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CANNIBALISATION OF AIRCRAFT PARTS: MANAGING THE MAINTENANCE LOADS INDUCED BY CANNIBALISATION

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Abstract: **Cannibalisation is a term used commonly in defence aviation wherein serviceable part removed from an aircraft to replace an unserviceable part to make the aircraft serviceable. This research is intended to ascertain and provide comprehensive information about effective management of maintenance loads induced by cannibalisation of aircraft parts. Also, to analyse the maintenance loads induced by cannibalisation, which is otherwise perceived as logistic and supply chain management issues. I will discuss about how this potent tool has been over utilized in the proliferating defence aviation sector in the preceding years and its probable impact on maintenance personnel. This research report has two main sections. Firstly, a proposed mathematical model has been introduced to estimate the amount of additional workload required to perform by maintenance personnel for cannibalisation. Secondly, a survey questionnaire has been formulated to ascertain the effectiveness of managing the maintenance loads induced by cannibalisation. A total number of twenty five maintenance personnel have been participated in the survey. The participants are from defence aviation background with more than ten years of experience in the field. Also, each of them is from different areas of specialisation within the aviation field. The response to the questionnaire is obtained through email and telephonic interviews. Most of the cannibalisations decisions are made primarily due to the shortage of spare parts followed by sudden operational requirements. Fleet readiness is paramount in defence aviation and unforeseen events operational requirements are inevitable. Weak inventory management is the prime cause and strengthening the same could possibly reduce the dependency on cannibalisation. In defence aviation, the term cannibalisation became an integral part of the maintenance activities and adequate measures are there to manage the maintenance loads induced by cannibalisation.**

Keywords: **Cannibalisation, Maintenance Induced Loads (MIL). Line Replacement Unit (LRU), Aircraft on Ground (AOG), Equipment Out of Action (EOA), Component Performance Index (CPI).**

1. INTRODUCTION

1.1 Project Background:

At the end of World War II, most of the high quality military equipments were lying unusable or underutilised since those equipments were manufactured only for limited purpose. Eventually, the interchangeable parts of mechanical and electronic sub system were removed from equipments that were beyond economic repairs and utilised the same for rejuvenating existing repairable equipments. The procedure of cannibalisation evolved over a period and it is extensively utilised in Military Aviation. It is considered a potent tool that often used as an alternative to make an aircraft serviceable in the absence of required spare parts. The term cannibalisation is usually not common in civil aviation, however it is considered as the most viable option in the event of spares shortage and long haul maintenance delays. Whereas in military aviation, the cannibalisation gradually became a routine maintenance activity to ensure the fleet readiness. It is highly under estimated within a particular group / variant of aircrafts where the inventory of spare parts pool are in limited quantity due to budgetary constraints.

In general, cannibalisation viewed as spare parts shortage; however, its impact is underestimated due to pressure for operational readiness of the aircrafts. When an aircraft is down for any given reasons and waiting for spare parts that is not in the inventory, the least possible and viable option to make it serviceable is through cannibalisation. There is a general perception amongst aviation professionals, that the term cannibalisation is perceived as a logistic problem. In real, the additional effort needs to be put in by the maintenance personnel have not been quantified often. The defence personnel are serving for the nation and hence they have to undergo work pressure frequently even if they are not paid for the additional works they do is fine. However, the term is highly disregarded when it indirectly affects the morale of the maintenance personnel.

The defence aviation industry is consistently working on the Research & Development of modern yet complexly designed aircrafts for specific purpose of operations. Once, the completion of initial induction of a newly designed aircraft, the fleet sustainment is significantly depends on the cannibalisation to meet the sudden operational requirements. The term cannibalisation is often related to sustainment issues by the industry people. Wasting of precious man-hours has deliberately overlooked and there is a growing trend of dissatisfaction amongst maintenance personnel that often led to incidents due to maintenance flaws.

There are piles of research about cannibalisation covering almost every aspect. However, there are hardly any researches, perhaps few are available that has explicitly covered management of the maintenance loads induced by cannibalisation. The amount of additional efforts required for any cannibalisation apart from the routine work is hardly considered.

Government Accountability Office in USA released a report in 2001 declares that in financial year 1996 to 2001 the US Navy and Air force performed 850,000 cannibalisation activities that amounts to nearly five million man-hours and nearly 175,000 cannibalisation per year. Cannibalisation immediately increases the operational capability at the cost of high labour involvement (WW Fisher, 1989). The cannibalisation procedures require twice as long as normal repair. The maintenance personnel are in constant pressure to meet the sudden operational requirements that often highly disregarded.

1.2 Research Question and Objective:

The very reason behind this research is that, this age-old process has been perceived as logistic and budgetary constraint issues in the defence aviation context. In this report, an attempt is made to examine the research question "**does the cannibalisation induced maintenance loads managed effectively?**' Further, the research question has been supplemented by four objectives viz:-

(a) To ascertain the factors mandating the procedure for cannibalisation

(b) To find repercussions of cannibalisation on maintenance personnel

(c) To explore the corollary of cannibalisation on aircraft maintenance

(d) To ascertain alternatives to reduce the dependency on cannibalisation.

This study has two significant aspects. Firstly, a proposed mathematical model based on multiplication to estimate the amount of additional work required to carry out cannibalisation procedure. Secondly, a survey carried out amongst defence aviation maintenance professionals with different trade and DAM (Defence Aviation Maintenance) expertise to ascertain four different factors to examine effective management of cannibalisation induced maintenance loads.

2. LITERATURE REVIEW

The primary need of cannibalisation is to meet the operational requirements and to keep the serviceability at high to cater for the sudden mission requirements. However, to the contrary the induced maintenance loads due to the cannibalisation is often underestimated. It is evident that inventory of spares plays a crucial role in fleet serviceability. However, due to the limited utilization and specific purpose of military aircrafts, it eventually coerces the manufacturers and vendors to produce the spare parts in limited quantity. The certification of each aircraft spares made them highly expensive to meet the airworthiness standard requirements (Honeycutt, 2002).

Most of the military aircrafts are manufactured as per customised requirements with respect to their geographical and specific area of operation. Hence, the mission critical equipments and systems are manufactured viz as viz to the order placed to the manufacturers / vendors. Cannibalisation per se is a procedure to utilise in emergency; however, it became an inevitable part of aircraft maintenance. Apart from routine maintenance, most of the cannibalisation activities are less reported and or they are perpetually overlooked by the maintenance personals (Curtin, 2001).

It is prudent that cannibalisation has accidental negative impacts and unscrupulous event if it is not carried out diligently. The actions generally have deleterious connotations as it is widely seen as problem in supply chain and spares management. Unless this potent tool utilised religiously, the maintenance induced accidents / incidents will remain unattended for the years to come (Oliveira, n.d).

In many cases, the maintenance fraternity use cannibalisation as a tool for diagnosing in the absence of proper test equipments. The test equipments itself has a limited usage; most of the operators does not include them into their procurement plan or budget. This particular practice is used when there is lack of proper trained people and minimal time for operational readiness of the aircraft. It tends to be more absurd, however many snag rectification activities are carried out in the same way. On the other side, it is just because of inadequate spare parts supply from the manufacturers or by the declining vendor base (Hoover, 2002).

Cannibalisation is an effective method to keep the operations alive with high availability and reliability. It is specially considered when an inert repair activity is required when there is shortage in spare parts supply. This procedure entails additional complexities, the detailed decision making studies for cannibalisation is not perceived in the literature context. It further manifolds the unforeseen complexities resulted by cannibalisation as a whole (Zhang, 2005). Over a period of time, it became more common practice that in any operational base at any given time there will be chances of having aircraft cannibalised (Halloran, 1987).

Cannibalisation should be carried out only in the event of any possible solution is not available. Each instance has wider impacts on the aircrafts beyond logistic issues. In most cases, the cannibalisation has to be carried out along with the scheduled maintenance to complete the activities within the deadlines to meet the operational requirements. This in turn results in additional burden to the maintenance personal working in adverse weather conditions (National Audit Office, 2017).

The effectiveness of cannibalisation depends on the variable decisions made with respect to the selection of aircrafts, downtime to recovery, turnaround time (TAT) to complete the entire procedure to make the affected aircraft fly worthy. But, the cannibalisation recovery of a long pending spares shortage would be great burden to the maintenance personal to perform additional tasks which is absolutely unwanted (Prescott, 2017).

Cannibalisation is proven the best option for making an aircraft serviceable in emergencies or in the absence of spares. However, its impact on various aspects of flight safety has been often underestimated or miscalculated. The scope of cannibalisation is not to enhance the fleet serviceability but to ensure the redundancy in the event of emergency. The decisions for this procedure are not optional rather it became a routine for various reasons. Procedure for cannibalisation itself has an adverse impact on maintenance personal by increasing their workload and low morale since it is an out of schedule activity. The defence forces have many reasons for cannibalisation and have a strong inducement to do the same in future. In the event of cannibalisation, the components has to undergo rigorous inspection process before it is being fitted in live aircraft (Sahay, 2012).

The maintenance personnel often use cannibalisation as a diagnostic tool to carry out the functional check of a component in the absence of proper test equipment. The cannibalisation can be reduced by optimizing the supply chain channel, design improvements and increasing the availability of the spare parts (Hoover, 2002). Cannibalisations perhaps have severe effects on moral and retention of the personnel by increasing maintenance cost and workload. Over half of all aircraft maintenance technicians work more than 50 hours a week compared with an average of 40 hours. Sometimes, the working hours may extend up to 70 hours a week (U.S. General Accounting Office, 2001).

Cannibalisation could take place in the event of spare parts availability is incorrectly constructed due to funding constraints, high demand of specific component due to ageing factor, demand surge in war like situation, change in parameters such as reliability / increased maintenance time, sudden operation requirements and diminishing of vendor base line that increase the waiting time for spares supply. The general perception of cannibalisation is negative however; it became an inevitable part of maintenance for operational preparedness (Zettler, 2004).

There is apparently important difference between commercial and military aviation as the commercial aircrafts are utilized more extensively as compared to the military aircrafts. The commercial aircrafts are logged more flying hours than military aircraft of similar age. The data of commercial aircraft maintenance cost would provide more comprehensive information than military aircraft maintenance cost. The nature of operation requirements is certainly different from one another and hence the term cannibalisation could be more justifiable in military aircraft context (Dixon, 2009).

Cannibalisation activities could consume more man-hour than routine part removal and spare part installation and thereby increase the maintenance workload and morale. Often the potential maintenance induced damage are unsolicited however, there is an indirect benefit by using this procedure. Swapping parts in the event of spares shortage reduces the maintenance down time for a failed unit of equipment. Any delay in the maintenance activities will severely affects the fleet readiness (TU Delft, 2009).

The military aviation organisation that operates costly repairable equipment is encountered with enormous challenges pertaining to specific maintenance policies and the sharing maintenance resources. The allied maintenance decisions could have a severe impact on fleet performance. Due to the importance of procurement costs related to the components that are part of the equipment in the fleet, the term cannibalisation is used in the absence of required spare parts to allow decision making authorities to satisfy operational readiness constraints (Salman, 2007).

Cannibalisation is a powerful management adaptation to mitigate the impact due to uncertainty in the logistic channel. The organisations required to forecast their budgetary requirements in order to ensure the fleet readiness in the event of inadvertent situation. It is difficult to make precise forecast for spare parts requirement. Most of the spare parts forecast are based on the flying hours and the component performance index of a particular component. However, it remain futile in the military aviation context due to its unforeseen operational requirement that it mandates to exercise all possible options to make the aircraft serviceable even the same necessitates robbing parts from another aircraft (John L. Adams, 1993).

Keeping in mind of the global threats and political instability, the deployment emergencies requires highest level of operational readiness of an aviation squadron. It is difficult to maintain the supply chain channel effective with war reserve spare kit (WRSK) equipped with important spares and components in the event of war. However, due to the budgetary constraints, these spares are either consumed in operational requirements in other than war or it will be vouchered on loan to other squadrons with same variant or different variant with commonality (John Abell, 1993).

The cost of spare parts in the inventory shows a significant expenditure in the budget however, reducing the spare parts demand based on the availability without proper integrated planning bound to be arise future spare parts shortage. Each year the cost of the spare parts are tend to be expensive than the preceding years and the cost of repairing the existing components are cumbersome. In the military aviation context, the budgets allocated for this specific purpose is expenditure rather than investment as the defence aviation does not yields any remuneration. Only about fifty per cent of spares planned are turn to be right for heavy and base maintenance activities. The rest is mainly utilized in unplanned and unscheduled maintenance. The uncertain maintenance requirements are due to the inherent reliability of the component and the unplanned maintenance activities such as cannibalisation has serious consequences involving a large number of materials and resources (Samaranayake, 2006).

Cannibalisation in aviation being hi tech environment is used due to non-availability of expensive spare parts and reduced maintenance turnaround time requirements. The corresponding maintenance decisions can have impacts on operation costs in various areas especially in labour and man-hours the strategy of cannibalisation institute poor performance when average utilisation of labour is very low or the cannibalisation procedure is quicker than the repair. (Ormon, 2004).

This process could be applied to all sizes and classification of components ranges from normal split pin to vital and dynamic components. This age-old process is primarily carried out due to operational requirements but they come at high cost. The maintenance personnel obliged to do the removal / installation process twice and thus they are exhausted to additional loads (Okyere-Boateng, 2015).

In one particular case, the U.S Naval Aviation maintenance personnel revealed that they improperly pulled out the serviceable aircraft parts to meet the operational requirements and they maintained improper maintenance records that are absolutely against to the naval aviation cannibalisation policy. It has been revealed that it is more common in their base as there is much more physical swapping of components than it is recorded in the documents. In addition, they are hiding the problems in their supply system to keep the fleet ready rather than exposing it and get the needful help (CNBC, 2015).

There are four main classifications of spares in the aviation maintenance industry namely, Rotables, Repairable, Expendables and Consumables. Normally, the rotable and the repairable has serial numbers with a component log cards and every removal / installations / repair activities carried out on the component has to be recorded and maintained. It is prudent that these components should not be removed from or installed to an aircraft without proper documentation. On the other hand, on a surprising note, that reporting of cannibalisation has been deliberately concealed by maintenance

personnel from the authorities for a particular type of spares. However, the problem arises in the spares from other two categories where as they do not necessarily have serial numbers and log cards. Few of the spares from these two categories are still significant for functioning of a critical system or LRUs (Zhang, 2005).

The additional maintenance hours logged by the maintenance personnel in U.S Navy and Air force during a five year period amounts to five million hours. The cost of this workload is nowhere recorded in the fiscal balance sheets since the defence personnel does not paid for overtime. In due course, the maintenance personnel got the overload in addition to the workforce that is already in consistent pressure by the operational tempo and often it lead to retention of the maintenance personnel from defence aviation. Well! Cannibalisation alone cannot be the problem for retention; however, it contributes a certain amount for this factor. When the trained people leave the forces for any reason, the induction of new people and the interim operational requirements faces huge impacts. Service policies all call for minimizing the use of cannibalization, but there are really no incentives or guidance to meet that goal. The real incentives are on the other side to push for that high maintenance level, that high readiness level (CGRHR, 2001).

The engineers are required to perform cannibalisation and there is no respite for them. It is certainly acts as a factor for low morale in the engineering department. There is continuous struggle in managing the additional loads since less than half of the parts are being cannibalised to meet the sudden operational requirements. This was not in the case twenty years ago, and that was plentiful then with huge impact on the morale of the maintenance personnel (Farmer, 2017).

In an investigation, the marines who are deployed away from Australia are returning back to Hawaii because of the long working hours and low morale. The MHM-463 helicopter's mishap, the unsuccessful maintenance check in September 2015 and the accident flight on 14 January 2016, HMH-463 Marines worked extended hours, often including weekends, and felt the effects of long-term, increasing exhaustion (Paulson, 2016).

3. RESEARCH METHODOLOGY

The purpose of this research is to examine whether the cannibalisation-induced maintenance loads were managed effectively with the help of four objectives viz factors, ramifications, corollary and alternatives. A questionnaire (attached as Appendix-1) has been formulated with set of twenty-five questions with closed ended statements on a likert scale ranges from strongly disagree to strongly agree along with neutral option. In order to get the exact response for the questionnaire, twenty five defence maintenance professionals has been selected randomly with different area of specialisation. This research has been formulated with two main sections viz proposed mathematical model to estimate the amount of additional workload required for cannibalisation and primary research with the help of questionnaire.

3.1 Research Design:

There are two main segments in this research. Firstly, an attempt is made to introduce a proposed mathematical model to estimate the maintenance induced workload by cannibalisation with illustrative example. Secondly, primary research has been carried out to ascertain whether the maintenance induced loads by cannibalisation are managed effectively or not.

3.2 Research Sampling:

The primary research has been carried out by formulation of a questionnaire distributed amongst twenty five defence aviation professionals in a single defence aviation squadron whom have significant experience in maintenance industry (more than 10 years) for sampling. These professionals were chosen randomly from different areas of specialisation such as structures, power plant, electrical, instruments/radio navigation, avionics and weaponries.

3.3 Measurement:

The measurement of the questionnaire has been designed by the degree of agreement by the respondents with respect to the statements in the questionnaire. The raw data has provided a general idea about how likely impact is the response with respect to the statement have in this report.

3.4 Data Collection and Mining:

(a) The raw data obtained through email and telephonic interviews as response to the questionnaire and the same has been fed into software programme Minitab for plotting the data and converted into appropriate graphical representation for analysis.

(b) The information for literature review from the secondary research has been collated mainly from the research articles and journals with occasional blogs and articles from credible magazines. The same has been cited in APA style referencing.

3.5 Limitation:

The data for the proposed mathematical model is illustrative, as the collation of real data for validating the model is not possible at this juncture due to confidentiality. Also, this research was conducted in a developing country (not disclosed due to confidentiality) with extensive flying operations. The scenario might be different if the research carried out in different country. The policy for cannibalisation may vary for each operator, however; the cannibalisation management policy for this research has not been perused to ensure its effectiveness. Opinions of the decision making authorities has not been taken for this research due to time constraints. If this is not the case, the response for the questionnaire might yield different results.

4. PROPOSED MATHEMATICAL MODEL

4.1 Formula & Derivation:

This particular mathematical model gives an estimate of additional workload in terms of time. This model would help the decision making authorities to calculate the additional time taken for each cannibalisation procedure and to keep a record of it. There are four variables taken into consideration namely time (*T*), manpower (*M*), total number of activities (*A*), total number of LRUs / components (*N*. This model is only for illustrative purpose and it has no connection with the primary research. However, it would be fruitful in calculating the percentage of additional man-hours for cannibalisation of different components to manage the additional loads effectively.

$$T_N = \frac{M(An)}{Nn}$$

$$T_C = \frac{M(Ac)}{Nc}$$

$$\Delta_T = T_C - T_N$$

$$\sum W\% = \Delta_T / T_n \; X\,100$$

$\sum_W$	-	Percentage of additional workload per hour
Δ_T	-	Increment in time taken between each procedure
T_N	-	Time taken for normal replacement procedure per activity
T_C	-	Time taken for cannibalisation procedure per activity
M	-	Manpower
A_n	-	Total number of activities in replacement procedure
A_c	-	Total number of activities in cannibalisation procedure
N_n	-	Number of LRUs / Components in normal procedure
N_c	-	Number of LRUs / Components in cannibalisation procedure

An illustrative example with model numbers is explained below for better understanding of the mathematical model. Assuming, an aircraft is on ground (AOG) for two vital LRUs, and the same is available in the inventory with a requirement of four technicians. There are a total number of eleven activities required to complete the procedure and the resultant time taken for the entire procedure is:-

$$T_N = \frac{Nn(An)}{M}$$

$$T_N = 02\,(11) / 4$$

$$T_N = 5.5$$

In the above example, if the required spare parts are not available in the inventory and there are three aircrafts are involved in this procedure including the aircraft being made serviceable by cannibalising the parts with the same manpower involved. Ac will be 2.5 times more than the activities involved in An including removal and installation of each of the components, then the resultant time taken will be :-

$$T_C = \frac{Nc\ (Ac)}{M}$$

$$T_C = 02\ (27.5) / 4$$

$$T_C = 13.75$$

The change in time taken for each procedure is the difference between normal procedure and the cannibalisation procedure.

$$\Delta_T = T_C - T_N$$

$$\Delta_T = 13.75 - 5.5$$

$$\Delta_T = 8.25$$

The resultant percentage of additional workload per procedure is as below:-

$$\sum W = \Delta_{T/} T_N \ X\ 100$$

$$\sum W = 8.25 / 5.5\ X\ 100$$

$$\sum W = 150\%$$

4.2 Advantages:

The important advantage of this mathematical model is that it is easy to compute and it has fixed boundaries in terms of values of the different variables (i.e. the value of the variables will not be in fractions and it gives an estimation of additional workload with respect to the nature of components being cannibalised). This data will be much more suitable with the real time data and provides a rough estimation of workload required to cannibalise each component, also it will be beneficial for the decisions making authorities to resort cannibalisation with available resource and time.

Also, it gives you the basic understanding of how much effort has to be put in by the maintenance personnel to perform the cannibalisation procedure. This gives a pragmatic approach towards resorting cannibalisation after exploring all other viable options in the event of sudden operational requirement. In addition, this will be fruitful in expediting the demands in the logistic channel of those components that requires the highest percentage of additional workload. A proactive measure for critical components can be identified and the same can be demanded and kept in the spare parts pool if the budgetary constraint allows it.

4.3 Measurements & Limitations:

As this model is pretend to measure and estimate the additional workload required for cannibalisation procedure with normal replacement procedure, there are few important aspects that could affect the effectiveness of this mathematical model.

(a) The number of activities for each component will be different and hence, the percentage of workload might increase / decrease.

(b) Manpower involved in the cannibalisation activities would increase / decrease the percentage of additional workload.

(c) This model is simplified estimation of the additional workload and does not include problems in greater details.

(d) It would be helpful in understanding the percentage of additional workload and thus the manpower involvement with respect to the deadlines could be estimated and managed effectively.

5. RESULTS / FINDINGS

The raw data collected form the questionnaire is mainly divided in four sub sections namely Factors, Ramifications, Corollary and Alternatives. The results obtained are plotted into appropriate graphical representation for clear understanding. The details of raw data collected from the questionnaire are attached as Appendix-2 to this report.

5.1 Factors:

Prima facie raw data for the factors that mandates cannibalisation is highly considered as shortage of spares parts in the logistic channel. This state might be due to various reasons although it stands at first and it is followed by other reasons. Failure in spare parts pool and forecast based inventory management plays a vital role in obviating the cannibalisation procedure. The data reflects that more than seventy per cent of the respondents, with profound knowledge in the defence aviation field, felt that primary cause for the cannibalisation is due to spares parts shortage. Twenty per cent of them not agreed with it, as they believe that spare parts are available for schedule maintenance and a considerable amount of spares are kept in pool to meet unscheduled maintenance activities as a routine practice in the aviation industry. Even though there are few other reasons for resorting cannibalisation, spares parts shortage stands at the top amongst all.

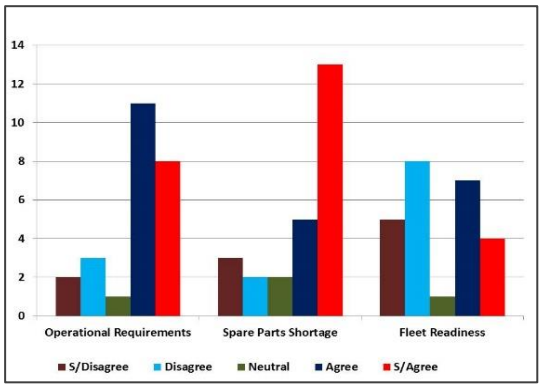

Fig 1: Factors mandating cannibalisation

The second important factor that mandates cannibalisation is sudden operational requirements. More than seventy-five per cent of the maintenance personnel agreed that whatever it takes them to make the aircraft serviceable to meet the operational requirements. They aware that the cannibalisation procedure calls for unsolicited workload that gives them no reaction time to explore possible options. However, twenty per cent of the maintenance personnel still disagree with operational requirements being a cause for cannibalisation.

The data for the third main cause for cannibalisation is fleet readiness reflects less than fifty per cent of the maintenance personnel agreeing to it. Most of the maintenance activities are scheduled and they are planned well in advance to make stagger planning so that they does not clash with the fleet availability per cent that is already determined by the squadron commanders with respect to the area of their operation.

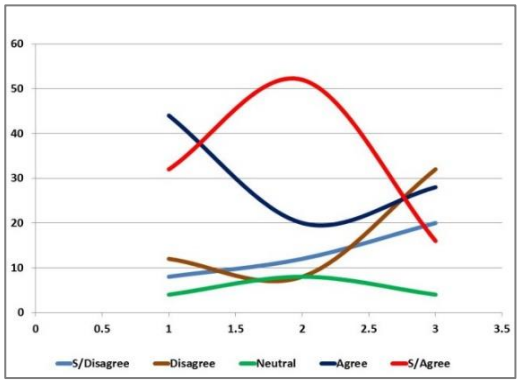

Fig 1.2: Percentage Indicators

5.2 Ramifications:

The highest number of persons agreed that cannibalisation increases the workload directly or indirectly. More than seventy-five per cent of them agreed or strongly agreed and it stands highest amongst other two reasons in the graphs. On the other side, few of them (less than twelve per cent) still consider that cannibalisation has no ramification on workload. There is slight ambiguity in less than fifteen per cent of the people who still do not have clue about whether cannibalisation increases the workload or not. However, amongst all other reasons the overall trend reflects that there is an indictment that cannibalisation certainly increase the workload.

The second major factor that the cannibalisation inclines the maintenance personnel that they deliberately hesitate to report small items being cannibalised from AOG aircraft to a live aircraft. Though,

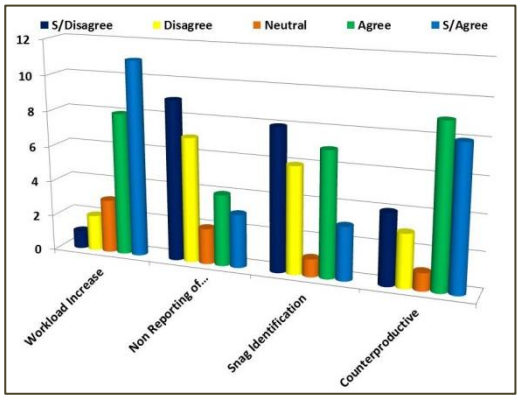

Fig 2: Ramifications of Cannibalisation

nearly sixty five per cent of them are against to non-reporting of small items, however there is significant amount of people who are agreed that it is not important to report each and every items being cannibalised especially the items are expendable or consumable in nature.

Ten out of twenty-five maintenance personnel agree that it is acceptable to swap the serviceable aircraft component for identification of snags and systems validation. However, fifteen out of twenty five (sixty per cent) are against swapping the components. It is just because that most of the components are part of a system as single consolidated unit. The removal and installation of all the components are not possible, as it will complicate further maintenance procedure to reinstate them in to their previous condition.

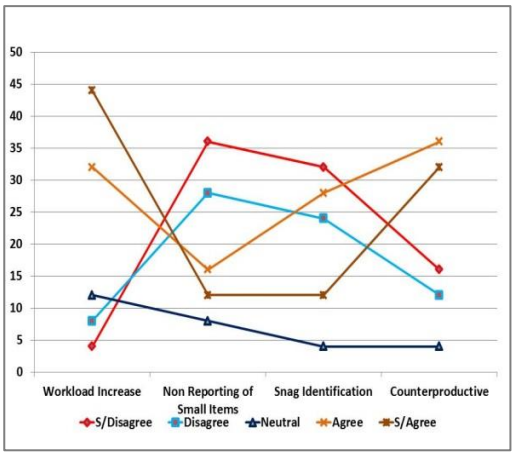

Fig 2.1: Percentage Indicator

When the maintenance personnel were questioned about whether the cannibalisation procedure per se is counterproductive in terms of man-hours consumption, the results obtained are certainly positive towards agreement to it. However, one quarter out of the twenty-five respondents are against the term counterproductive. In other words, they believes that it will enhances the hands on experience of the maintenance personnel though it consumes additional man-hours and it does not affect as the decisions are already made and they just want to execute it in a positive way.

5.3 Corollary:

Since the potential of aircraft recovery is much, depend upon the lead-time of the maintenance activities being performed in aircraft. Once a component is cannibalised from an aircraft to another, the serviceable component removed from an aircraft that is otherwise not flightworthy for another component, the cumulative shortage of spare parts increases and further compounded in to increase downtime for aircraft recovery. Sixteen out of twenty-five maintenance personnel agree that has potential impact on downtime for recovery of an aircraft that amounts to nearly three quarter of the participants.

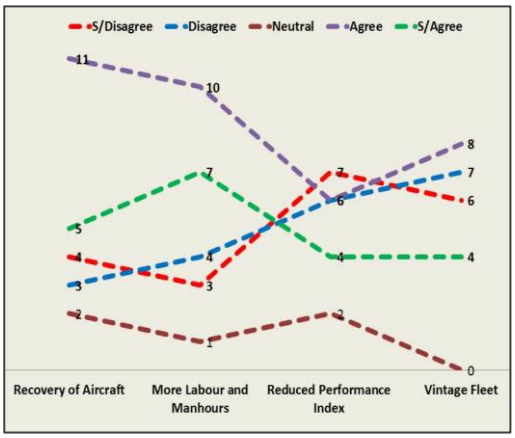

Fig 3: Corollary of cannibalisation

This trend is in the same case of cannibalisation causing more labour and man-hours. The disagreement of the aforementioned two aspects amounts the same percentage for about one quarter of the participants. If we neglect the one quarter of disagreement, the results are indicating that the cannibalisation has serious ramifications on aircraft recovery and thus increases the maintenance workload that eventually transposed into unscrupulous maintenance activities.

In another aspect wherein maintenance personnel were asked, whether they aware of cannibalised parts tends to be failure before the designed life cycle. The results are quite surprising as the participants are equally agreed or disagreed to the question. There lies the ambiguity that the decision making authorities whether aware of this problem or they are just resorting cannibalisation as temporary measure for any given reasons. However, the restoration of the cannibalised aircraft takes longer than the expected timeline.

There is a known factor that vintage aircrafts tend to break down more frequently as compared to the new ones. It consumes longer than the normal maintenance activities and therefore available to minimal operations. However, more than half of the participants are expressed

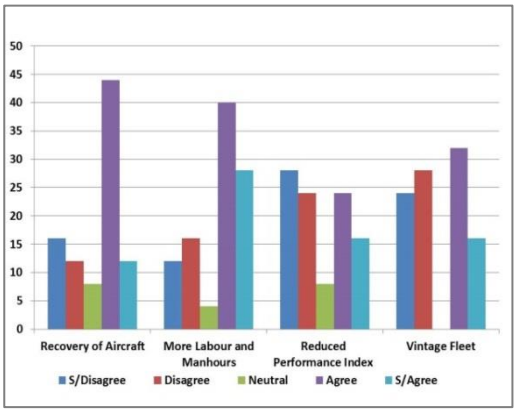

Fig 3.1: Percentage Indicator

their disagreement to this statement. This is perhaps due to the aircraft maintenance industry mainly depends on preventive maintenance. Though obsolesce of systems can be a serious problem, so as the spare parts consumption pattern of particular component of system.

5.4 Alternatives for cannibalisation:

In an attempt to find out what are the alternatives for overcoming cannibalisation procedure, the results obtained are quite interesting. Around thirty sixty per cent of them responded that developing prognostic skills at the decision making authorities will significantly reduce the dependency on cannibalisation. The disagreement to this statements stands at high with sixty per cent whereas fifteen per cent of them remained neutral. As referred by Prescott [10] the effectiveness of the cannibalisation depends on prognostic skills at the decision making authorities. However, the results obtained are bit contrary to the statement as there is no specific literature for cannibalisation decision making and so far, it is carried out by the expertise of decision making authorities. This corroborates with findings of Zhang [17] that the detailed decision making studies for cannibalisation is not perceived in the literature context.

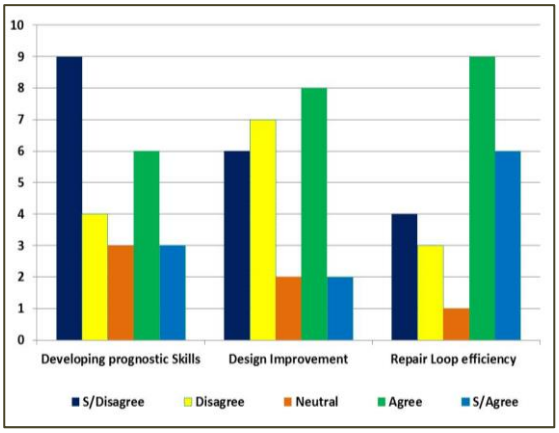

Fig 4: Alternatives for cannibalisation

The other factor considered in this category whether design improvements have impacts in improving the life cycle of a component; the resultant responses are slightly negative as only forty per cent of the respondents feel that design improvements can be alternative for reducing cannibalisation while more than fifty per cent of them remain disagreed to the factor. The results obtained are slightly against Hoover's [5] findings that cannibalisation can be reduced by making design improvements.

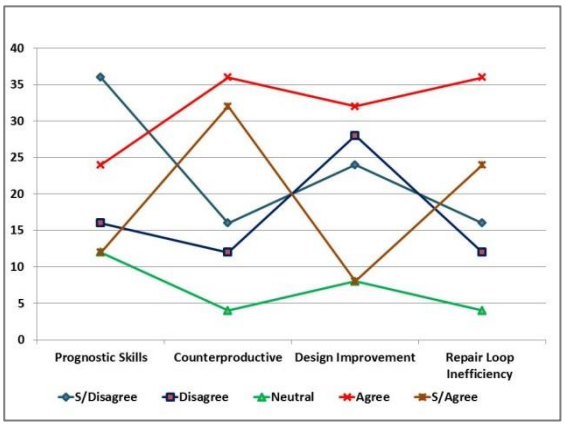

Fig 4.1: Percentage Indicator

In another attempt, the respondents were asked whether the efficiency in repair loop has any effect in reducing, the cannibalisation and the response are surprising as one quarter of the respondents disagreed with it and more than sixty per cent agreed that effective repair loop could significantly reduce the dependency on cannibalisation. However, it does not corroborate the findings of Samaranayake [13] that the cost of repairing the existing components is cumbrous. The overall response to the factor to find alternatives for cannibalisation is that the design improvements in frequently failing components and an effective repair loop can drastically reduce the dependency on cannibalisation whereas developing prognostic skills for decision-making authorities are not significantly considered.

6. ANALYSIS

During the research process, one important aspect that has huge impact on cannibalisation is the spare parts shortage. Wide of the mark, there is nothing wrong as cannibalisation perceived as logistic issues and an effective and forecast based spares management can significantly increases the fleet readiness in the event of inadvertent situation. [7] As seen in the figure.1, it is evident that nearly seventy per cent of the respondents agreed that spares parts shortage is the prime concern for cannibalisation. This situation is might be primarily due to budgetary constraints and or poor inventory management. Unlike every maintenance industry, defence aviation maintenance considered as the most expensive in terms of spare parts and precious man hours consumed during the activities as there is no profitable income like commercial aviation operations. [13] The other two factors viz operational requirements and fleet readiness can be achieved without cannibalisation when the required spare parts are available. In defence aviation context, the sudden operation requirements and maintaining fleet readiness is paramount and it is yet inevitable. It is evident that adequate spares parts availability could reduce the dependency on cannibalisation and it is directly linked to sustainment of a particular fleet. These two factors have parallel effects on each other as higher the fleet readiness, maximum operation capabilities. Is the

decision-making authorities are well aware of their area of operations? If yes, then there will be a backup plan always ready for inadvertent situation. The decisions making authorities that also comprises of maintenance engineers would be well aware of the things that might pop during any situations.

While analysing the survey results of ramifications from Fig.2, it is certain that cannibalisation increases the workload; however, it appears that defence aviation personnel have not considered it as significant. The most important thing that drives the defence aviation personnel is the motivation towards serving their country. Many of them responded that they are comfortable in working under pressure and for extended time, even though not being paid for it. However, this does not alone justify the maintenance load induced by cannibalisation; rather it implies accidental negative impacts that could lead to potential catastrophe. [9] But what sort of negative impacts does cannibalisation have? The fig.2.1 shows that there is an increase in trend of not reporting the small items being / been cannibalised. Also, few of the items are being cannibalised to identify the snags of a system or component and there happens to be no proper documentation or record for it and this is absolutely against the aviation maintenance policy worldwide. [1]

The result shown at fig.2 reflects that the maintenance personnel aware that the cannibalisation process if counterproductive. The spares parts shortage has a cascading effect on counterproductive as these two factors have inversely proportional effect on each other. Higher the spares parts availability reduces the counter productiveness. Rest of the two factors namely operational requirements and fleet readiness are mostly influenced by the spares parts availability. It is not possible to get all of the required spares are stocked in the stores though; an effective repair loop facility could possibly increase the spares availability. Adequate spares parts storage can potentially increases the serviceability and availability of a fleet however, the complex design and limited usage of the defence aviation spare parts curtails the vendors to manufacture them and the certification is another cumbersome process. [4] It is prudent that the spares parts availability will certainly increases the operational readiness, surpasses the four aspects viz workload increase, non-reporting of small items, components being removed for snag identification and counter productiveness.

While ascertaining the effects of cannibalisation, four main aspects considered significant in this research as mentioned in fig.3. It is certain that the entire cannibalisation procedure increases the workload of the maintenance personnel; however, the proposed mathematical model at Para 4 would help to estimate the amount of efforts needs to be put in for cannibalisation procedure from a normal replacement. Amongst considering all other factors, recovery of aircraft remains the big burden for the maintenance personnel. It has two ancillary effects viz consumption of more labour and man-hours and reduced performance index. The longer the time taken for recovery of aircraft will increase the labour for reinstating them in to fly-worthy. It has another additional effect that the components being cannibalised tends to be failing before their designed life cycle. However, keeping a track on these vital components would be fruitful in forecasting spares requirements and maintenance planning. So far, there is no literature study to quantify the maintenance load induced by cannibalisation and additional workload is still considered significant.

The consequences of cannibalisation have influence on four main aspects viz recovery of cannibalised aircrafts, consumptions of more labour and man-hours, reduced performance of cannibalised parts and frequent failures on vintage fleets. Once a component cannibalised from an aircraft, the same has to be grounded and the time taken for liquidating the demands for the shortage spares plays a crucial role in restoring the aircraft to fly-worthy. As discussed, due to the limited usage and diminishing vendor base, if the cannibalised part is of such nature, the downtime for recovery will be protracted. Prolonged grounding of aircraft due to non-receipt of cannibalised parts is another cause of serious concern as it increases the maintenance activities for storage and preservation requirements of the aircraft recommended by the manufacturer. The restoration of these aircrafts is another cumbersome process as the same has to undergo for detailed checks that otherwise obviated by spares parts availability. The performance index of the cannibalised parts tends to be reduced as there are chances of potential physical damage to the components during the removal / installation procedures. Also, there is a chance of electronics parts losing intactness in the event of mishandling. Though, this factor can be neglected due to its probability of occurrence and the degree of importance in operational requirements.

As seen from the fig.3, aircrafts are frequently prone to snags and malfunctions due to vintage. The critical part of maintaining the vintage aircrafts are compounded into many technical difficulties and the fleet sustainment is either depends on spares parts availability or by cannibalisation. It also increases the spare parts consumption, the obsolescence is other major factor. In this research, it has come into light that there is a feel among the maintenance personnel that there is no need for recording small items being cannibalised. This might turn as potential threat in terms of flight safety and it requires immediate attention and solutions to overcome it.

Another fact that came to notice is that there is a practice of swapping components for snag identification without any proper documentation or consent from the competent authorities. In most of the cases, the sanction for cannibalisation has

to be obtained from the competent authorities, possibly from the higher command in defence aviation before commencing the procedure. On the light, an undisclosed process that commences the cannibalisation procedure before obtaining sanction is getting attention in the preceding years. However, most of the maintenance personnel are against this process, but it is a growing concern amongst the maintenance fraternity since it has serious implications on safety maintenance procedures.

It is evident that cannibalisation activities are counterproductive and it consumes more precious man-hours than the routine maintenance procedure. Surprisingly, there is another factor came to light that cannibalisation procedure can be used for training purposes to enhance the hands on experience of technicians. Moreover, the maintenance personnel have no role on decision-making and they just have to execute the decisions made by the authorities. The decision-making authorities should be proactive in forecasting maintenance requirements, as they are very much aware of their area of operations and need to have meticulous planning to mitigate the dependency on cannibalisation being counterproductive.

In response to find the alternatives to reduce the cannibalisation, the fig 4 shows three main factors that are considered significant viz prognostic skills of decision making authorities, design improvements on frequently failing components and strengthening repair loop facilities. Decisions making authorities are consistently in pressure to meet the operational requirements as it takes meticulous planning to run an aviation squadron. There is no doubt in capabilities of decisions making authorities, however cannibalisations are resorted for being last and only possible option in the event of sudden operational requirement. However, the consumption pattern and nature of failure of a particular component can be monitored and necessary design improvements shall be incorporated to overcome the issue.

Effective repair loop facility has significant impact in reducing the maintenance loads as it has direct impact on dependency of cannibalisation. Strengthening the same would increase the spares availability in the inventory and it reduces the downtime of grounded aircraft restoration. If these two major factors are improved, the dependency will be ultimately reduced. The same has been widely accepted by the respondents as seen from fig 4.1

7. CONCLUSION

Cannibalisation is a potent tool used in the event of spare parts shortage to meet the sudden operational requirements. Every year, there is thousands of cannibalisation activities are taking place in defence aviation industry that increases the maintenance workload and consumes precious man hours. This report examine about effective management of maintenance loads by estimating the additional maintenance loads through mathematical model and key research to ascertain four main factors pertaining to cannibalisation. Is the cannibalisation induced maintenance loads are managed effectively? Well! The answer is yes but how?

The main reason behind the decision making authorities opting cannibalisation is the shortage of spare parts in the inventory. There are adequate research made to strengthen the inventory management and in most of the cases it is effective too. But, due to the budgetary constraints and diminishing vendor base for some of the vital components tends to results in creating the situation. It is the also the main reason that abates the concerted effort made by the decision making authorities to avoid cannibalisation. If this is not the case, the maintenance fraternity is much aware of their strategies for operational requirements and fleet readiness.

Off the mark, it is obvious that cannibalisation increases unsolicited workload and it is inevitable too. The only way to mitigate the dependency on cannibalisation is to increase the spares parts availability. The ancillary effects of cannibalisation due to spare parts shortage resulting in non-reporting of small items and swapping the components for snag identification. The later effect is due to non-availability of test facility in the operating base as most of spare parts are fed into repair loop even for functional checks and snag confirmations. Inefficiency of repair loop facility is another cause of concern in this case.

In wider context, the sophisticated design and mission specific requirements coerces the manufactures to produce the spare parts in limited quantity and its certification process is another key concerning factor. The non-availability of spare parts severely affecting the downtime recovery of aircraft. Sustainment of fleet is the resultant of weak inventory and cannibalisation is the only available option left with decision making authorities to meet the operation requirements.

The scenario might be different in commercial aviation or with different variant of aircrafts since this research is conducted within the defence aviation squadron with single variant of aircraft in a particular country. However, the situation will be the same for each variant of aircrafts that eventually increases the workload of maintenance personnel irrespective of the country or area of operation. Apropos, the maintenance induced loads are effectively managed by the authorities, provided; inventory of spares will circumvent the dependency of cannibalisation.

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APPENDICES

Appendix -1

SURVEY QUESTIONNAIRE ON CANNIBALISATION IN AVIATION: MAINTENANCE INDUCED LOADS:

Dear Participants,

I am a Graduate Student at Nelson Marlborough Institute of Technology (NMIT) Auckland campus. This study is being carried out in fulfilment of the requirement for the award of **Graduate Diploma in Management**. The study is embarked upon to understand maintenance induced loads by cannibalisation. The study will assess to determine the factors mandating the cannibalisation and how it can be quantified.

The questionnaire takes approximately **5-10 minutes** to complete.

Please be honest as you can in your responses. For any clarification, please contact the researcher on this email address: danmanjoor@gmail.com or +640223969468.

	Question statement	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
1	Cannibalisation should be exercised only for operational requirements					
2	Cannibalisation is perceived as spare parts shortage					
3	The fleet readiness can be achieved out by cannibalisation					
4	Organisations should allocate budget to form vital spare parts pool					
5	Cannibalisation increases unsolicited workload for maintenance personnel					
6	You are comfortable to work under pressure to meet the operational requirements					
7	You are satisfied working for additional hours even if you are not paid for it					
8	Non reporting of cannibalisation for small items is acceptable					
9	Swapping the vital spare parts (LRUs) is acceptable for snag identification					
10	Cannibalisation has huge impact in terms of collateral damage to associated systems					
11	The effectiveness of cannibalisation is depends on downtime to recovery of an aircraft					
112	Long pending spares shortage affects recovery of an cannibalised aircraft					
113	Cannibalisation per se is not a part of maintenance activity that increases burden on maintenance personnel					
114	Cannibalisation consume more labour and man-hours than standard procedures					
115	Component Performance Index (CPI) of cannibalised parts tends to be failure before their designed life cycle					
116	Cannibalisation is generally mandated in vintage fleet of aircrafts					
117	Adequate spare parts pool can reduce the dependency for cannibalisation					
118	Anticipatory demands in logistic channel for components that has low CPIs will reduce the dependency for cannibalisation					
119	Cannibalisation can be otherwise perceived as lack of prognostic skills at the level of decision making authority					
220	Cannibalisation enhances the availability and reliability of the fleet to meet the sudden operational requirements					

221	Cannibalisation is fruitful in fleet sustainment					
222	The major concern of cannibalisation is counterproductive in terms of man-hours consumption					
223	Frequently failing components should be reused only after necessary design improvements rather than normal repair					
224	Cannibalisation can be otherwise perceived as lack of prognostic skills at the level of decision making authority					
225	Defective components / assemblies that are fed in to the repair loop will not available for operation, thus affects the optimal usage of critical and expensive spare parts					

Appendix -2

Raw Data

Event	S/Disagree	Disagree	Neutral	Agree	S/Agree
Operational Requirements	2	3	1	11	8
Percentage	8	12	4	44	32
Spare Parts Shortage	3	2	2	5	13
Percentage	12	8	8	20	52
Fleet Readiness	5	8	1	7	4
Percentage	20	32	4	28	16
Workload Increase	1	2	3	8	11
Percentage	4	8	12	32	44
Non Reporting of Small Items	9	7	2	4	3
Percentage	36	28	8	16	12
Snag Identification	8	6	1	7	3
Percentage	32	24	4	28	12
Recovery of Aircraft	4	3	2	11	3
Percentage	16	12	8	44	12
More Labour and Manhours	3	4	1	10	7
Percentage	12	16	4	40	28
Reduced Performance Index	7	6	2	6	4
Percentage	28	24	8	24	16
Vintage Fleet	6	7	0	8	4
Percentage	24	28	0	32	16
Lack of Prognostic Skills	9	4	3	6	3
Percentage	36	16	12	24	12
Counterproductive	4	3	1	9	8
Percentage	16	12	4	36	32
Design Improvement	6	7	2	8	2
Percentage	24	28	8	32	8
Inefficiency in Repair Loop	4	3	1	9	6
Percentage	16	12	4	36	24