

Calculation Of Manhours and Labour Requirements for Non-Destructive Tests at Wheel and Brake Shop Using Vogel's Approximation Method (Vam)

Hardanny*¹, Mufti Arifin², Ayu Martina³

Marshal Suryadarma Aerospace University Jl. Protokol Halim Perdanakusuma-East Jakarta, Jakarta.

Article Info	ABSTRACT
<p>Article History: Submitted: 30 Agustus 2024 Revised : 11 January 2025 Accepted : 28 February 2025</p> <hr/> <p>Keywords: <i>Maintanance, Non-Destructive Test, Manhours, Wheel and brake Shop, Vogel Approximated Method</i></p>	<p>An airplane is a means of air transportation used to transport passengers and goods from one place to another. Just like other transportation in general, aircraft also require maintenance. One of the aircraft maintenance activities is maintenance on the Main Wheel and Brake of the aircraft which has an important role on the aircraft. In Wheel and Brake maintenance is examined in detail with various methods, one of the methods used in Wheel and Brake maintenance is the Non-Destructive Test (NDT) method. In this case, to carry out the Non-Destructive Test inspection the company must be able to distribute Manpower needs with a good and appropriate Manhour. This study aims to optimize the allocation of manpower and time (manhour) in the implementation of Non-Destructive Test (NDT) inspections at the Wheel and Brake Shop using the Vogel Approximation Method (VAM), resulting in savings in human resources and increased efficiency in the implementation of Non-Destructive Test (NDT) inspections at the Wheel and Brake Shop. From the results of the analysis, it can be seen the distribution of manhour on various NDT component jobs and it is found that using the Vogel's approximation method (VAM) calculation gets a manhour of 588.3 manhours. it is known that by using the VAM method the difference obtained is 47.7 manhours faster than the actual data which is 636 manhours with a percentage of 13.2% faster.</p>

Copyright © 2025 Author(s). All rights reserved

Correspondence Author:

Hardanny
Email:
Hardanny737@gmail.com

INTRODUCTION

Aircraft serve as a vital means of air transportation for carrying passengers and cargo from one location to another. Like other modes of transportation, aircraft also require routine maintenance to ensure safety and airworthiness. In accordance with Indonesian Law No. 1 of 2009, Article 46, it is mandated that every aircraft operator must maintain aircraft, aircraft engines, propellers, and components to ensure continuous reliability and airworthiness [1]. One of the critical maintenance activities in aircraft operations involves the Main Wheel and Brake systems. These components bear substantial dynamic loads during take-off and landing phases, thus necessitating specialized inspections. Such inspections are typically carried out in designated Wheel and Brake Shops using advanced diagnostic techniques, one of which is the Non-Destructive Test (NDT). NDT enables the detection of cracks and defects without damaging the component being tested, allowing technicians to take timely corrective actions according to established standards [3].

Given the technical and time-sensitive nature of these inspections, the effective distribution of labor (manpower) and time (manhours) is essential for operational efficiency. To meet this need, the present study explores the optimal allocation of manpower and manhours for NDT tasks in a Wheel and Brake Shop using the Vogel's Approximation Method (VAM). VAM is a technique within operational research used for solving transportation problems by minimizing costs through heuristic allocation strategies. Compared to other optimization methods such as the Northwest Corner and Least Cost Method, VAM often yields more efficient solutions due to its ability to consider opportunity costs in the allocation process [7]. This method has been shown to reduce unnecessary costs and better identify optimal distributions [8], making it suitable for application in maintenance labor allocation scenarios where both time and resource optimization are paramount. Therefore, the objective of this research is to identify the optimal allocation of manpower and manhours for Non-Destructive Test activities in the Wheel and Brake Shop, leveraging the advantages offered by the Vogel's Approximation Method.

METHODS

This research follows a systematic approach illustrated in the flowchart in Figure 1. It begins with a literature study related to Non-Destructive Testing (NDT), aircraft maintenance, manpower allocation, and optimization methods including the Vogel's Approximation Method (VAM). The study also involves data collection from actual NDT Report Logbooks used in aircraft maintenance operations.

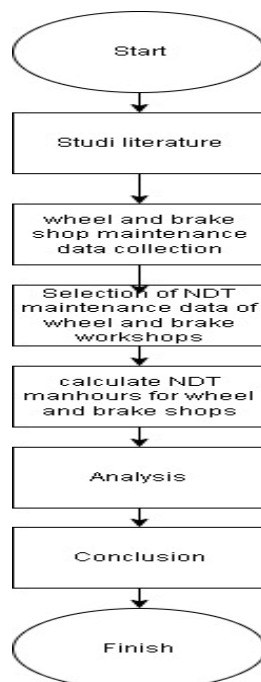


Figure 1 Research Flowchart

2.1 Maintenance

Maintenance is an effort to preserve an asset in a serviceable condition. In the aviation industry, maintenance is defined as the actions required to ensure the continued airworthiness of an aircraft. These actions may consist of a single type of maintenance activity or a combination thereof, including overhaul, inspection, repair, and component testing [2]. Maintenance activities are generally categorized into two types: scheduled maintenance and unscheduled maintenance. Scheduled maintenance refers to planned preventive or corrective tasks, whereas unscheduled maintenance occurs without prior planning and is typically performed in response to unexpected faults. Scheduled maintenance itself includes preventive maintenance, which aims to avoid failures before they occur, and corrective maintenance, which involves restoring a system after a failure has been identified. Figure 2 illustrates an example of scheduled maintenance being conducted in an aircraft hangar, where technicians perform routine inspections and servicing to ensure compliance with airworthiness standards.



Figure 2 Scheduled Maintenance being conducted in an aircraft hangar[2]

2.2 Non-Destructive Test (NDT)

Non-Destructive Testing (NDT) is a physical examination method applied to materials or components to detect defects without causing damage or destruction to the test object. The primary objective of NDT is to identify flaws using specific procedures conducted by a qualified operator or technician. The outcome of the test determines whether a component should be replaced or repaired, based on the extent of the detected defects, while still referring to established standards [3]. There are various NDT techniques commonly used in the inspection process, including visual inspection, liquid penetrant testing, magnetic particle inspection, ultrasonic testing, eddy current testing, and radiographic testing [3]. Figure 3 displays the application of NDT on an aircraft wheel component.

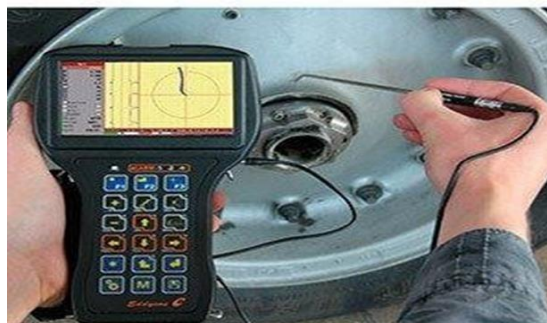


Figure 3 the application of NDT on an aircraft wheel component[3]

2.3 Wheels and Brake Shops

The wheel and brake shop in an aircraft maintenance facility is responsible for servicing and repairing the aircraft's wheel and brake systems. The operational workflow of this shop includes several critical procedures [4]:

1. Initial inspection – During scheduled maintenance, the wheels and braking systems are examined for signs of wear and damage.
2. Tire replacement – If the aircraft tires show signs of wear or damage, they are replaced with new ones that comply with regulatory standards.
3. Brake system inspection – This includes checking the brake pads, discs, calipers, and other related components.
4. Wheel repair – If any excessive wear or damage is found on the wheel assemblies, necessary repairs or replacements are carried out accordingly.
5. Non-Destructive Testing (NDT) – Certain components undergo NDT methods such as ultrasonic, penetrant, or radiographic testing to detect internal or non-visible defects.
6. Functional testing and certification – After all repairs and replacements are completed, the wheel and brake systems undergo functional testing to ensure proper operation, followed by certification before being returned to service on the aircraft.

2.4 Multiplier Factor

In mathematics, the concept of a multiplier factor is fundamental and widely applied in various types of calculations. A multiplier factor refers to a number or variable used to multiply another number or mathematical expression [5]. It may take the form of an integer, decimal, fraction, or even a symbolic variable. Multiplier factors are utilized across different mathematical operations, including addition, subtraction, multiplication, and division [6]. A common example of a multiplier is a decimal value such as 0.5, 1.0, 1.3, 1.75, or 2.9. As the name implies, the primary function of a multiplier factor is to scale or adjust a value by multiplying it.

2.5 Vogel's Approximation Method (Vam)

Vogel's Approximation Method (VAM) is one of the methods found within the field of operations research, specifically under the category of transportation problems. It is a widely used approach to determine the minimum cost required for transportation-related optimization issues [7]. This method often produces better solutions compared to other basic allocation methods and is particularly effective in identifying and minimizing unnecessary costs. The VAM follows a systematic set of steps to achieve an optimal allocation [8]:

1. Identify the two lowest costs in each row and column, then calculate the difference between them.
2. Select the row or column with the highest difference (penalty). If multiple rows or columns share the same highest difference, select one arbitrarily.
3. Allocate as much as possible to the cell with the lowest cost in the selected row or column, based on available supply and demand.
4. Once a row or column is fully allocated, it is eliminated from further consideration in subsequent steps.
5. Repeat steps 1 through 4 until all supply and demand requirements are fully allocated.

RESULT AND DISCUSSION

After collecting data from the NDT Report Logbook, the information was filtered and processed. The processed data included types of NDT component tasks, work order numbers, estimated manhours, and actual manhours. Table 3.1 presents the organized data used in the analysis.

Work Order No.	Deskripsi Inspeksi NDT	Est. ManHours	Actual Manhours
1116812	Main Wheel	1.50	2.0
1117061	Nose Wheel	1.50	1.75
1402356	Torque Bar	1.0	1.20
1383667	Torque Bar Bolt	0.40	1.0
1365000	Bolt/Screw	0.30	1.0
1394447	Pin Adjuster	0.30	1.0

Table 1 NDT report logbook

Following data collection and filtering, tasks were grouped based on component type, total job count, estimated manhours, and actual manhours. As shown in Table 2, the total estimated manhours amounted to 400, while the actual manhours totaled 637. The totals were obtained by multiplying each component's estimated or actual manhours by its respective job frequency. The estimated manhours were used as demand input in the VAM simulation, while actual manhours served as a reference for evaluating the results.

Komponen	Pekerjaan	Estimated Manhours	Actual Manhours
Main wheel	55	82	110
Nose Wheel	25	37	44
Torque Bar	183	183	219
Torque Bar Bolt	184	74	184
Screw/Bolt	60	18	60
Pin Adjuster	20	6	20
Total	527	400	637

Table 2 NDT Work Grouping

It can be seen in Table 2 the total estimated manhours and actual manhours of each component work for est manhours total 400 manhours and actual manhours total 637 manhours. To get the total manhours from est and actual, it is obtained by means of est manhours for each component x the total work of each component and vice versa with actual manhours. Estimated manhours is what will be used for simulation calculations in this study. The study categorized personnel into five groups, comprising Junior Mechanics, Senior Mechanics, and Engineers. These groupings were derived from interviews with NDT personnel. Each worker was assumed to work five days per week, four hours per day, totaling 20 manhours per week. Therefore, each group was assigned a weekly manpower supply of 20 manhours, as shown in Table 3 These personnel served as the "supply" side in the transportation model.

JABATAN	KELOMPOK				
	1	2	3	4	5
ENGINER	1	1	1	1	1
SENIOR	3	2	4	1	1
JUNIOR	2	-	-	2	-
TOTAL	6	3	5	4	2
MANHOUR	120	60	100	80	40

Table 3 Personel Grouping

In aircraft maintenance, labor cost is determined by the number of manhours used, in addition to material costs. Several variables influence these costs, including personnel skill levels, task complexity, tool positioning, and material availability. Each personnel group was assigned a different

multiplier factor to reflect these variables, represented by decimal values. These multipliers were calculated by dividing the total manhours per personnel group by the total manhours required for each task component. Table 4 shows the derived multipliers

Dari \ Ke	Main Wheel	Nose Wheel	Torque Bar	Torque Bar Bolt	Screw/bolt	Pin Adjuster
1	1,4	3,2	1,5	1,6	6,6	60,0
2	1,3	1,6	3,0	1,2	3,3	10,0
3	1,2	2,7	1,8	1,3	5,5	16,6
4	0,9	2,1	2,2	1,0	4,4	13,3
5	2,0	1,0	4,2	1,8	2,2	6,6

Table 4 Multiplier Factor for manhours

while Actual Manhours will be used for comparison on the calculation simulation results. Therefore, the estimated manhours of the aircraft component area is what must be done (goal), so it becomes the demand (Demand). After defining job tasks as demand and personnel groups as supply, and calculating multiplier-based cost coefficients, the VAM simulation was initiated. Table 5 presents the input matrix containing the demand, supply, and cost (multiplier) values.

Dari \ Ke	Main Wheel	Nose Wheel	Torque Bar	Torque Bar Bolt	Screw/bolt	Pin Adjuster	Supply Manpower
1	1,4	3,2	1,5	1,6	6,6	60,0	120
2	1,3	1,6	3,0	1,2	3,3	10,0	60
3	1,2	2,7	1,8	1,3	5,5	16,6	100
4	0,9	2,1	2,2	1,0	4,4	13,3	80
5	2,0	1,0	4,2	1,8	2,2	6,6	40
Demand Manhours	82	37	183	74	18	6	400

Table 5 VAM Method

- X** = Number of **manhours** to be allocated
- Group 1** = **MW** = Main Wheel
- Group 2** = **NW** = Nose Wheel
- Group 3** = **TQ** = Torque Bar
- Group 4** = **TQQ** = Torque Bar Bolt

3.1 Simulation of Vogel's Approximation Method Calculation

This sub chapter presents the VAM distribution calculation, which is carried out through five sequential conditions that must be followed. These five conditions constitute the initial distribution phase and explain the procedural steps involved in applying the Vogel's Approximation Method (VAM) for workload allocation.

Dari \ Ke	Main Wheel	Nose Wheel	Torque Bar	Torque Bar Bolt	Screw/bolt	Pin Adjuster	Supply Manpower	Selisih Baris
1	1,4	3,2	1,5	1,6	6,6	60,0	120	
2	1,3	1,6	3,0	1,2	3,3	10,0	60	
3	1,2	2,7	1,8	1,4	5,5	16,6	100	
4	0,9	2,1	2,2	1,2	4,4	13,3	80	
5	2,0	1,0	4,2	1,8	2,2	6,6	40	
Demand Manhours	82	37	183	74	18	6	400	
Selisih Kolom								

Table 6. First Condition of VAM

As shown in Table 3.6 above, the table is populated based on the demand and supply data derived from the NDT task classification and personnel grouping tables, along with the respective costs in each cell determined using the multiplier factors.

Dari	Ke	Main Wheel	Nose Wheel	Torque Bar	Torque Bar Bolt	Screw/bolt	Pin Adjuster	Supply Manpower	Selish Baris
1		1,4	3,2	1,5	1,6	6,6	60,0	120	0,1
2		1,3	1,6	3,0	1,2	3,3	10,0	60	
3		1,2	2,7	1,8	1,4	5,5	16,6	100	
4		0,9	2,1	2,2	1,2	4,4	13,3	80	
5		2,0	1,0	4,2	1,8	2,2	6,6	40	
Demand Manhours		82	37	183	74	18	6	400	
Selish Kolom									

Table 7 Second condition of VAM

Table 7 also presents the second condition of the VAM process, where the smallest costs and their differences are clearly visible. In the first row, for example, the two lowest costs are 1.4 and 1.5, resulting in a row difference of 0.1

Dari	Ke	Main Wheel	Nose Wheel	Torque Bar	Torque Bar Bolt	Screw/bolt	Pin Adjuster	Supply Manpower	Selish Baris
1		1,4	3,2	1,5	1,6	6,6	60,0	120	0,1
2		1,3	1,6	3,0	1,2	3,3	10,0	60	0,1
3		1,2	2,7	1,8	1,4	5,5	16,6	100	0,2
4		0,9	2,1	2,2	1,2	4,4	13,3	80	0,3
5		2,0	1,0	4,2	1,8	2,2	6,6	40	0,8
Demand Manhours		82	37	183	74	18	6	400	
Selish Kolom		0,3	0,6	0,3	0,0	1,1	3,4		

Table 8 Third Condition of VAM

Table 8 illustrates the third condition of the VAM process, where the row and column penalties (cost differences) have been filled in. The method used to determine these penalties is the same as in the previous condition—by identifying the two lowest costs in each row and column and calculating their difference.

Dari	Ke	Main Wheel	Nose Wheel	Torque Bar	Torque Bar Bolt	Screw/bolt	Pin Adjuster	Supply Manpower	Selish Baris
1		1,4	3,2	1,5	1,6	6,6	60,0	120	0,1
2		1,3	1,6	3,0	1,2	3,3	10,0	60	0,1
3		1,2	2,7	1,8	1,4	5,5	16,6	100	0,2
4		0,9	2,1	2,2	1,2	4,4	13,3	80	0,3
5		2,0	1,0	4,2	1,8	2,2	6,6	40	0,8
Demand Manhours		82	37	183	74	18	6	400	
Selish Kolom		0,3	0,6	0,3	0,0	1,1	3,4	$\sum_{i,j} PA = 6$	

Table 9 Fourth Condition of VAM

After obtaining the row and column differences in Table 4.7, the next step is to identify the largest difference from the table. Table 4.8 displays the highest penalty value of 3.4, which results from the difference between the two lowest costs: 10.0 and 6.6. This occurs in the column for Pin Adjuster as the demand and Worker Group 5 as the lowest-cost supplier. Following the identification of this maximum penalty, the first allocation is made in cell X5, PA with a value of 6 manhours

Dari	Ke	Main Wheel	Nose Wheel	Torque Bar	Torque Bar Bolt	Screw/bolt	Pin Adjuster	Supply Manpower	Selish Baris
1		1,4	3,2	1,5	1,6	6,6		120	0,1
2		1,3	1,6	3,0	1,2	3,3		60	0,1
3		1,2	2,7	1,8	1,4	5,5		100	0,2
4		0,9	2,1	2,2	1,2	4,4		80	0,3
5		2,0	1,0	4,2	1,8	2,2		34	0,8
Demand Manhours		82	37	183	74	18		394	
Selish Kolom		0,3	0,6	0,3	0,0	1,1			

Table 10 Fifth Condition of VAM

After completing the fourth condition in Table 9, the demand for the Pin Adjuster column is fully satisfied with 6 manhours allocated from Worker Group 5. Consequently, the column is removed from further calculations. Worker Group 5, which originally had 40 manhours, now has 34 remaining manhours, as shown in Table 10. Upon completing all five conditions, the VAM distribution process continues by repeating the same steps from Conditions 1 to 5 until all demand and supply are fully allocated.

Dari	Ke	Main Wheel	Nose Wheel	Torque Bar	Torque Bar Bolt	Screw/bolt	Pin Adjuster	Supply Manpower			
1		1,4	3,2	1,5	1,6	6,6	60,0	120			
2		1,3	21	1,6	3,0	39	1,2	3,3	10,0	60	
3	2	1,2	2,7	63	1,8	35	1,3	5,5	16,6	100	
4	80	0,9	2,1	2,2	1,0	4,4	13,3	80			
5		2,0	16	1,0	4,2	1,8	18	2,2	6	6,6	40
Demand Manhours		82	37	183	74	18	6	400			

Table 11 Result VAM

As shown in Table 11, the final result of the VAM distribution calculation presents the completed allocation of manhours for each cell, representing the optimal manpower assignment using the Vogel's Approximation Method.

3.2 Analysis

After performing the calculations using the Vogel's Approximation Method (VAM), the Table 12 presents the distribution of manhours and their associated costs for each task and worker group. It also shows the allocation of labor groups to each specific task in the NDT wheel and brake shop. Following the determination of manhour distribution and cost using the VAM method, a total cost calculation was then conducted as follows:

$$\begin{aligned} \text{Total Cost} &= (120 \times 1,5) + (21 \times 1,6) + (39 \times 1,2) \\ &+ (2 \times 1,2) + (63 \times 1,8) + (35 \times 1,3) + (80 \times 0,9) \\ &+ (16 \times 1,0) + (18 \times 2,2) + (6 \times 6,6) \end{aligned}$$

$$\text{Total Cost} = 588,9 \text{ manhour}$$

VAM	Pekerjaan	Distribusi Manhour	Biaya Manhour	
Kelompok Pekerja	1	Torque Bar	120	1,5
	2	Nose Wheel	21	1,6
		Torque Bar Bolt	39	1,2
	3	Main Wheel	2	1,2
		Torque Bar	63	1,8
	4	Torque Bar Bolt	35	1,3
		Main Wheel	80	0,9
	5	Nose Wheel	16	1,0
		Screw/Bolt	18	2,2
		Pin Adjuster	6	6,6

Table 12 Result of Analysis VAM

The total distribution cost calculated using the Vogel's Approximation Method (VAM) was 588.9 manhours. This result was obtained based on the analysis carried out through the VAM calculation. The total manhours determined through this method amounted to 588.9 manhours. In comparison, the actual manhours recorded in the NDT Report Logbook for work performed in the Wheel and Brake Shop were 637 manhours. When compared with the calculated result, it was found that the NDT tasks could be completed 48.1 manhours faster using the VAM approach, representing a 13.2% improvement in efficiency over the actual recorded time.

CONCLUSION

Based on the simulation, calculations, and analysis conducted in this study, it can be concluded that the application of the Vogel's Approximation Method (VAM) for determining manhour requirements in the NDT Wheel and Brake Shop resulted in a total calculated manhour of 588.9. This value is significantly lower than the actual recorded manhours in the NDT report logbook, which amounted to 637 manhours. The difference of 48.1 manhours reflects a 13.2% improvement in efficiency when using the VAM approach. Additionally, the analysis of the VAM-based allocation revealed that the highest manhour requirement was assigned to the Torque Bar component, totaling 120 manhours, while the lowest was for the Main Wheel component, requiring only 2 manhours.

REFERENCES

- [1] Republik Indonesia, Undang-Undang Republik Indonesia Nomor 1 Tahun 2009 Tentang Penerbangan, Dewan Perwakilan Rakyat Indonesia Dan Presiden, Jakarta, 2009.
- [2] W. Pradana, "Potret Bengkel Raksasa Milik Lion," Cnbc Indonesia, [Online]. Available: <http://www.cnbcindonesia.com/news/potret-bengkel-raksasa-milik-lion/> [Accessed: Nov. 6, 2023].
- [3] A. Abrianto, Penggunaan Standar Inspeksi Ndt, Skripsi, Universitas Jenderal Ahmad Yani, Cimahi, 2016.
- [4] J. Hirsimäki, Developing The Wheel and Brake Shop Maintenance Processes, Thesis, Industrial Engineering Study Program, Metropolia University of Applied Sciences, Austria, 2020.
- [5] Perhubungan Republik Indonesia, Casr 65 Licensing of Aircraft Maintenance Engineer, Edition 1, Amendment 0, Civil Aviation Safety Regulation, Jakarta, 2017.
- [6] Materiedu, "Faktor Pengali: Mengenal Konsep Dan Pentingnya Dalam Matematika," [Online]. Available: <https://www.caracek.net/faktor-pengali-mengenal-konsep-dan-pentingnya-dalam-matematika/> [Accessed: Dec. 7, 2023].
- [7] M. R. Mahendra, Simulasi Distribusi Manpower Pemeliharaan Maskapai X Dengan Metode Northwest Corner, Least Cost, Dan Vogel's Approximation Method, Skripsi, Universitas Dirgantara Marsekal Suryadarma, Jakarta, 2022.
- [8] A. Erika, Perbandingan Metode Vam-Modi Pada Pengoptimalan Biaya Distribusi Barang (Studi Kasus: Pt. Mega Eltra Cabang Medan), Skripsi, Fakultas Matematika Dan Ilmu Pengetahuan Alam, Universitas Sumatera Utara, Medan, 2019.

- [9] D. Prizio, "Maintenance Matters," Kitplanes, [Online]. Available: <https://www.kitplanes.com/maintenance-matters-16/> [Accessed: Nov. 10, 2023]