can be calculating as below

Average workforce productivity =

Total Man-hours Available – Average Non-value added time (6)

E. Maintenance Requirement Analysis (Maintenance Requirement Factor calculation)

Aircraft maintenance requirement per day is a variable quantity, which will depend on few other unique components. Defining an equation for maintenance requirement is quite practical scenario. It is depending on type of organization and its maintenance manpower philosophy. In today's world, aircraft operations divided into two types. i.e. Military and Commercial. However, in a common background both organizations are performing line maintenance and base maintenance activities.

Maintenance Requirement factor (MRF) is a constant parameter which does not vary in a short time period. It is derived to calculate the number of persons need to fulfill forecasted maintenance man-hours required by the operator if the total workforce is engaging work with their maximum possible working hours. MRF can be derived in 2 phases with respect to line and base maintenance for both military and commercial maintenance organizations.

1) MRF Calculation for Military Organization:

In military type maintenance organizations Duty crew, Non Duty crew concept is directing maintenance activities. Therefore, calculating MRF will based upon that same concept. Moreover, manpower productivity hours will calculate according to Duty or Non- duty crew individually.

Total Line Maintenance Requirement per Month
= LM Hrs. month

Total Base Maintenance Requirement per Month
= BM Hrs. month

Calculating Daily Line Maintenance & Base Maintenance Hrs. Requirement

For DC, BM hrs. requirement = A % BM Hrs. month
For NDC, BM hrs. requirement = (100–A) % BM Hrs. month
For DC, LM hrs. requirement = B % LM Hrs. month
For NDC, LM hrs. requirement = (100 – B) % LM Hrs. month

Calculating Daily Man-hour Requirement

Daily man hour requirement for perform necessitate maintenance for both DC and NDC is calculated as,

DC man-hours requirement per day

$$= \frac{(LM\ Hrs\ x\ B\% + BM\ Hrs\ x\ A\%)}{DC\ working\ days\ month} \quad (7)$$

NDC crew man-hours requirement per day

$$= \frac{(LM\ Hrs\ x\ (100-B)\% + BM\ Hrs\ x\ (100-A)\%)}{NDC\ working\ days\ month} \quad (8)$$

Calculating Daily Manpower requirement

Man power requirement will have described the amount of physically available men whom needed to perform maintenance activities.

DC Man power requirement per day

$$= \frac{DC\ man-hours\ requirement\ per\ day}{DC\ daily\ productivity}$$

$$= \frac{\frac{(LM\ Hrs\ x\ B\% + BM\ Hrs\ x\ A\%)}{DC\ working\ days\ month}}{DC\ daily\ productivity} \quad (9)$$

NDC Man power requirement per day

$$= \frac{NDC\ man-hours\ requirement\ per\ day}{NDC\ daily\ productivity}$$

$$= \frac{\frac{(LM\ Hrs\ x\ (100-B)\% + BM\ Hrs\ x\ (100-A)\%)}{NDC\ working\ days\ month}}{NDC\ daily\ productivity} \quad (10)$$

Calculating Daily Manpower requirement with respect to Line and Base maintenance

After identifying amount of manpower required for both Duty Crew and Non-Duty crew by using Eq. (9) and Eq. (10), it is required to divide those into type of maintenance i.e. Line and Base.

Total manpower requirement =

Daily Line Maintenance manpower requirement +
Daily Base Maintenance manpower requirement

$$= LM\ Hrs \left\{ \frac{B\%}{DC\ working\ days\ month\ x\ DC\ daily\ productivity} + \frac{(100-B)\%}{NDC\ working\ days\ month\ x\ NDC\ daily\ productivity} \right\}$$

$$+ BM\ Hrs \left\{ \frac{A\%}{DC\ working\ days\ month\ x\ DC\ daily\ productivity} + \frac{(100-A)\%}{NDC\ working\ days\ month\ x\ NDC\ daily\ productivity} \right\}$$

LM Hrs. and BM Hrs. are variables that change in daily or monthly basis. However, other factors include in brackets will not vary with time to time at least for short period. Therefore, the above equation can have simplified as

Total manpower requirement
$= LM\ Hrs\ x\ Line\ Maintenance\ Requirement\ Factor\ (LMRF)$
$+ BM\ Hrs\ x\ Base\ Maintenance\ Requirement\ Factor\ (BMRF$

By considering above facts Maintenance Requirement Factor (MRF) for **Military Organization** can be defined as,

Line Maintenance Requirement Factor (LMRF) =

$$\left\{ \frac{B\%}{DC\ working\ days\ month\ x\ DC\ daily\ productivity} + \frac{(100-B)\%}{NDC\ working\ days\ month\ x\ NDC\ daily\ productivity} \right\} \quad (12)$$

Base Maintenance Requirement Factor (BMRF) =

$$\left\{ \frac{A\%}{DC\ working\ days\ month\ x\ DC\ daily\ productivity} + \frac{(100-A)\%}{NDC\ working\ days\ month\ x\ NDC\ daily\ productivity} \right\} \quad (13)$$

2) MRF Calculation for Commercial Organizations:

In commercial type maintenance organizations "Shift" concept is scheduling aircraft maintenance activities. Shifts are basically two types. Day Shifts and Night Shifts. Therefore, calculating MRF will based upon that same concept. And also manpower productivity will calculate considering Day & Night shift individually.

Total Line Maintenance Requirement per Month
= LM Hrs. month
Total Base Maintenance Requirement per Month
= BM Hrs. month

Calculating Daily LM hrs. & BM hrs. Requirement

Line Maintenance hrs. requirement per day

$$= \frac{Total\ Line\ maintenance\ hrs}{30} \quad (14)$$

Base Maintenance hrs. requirement per day

$$= \frac{Total\ Base\ maintenance\ hrs}{30} \quad (15)$$

(Average No. of days in a month was taken as 30)

Calculating Daily Man-hour Requirement

Initially, Both Line and Base Maintenance workload must be divided into Day and Night shift in a systematical manner in order to calculate daily man-hour requirement.

Line Maintenance

In order to allocate LM workload among Day & Night shifts, Monthly workforce percentage per shifts was taken account individually.

Monthly Day shift workforce percentage

$$= \frac{Total\ workforce\ (LM) in\ Day\ shifts}{Total\ Available\ Workforce\ (LM)} \text{ x } 100\% \quad (16)$$

Monthly Night shift workforce percentage

$$= \frac{Total\ workforce\ (LM)\ in\ Night\ shifts}{Total\ Available\ Workforce\ (LM)} \text{ x } 100\% \quad (17)$$

After calculating workforce percentages per each shift, LM workload requirement per shift can have state as,

Line Maintenance man hrs. requirement per Day shift
= LM hrs. Requirement per day
x Monthly Day shift workforce percentage (18)

Base Maintenance man hrs. requirement per Day shift
= BM hrs. Requirement per day
x Monthly Day shift workforce percentage (19)

Base Maintenance

In order to allocate BM workload among Day & Night shifts, Monthly day & night shift percentages are taken into account individually.

Monthly Day Shift Percentage

$$= \frac{Monthly\ Total\ Day\ Shifts}{Monthly\ Total\ Shift\ Allocation} \text{ x } 100\% \quad (20)$$

Monthly Night Shift Percentage

$$= \frac{Monthly\ Total\ Night\ Shifts}{Monthly\ Total\ Shift\ Allocation} \text{ x } 100\% \quad (21)$$

After calculating Monthly Shifts percentages, BM workload requirement can be divided into Day & Night shifts

Line Maintenance man hrs. requirement per Day shift
= LM hrs. requirement per day
x Monthly Day shift percentage (22)

Base Maintenance man hrs. requirement per Day shift
= BM hrs. requirement per day
x Monthly Day shift workforce percentage (23)

Calculating Daily Manpower requirement

This calculation is done accordance with getting ratio between man-hours requirement and productivity.

Line Maintenance

LM man power requirement per Day shift

$$= \frac{Line\ Maintenance\ man\ hrs.requirement\ per\ Day\ shift}{Average\ Day\ shift\ crew\ productivity} \quad (24)$$

LM man power requirement per Night shift

$$= \frac{Line\ Maintenance\ man\ hrs.requirement\ per\ Night\ shift}{Average\ Night\ shift\ crew\ productivity} \quad (25)$$

Base Maintenance

BM man power requirement per Day shift

$$= \frac{Base\ Maintenance\ man\ hrs.requirement\ per\ Day\ shift}{Average\ Day\ shift\ crew\ productivity}$$

BM man power requirement per Night shift

$$= \frac{Base\ Maintenance\ man\ hrs.requirement\ per\ Night\ shift}{Average\ Night\ shift\ crew\ productivity} \quad (27)$$

Calculating Daily Manpower requirement with respect to Line and Base maintenance

After identifying amount of manpower required for Day Shift and Night Shift by use of Eq. (24), (25), (26) & (27); it is required to divide those into type of maintenance i.e. Line and Base.

Total manpower requirement

= Daily Line Maintenance manpower requirement + Daily Base Maintenance manpower requirement

$$= LM\ Hrs\ \left\{\frac{Monthly\ Day\ Shift\ Workforce\ \%}{30\ x\ Day\ Shift\ Productivity} + \frac{Monthly\ Night\ Shift\ workforce\ \%}{30\ x\ Night\ Shift\ productivity}\right\}$$

$$+ BM\ Hrs\ \left\{\frac{Monthly\ Day\ Shift\ \%}{30\ x\ Day\ Shift\ Productivty} + \frac{Monthly\ Night\ Shift\ \%}{30\ x\ Night\ Shift\ Productivity}\right\} \quad (28)$$

LM Hrs. and BM Hrs. are variables which change in daily or monthly basis. But other factors include in brackets will not vary with time to time at least for short period. Therefore, the above equation can have simplified as

Total manpower requirement

$$= LM\ Hrs\ x\ Line\ Maintenance\ Requirement\ Factor(LMRF) + BM\ Hrs\ x\ Base\ Maintenance\ Requirement\ Factor\ (BMRF)$$

By considering above facts Maintenance Requirement Factor (MRF) for **Commercial Organization** can be defined as,

Line Maintenance Requirement Factor (LMRF) =

$$\left\{\frac{Monthly\ Day\ Shift\ Workforce\ \%}{30\ x\ Day\ Shift\ Productivity} + \frac{Monthly\ Night\ Shift\ workforce\ \%}{30\ x\ Night\ Shift\ productivity}\right\} \quad (29)$$

Base Maintenance Requirement Factor (BMRF) =

$$\left\{\frac{Monthly\ Day\ Shift\ \%}{30\ x\ Day\ Shift\ Productivty} + \frac{Monthly\ Night\ Shift\ \%}{30\ x\ Night\ Shift\ Productivity}\right\} \quad (30)$$

F. Actual Manpower Requirement Calculation

All of the above manpower requirement calculations are made on a basis of total workforce will involve in daily maintenance activities. But in real life scenario workers may attend leave or duty off which will resulting only partial of workforce available per day to day activities. Therefore, it is required to calculate actual manpower requirement for both Line & Base maintenances where,

Workforce Daily Availability %

$$= \frac{Daily\ Productive\ workforce}{Total\ Workforce} \quad (31)$$

Actual Manpower requirement for both line and base maintenance activates can be calculated as

Actual daily Line Maintenance manpower requirement

$$= \frac{LM\ Man\ power\ requirement\ per\ day}{Workforce\ Daily\ Availability\ \%} \quad (32)$$

Actual daily Base Maintenance manpower requirement

$$= \frac{BM\ Man\ power\ requirement\ per\ day}{Workforce\ Daily\ Availability\ \%} \quad (33)$$

LM and BM manpower requirement can be denoted as LM Hrs. X LMRF and BM Hrs. x BMRF respectively.

Therefore,

Actual daily manpower requirement =

$$\frac{LM\ hrs.\ x\ LM\ \text{requirement factor}}{Workforce\ Daily\ Availability\ \%} + \frac{BM\ hrs\ x\ BM\ requirement\ factor}{Workforce\ Daily\ Availability\ \%} \quad (34)$$

Eq. (1) was establishes a relationship between Total Aircraft Friendliness factor(TMFF) and total maintenance hours (TM). Hence the total maintenance is combination of both line and base maintenance, Eq. (1) can be further differentiate into two equations in order to build a relationship between Aircraft Friendliness factor related to Line and base maintenance hours separately.

If K1 is defined as Aircraft Friendliness factor for Line maintenance (LMFF) and K2 is Aircraft Friendliness factor for Base maintenance (BMFF),

$$K1 = \frac{LM}{FH} \quad \text{and} \quad K2 = \frac{BM}{FH} \quad (35)$$

Therefore,

LM = K1. FH (36)

BM = K2. FH (37)

By substituting LM & BM values to Eq. (32); correlation between the maintenance manpower requirement cater to overall aircraft flying hour ratio demand can be obtained as,

Actual daily manpower requirement

$$= \left\{\frac{LM\ \text{requirement factor}}{Workforce\ Daily\ Availability\ \%}\right\}\ x\ K1.FH$$

$$+\left\{\frac{BM\ \ requirement\ factor}{Workforce\ Daily\ Availability\ \%}\right\}\ x\ K2.FH \quad (38)$$

III. DATA ANALYSIS

Hence, this research mainly aims at the design a manpower optimization model in identifying an appropriate correlation between maintenance manpower requirement with respect aircraft flying hour demand. A case study has been carried out to Sri Lankan Airlines and SLAF to identify any shortfalls or surpluses in manpower quantities and means of model validation.

A. Case study – Sri Lankan Airlines

A case study is carried out to Sri Lankan airlines, the national flag carrier of Sri Lanka in order to validate manpower planning model for commercial aviation applications. Particular model is applied Airbus-A330 aircraft fleet with considering B2 Avionics and E & I workforce of Sri Lankan Airlines B747 Hanger. All data sets were obtained to the month of March – 2016.

1) Maintenance Friendliness Factor Calculations:

Total Line and Base maintenance hours were derived using operator's monthly maintenance forecast and flying hours' demand were obtained referring to monthly flight schedule for A330 aircrafts.

Total LM Hrs = 2258.45, Total BM Hrs = 3950.01

Total flying Hrs Demand = 3946.87

Using Eq. (35) LMFF (K1) and BMFF (K2) for Airbus A330 fleet can be calculated as,

K1 = 0.572214 & K2= 1.000796

2) Manpower Productivity Analysis:

A questioner was conducted for aircraft maintenance personals in B747 hanger and findings are average shift crew productivity for Day shift is **6.83 Hrs**. and for Night shift **5.75Hrs**

3) Manpower Availability Calculation:

Calculating total strength of the workforce

Total base maintenance technicians Σ (BMT) = 47

Total line maintenance technicians Σ (LMT) = 27

Total technicians = 74

Monthly total Day and Night shift amount was counted using Roster chart of the particular month as **178** Dayshifts and **16** Nightshifts. Thereafter by using Eq. (20) and Eq. (21) Day Shift and Night shift percentages were calculated as **92%** and **8%** respectively.

Monthly available total workforce for each shift is calculated as **209** workers in Dayshifts and **204** in Nightshifts. Thereafter by using Eq. (16) and Eq. (17) Monthly Day shift and Night shift workforce percentages are calculated as **50%** & **49%** respectively. By referring currently established workforce schedule which is derived by the roster chart of particular month, average daily available workforce for base maintenance in B747 hanger is **30.0760** and for line maintenance its **14.6671**

Workforce daily availability can be calculated using Eq. (31) as **60%** where Total Daily Available Workforce is 30.0760 + 14.6671 which resulting approximately **45** workers.

4) Maintenance Requirement Factor Calculation:

LMRF for commercial airline was calculated using Eq. (29) as **0.005255658** and BMFF was found as **0.004953847** by substitute values to Eq. (30)

5) Actual Manpower Requirement Calculation:

Total monthly Flying Hours (FH)	= 3946.87 Hrs.
Line Maintenance Friendliness factor (K1)	= 0.573612154
Base Maintenance Friendliness factor (K2)	= 1.000795582
LM Requirement Factor (LMRF)	= 0.005255658
BM Requirement Factor (BMRF)	= 0.004953847
Workforce Daily Availability	= 60%

By substitute above values to Eq. (38) it is found that in B747 hanger the actual daily manpower requirement for cater the flying hour ratio demand will be approximately 40.

6) LMT & BMT Utilization Disparities:

LMT portion of Actual requirement

$$= K1.FH\ x\ \frac{LMRF}{Workforce\ Daily\ Availability\ \%} \quad (39)$$

= 0.573612154 x 3946.87x 0.005255658/ 60%

= 19.6790 ≈ 20

Available LMT	=	27
Disparity in BMT availability	=	27 – 20
LMT surplus/ Deficiency	≈	7

BMT portion of Actual requirement

$$= K2.FH\ x\ \frac{BMRF}{Workforce\ Daily\ Availability\ \%} \quad (40)$$

= 1.000795582 x 3946.87 x 0.004953847)/60%

= 19.5677 ≈ 20

Available BMT	=	47
Disparity in BMT availability	=	47 - 20
BMT surplus/ Deficiency	≈	27

7) Percentage Productivity Calculation:

Actual Daily Man power requirement

= LMT portion of Actual requirement + BMT portion of Actual requirement

= 20+20 = 40

$$\text{LMT Surplus/deficiency (\%)} = \frac{\text{LMT surplus/ Deficiency}}{Total\ LMT\ employeed}$$

= (7/27) x 100% = 27%

$$\text{BMT Surplus/deficiency (\%)} = \frac{\text{BMT surplus/ Deficiency}}{Total\ BMT\ employeed}$$

= (28/47) x 100% = 58%

B. Case Study – Sri Lanka Air force

A case study had been carried out to the Y12 aircraft fleet of No 8 squadron Srilanka Air force, in order to validate manpower planning model for Military aviation applications. This case study will provide a detailed analysis to utilize disparities between the current available manpower allocations against the actual manpower requirement in SLAF. All data sets were obtained to month of March – 2016.

1) Maintenance Friendliness Factor Calculations:

Total LM Hrs = 518.36, Total BM Hrs = 895.5

Total flying Hrs Demand= 183.39

Using Eq. (37) LMFF (K1) and BMFF (K2) for Y-12 fleet can be calculated as,

K1 = 2.8265 & K2 = 4.8830

2) Manpower Productivity Analysis:

A questioner was conducted for aircraft maintenance personals in NO. 8th squadron and findings are average duty crew and non-duty crew productive hours are **14.5 hrs**. and **4 hrs**. respectively.

3) Manpower Availability Calculation:

Available total technicians	= 192
Line maintenance technicians (LMT)	= 58
Base maintenance technicians (BMT)	= 115
Trainees	= 19
DC working days per month	= 30
NDC working days per month	= 20
BM allocation for DC (A)	= 40%
LM allocation for DC (B)	= 100%
Authorized leave percentage	= 20%

Daily productive work force =

(Total Availble technicians −

Total available technicians x 20% − Duty crew off − Trainees)

$= [192 - (192 \times 20\%) - 23 - 19] = 112$

By using Eq. (33), Workforce daily availability was calculated as **58.33%**

4) Maintenance Requirement Factor Calculation:

LMRF for military organization was calculated using Eq. (12) as **0.0022989** and BMFF was found as **0.00841954** by substitute values to Eq. (13)

5) Actual Manpower Requirement Calculation:

Total monthly Flying Hours (FH)	= 29.19 Hrs.
Line Maintenance Friendliness factor (**K1**)	= 17.7535
Base Maintenance Friendliness factor (**K2**)	= 29.9794
LM Requirement Factor (LMRF)	= 0.0022989
BM Requirement Factor (BMRF)	= 0.00841954
Workforce Daily Availability	= 58.33%

By substitute above values to Eq. (38) it is found that in No. 8th squadron the actual daily manpower requirement for cater the flying hour ratio demand will be approximately 15.

6) LMT & BMT Utilization Disparities:

By Eq. (39) LMT portion of Actual requirement

$= 17.7535 \text{ x } 29.19\ x 0.0022989\ ) / 58.33\%$

= 2.04 ≈ 2

Available LMT	=	58
Disparity in BMT availability	=	58 – 2
LMT surplus/ Deficiency	=	56

By Eq. (40) BMT portion of Actual requirement

$= 29.9794 \text{ x } 29.19\ x\ 0.00841954) / (58.33\%$

= 12.626 ≈ 13

Available BMT	=	115
Disparity in BMT availability	=	115 - 13
BMT surplus/ Deficiency	=	102

7) Percentage Productivity Calculation:

Actual Daily Man power requirement

= LMT portion of Actual requirement +BMT portion of Actual requirement

= 2 + 13 = 15

LMT Surplus/deficiency (%) = $\frac{\text{LMT (Surplus/Deficiency)}}{Total\ LMT\ employeed}$

$= \frac{56}{58}\ x\ 100\%$ = 96.55%

BMT Surplus/deficiency (%) = $\frac{\text{BMT (Surplus/Deficiency)}}{Total\ BMT\ employeed}$

$= \frac{102}{115}\ x\ 100\%$ = 88.69%

IV. CONCLUSIONS & RECOMMENDATIONS

A. Conclusions

1. *Establishment of a correlation for the man-hour requirement as per the flying demand to cater the aviation organizations' most profit making criteria.*
2. *Ensuring the capability of the above correlation the allocation of maintenance technicians with the required competency levels for line and base maintenance tasks performance independently.*
3. *Model been validated for both commercial and military aviation using case studies by means of calculating actual daily manpower requirement for cater operators required flying hour demand.*
4. *Difference between the actual manpower requirement for a specific maintenance type and the formerly allocated number of workers to identify the manpower surplus or the deficiency.*
5. *Line Maintenance Friendliness Factor (LMFF) and the Base Maintenance Friendliness Factor (BMFF) are defined, which derives the total maintenance friendliness of an aircraft.*

6. *In case of manpower productivity analysis, the applications where technicians and other maintenance staff are being malpractice, for example; waiting for instructions, slack time etc. can be identified.*

B. Recommendations

1. Through manpower productivity analysis identify means of productivity wastage and implement appropriate productivity enhancement initiatives in compliance with the aviation and organization rules and regulations (here the Human Factor considerations should also get prioritized)
2. Implementation of a good reporting and recording system for the evaluation of maintenance man-hour allocation effectiveness, delayed discrepancies of the maintenance schedules, maintenance manpower productivity and so on which cooperates with the proficiency enrichment of entire maintenance workforce and organization.
3. Execution of Lean management in the maintenance operation background might also cause in identifying and reducing the wastages that create manpower productivity losses.

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