Aircraft maintenance manpower shift planning with multiple aircraft maintenance licenced

C I Permatasari1, Yuniaristanto2, W Sutopo2, and M Hisjam2
1Logistics System and Business Laboratory, Universitas Sebelas Maret Surakarta, Indonesia
2Department of Industrial Engineering, Universitas Sebelas Maret Surakarta, Indonesia

E-mail: carinaintan1996@gmail.com

Abstract. Effective manpower shift planning can reduce labor costs, improve service, and customer satisfaction. This can be an (Maintenance, Repair, and Overhaul) MRO industry effort to minimize cost. MRO industry must be able to ensure that labor is always available when there is an incoming service and shift planning. This research will develop a mathematical model that can be used to determine the optimal allocation and shift planning of the manpower. Optimal allocation and shift planning of the manpower will affect the total cost, so a minimum total cost is obtained. For this research the method chosen was Integer Linear Programming (ILP). With the help of software ILOG CPLEX 12.8.0.0. From the results, it was found that there was 30% decrease in cost.

1. Introduction
Shift planning is the process to prepare the manpower schedule to meet service requests at the right time and the right cost. The process involves determining the number of manpower based on licence and service fulfillment [1]. Licence is something that indicates where the manpower has a guarantee to handle certain types of work and service fulfillment is the ability of an industry to satisfy the service to customers. Effective manpower shift planning can reduce labor costs, improve service, and customer satisfaction [2]. Labor costs are a direct component of costs, where a few percent deduction is beneficial [3] and the most important part that forms maintenance cost [4]. Maintenance costs are formed to ensure aircraft safety and reliable shift planning [5]. For industry that engaged in maintenance, repair and overhaul sector, this is very appropriate when reviewed about allocation and shift planning. Cause the role of MRO industry is to provide services with minimum operational costs and optimize comfort [6]. The allocation of the manpower is also needed to minimize cost in addition to using shift planning [7]. Then it is necessary to allocate the right resources to reduce these costs [8]. More than 64% of MRO companies expect the allocated manpower to be right so that it can lead to long-term efficiency [9], [10]. At the MRO company, the manpower allocation is complicated yet important for determining manpower appropriate, work with the services required [11].

Present day, the MRO industry has continuously increased in operational cost which is a direct impact of its effort to improve the comfort of the aircraft. The MRO industry need to be solved at the operational level of the company's management Maintenance, Repair and Overhaul (MRO) is that it must be able to determine the best proportion between workload and labor to minimize operational cost [12]. In addition, management must be able to ensure that labor is always available when there is an incoming service and also the shift planning [13], [14], [15]. Therefore, the MRO industry is trying to develop a mathematical model that can represent the system of allocation manpower to determine the optimal quantity of resource allocation. If the model is successfully developed, the simulation of resource allocation can be done much more easily [16]. For this reason, this research will develop a mathematical model that can be used to determine the optimal allocation and shift planning of labor. This will affect the total cost, so that a minimum total cost is obtained.

GMF AeroAsia (Garuda Maintenance Facility) is one of the MRO industries, where the process of allocating resources to all line maintenance units in GMF AeroAsia is carried out by the operational division at headquarter. The resource allocation process is carried out centrally, where each operational station can request resource but still require approval from planning division in GMF AeroAsia's central. At the moment demand enters, the central (Production Planning and Inventory Control) PPIC division will allocate resources. Allocation in GMF AeroAsia is prioritizes permanent manpower rather than subcontract.

The model of this research using ILP (integer linear programming) method, ILP or Integer Linear Programming is a simple and sometimes practical method to solve integer programming by rounding up the results of decision variables obtained through linear programming. An integer programming problem is mathematical optimization where several or all variables are bound to be integers. In many settings, the term
refers to integer linear programming (ILP), where objective functions and constraints (other than integer constraints) are linear. This approach is easy and practical in terms of effort, time, and costs needed to obtain a solution. In fact, the rounding approach can be a very effective way to deal with large integer programming problems where the cost of the calculation is very high or for the value problem the decision variable solution is very large [17]. ILP has been widely used in research related to optimization. Two decisions are taken to minimize labor costs, namely the right employees to meet customer demands over time and accurate shift planning to translate manpower availability into an adequate shift in structure [18]. Another previous research of ILP implementation is programming for manpower scheduling [19]. Formulated the model for aircraft maintenance for optimization maintenance shift planning [19], [20], [21], [22]. Used the ILP model to solve the problem of minimizing operational costs in aircraft maintenance companies and the output is a maintenance shift planning [3], [7], [23], [24], [25], [26], [27]. Integer linear programming model to allocate the worker, considering annualized hours [28]. The ILP model to solve problems with, pay attention multi skills and duration [1]. Integer Programming model for shift planning problem with multiple shift [29]. Integer Linear Programming (ILP) to shift planning in MRO company with pay attention single skill, shift, and duration [30], [31]. Because of the high operational costs incurred by the MRO industry to carry out a service. Hence, this research trying to determine the optimal of allocation and shift planning manpower in MRO industry to minimize the operational cost by changing the current state into a mathematical model.

2. Method
In this study the business process is described in accordance with the actual situation in the central station of the MRO industry in Indonesia. Central station has 2 services for maintenance the aircraft., That is transit check (TR) and remain overnight (RON). Aircraft that are serviced change type A330, ATR, B737, B777, and CRJ. Each service is supported by two types of technician, namely permanent and subcontract. For technician to be divided according to the licence held, that are Aircraft Maintenance Engineering (AME) and Aircraft Maintenance Technician (AMT). Then the licence will later adjust from the five types of aircraft.

In this research ILP model was chosen to solve the problem of minimizing operational cost. ILP or Integer Linear Programming is a simple and sometimes practical method to solve integer programming by rounding up the results of decision variables obtained through LP. This approach is easy and practical in terms of effort, time and costs needed to obtain a solution. In fact, the rounding approach can be a very effective way to deal with large integer programming problems where the cost of the calculation is very high or for the value problem the decision variable solution is very large [17]. ILP is an optimization model that is suitable for use in this research because it can accommodate a decision variable in the form of costs and can round up.

This research is divided into three stages namely the initial identification stage, the model development stage, and the simulation and model analysis stage

- Initial Identification Stage
  The initial identification stage is the first step in this research process. This stage consists of preliminary studies and objects of study, problem investigation, problem formulation, objectives, and research benefits, study of basic methods and prior research, and determination of problem boundaries and assumptions used.

- Model Development Phase
  At this stage the data collection and processing process is carried out to determine an efficient labor allocation and scheduling model. This stage consists of describing business processes, collecting data, determining system operations and model components, modeling, and model validation.

- Stage Model Optimization and Analysis
  In the optimization stage and model analysis, coding is done using IBM ILOG CPLEX 12.8.0 software and analysis of the model simulation results. This stage consists of model coding and model analysis.

3. Model Formulation
This section describes and explains the formula used in ILP. This model is the development of the previous model about ILP to minimize operational cost [33], [34], [35]. Where the difference from the previous model are dividing manpower based on the licence they have and the allocation of manpower for each service. Here are the variables and parameters used:
\( j \in J \) = job set \\
\( t \in T \) = technician licence type set \\
\( d \in D \) = day set \\
\( s \in S \) = shift set \\
\( c_{ts} \) = hiring costs for technician \( t \) in shift \( s \) (dollar) \\
\( a_{tj} \) = manning (crew size) required for work technician \( t \) in job \( j \) (man) \\
\( r_{tj} \) = duration of work for technician \( t \) in service \( j \) (hour) \\
Introduction decision variable, \\
\( n_{ts} \) = number allocation of technician \( t \) in shift \( s \) (man) \\
\( x_{jtsd} = \begin{cases} 
1, & \text{if job } j \text{ is assigned to technician } t \text{ in shift } s \\
0, & \text{otherwise} 
\end{cases} \) \\
\( d \) = day \\

The formula is made with attention to business process in central station. The objective is to minimize manpower costs.

Minimize: 
\[
\sum_{s \in S} \sum_{t \in T} c_{ts} n_{ts} 
\]
subject to:
\[
n_{ts} - \sum_{j \in J} a_{tj} x_{jtsd} \geq 0 
\]
\[
\sum_{d \in D} \sum_{s \in S} x_{jtsd} = r_{tj} 
\]

The objective function of this model represents the total manpower cost (1). The total manpower cost is formed from the sum of each costs incurred in all shifts and technician licence type. Constraint set (2) ensures the number of workforce allocations that are scheduled to meet the minimum worker limit for each service. Constraint set (3) ensures that the scheduling for each service is the same as the message. So, all services can be resolved according to the planning horizon.

4. Result and Discussion
Hierarchical of technician allocation from this research is described in figure 1.

Figure 1. Hierarchical of Technician Allocation in MRO Industry

From figure 1 is described about the hierarchical of technician allocation in MRO industry. The allocation of manpower using central system. Where the central airport will request manpower in the planning division. Then the planning division will allocate manpower to the airport. The allocation of manpower is allocated to fulfill the 2 services, namely TR and RON. Where each of these services has 3 shifts.

The computational study is using ILOG CPLEX software. There are 2 types of services, transit check and remain overnight, which is divided into 3 shifts. The manpower of each station is divided into 2 types, there are permanent and subcontract. The permanent manpower has the least cost of the other manpower, where in one day the manpower worked for 8 hours. For AME, the labor cost amount of USD 76, AMT amount of USD 68, and subcontract amount of USD 100. Then from each type of the worker, there is a minimum amount that must be fulfilled in providing services. The amount as in table 1. The data was taken in April, 2018.
Table 1. The number of minimum manpower

| Service | AME  | AMT | Sub contract |
|---------|------|-----|-------------|
|         | A330 | ATR | B737        | B777 | CRJ |       |
| TR      | 3    | 0   | 34          | 2    | 1   | 1     |
| RON     | 8    | 0   | 15          | 3    | 3   | 1     |

From the table it can be seen, there are 2 service, namely TR (Transit Check) and RON (Remain Overnight). There are 5 licence for AME, namely A330, ATR, B737, B777, and CRJ. The table above about the number of minimum manpower. They must have 3 manpower for A330, 34 manpower for B737, 2 manpower for B777, 1 manpower for CRJ, 1 manpower for AMT, and 1 manpower for subcontract in TR service. They must have 8 manpower for A330, 15 manpower for B737, 3 manpower for B777, 3 manpower for CRJ, 1 manpower for AMT, and 1 manpower for subcontract in RON service. The duration of work for each service. For transit check (TR) the duration is 21 shifts and for remain overnight (RON) the duration is 7 shifts. Then in table 2, the results of the calculation form of allocation for each shift and type of the manpower to be served are presented.

Table 2. Number allocation of the manpower

| Worker Type | Shift |
|-------------|-------|
|             | 1 2  3|
| A330        | 3 11 3|
| ATR         | 0  0 0|
| AME         |       |
| B737        | 34 49 34|
| B777        | 2  5  2|
| CRJ         | 1  4  1|
| AMT         | 1  2  1|
| Sub-contract| 1  2  1|

The assignment of manpower divided into each shift, as in the table below. The table is explained about the number allocation of the manpower which is divided into each type of worker. There are 3 manpower in shift 1, 11 manpower in shift 2, and 3 manpower in shift 3 for A330. There are 34 manpower in shift 1, 49 manpower in shift 2, and 34 manpower in shift 3 for B737. There are 2 manpower in shift 1, 5 manpower in shift 2, and 2 manpower in shift 3 for B777. There are 1 manpower in shift 1, 4 manpower in shift 2, and 1 manpower in shift 3 for CRJ. There are 1 manpower in shift 1, 2 manpower in shift 2, and 1 manpower in shift 3 for AME. There are 1 manpower in shift 1, 2 manpower in shift 2, and 1 manpower in shift 3 for subcontract. After the allocation of the manpower, the next form is shift scheduling. Table 3 for the assignment manpower at central station.
Table 3. Assignment manpower

| Service Type | Worker Type | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
|--------------|-------------|--------|---------|-----------|----------|--------|----------|--------|
| AME          | A330        | 1      | 2       | 3         | 1        | 2      | 3        | 1      |
| ATR          |            | 11     | 11      | 11        | 11       | 11     | 11       | 11     |
| B737         |            | 0      | 0       | 0         | 0        | 0      | 0        | 0      |
| B777         | CRJ         |        |         | 0         | 0        |        | 0        |        |
| AMT          | SC          |        |         | 0         | 0        |        | 0        |        |

From the result above can be seen about shift planning. From the table, there is a colored and colorless column. For the colored column it indicates that at that time there was a scheduling of manpower on the shift, service and type of manpower. Then, for the colorless column it indicates that at that time there was no scheduling of manpower on the shift, service and type of manpower.

Table 4. Comparison current system with proposed model

| Worker Type | Current System | Proposed Model | Gap |
|-------------|----------------|----------------|-----|
| A330        | 3 11 3 11 11 11 | -8 0 | -8 |
| ATR         | 0 0 0 0 0 0   | 0 0 | 0 0 |
| AME         | B737 34 49 34 49 49 | -15 0 | -15 |
| B777        | 2 5 5 5 5 5   | -3 0 | -3 |
| CRJ         | 1 4 4 4 4 4   | -3 0 | -3 |
| AMT         | 1 2 1 2 2 2   | -1 0 | -1 |
| Sub-contract| 1 2 1 2 2 2   | -1 0 | -1 |

There is a difference between the current system and the proposed model. The difference then called the gap. If the number of proposed manpower is less than the current system or the gap value is negative, then the proposal is considered efficient. Conversely, if the number of proposed manpower is greater than the current workforce or a positive gap value, then the proposal is considered to be less efficient. The amount of manpower can be allocated to another hangar. Then, Figure 2 presents a comparison of current costs with the proposed model.
Figure 2. Comparison of Total Labor Costs Based on the Proposed Model and Current System

From the figure 2 the cost from the model amount of USD 1,560. A decrease of 30% from the current cost. So, that industry can save USD 668 of the labor cost. Saving cost established cause manpower allocation based each licence and shift planning. This output can help the planning division in manpower allocation in an emergency situation in the form of a simulation.

5. Conclusion
From the result of the research it can be concluded that the ILP model can be used to solve optimization problem. The purpose of this research was also achieved, namely minimizing operational cost by decrease amount of 30% and the result shown in ILOG CPLEX amount of USD 1.560. In addition, there is also an optimal allocation of labor and shift planning using the software.

For future studies need to be explained more about overtime, delays of the worker, and manpower changes.

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