Resource Allocation Model to Find Optimal Allocation of Workforce, Material, and Tools in an Aircraft Line Maintenance

Rillo S. Wahyudin, Wahyudi Sutopo, Muh Hisjam, R. Suryo Hardiono

***Abstract*—This paper presents a multi-objective mixed-integer linear programming (MILP) optimization model aimed at finding optimal resource allocation based on the study of an aircraft line maintenance. Some research had already been done to develop such model, but they mainly focus only on finding the optimal allocation based on man-hour needs without considering the related-cost, such as different hiring cost. Assignment of the workforce is presumably highlighted only in respective skills or task with no consideration of least hiring cost. Most research also considers only one resource in the model, which commonly is the workforce. This study proposes a resource allocation model in an aircraft line maintenance, which involves not only the workforce but also the material and tools. In this paper, we also accommodate the relationship between stations in terms of the possibility of resource transfers amongst them. The model is solved using the IBM® ILOG®CPLEX software. The result shows that the proposed model can be used to find an optimal resource allocation and the minimum total cost.**

***Index Terms*— Resource Allocation, MILP, Aircraft Line Maintenance, Least Hiring Cost**

I. Introduction

LINE maintenance, which alternatively called as a short routine maintenance, includes regular short inspections of an aircraft between arrival and departure at an airport [1]-[2]. In some aircraft maintenance companies, line maintenance also includes a daily inspection aimed for checking a remaining overnight air fleet. In an aircraft line maintenance, flight schedule has basically become the basis of the master plan [2]. Once a flight schedule is established, the maintenance company can assign a maintenance schedule to each maintenance station. Based on this schedule, the company then builds a staff scheduling model, considering the fleet type, specific client requests, etc. [1]-[3]. Furthermore, maintenance schedule will also consider type of service, the capabilities of the specific station, and other resources such as tooling, hangar, etc. [1].

Resource allocation has vastly become salient in line maintenance. Over 64% of the aircraft maintenance company is expected to set the efficiency of resources as their main goals in the future time [1], [10]. The employees working in this field are highly qualified and specially accredited. Therefore, the supply of new employees is limited [14]. At the same time, the wages of such labor are high. Consequently, the capacities have to be planned as accurately as possible. This comes to no surprise as well since the cost of line maintenance is mostly attributed to labor costs [6], [10]. Workforce planning is thus crucial in improving system performance, efficiency and minimizing costs. [12].

The resource allocation supply chain basically involves two main processes: resource procurement and resource transfer. Resource procurement begins with the resource planning based on the historical data or demand forecasting in which flight schedule has generally become the basis of the planning [1], [3]. Flight schedule is in other words the demand/load. After the load is known, management then builds a staffing model for that station, which specifies the manpower requirement and scheduling to meet the schedule's objectives [1], [9], [12]. In along with workforce resource, material and tools are also becoming the allocated resources [2], [16]. The allocation of these two resources is no different to the workforce where basically the load from schedules is specified according to its fleet type and service to determine the material and tools needs [9], [16].

The next step is the resource transfer. In this process, the resource is transferred and assigned to every station with regard to their respective actual load. What sets the allocation of workforce and material and tools apart is the approach of the allocation. In allocating the workforce, task, skills, and man-hour are what vastly used as the allocation approach [6], [11], [12]. Meanwhile, in allocating the material and tools, the designated number of allocations is defined in unit approach [2].

Several research studies have attempted to develop a resource allocation model in an aircraft line maintenance. Most research basically only considers workforce resource in the model. The allocation approach is usually with regard to task or skills of the respective workforce [5], [6], [7]. Some research also considers part or material resource into their model, but likewise, it only includes the part or material resource without considering any other resources,

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like workforce, altogether in the model [2], [16]. In this paper, we try to develop a resource allocation model in an aircraft line maintenance, which involves not only the workforce but also the material and tools. We also accommodate the relationship between stations in terms of the possibility of resource transfers amongst them. The model will generate an output in the form of number of workforce needed based on man-hour approach, not a schedule in a timely manner like most of existing research. The allocation of material and tools, in the other hand, will be in number of units needed.

This paper is organized as follows. In Section I, we describe the background of our research and describe the real problem. In Section II, we describe the methods. In Section III, we provide the mathematical model formulation. In section IV we provide discussion and In Section V, we deliver the conclusion and future research.

II. Methodology

A. System Description

We illustrate our model using real life system and data from a disguised aircraft maintenance company in Indonesia. The scheme of the model is depicted in fig. 1 below. The resource allocation is carried out by a planning division in company's central office. All stations only act as a feeder assigned to transfer information about its current load or demand, not as the resource planner. The operational station spreaded out over the land can request additional resources or submit its own resource allocation scheme, but the validation is still being made by the planning division in central office.

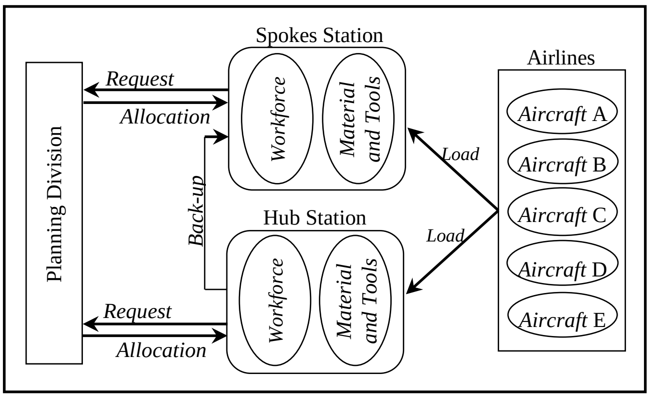

Fig. 1. The Resource Allocation Model used in this paper

There are two types of operational stations, i.e. spokes station and hub station. Spokes station is a unit located in spokes airport where basically the existing air traffic will be bound for the hub airport (traffic feeder). Spokes airports typically have lower load/demand than hub airports do. Hub station is a unit located in hub airport which acts as the hub of several airports that become its spokes. In other words, a hub airport oversees several spokes airports. Besides being a traffic center, hub station also plays to be a back-up resource of workforce to spokes stations. If a spokes station experiencing a shortage of workforce resources, the station which becomes the hub can provide its available or remaining workforce to spokes stations requiring them.

The demand/ load is generated from the airlines. Load types are categorized by the type of aircraft used by the airline. Load arrives based on a successive span of time or is assumed not experiencing a clash load in terms of time occurrence. Loads are then reclassified by types of service. There are three services provided in the aircraft line maintenance: before departure check (BD), transit check (TR), and daily check (DY). Each service has its own respective standard man-hour and it varies depending on its type of load. By multiplying the total load with its respective standard man-hour per services, the total man-hour needed will be obtained.

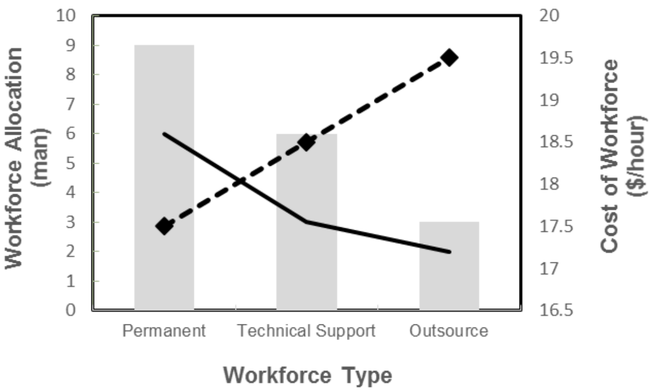

Fig. 2. Least hiring cost scheme for workforce assignment. The gray column charts indicate the number of workforce that is allocated (Left Axis). The square point shows the cost of workforce per person (Right Axis)., while the dash line shows the trend. The dark line shows the trend of allocation, where the least expensive workforce is allocated more than the expensive one.

Types of workforce are classified into 3 categories: permanent worker, technical support, and outsource worker. In the assignment procedure, permanent worker poses the highest priority of selection. This is because the cost of hiring a permanent worker is the least expensive as compared to the other two. The number of permanent workers is limited in accordance with the number of employees owned by the company. On the other hand, technical support is workers assigned from a hub station to a spokes station under its subordinate. Technical support is taken from the permanent workers at the hub station who is not on the assignment. The availability of technical support is entirely dependent to the remaining permanent workers poses by the hub station. While outsource worker is a workforce hired from outside of the company or outsourced. Outsource worker is hired on a short term in order to meet the load requirements that cannot be met by one station's capacity at the time. The hiring cost of outsource workers is generally the highest among others. This leads outsource workers to be practically the least priority in workforce allocation. In contrast to the permanent workers, outsource workers do not have limits for specified amount or are assumed always available.

In materials and tools allocation, both resource needs are aggregated into a single one unit. Aggregation of materials and tools is further classified based on the type of load and type of services. This aggregation is to simplify the determination of the allocation of materials and tools which involves a lot of types and variants. Every service for every load may impose different kind of aggregation. The provided aggregate of materials and tools is not limited to a specified amount or is always available.

B. Variables and Notation

The variables and parameters used in this paper are shown in table I, while the decision variables are shown in table II. There are seven decision variables in the model. The decision variable is generally to find the optimal allocation of workforce, material, and tools in order to satisfy the load. The performance criteria of the model is to minimize the total allocation cost..

TABLE I
VARIABLES AND PARAMETERS

Symbol	Denoted
$i \in I$	hub station set
$j \in J$	spokes station set
$k \in K$	load set
$l \in L$	service set
$m \in M$	material and tools set
α	modifier coefficient of number of workers into *manhour* (minute)
f_{jk}	hiring costs of permanent workers in spokes station *j* for *load k* (dollar)
g_{jk}	hiring costs of technical support in spokes station *j* for *load k* (dollar)
h_{jk}	hiring costs of subcontract workers in spokes station *j* for *load k* (dollar)
f_{ik}	hiring costs of permanent workers in hub station *i* for *load k* (dollar)
h_{ik}	hiring costs of outsource workers in hub station *i* for *load k* (dollar)
$D_j^{(kl)}$	number of load *k* in spokes station *j* for service *l* (man)
ϖ_{kl}	service time of *load k* and service *l* (minute)
S_j	number permanent workers available in spokes station *j* (man)
S_i	number permanent workers available in hub station *i* (man)
$D_i^{(kl)}$	number of load *k* in hub station *j* for service *l* (unit)
O_m	costs of material *m* (dollar)

TABLE II
DECISION VARIABLES

Symbol	Denoted
Q_{jt}	number of allocation of permanent workers in spokes station *j* for *load k* (man)
b_{jk}	number of allocation of technical support in spokes station *j* for *load k* (man)
q_{jk}	number of allocation of outsource workers in spokes station *j* for *load k* (man)
Q_{ik}	number of allocation of permanent workers in hub station *i* for *load k* (man)
q_{ik}	number of allocation of outsource workers in hub station *i* for *load k* (man)
$M_j^{(klm)}$	number of allocation of material and tools *m* in spokes station *j* for *load k,* and service *l* (unit)
$M_i^{(klm)}$	number of allocation of material and tools *m* in hub station *i* for *load k,* and service *l* (unit)

III. MODEL FORMULATION

The resource allocation is carried out by the planning division in collaboration with both spokes and hub stations which provide the information about recent and actual load of their respective stations. In order to obtain the optimal cost and resource allocation, resource selection in terms of least hiring cost, man-hour needs and availability, number of units of material and tool needs are taken into the rules of allocation. The objective is involving two stakeholders: the spokes station and the hub station.

A. The Resource Allocation

The incoming load will generate the resource needs of workforce, material and tools. When loads come to a station, each of them must be fulfilled entirely. There should not be any unfulfilled or unsatisfied load. Every load must be met whether using the resource from inside of the station or outside of the station. The fulfillment of one load will consume a certain amount of man-hour and a unit of material and tools aggregate. Man-hour consumptions as well as the material and tools aggregate vary according to load type and the service it takes.

The workforce needs depends on the number of man-hour needed to fulfil all loads. Permanent and outsource workers provide a total of 6 effective working-hour a day. While technical support provide 4.5 effective working-hour a day. The available working hour in-station is generated only from the total working hour of the permanent workers. If the available working hour in-station is not sufficient to fulfill the man-hour needed to satisfy all loads, the additional out-station man-hour should be provided to overcome the deficit. It may come whether from the technical support or the outsource worker. For hubs station, only outsource worker feasible to be allocated apart from the permanent workers.

The relationship between the allocated man-hour and the numbers of man-hour needed to fulfil the load is formulated in Eq. (1) and Eq (2) below. Both Eq. (1) and Eq. (2) expresses that the total man-hour to be allocated must be equal or greater than the total man-hour needed to fulfil the load. Eq. (1) represents the spokes station while Eq. (2) represents the hub stations. Eq. (3) and Eq (4) formulates the relationship between numbers of material and tools to be allocated and numbers of unit needed. Both equations expresses that the allocation of material and tools should be equal or greater than the numbers of unit needed. Eq. (3) represents the spokes station while Eq. (4) represents the hub stations. Unlike the workforce, the availability of material and tools resource is assumed to be always available.

$$\sum_{j\in J}\sum_{k\in K} Q_{jk}\alpha \ \sum_{j\in J}\sum_{k\in K} b_{jk}\alpha + \sum_{j\in J}\sum_{k\in K} q_{jk}\alpha \geq \sum_{j\in J}\sum_{k\in K}\sum_{l\in L} D_j^{(kl)}\varpi_{kl} \tag{1}$$

$$\sum_{i\in I}\sum_{k\in K} Q_{ik}\alpha_k + \sum_{i\in I}\sum_{k\in K} q_{ik}\alpha_k \geq \sum_{i\in I}\sum_{k\in K}\sum_{l\in L} D_i^{(kl)}\varpi_{kl} \tag{2}$$

$$\sum_{j\in J}\sum_{k\in K}\sum_{l\in L}\sum_{m\in M} M_j^{(klm)} \geq \sum_{j\in J}\sum_{k\in K}\sum_{l\in L} D_j^{(kl)} \tag{3}$$

$$\sum_{i\in I}\sum_{k\in K}\sum_{l\in L}\sum_{m\in M} M_i^{(klm)} \geq \sum_{i\in J}\sum_{k\in K}\sum_{l\in L} D_i^{(kl)} \tag{4}$$

B. Spokes Station Objectives

Spokes station's objective is to minimize the total allocation cost. The cost of allocation is obtained by enumerating all resource allocation cost, making up the total

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cost. In spokes station, there are four kinds of resources involved: permanent worker, technical support, outsource worker, and material and tools. The spokes station's objectives can be formulated as in Eq. (5). The first three terms represent the cost of the workforce, which consists of permanent workers cost, technical support cost, and outsource workers cost. Though the source is taken from the hubs, the cost of technical support is charged to the beneficiaries, which in this case is the spokes station. The last remaining term of the equation represents the total allocation cost of material and tools.

$$\sum_{j\in J}\sum_{k\in K} Q_{jk}\alpha \;\; f_{jk} + \sum_{j\in J}\sum_{k\in K} b_{jk}\alpha_k g_{jk} + \sum_{j\in J}\sum_{k\in K} q_{jk}\alpha \;\; h_{jk} + \sum_{j\in J}\sum_{k\in K}\sum_{l\in L}\sum_{m\in M} M_j^{(klm)} o_m \quad (5)$$

C. Hub Station Objectives

The hub station's objective is to minimize total allocation cost which in other words optimizing the resource allocation. Unlike spokes station, the hub station comprises only three kinds of resources: permanent worker, outsource worker, and material and tools. The technical support is not taken into the hub station objective consideration since it is basically only feasible to spokes station. Though the source of technical supports is originated from the hub station, the expenses of the workforce are charged to the spokes station, which benefits the resource, not the original hub stations assigned the workforce. Hence the hub station objective can be formulated as in Eq (6).

$$\sum_{i\in I}\sum_{k\in K} Q_{ik}\alpha \;\; f_{ik} + \sum_{i\in I}\sum_{k\in K} q_{ik}\alpha \;\; h_{ik} + \sum_{i\in I}\sum_{k\in K}\sum_{l\in L}\sum_{m\in M} M_i^{(klm)} o_m \quad (6)$$

The first term of Eq. (6) is the first objective of hub station, which is to minimize the permanent worker cost. The second term presents the second objective of hub station, which is to minimize the outsource worker cost. While the last term defines the third objective which is to minimize the material and tools cost. The multi objectives of Eq. (7) are to minimize both allocation of spokes station and hub station. It comprises of two terms, Z1 represents the total allocation cost of spokes airport and Z2 represents the total allocation cost of hub station.

$$\text{Max. } Z1 + Z2 \quad (7)$$

$$Z1 = \sum_{j\in J}\sum_{k\in K} Q_{jk}\alpha \;\; f_{jk} + \sum_{j\in J}\sum_{k\in K} b_{jk}\alpha_k g_{jk} + \sum_{j\in J}\sum_{k\in K} q_{jk}\alpha \;\; h_{jk} + \sum_{j\in J}\sum_{k\in K}\sum_{l\in L}\sum_{m\in M} M_j^{(klm)} o_m \quad (8)$$

$$Z2 = \sum_{i\in I}\sum_{k\in K} Q_{ik}\alpha \;\; f_{ik} + \sum_{i\in I}\sum_{k\in K} q_{ik}\alpha \;\; h_{ik} + \sum_{i\in I}\sum_{k\in K}\sum_{l\in L}\sum_{m\in M} M_i^{(klm)} o_m \quad (9)$$

Subject to:

$$\sum_{j\in J}\sum_{k\in K} Q_{jk}\alpha \;\; \sum_{j\in J}\sum_{k\in K} b_{jk}\alpha \;\; + \sum_{j\in J}\sum_{k\in K} q_{jk}\alpha \;\; \geq \sum_{j\in J}\sum_{k\in K}\sum_{l\in L} D_j^{(kl)} \varpi_{kl} \quad (10)$$

$$\sum_{j\in J}\sum_{k\in K} Q_{jk} \leq S_j \quad (11)$$

$$\sum_{i\in I}\sum_{k\in K} Q_{ik}\alpha_k + \sum_{i\in I}\sum_{k\in K} q_{ik}\alpha_k \geq \sum_{i\in I}\sum_{k\in K}\sum_{l\in L} D_i^{(kl)} \varpi_{kl} \quad (12)$$

$$\sum_{j\in J}\sum_{k\in K}\sum_{l\in L}\sum_{m\in M} M_j^{(klm)} \geq \sum_{j\in J}\sum_{k\in K}\sum_{l\in L} D_j^{(kl)} \quad (13)$$

$$\sum_{i\in I}\sum_{k\in K}\sum_{l\in L}\sum_{m\in M} M_i^{(klm)} \geq \sum_{i\in J}\sum_{k\in K}\sum_{l\in L} D_i^{(kl)} \quad (14)$$

$$\sum_{i\in I}\sum_{k\in K} Q_{ik} + \sum_{j\in J}\sum_{k\in K} b_{jk} \leq S_i \quad (15)$$

$$Q_{jt}, b_{jk,} q_{jk}, Q_{it}, q_{ik}, M_j^{(klm)}, M_i^{(klm)} \in \mathbb{Z}_+ \quad (16)$$

The available permanent workers in spokes stations is expressed in Eq. (11). This expression is to ensure that the allocation of permanent workers does not exceed the supply the station house. Similar to Eq. (11), Eq. (15) also expresses the available permanent workers, but for hubs stations. Since hub stations are able to send some of their permanent workers to the spokes station as a technical support, the available permanent workers will be deducted by the number of technical support assigned to spokes stations. The last equation is utilized to force non-negativity for all decision variables (Eq. 16).

IV. Discussion

For computational study, IBM® ILOG® CPLEX Academic version is used as a tool for solving the model. ILOG® CPLEX is basically similar to some other common programming softwares, however ILOG® CPLEX is particularly designed to be capable of solving, mostly, about optimization and various equations or modeling.

In this study, there are a total of 4 hub stations and 8 spokes stations with *i* = Hub 1, Hub 2, Hub 3, Hub 4; and *j* = Spo 1, Spo 2, Spo 3, Spo 4, Spo 5, Spo 6, Spo 7, Spo 8. Hub 1 subordinates Spo 1 and Spo 2 while Hub 2 subordinates Spo 3, Spo 4, and Spo 5. Hub 3 subordinates Spo 6 and Spo 7, and Hub 4 subordinates Spo 8.

TABLE III
COST OF MATERIAL

	Material Type														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cost ($/unit)	6	5	34	8	5	34	6	5	34	6	5	34	6	5	34

Material and tools comprise 15 types of aggregate with *m* = Mat 1, Mat 2, Mat 3, Mat 4, Mat 5, Mat 6, Mat 7, Mat

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8, Mat 9, Mat 10, Mat 11, Mat 12, Mat 13, Mat 14 and Mat 15. Each material and tools aggregate has its own respective cost shown in table III while cost of workforce is shown in table IV.

The permanent worker's hiring cost is the least expensive among the others. Technical supports' hiring cost stands next to permanent workers as the second least expensive cost. Hub stations do not have a technical support allocation since it is not eligible for them to have one. While outsource workers come at last having the highest hiring cost.

TABLE IV
COST OF WORKFORCE

Station	Permanent Worker ($/hour)	Technical Support ($/hour)	Outsource Worker ($/hour)
Hub 1	8.5	N/A	25.5
Spo 1	8.5	16.5	25.5
Spo 2	8.5	24.5	25.5
Hub 2	8.5	N/A	25.5
Spo 3	8.5	19.5	25.5
Spo 4	8.5	18.5	25.5
Spo 5	8.5	17.5	25.5
Hub 3	8.5	N/A	25.5
Spo 6	8.5	17.5	25.5
Spo 7	8.5	16.5	25.5
Hub 4	8.5	N/A	25.5
Spo 8	8.5	21.5	25.5

On the other hand, there are 5 types of load with k = A, B, C, D, E while service comprises three types of service with l = DY, TR, BD. Not all stations have every type of load and service. Some stations may only have two or three loads and several service types. Load data are shown in table V below.

TABLE V
LOAD DATA

Load	Service	Station											
		Hub 1	Spo 1	Spo 2	Hub 2	Spo 3	Spo 4	Spo 5	Hub 3	Spo 6	Spo 7	Hub 4	Spo 8
A	TR	44	16	12	28	16	8	16	68	48	32	236	8
	BD	0	8	0	4	4	0	4	20	4	4	4	4
	DY	4	4	0	4	4	0	4	16	4	4	8	4
B	TR	0	8	0	24	12	8	12	40	4	8	32	4
	BD	4	0	0	12	0	0	0	0	0	0	20	8
	DY	4	0	0	12	0	0	0	0	0	0	20	8
C	TR	0	0	0	0	0	0	0	0	0	0	0	0
	BD	0	0	0	0	0	0	0	0	0	0	4	0
	DY	0	0	0	0	0	0	0	0	0	0	4	0
D	TR	12	4	0	20	32	0	16	116	4	8	20	0
	BD	0	0	0	0	4	0	0	4	0	0	0	0
	DY	0	0	0	0	8	0	0	4	0	0	0	0
E	TR	0	0	16	0	0	0	0	0	0	0	0	0
	BD	0	0	4	0	0	0	0	0	0	0	0	0
	DY	0	0	4	0	0	0	0	0	0	0	0	0

The results of the model is depicted in a graph in Fig. 3 and in a table in table VI. It is found that all allocated workforce has satisfied the total man-hour needed and all allocated material and tools has satisfied the total unit needed to serve the load. Based on the result, the average slack or remaining unused man-hour of the allocated workforce is in its most possible closest number to the man-hour needed, which is no greater than 8%. While the slack of material and tools remains 0. From the following Fig. 3, it can be inferred that some stations are still able to meet the man-hour needs from the in-station workforce resource while some is not.

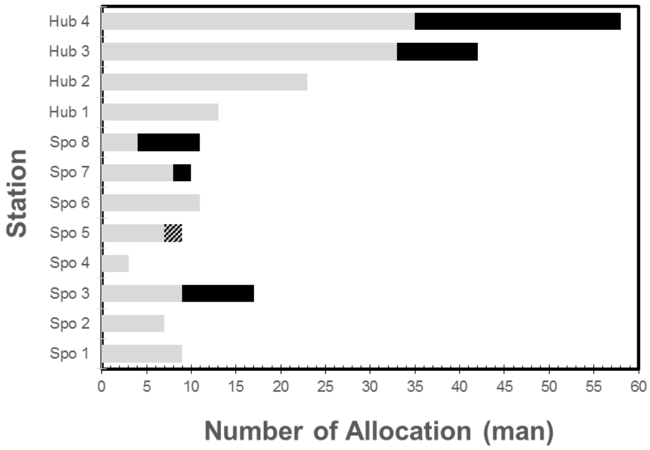

Fig. 3. Allocation of workforce. Black columns indicate outsource worker allocation. While grayscale column and dash-filled columns indicate permanent worker and technical support allocation respectively.

TABLE VI
ALLOCATION OF MATERIAL AND TOOLS

Material Type	Spo 1	Spo 2	Spo 3	Spo 4	Spo 5	Spo 6	Spo 7	Spo 8	Hub 1	Hub 2	Hub 3	Hub 4
Mat 1	16	12	16	8	16	48	32	8	44	28	68	236
Mat 2	8	0	4	0	4	4	4	4	0	4	20	4
Mat 3	4	0	4	0	4	4	4	4	4	4	16	8
Mat 4	8	0	12	8	12	4	8	4	0	24	40	32
Mat 5	0	0	0	0	0	0	0	8	4	12	0	20
Mat 6	0	0	0	0	0	0	0	8	4	12	0	20
Mat 7	0	0	0	0	0	0	0	0	0	0	0	0
Mat 8	0	0	0	0	0	0	0	0	0	0	0	4
Mat 9	0	0	0	0	0	0	0	0	0	0	0	4
Mat 10	4	0	32	0	16	4	8	0	12	20	116	20
Mat 11	0	0	4	0	0	0	0	0	0	0	4	0
Mat 12	0	0	8	0	0	0	0	0	0	0	4	0
Mat 13	0	16	0	0	0	0	0	0	0	0	0	0
Mat 14	0	4	0	0	0	0	0	0	0	0	0	0
Mat 15	0	4	0	0	0	0	0	0	0	0	0	0

The allocation of the workforce in stations experiencing a man-hour shortage is partially covered by the outsource workforce, and some other station is covering the shortage through workforce transfer of technical support from the hub. This occurs especially in Spo 5 in which its hub, the Hub 1, still has a remaining unassigned workforce. The allocation of material and tools is generally made up by Mat 1 about 47%, followed by Mat 10 and Mat 4 with percentage of 19% and 13% respectively. The minimum total allocation cost of workforce, material, and tools is obtained at USD 31,880.

V. CONCLUSION

In this paper, we propose a resource allocation model for an aircraft line maintenance considering the resource of workforce, material, and tools. Multi-objective optimization programming was employed to determine the optimal resource allocation of the workforce together with the allocation of material and tools. The result shows that the model is capable to find the optimal solution in along with the minimum allocation cost. The resource allocation model determines not only the allocation of the workforce, but also the allocation of material and tools. The relationship of a spokes and a hub station in terms of resource transfer can also be explained which in so many models the relationship has never been taken into consideration.

There are some extensions of this study that could be derived to elaborate the formulation of this proposed mathematical model, such as the possibility in which the incoming loads arrives concurrently. This will lead to some modification of constraint in the model because it is not possible for the workforce to serve several loads at the same time. In the future, the addition of several more types of worker in terms of skill capability, apart from the occurrence of different hiring cost, may also be taken into consideration to make the model more versatile.

VI. Acknowledgment

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