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THE INFLUENCE OF TRAFFIC LOAD ON RUNWAY PAVEMENT CONDITION AT JENDERAL AHMAD YANI AIRPORT SEMARANG, USING MECHANISTIC APPROACH

Donny Anggara Noviansyah [1], Atmy Verani Rouly Sihombing [1*]

[1]) Civil Engineering Departement, Bandung State Polytechnic, Bandung.*
Corresponding Author's Email: atmyvera@polban.ac.id
Corresponding Phone Number: 0811231324

ABSTRACT

The increasing number of passengers and flights at Jenderal Ahmad Yani Airport Semarang is predicted to continue to increase after the Covid-19 pandemic. According to data, the increase that occurred after the pandemic increased by 57% in the period 2021-2023. This increase has the potential to affect the condition of the runway pavement. In 2018, maintenance activities on the runway that have been carried out with the Overlay and Leveling method are planned to maintain pavement conditions until 2038 or 20 years of service life. To anticipate these conditions, flight traffic forecasting is required based on existing conditions until the end of the planning service life. The forecasting results show that the number of passengers can reach 14,369,352 people, which exceeds the planning of only 5,700,000 passengers. With a significant increase in the number of passengers, the results of the evaluation of pavement conditions using the COMFAA and FAARFIELD mechanistic program approaches are represented in the CDF (Cumulative Damage Factor) value. Stating in 2038 the CDF value = 21.25 with a remaining life of 0.9 years. Therefore, it is necessary to rehabilitate SFO by reconstructing the upper structure of the pavement. with the thickness of the upper structure recommended by the FAA of a minimum of 100mm which needs to be implemented in 2026 when the remaining life is 5 years.

Keyword: *CDF, Mechanistic, Forecasting, Pavement Life Remaining.*

1. INTRODUCTION

The increase in traffic volume, both domestic and international, is influenced by the efficiency of air transportation travel time and population growth that encourages movement to help a country's economic growth [1]. That support the increase in passengers that occurs, qualify facilities are needed to maintain safety and security factors [2]. One of them is the runway facility, which is the main factor of infrastructure at the airport that is useful for planes to take off and land [3]. This factor makes it necessary for the runway to meet the standards set by the FAA (Federal Aviation Administration) both in terms of thickness and material, to fulfill the 20-year planning life requirement [4]. One of them this growth at Jenderal Ahmad Yani Airport in Semarang, which has been operating as a commercial airport since 1966. The airport, which has a runway with a length of 2560m x 45m and main structure of runway was flexible pavement with a pavement classification value of 61 /F/D/X/T.

Throughout its operational period, Jenderal Ahmad Yani Airport has carried out reconstruction and maintenance activities, one of which was the last reconstruction carried out in 2018, which included the construction of a new Terminal using the Overlay and Leveling maintenance method. Maintenance activities that have been carried out on the runway are planned to serve up to 5,700,000 passengers or 53,700 aircraft

movements, with the target that the pavement can be used for up to 20 years or until 2038. However, after the Covid-19 pandemic there was a significant increase in the volume of passenger traffic, with the number of passengers increasing by 57% in the period 2021-2023, The increase in traffic volume that occurred, resulted in the pavement structure getting longer loading and resulted in a decrease in pavement conditions [5]. Therefore, periodic inspection of the runway pavement structure is needed to determine the age and strength of the pavement after passing the existing flight conditions [6].

So this research is intended to determine the remaining life of the runway pavement, based on the increasing number of flights that are increasing every year. By identifying the type of existing traffic mix at Jenderal Ahmad Yani Airport Semarang, especially the type of critical aircraft type Boeing 737-900, the determination of critical aircraft based on MTOW (Maximum Take Off Weight) weight with ACN (Aircraft Classification Number) value 57. Based on the planning value of critical aircraft is still classified as safe with the value of ACN < PCN, then to find out the increase in the number of flights in the future, especially on critical flights is done by determining through the analysis of mechanistic approach, the mechanistic programme serves to determine the strength of the pavement in accepting loads through the COMFAA and FAARFIELD programmes expressed in the value of CDF (Cumulative Damage Factor) [7]. To determine the strength of the pavement, it is necessary to forecast up to the planned life of the pavement for 20 years to determine the actual conditions that occur during the service life of the pavement [8]. Forecasting is done by collecting Time Series passenger movement data to determine the increase or decrease that occurs [9] With the variation of data on the existing conditions owned by Jenderal Ahmad Yani airport, forecasting is carried out using an optimistic recovery scenario to determine the recovery due to the pandemic that has occurred [10]. From the results of the recovery graph, it can be projected that the number of passengers will increase until the end of the runway pavement service life in 2038. Then the output of the analysis results can be predicted from the condition of the pavement until the end of the service life, where the pavement is still able to serve and is feasible in increasing the number of flights for the next 20 years.

2. RESEARCH METHODOLOGY

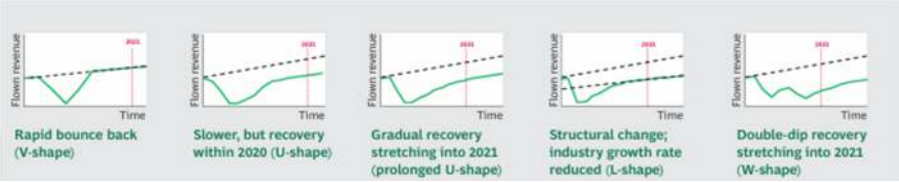
2.1 Forecasting

In conducting forecasting analysis in this study, it is carried out by collecting passenger data based on real existing conditions. The analysis process is carried out in a Time Series manner by analysing the behaviour of the data by involving the identification of seasonality and stationarity through modelling [11]. The results of the analysis can then be used as a basis for predicting future increases based on varying historical data [12]. The data presented in Table 1 is the movement of passengers in 2015-2023 owned by PT Angkasa Pura 1 Jenderal Ahmad Yani Airport Semarang.

Table 1. Number of Passengers in 2015-2018

Number of Passengers at SRG			Condition
Years	PAX / Years	PAX / Day	
2015	3,682,108.00	10,228.08	Before Covid
2016	4,219,815.00	11,721.71	
2017	4,429,058.00	12,302.94	
2018	5,162,139.00	14,339.28	
2019	3,647,911.00	10,133.09	
2020	1,386,037.00	3,850.10	Pandemi Covid
2021	884,979.00	2,458.28	
2022	1,631,485.00	4,531.90	After Covid
2023	2,100,836.00	5,835.66	

Based on the data in Table 1, there are 2 conditions, namely conditions during Covid-19 and after Covid-19. From the data presented, the conditions that occurred during Covid 19 occurred a significant decrease compared to previous data which tended to increase, but after the Covid-19 pandemic ended, a significant increase occurred again. So from the movement of this data, it can be predicted that an increase will occur using the method carried out by BCG (Boston Consultant Group), the method aims to find out the plan to increase again by using several recovery methods that occur based on existing condition data [13].



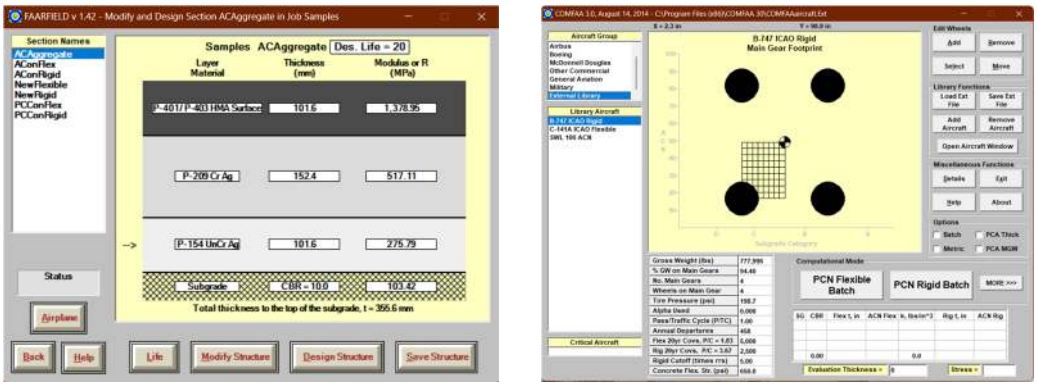
Source: Boston Consultan Group [13]

Figure 1. Type of Recovery Determination Scenario Chart

Figure 1 shows the improvement method based on the conditions of each airport with the level of recovery that occurs after Covid-19. Based on the conditions that occur at Jenderal Ahmad Yani Airport Semarang, the data that occurs can use the Optimistic profile. With the prediction of this recovery, the occurrence of the Covid outbreak that occurred in 2019-2021 can be resolved by analysing predictions of future increases [14]. To obtain this increase can be done by calculating the number of passengers and aircraft by calculating the number of passengers on the aircraft by converting the available seat capacity based on the type of aircraft [15]. With the critical aircraft conditions at Jenderal Ahmad Yani Airport with the Boeing 737-900 type, then in determining the Load Factor based on the Air Transportation Policy carried out by the Ministry of Transportation with the final forecasting period in 2024, the assumption of fully occupied seat capacity is used during the 2020-2024 period by using a value of 73-80% of the seat capacity of each aircraft type [16].

2.2 Mechanistic Program

In conducting the analysis of runway pavement conditions, using the FAARFIELD (FAA Rigid and Flexible Iterative Elastic Layered Design) and COMFAA mechanistic programmes, the use of both mechanistic programmes referring to FAA (Federal Aviation Administration) regulations equipped with Elastic Layer and Finite Element [17].



(a) (b)

Figure 2. (a.) Program FAARFIELD, (b.) Program COMFAA.

In Figure 2, the difference between the two programmes has their respective designations, as in Figure 2 (a) FAARFIELD which serves to evaluate technical design and thickness based on traffic mix based on existing conditions [18]. And in Figure 2 (b) which is a COMFAA program that functions to evaluate the output generated by the FAARFIELD program, using the COMFAA program, the value of the pavement condition is obtained after being given a mixed aircraft traffic load by taking into account the damage that occurs due to the contribution to the load expressed in CDF (Cummulative Damaged Factor) units [19] The mechanistic analysis uses several main components such as the thickness of the pavement layer and the wheel configuration of each type of aircraft. As well as the material properties used in the pavement layer as described in table 2 below.

Table 2. Material Properties Pavement Structure

No.	Material Type	Maximum Airplane Gross Weight Operation			Modulus (Mpa)
		<12.500 lbs	<100.000 lbs	>100.000 lbs	
1	P-401/P403 HMA Surface	75mm	100mm	100mm	1.379
2	P-401/P403 Flexible	75mm	100mm	100mm	2.760
3	P-209 Agregate	75mm	150mm	150mm	446
4	Subgrade 3% 5% 8% 10% 12% and 15%	100mm	100mm if required	100mm if required	Varies

Source : FAA 150/5320/6F

From the Modulus value in Table 2, it can be used as the basis for calculations in the mechanistic method in the FAARFIELD programme using the thickness of the existing conditions at Jenderal Ahmad Yani Airport Semarang. By using the material properties, the optimum planning CDF value can be determined with a value of CDF < 1 to express the contribution to pavement failure from the number of movements with a pavement plan value of 20 years [20]. The value refers to Miner's law with the traditional theory contained in the COMFAA programme, which is listed in equation 1 below.

$$\text{CDF} = \frac{(\text{Annual Departure}) \text{ x } (\text{life in Years})}{\left(\frac{\text{Pass}}{\text{Coverage Ratio}}\right) \text{x } (\text{Coveraged to Failure})} \quad (1)$$

3. RESULT AND DISCUSSION

3.1 Forecasting Passengers

To do forecasting, it is done by observing the data that has been collected in the following Table 1. From these data observations, observations are made based on graphs to determine the increase or decrease that occurs as in the following figure 3.

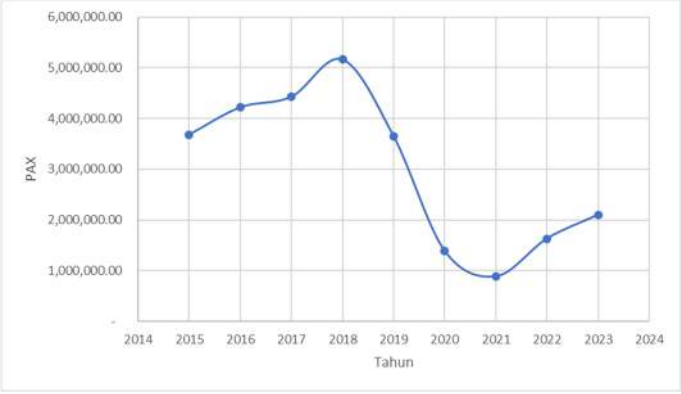


Figure 3. Passenger Chart of Jenderal Ahmad Yani Airport Semarang 2015-2023

The decreasing that occurred was due to reduced flight volumes and restrictions on the number of seats due to the Covid-19 pandemic. It can be seen that in the 2019-2021 period there was a drastic decline, but in the 2022-2023 period there was an increase in flights indicating a recovery in flight traffic. To forecast the increase in passengers, the optimistic method is used using linear equations, from the results of linear analysis in the two periods, before and after Covid-19, the equation is obtained as described in Figures 4 and 5.

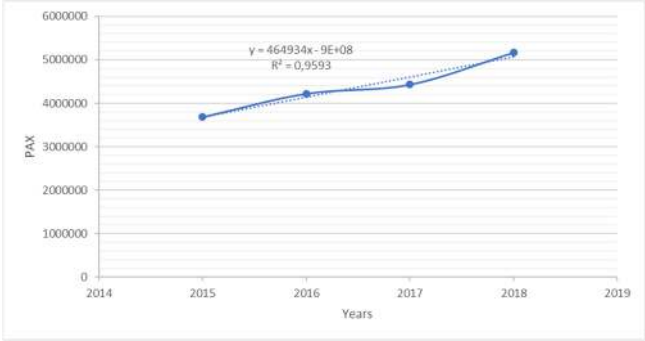


Figure 4. Linear Equations 2015-2018

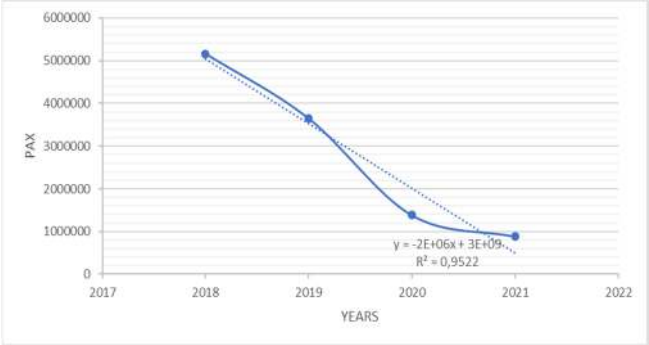


Figure 5. Linear Equations 2019-2021

From the equations in Figures 4 and 5 below, a linear equation is obtained based on conditions before and after Covid. In Figure 4 based on the value before Covid in the 2015-2018 period, an increase was obtained with the equation value Y = 464.934x - 9E +08. And in Figure 5 after Covid in the 2019-2021 period there was a fairly drastic decline with the value of the linear equation Y = -2E+06x + 3E+09. The results of the equation can be used as the basis for calculating the recovery that occurs based on the method described in Figure 1 by the Boston Consultant Group. Based on the data in Figure 3, the increase that occurred in 2021-2023, a projection of the increase in passengers in the following year, namely 2024, was carried out using the following equation 2.

$$a = \frac{y-y_1}{x-x_1} \qquad (2)$$

By using equation 2, a projection is made using data in 2024, assuming a normal increase such as the value of passengers in 2019 of 3.647.911, the following value is obtained.

$$2.000.000 = \frac{y - 3.647.911}{x - 2024}$$

$$a = 2.000.000(x - 2025) + 3.647.911$$

$$2025 = 5.647.911.$$

From the results of the analysis method using equation 2 below, the recovery of the number passengers in 2025 obtained a total of 5,647,911 passengers.

Table 3. Results of Forecasting Number of Passengers 2018-2038

SRG Airport Passenger Movement 2018-2038		
Years	PAX / Years	PAX / Days
2018	5,162,139	14,339
2019	3,647,911	10,133
2020	1,386,037	3,850
2021	884,979	2,458
2022	1,631,485	4,532
2023	2,100,836	5,836
2024	3,647,911	10,133
2025	5,647,911	15,689
2026	7,647,911	21,244
2027	9,255,083	25,709
2028	9,720,016	27,000
2029	10,184,950	28,292
2030	10,649,884	29,583
2031	11,114,817	30,874
2032	11,579,751	32,166
2033	12,044,684	33,457
2034	12,509,618	34,749
2035	12,974,552	36,040
2036	13,439,485	37,332
2037	13,904,419	38,623
2038	14,369,352	39,915

Based on the analysis results in Table 3, it is stated that with the linear forecasting method, the recovery of the number of passengers at Jenderal Ahmad Yani Airport Semarang for the period 2025-2038 shows an increase for 20 years in 2038 of 14,369,352/year.

3.2 Forecasting Aircraft

To determine the number of aircraft movements, calculations were made based on the number of passenger movements by converting the capacity of existing aircraft. The number of aircraft used refers to the existing conditions of each type of aircraft at Jenderal Ahmad Yani Airport Semarang, according to the data listed in Table 4. The percentage of the number of flights is calculated based on the existing aircraft movements at Jenderal Ahmad Yani Airport Semarang.

Tabel 4. Aircraft Traffic Movement of Jenderal Ahmad Yani Airport Semarang

Annual Departure of Jenderal Ahmad Yani Airport				
Years	A320	B738	B739	B735
2018	7,398	12,115	4,435	3,396
2019	18,375	21,125	7,905	5,393
2020	23,188	25,263	10,300	5,607
2021	25,215	26,931	11,529	5,775
2022	30,682	30,401	13,662	6,599
2023	38,016	33,326	16,156	7,289
Total Aircraft	142,874	149,161	63,987	34,059
Percentage	37%	38%	16%	9%

Source: PT Angkasa Pura I Jenderal Ahmad Yani

In the conversion calculation, the assumption of the number of seats available under normal conditions is made by referring to the load factor data used by the Ministry of Transportation with a value of 73-80% in the 2020-2024 period. Because the forecasting occurs in 2024-2038, a load factor with a value of 80% of the seat capacity is used. Then the load factor value is entered into the analysis in equation 2 to get the number of aircraft movements based on existing conditions.

$$F = \frac{\sum \text{Pax x Aircraft Rate \%}}{\text{SA x \%SLF}} \quad (3)$$

By taking an example based on passenger data in 2024, where the critical aircraft at Jenderal Ahmad Yani Semarang airport is Boeing 737-900, the aircraft data is entered into equation 2 with a seat capacity of 220. Then the number of flights in 2024 for one year obtained the number of Boeing 737-900 flights as many as 3,400 aircraft.

$$B\ 737\ 900 = \frac{3.647.911\ x\ 16\%}{220\ Seat\ x\ 80\%}$$

$$B\ 737\ 900 = 3.400\ Aircraft$$

3.3 Mechanistic Program (FAARFIELD, COMFAA)

With the collection of aircraft movement data, mechanistic analysis can be carried out using the COMFAA and FAARFIELD programmes. In carrying out the mechanistic analysis, it is carried out using the number of flights forecast up to the plan year, by entering the runway material properties such as by referring to the runway section drawing covering Sub Base, Aggregate, top layer and Overlay.

Table 5. Existing Layer Condition of General Ahmad Yani Airport SRG 2018

Segment	Overlay	Surface Course	Agregate	Sub Base course
Segment 1	215mm	270mm	400mm	300mm
Segment 2	215mm	270mm	400mm	300mm
Segment 3	245mm	290mm	450mm	300mm
Segment 4	225mm	260mm	550mm	550mm

Source: PT Angkasa Pura I Jenderal Ahmad Yani

In Table 5, the existing thickness of the runway pavement is collected in each segment, the pavement layer at Jenderal Ahmad Yani Airport Semarang has 4 segments with different thicknesses, this is in accordance with the original condition of the existing pavement layer. Then the thickness is entered in each segment in the FAARFIELD mechanistic programme as shown in Figure 6.

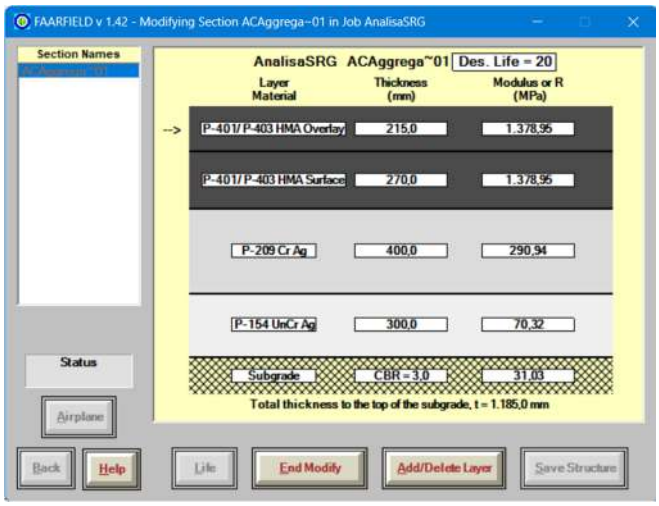


Figure 6. Running Program FAARFIELD

In Figure 6, the existing thickness that has been entered by given a traffic mix load with the traffic Movements in the 2018-2038 period or during the 20-year planning period in each segment, from the results of running the program, the optimum design is obtained based on the available traffic mix load and existing thickness presented in Table 6.

Table 6. Result Output Program FAARFIELD

Area	Overlay	Surface Course	Agregate	Sub Base course
Segmen 1	50.8mm	270mm	400mm	300mm
Segmen 2	50.8mm	270mm	400mm	300mm
Segmen 3	50.8mm	290mm	450mm	300mm
Segmen 4	50.8mm	260mm	550mm	550mm

From the results of running the program in Figure 6, the optimum Overlay Thickness value is obtained based on the mixed traffic movement that occurred during the period 2018-2038. From these results, the optimum thickness value is obtained at 50.8 mm for each segment obtained based on random flight conditions on each type of aircraft. then by using the optimum thickness results from the FAARFIELD program, an evaluation is carried out with the COMFAA program to determine the impact value given to each type of aircraft, especially on the critical type of aircraft, namely the Boeing 737-900 by representing it in the CDF value presented in Table 7.

Table 7. CDF Value Program COMFAA

Years	Aircraft Movement	CDF Value	Life Remaining
2018	27,344	0.56	35.9
2019	52,798	1.02	19.6
2020	64,358	1.28	15.6
2021	69,450	1.4	14.3
2022	81,344	1.63	12.3
2023	94,787	1.89	10.6
2024	120,310	2	8.6

Years	Aircraft Movement	CDF Value	Life Remaining
2025	159,827	3.03	6.6
2026	213,338	3.98	5.0
2027	278,093	5.12	3.9
2028	346,535	6.35	3.2
2029	417,796	7.6	2.6
2030	492,310	8.9	2.2
2031	570,078	10.29	1.9
2032	651,098	11.68	1.7
2033	735,372	12.75	1.6
2034	822,898	14.46	1.4
2035	913,678	16.35	1.2
2036	1,007,710	17.53	1.1
2037	1,104,995	19.68	1.0
2038	1,205,534	21.25	0.9

From the results addressed in table 7. Proving that the existence of random flights during the 2018-2038 period causes the CDF value to increase, this occurs due to an increase in the number of flights at Jenderal Ahmad Yani airport. That way, based on the results of the evaluation of the implementation of improvements with flight plans until 2038, it is not able to withstand flight loads for up to 20 years. This is reinforced by the remaining life given in the 20th year of 0.9 years with a random number of flights of 1,205,534 movements. So to avoid this increasing, it is necessary to carry out further analysis of the pavement design with reference to FAA 150-5320-6F (Advisory Circular), it is necessary to carry out a rehabilitation SFO with process in 2026 with a minimum surface course and overlay thickness of 100mm for aircraft weights >100,000 lbs to avoid future pavement damage.

4. CONCLUSION AND RECOMMENDATION

The results of the analysis stated that from forecasting the increase in the number of flights and passengers, there was an increase in the number that exceeded the planning carried out in 2018 by 5,700,000 passengers. The increase increased to 14,369,352, so this affects the number of aircraft movements that occur at Jenderal Ahmad Yani Airport, especially in the Boeing 737-900 Critical aircraft model. From the results of the analysis, the CDF value based on the traffic mix that occurs until the plan year in 2038 is CDF = 21.25 with a remaining life of 0.9 years. This makes that the maintenance planning process carried out in 2018 is not able to reach the planned life of 20 years, so the recommendation to minimise this by carrying out rehabilitation with reconstruction the upper pavement structure with a minimum thickness of 100mm including scrapping old pavement which needs to be rehabilitation in 2026 or when the remaining life is 5 years.

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