

Study of Flexible Pavement Structure Maintenance in Runways with Pavement Condition Index (PCI) Method

(Case Study: Balikpapan Sultan Aji Muhammad Sulaiman Sepinggan Airport)

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Abstract

Runway is an area in an airport for aircrafts to land and take off. The maintenance of the facilities on both the airside and landside must be taken care of in order to maximize the performance of the airport. Based on the aircraft type service plan of Balikpapan Sultan Aji Muhammad Sulaiman Sepinggan Airport and to maximize the performance of airports at present and in the future, an assessment of the condition of the runway with a Pavement Condition Index (PCI) value parameter on the flexible pavement to obtain the optimal repair or maintenance needs was carried out. The PCI obtained in 2019 was 61 (fair). Based on the PCI value in the runway, an evaluation was conducted with COMFAA and FAARFIELD to obtain the most critical aircraft PCN value in 2019. Segment 1, which is assumed to be half of the runway length which is sta 0 + 000 to 1 + 250, has a PCN value of 34.3 and segment 2, assumed to be of sta 1 + 250 - 2 + 500, has a PCN value of 33.2 where the ACN value for critical aircraft B777 - 300 ER is 89.3. In accordance with the recommendation of FAA AC-5380-6C, the most optimal scenario is scenario 2, which is major rehabilitation with the handling type of inlay - scrape and fill every 7 years when the PCI value is 49 (poor) and in the following years, routine maintenance would be done with patching. The total handling fee for 20 years of maintenance with scenario 2 is Rp. 195,377,000,000.

Keywords: Pavement condition index, runway, PCN

Abstrak

Runway merupakan area pada bandar udara untuk tempat mendarat dan lepas landas bagi pesawat. Fasilitas – fasilitas sisi udara dan sisi darat harus diperhatikan pemeliharaannya agar dapat memaksimalkan kinerja bandar udara. Berdasarkan rencana pelayanan tipe pesawat Bandar Udara Sultan Aji Muhammad Sulaiman Sepinggan Balikpapan dan untuk memaksimalkan kinerja bandar udara pada masa sekarang maupun pada masa yang akan datang, maka dilakukan penilaian kondisi perkerasan runway dengan parameter nilai Pavement Condition Index (PCI) pada perkerasan lentur untuk mendapatkan kebutuhan perbaikan atau pemeliharaan yang optimal. Nilai PCI yang diperoleh pada tahun 2019 adalah sebesar 61 (fair). Berdasarkan nilai PCI pada runway tersebut dilakukan evaluasi dengan COMFAA dan FAARFIELD untuk mendapatkan nilai PCN pesawat terkritis pada tahun 2019. Pada segmen 1 yang diasumsikan setengah dari panjang runway yaitu sta 0+000 sampai 1+250 memiliki nilai PCN 34,3 dan segmen 2 diasumsikan dari sta 1+250 – 2+500 memiliki nilai PCN 33,2 dimana nilai ACN untuk pesawat kritis B777 – 300 ER adalah 89,3. Sesuai dengan rekomendasi FAA AC-5380-6C Skenario yang paling optimal adalah skenario 2 yaitu rehabilitasi mayor dengan jenis penanganan pengupasan dan pengisian perkerasan pada surface (inlay – scrape and fill) setiap 7 tahun sekali ketika nilai PCI sebesar 49 (poor) dan pada tahun – tahun berikutnya dilakukan pemeliharaan rutin dengan patching. Total biaya penanganan selama 20 tahun masa pemeliharaan dengan skenario 2 sebesar Rp. 195.377.000.000.

Kata Kunci: Pavement condition index, runway, PCN

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1. Introduction

Every airport is divided into landside and airside, where the landside consists of connecting road, parking lot and terminal building while the airside consists of the taxiway, holding pad, runway, space terminal, and flight paths in the sky. One important part that must be found at the airport is the runway. Runway is an area in the airport for proper landing and takeoff for aircrafts. The maintenance of the facilities on both the airside and landside must be taken care of in order to maximize the performance of the airport itself to meet the demand of movement both at present and in the future.

Referring to the aircraft type service plan by Balikpapan Sultan Aji Muhammad Sulaiman Sepinggan Airport and to maximize the airport performance to meet the current and future demand of movement, an assessment of the runway pavement condition at Balikpapan Sultan Aji Muhammad Sulaiman Sepinggan Airport with Pavement Condition Index (PCI) value parameter on flexible pavement to obtain repair or maintenance needs with several alternative scenarios was done. Next, the COMFAA software was used to determine the Aircraft Classification Number (ACN) value and Pavement Classification Number (PCN) value to assess the ability of the pavement structure on the runway to serve the load due to air traffic, so that appropriate and efficient maintenance can be planned, and the FAARFIELD software was used to plan the design of the pavement structure on Balikpapan Sultan Aji Muhammad Sulaiman Sepinggan Airport runway, so that the optimum solution was obtained for repair or maintenance of the Balikpapan Sultan Aji Muhammad Sulaiman Sepinggan Airport runway.

The general objective of this research was to evaluate the pavement structure on Balikpapan Sultan Aji Muhammad Sulaiman Sepinggan Airport runway for maintenance optimization which was carried out at Balikpapan Sultan Aji Muhammad Sulaiman Sepinggan Airport.

The specific objectives of this study were as follows:

1. To assess the pavement structure conditions at Balikpapan Sultan Aji Muhammad Sulaiman Sepinggan Airport runway using the Pavement Condition Index (PCI) method on flexible pavement.
2. To assess the ability of pavement structure and design of pavement thickness on Balikpapan Sultan Aji Muhammad Sulaiman Sepinggan Airport runway with COMFAA and FAARFIELD software.
3. To design an optimal maintenance method for 20 years from the plan's starting year (2019) to the plan's final year (2039) on the Balikpapan Sultan Aji Muhammad Sulaiman Sepinggan Airport runway.

2. Literature Review

2.1 Layering system on flexible pavements

In 2016, the FAA applied a flexible pavement thickness design method using the elastic layer theory. This theory considers the vertical and horizontal forces acting on the pavement structure. The deflection that occurs in the structure due to loading is a function of the material's elasticity, E (Young's modulus). The ratio of deflection in the transversal and vertical directions can be determined by the Poisson ratio, μ . In the FAARFIELD program, the elastic layer theory and CDF theory are used to determine the thickness of the pavement layers. FAA, through the advisory circular, has set a minimum thickness for each layer of pavement to be designed. The following are the minimum thickness for designing flexible pavement layers.

2.2 Pavement condition index (PCI) method

The PCI method aims to identify critical areas of pavement. Critical areas are followed up by identifying the causes of damage, such as pavement material, aircraft loads, wheel pressure, climate and others.

Pavement surface visual inspection is very useful because it can be used for (Brotten and Sombre, 2001):

1. Evaluating pavement condition during inspection

Table 1. Minimum thickness of flexible pavement layers

Layer Type	FAA Layer Requirements	Aircraft Maximum Load Above Pavement lbs (kg)		
		<12.500 (5.670)	<100.000 (45.360)	≥100.000 (45.360)
Surface Layer 1,2,3	P-401	3 inches (75 mm)	4 inches (100mm)	4 inches (100mm)
Stabilized Base Layer	P-401/P-403, P-304, P-306	Not necessary	Not necessary	5 inches (125mm)
Crushed Stone Aggregate Base Layer 5,6	P-209	3 inches (75 mm)	6 inches (150mm)	6 inches (150mm)
Base Layer 5,7,8	P-208	3 inches (75 mm)	Not used 7	Not used
Subbase Layer 5,8	P-154	4 inches (100mm)	4 inches (100mm) if necessary	4 inches (100mm) if necessary

(Source: FAA AC 150/5320-6F 2016)

2. Determining rehabilitation needs and pavement maintenance priority
3. Estimating maintenance quantity
4. Evaluating the performance of different ways for maintenance and rehabilitation

In the PCI method, the severity of pavement damage is a function of 3 main factors, namely the damage type, severity, and the amount or density of damage.

2.3 Indicators in the pavement condition index (PCI) method

a. Deduct Value, DV

Deduct value is obtained by adjusting the density value obtained into each damage graph in accordance with the severity of the damage. Deduct value is also distinguished by the severity of the damage for each damage type.

b. Density

Density is the percentage of the area or total length of one damage type to the area or total length of the measured road section, can be in ft² or m², or in feet or meter. Thus, the damage density is expressed by the equation:

Density (%)

$$\frac{A_d}{A_s} \times 100 \tag{1}$$

Or

Density (%)

$$\frac{L_d}{A_s} \times 100 \tag{2}$$

Where:

A_d = The total area of the pavement type for each severity level of damage (ft² or m²)

A_s = Total area of sample unit (ft² or m²)

L_d = The total length of the pavement type for each severity level of damage (ft or m)

c. Total Deduct Value, TDV

The total deduct value or TDV is the total amount of the deduct value for each sample unit.

d. Corrected Deduct Value, CDV

The corrected deduct value or CDV is obtained from the relationship curve between the total deduct value (TDV) and the deduct value (DV) by selecting the appropriate curve. If the CDV value obtained is smaller than the Highest Deduct Value (HDP) then the CDV used is the highest individual deduct value.

e. PCI Value

After obtaining CDV, PCI for each sample unit is calculated using the following equation:

$$PCI_s = 100 - CDV \tag{3}$$

Sample Unit

For pavements at airports, FAA (1982) suggested the distribution of sample units by considering aspects

related to pavement design, implementation history and airport traffic areas. FAA (1982) suggested the division of sample units as follows:

- For continuous concrete pavement, the maximum sample unit is 20 plates.
- For flexible pavement in airports, one sample unit is recommended to have an area of ±5000 ft² (465 m²).

$$n = \frac{NS^2}{\frac{e^2}{4}(N-1)+s^2} \tag{4}$$

Where:

N = the total number of sample units in one pavement section

e = allowable error in estimation of the PCI part

s = standard deviation of PCI between sample units in their parts.

After obtaining the minimum number of sample units, a selection of sample units is made.

$$i = \frac{N}{n} \tag{5}$$

Where:

N = number of sample units available

n = minimum number of sample units to be surveyed

i = sampling interval

But as a rule of thumb, ASTM D5340-12 (2012) provides an alternative determination of the number of samples reviewed based on the total sample size. The number of samples to be reviewed based on this scenario is seen in the **Table 2**.

Table 2. Determination of the total number of sample units surveyed based on total sample units

No	Given	Survey
1	1 to 5 sample units	1 sample unit
2	6 to 10 sample units	2 sample unit
3	11 to 15 sample units	3 sample unit
4	16 to 40 sample units	4 sample unit
5	Over 40 sample units	10%

(source: ASTM D5340-12 2012)

2.4 Damage type identification

Damage types in using the Pavement Condition Index (PCI) method for flexible pavement can be divided into several types of damage. Measurement of each type of damage is taken from each sample unit that has been selected at the pavement site that has been divided. Each severity level of damage consisting of the low, medium, and high must be measured. After that, it can be entered into the form provided. The types of damage are as follows:

- a. Alligator Cracking
- b. Bleeding

- c. Block Cracking
- d. Corrugation
- e. Depression
- f. Jet Blast Erosion
- g. Joint Reflection Cracking
- h. Long & Trans Cracking
- i. Oil Spillage
- j. Patching
- k. Polished Aggregate
- l. Raveling
- m. Rutting
- n. Shoving
- o. Slippage Cracking
- p. Swelling
- q. Weathering

2.5 Handling type and damage condition

The following are the types of handling carried out based on the reduction of the PCI value.

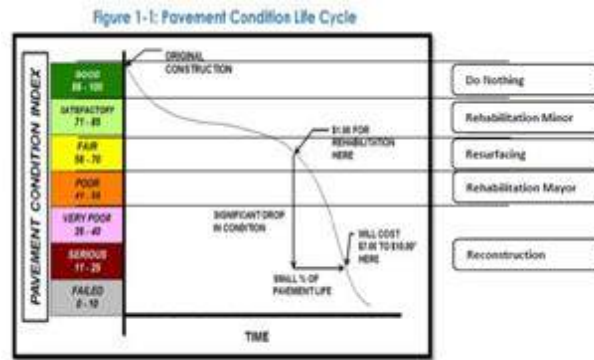
Figure 1 explains how pavement usually undergoes settlement and rehabilitation costs relative to various maintenance times. PCI values that provide criteria for runway pavement conditions are as follows:

- a. PCI value of 86 – 100 is within the good category, which is a pavement condition that does not need any action (do nothing),
- b. PCI value of 71-85 is within the satisfactory category, which is a pavement condition that needs a minor rehabilitation with patching in damaged points,
- c. PCI value of 56 – 71 is within the fair category, which is a pavement condition that needs resurfacing with overlay addition and inlay-scrape and fill,
- d. PCI value of 41 – 55 is within the poor category, which is a pavement condition that needs major rehabilitation on the overall area of runway pavement by dredging the upper foundation layer and lower foundation layer if the damage is indicated to cause more damage to the layer.

On the FAA AC 150-5380-6C (2012), there are guidelines for flexible pavement maintenance based on the type of damage that occurs. The following is a guideline **Table 3** for flexible pavement maintenance based on the type of damage that occurs.

2.6 Method/calculation using the COMFAA program

The ACN / PCN system is the only method applied by ICAO (International Civil Aviation Organization) to rate the performance/strength of airport pavement. By using this method, the effect/damage caused by an aircraft (with a certain weight and configuration, as well as certain pavement type and ground strength) can be represented by a number called the ACN (Aircraft



Source: FAA Advisory Circular 150 5380-7B Airport Pavement Management Program

Figure 1. Types of handling based on the reduction of the PCI Value
(source: FAA 150-5380-7B, 2014)

Classification Number). Conversely, the capacity/strength of a pavement can also be represented by a number without the need to specify the type of aircraft and detailed information about the pavement structure. This number is called the PCN (Pavement Classification Number). The pavement structure is considered capable of serving loads due to air traffic if the PCN value is greater than the ACN value for each aircraft operating at the airport. Information on the PCN value can then provide an overview of the pavement structure condition and is used by airport operators to determine strategies and policies in the maintenance of pavement structures. To determine the PCN value, a computer program called COMFAA is used. The data needed to run the COMFAA program is aircraft traffic data in the form of aircraft manufacturing, aircraft type, aircraft weight and number of annual departures.

The steps in the analysis process to get the PCN value using COMFAA software referred to the DGCA regulation Number KP: 93 of 2015 concerning Operational Technical Guidelines for Civil Aviation Safety Regulations Part 139 - 24. Some data is needed to get the PCN value.

1. Data traffic with growth up to 20 planned years
2. Characteristics of aircraft operating such as aircraft net load, annual departures, tire pressure, and others.
3. Equivalent pavement thickness resulting from the calculation and subgrade strength value.
4. The pavement thickness and CBR value that has been evaluated on the main COMFAA layer
5. P/TC value, based on the following **Table 4**.

Based on its condition, Sepinggan Balikpapan Airport has a parallel taxiway and refueling is done at the airport so that the value is 1.

2.7 Method/calculation using the FAARFIELD program

Pavement design with the FAARFIELD program is an iteration process for both flexible and rigid pavement

Table 3. Guidelines for maintenance of flexible pavement by the type of damage

Problem	Repair	Probable Cause
Weathering / Oxidation	Apply surface treatment	Environment
	Overlay	Lack of timely surface treatments
	Remove old sealer material if present	Age
	Clean and prepare cracks	Environmental Conditions
Cracks	Seal/reseal cracks	Bitumen too hard or overheated in mix
	Joint heating may be an option for longitudinal cracks when under the direction of an engineer. (Operate heaters to avoid excessive heat on the pavement)	Sealant defects (e.g., incorrect application temperature, improper, sealant selection, improper crack preparation)
Alligator or Fatigue cracking	Remove and replace damage pavement, including the base and/or subbase course if required	Base and/or subgrade failure, overload, under-design surface course (too thin)
Patches	remove/replace	Inadequate/improper repair detail/material
	Surface grinding/milling	Age
Surface irregularities (e.g., rutting, wash-boarding birdbaths)	remove and replace damage areas	Traffic
	Surface grinding/milling	Age
Loss of skid resistance	Remove rubber/surface contamination	Rubber deposits/surface contamination
	Apply surface treatment	Polished aggregate, Improper surface treatment
Bleeding	Blot with sand and remove sand prior to resuming aircraft operation. Excessive bleeding may require removal and replacement of pavement	Overlay rich mix/low air void content. Bleeding may be a precursor to other surface deformities forming, e.g., rutting, wash - boarding, etc.
	Grade pavement shoulders, clear drainage path	Poor maintenance of drainage facilities
Drainage	Clean out drainage structures. e.g., edge drains, outfall, etc	Poor maintenance of grade

(source: FAA AC 150-5380 – 6C, 2014)

Table 4. P/TC Value for various aircraft scenarios

Taxiway Facility	Refueling is done at the Airport	Refueling is not done at the Airport
Parallel Taxiway	1	2
Single Taxiway	2	3

designs. FAARFIELD will calculate the thickness of the overlay based on

1. Structure type and the thickness of the layer of the pavement to be analyzed
2. Aircraft type and its load
3. Residual life and compaction needs

2.8 Life cycle cost analysis

The calculation of life cycle cost analysis can be done using the *Present Worth Method* equivalent approach, using interest rate, analysis period, present time, and inflation can be ignored. Then LCC modeling is calculated without any residual value and with residual value (Firsani, 2012). Just as suggested in the study (WVDOH, 2004). To get the LCC value, use the Present Worth Method. The following is the formula of the approach:

$$P = F \left(\frac{1}{(1+i)^n} \right) \tag{6}$$

Where:

- P = Current year's value
- F = Desired year's value
- n = Growth period (years)
- i = Discount rate

2.9 Previous studies

Research on airports, maintenance of pavement structures using the PCI and LCCA methods have been carried out before. The studies are as follows.

Amanah (2019) conducted a study on optimization of runway maintenance using the PCI method and the application of LCCA where the results of the analysis of PCI values showed a decrease every year. The evaluation results of the runway pavement structural layer also obtained a bigger value of PCN compared to the ACN so that it could be concluded that the structural layer could serve the existing flight traffic. Handling costs were also based on handling volumes of previous years, unit price analysis, and calculating the present value during maintenance. The scenarios were built based on a decrease in the average PCI value. The analysis results of the scenarios that were built recommended that the minimum handling cost was scenario 4 with the handling type of inlay scrape and fill every 7 years when the PCI value was 60 (fair) with the total handling costs for 20 maintenance periods amounting to Rp.101,713,401,085,-

Widiyanto, B (2017) conducted a study on Halim Perdanakusuma Airport Pavement Condition Index (PCI). This PCI study was conducted in the Jakarta Halim Perdanakusuma Airport runway (flexible pavement) with an area of 3000 x 45 meters. PCI was analyzed using the ASTM D 5340-12 (Standard Test Method for Airport Pavement Condition Index Surveys) method with a sample of 10% of all the total sample area. From the results of the study, it was found that there were 3 different PCI values that indicated a decrease in the pavement condition, namely the existing PCI condition (before repair) was 69 (fair), the "do something" PCI condition (after repairing) was 65 (fair), and the "do nothing" PCI condition (if the aircraft is not repaired and rutting damage increases/occurs on the aircraft wheel path) was 59 (fair). These results indicated that the decrease in the PCI runway if it was repaired, had a smaller value than if the runway was not repaired.

3. Methodology

The methodology of the study conducted is in **Figure 2**. The following is a flowchart as a framework for thinking to help the process of the study and for problem solving. There are 10 stages described in the flowchart in this study. Stages begin with the formulation of the problem to get the best scenario. The best scenario is a conclusion for this research. The best scenario is expected to be able to optimize maintenance on the runway.

4. Data Processing

4.1 Primary survey results (pavement condition index)

The results of the survey conducted to fulfill the primary data in this study found several types of damage that existed in the Balikpapan Sepinggan Airport runway, namely corrugation, raveling, depression, patching, oil spillage, rutting, jet blast erosion, and alligator cracking. The damage consisted of various levels of damage, namely low, medium, and high. The following is a pie chart of the type of damage that exists in the Balikpapan Sepinggan Airport runway which can be seen in **Figure 3**.

Based on the picture, the greatest total damage density to the total area of each sample is a type of corrugation damage that is 389.09%.

4.2 Primary data processing

The steps taken to process primary data are as follows:

- Calculate Distress Density damage to the total area of each sample.
- Calculate the *Deduct Value* to get a deduct value of the damage type graph for each damage type. The determination of the deduct value is seen based on the graph of the type of damage that occurs. Each type of damage will have a different graph so that the value to be generated will be different.

- Calculate all distress density dan deduct value (DV) based on the damage type and severity of the damage and severity on each sample unit.
- Calculate the m value to ensure the damage type maximum number. Example: Sort the DV from the largest to the smallest, then calculate the m value from the HDV (highest deduct value).
- Calculate the deduct value and total deduct value of each q (number of entries with DV greater than 5)

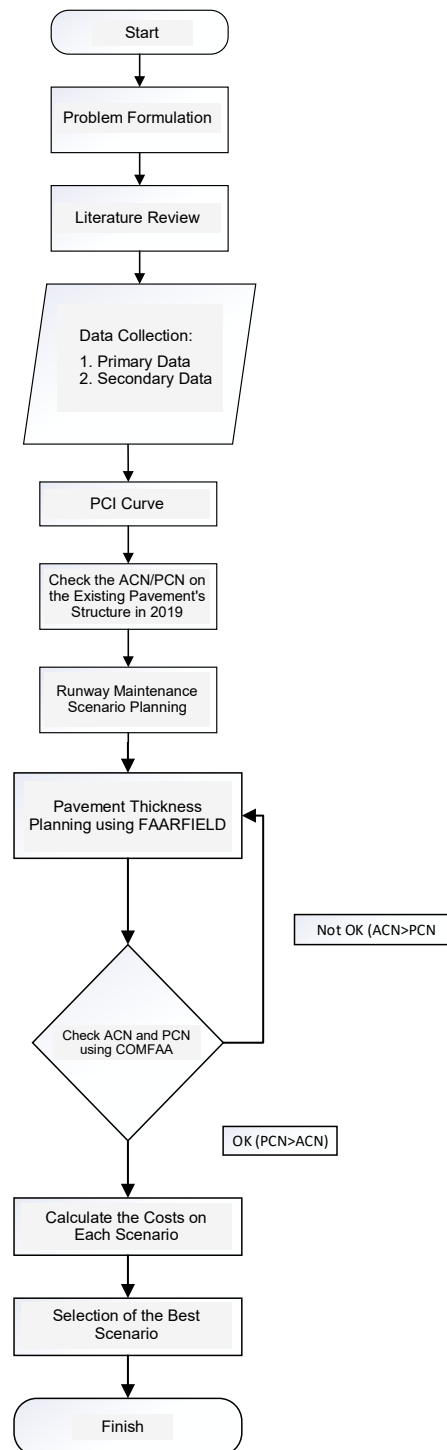


Figure 2. Research Flowchart

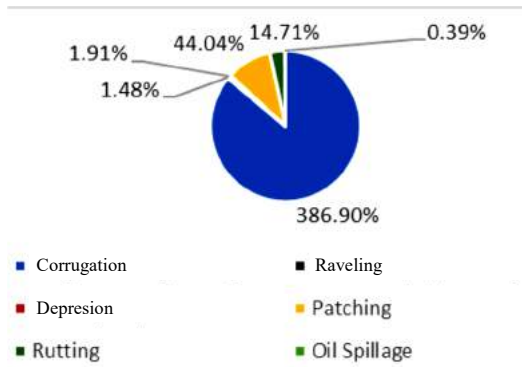


Figure 3. Pie chart of the damage type on the runway

- f. Calculate the corrected deduct value (CDV) from the total deduct value (TDV) data by using the corrected deduct value (CDV) graph (ASTM D5340-12).
- g. Calculate all pavement condition index (PCI) for each sample and calculate the overall sample value by averaging all pavement condition index (PCI) values for each sample. An average PCI value of 61 (Fair) was obtained for the Balikpapan Sepinggan Airport runway in the existing condition (2019) which can be seen in the Figure 6.

4.3 Secondary data processing

The following is the processing of secondary data. Airline flight traffic data for the planned critical aircraft.

The processing of aircraft traffic data at the Balikpapan Sepinggan Airport was based on annual number of passenger data from 2014 to 2018. The passenger growth at Balikpapan Sepinggan Airport was 5.7%. The following is an annual passenger and daily passenger data Table 5 from 2014 to 2018.

With a passenger growth of 5.7%, a calculation of the number of passengers up to the planned year (2039) was conducted. Based on the annual passenger data, annual aircraft requirements were calculated based on the capacity/module of each aircraft type for up to 20 plan years (2039). The following is a Table 6 of traffic calculation results based on annual number of passengers in 2019, 2024, 2029, 2034 and 2039.

The percentage of load distribution received by the majority on the rear landing gear (main) has a value of 95%. After calculating aircraft loads for each module, the annual Equivalent Annual Departures for critical/plan

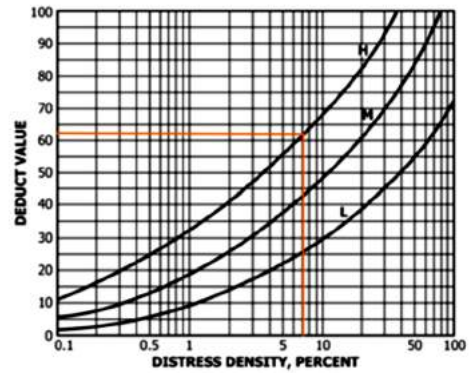


Figure 4. Corrugation damage graph (source: ASTM D5340-12,2012)

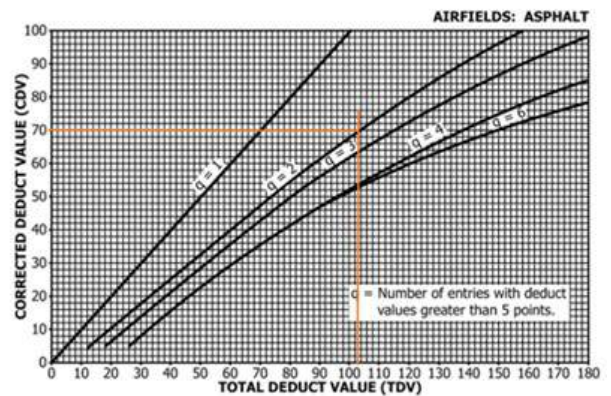


Figure 5. Determination of the CDV for each q

aircraft was calculated. The critical aircraft planned at Balikpapan Sepinggan Airport until the planned year (2039) is B777 - 300 ER. The following is aircraft traffic at Balikpapan Sepinggan Airport in 2019, 2024, 2029, 2034, and 2039.

B777 – 300 ER Aircraft Type Calculation:

$$R1 = R2 \sqrt{\frac{W2}{W1}} \tag{7}$$

$$W1 = \% \text{ main gear distribution} \times \text{MTOW of planned aircraft} \times \frac{1}{N}$$

$$W2 = \% \text{ main gear distribution} \times \text{MTOW of mixed aircraft} \times \frac{1}{N}$$

Wheel Load Ratio A320 on B777:

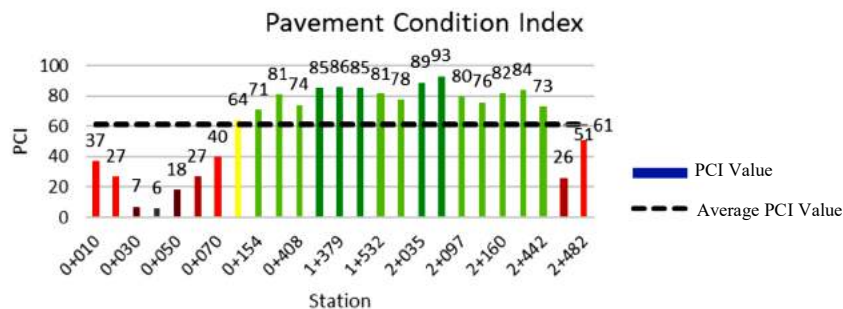


Figure 6. PCI Graph for 2019 (primary data)

Table 5. Annual passenger data of Balikpapan Sepinggan airport in 2014 - 2018

Year	2014	2015	2016	2017	2018	Desc.
Total Annual Number of Passenger	7.598.630	7.301.288	7.441.452	7.324.285	7.491.924	7.431.516
Total Daily Number of Passenger	20.819	20.004	20.388	20.067	20.526	20.361
Peak Hour Coefficient	0,045	0,045	0,045	0,045	0,045	0,045
Peak Hour Volume	937	901	918	904	924	917

(source: PT. Angkasa Pura I, 2019)

Tabel 6. Estimated annual number of modules

Type	Module (Capacity)	Load Factor	Capacity	Annual Number of Modules									
				2019	Number of Passenger	2024	Number of Passenger	2029	Number of Passenger	2034	Number of Passenger	2039	Number of Passenger
A320	186	0,8	149	1825	271560	5475	814680	9125	1357800	10950	1629360	12045	1792296
A332	335	0,8	268	3650	978200	6935	1858580	9125	2445500	9855	2641140	12775	3423700
ATR42	42	0,8	34	6205	208488	7665	257544	9490	318864	11315	380184	18250	613200
ATR72	72	0,8	58	5840	336384	7665	441504	9125	525600	10950	630720	14965	861984
B733	128	0,8	102	5475	560640	7665	784896	9490	971776	12775	1308160	16425	1681920
B735	149	0,8	119	5475	652620	7300	870160	9855	1174716	12775	1522780	17155	2044876
B738	189	0,8	151	7300	1103760	7300	1103760	9855	1490076	14600	2207520	18615	2814588
B739	220	0,8	176	7300	1284800	7665	1349040	10220	1798720	14965	2633840	18615	3276240
B777	396	0,8	317	5475	1734480	7300	2312640	9125	2890800	12775	4047120	17520	5550336
CRJX	100	0,8	80	9125	730000	7300	584000	8760	700800	13140	1051200	21900	1752000
Total	1817		1454	57670	7860932	72270	105051672	94170	13674652	124100	18052024	168265	23811140

Table 7. Equivalent annual departure in 2019

No	Aircraft Type	MTOW (lbs)	R2	N	W1 (lbs)	W2 (lbs)	Wheel Load Ratio	R1	Percent on Gear (%)	Tire Press (Kpa)
1	A320	171961	1825	10	30677	8168	0,52	48	47,5%	1220
2	A332	533519	3650	10	30677	25342	0,91	1729	47,5%	1420
3	ATR42	41005	6205	6	30677	3246	0,33	17	47,5%	552
4	ATR72	49603	5840	6	30677	3927	0,36	22	47,5%	552
5	B733	139500	5475	6	30677	11044	0,60	175	47,5%	1386
6	B735	136000	5475	6	30677	10767	0,59	164	47,5%	1388
7	B738	174200	7300	6	30677	13791	0,67	389	47,5%	1407
8	B739	187700	7300	6	30677	14860	0,70	488	47,5%	1517
9	B777	775000	5475	12	30677	30677	1,00	5475	47,5%	1524
10	CRJX	91800	9125	6	30677	7268	0,49	85	47,5%	552

$$\frac{W2}{W1} \tag{8}$$

Where:

- R1 = Equivalent traffic cycles of the critical aircraft
- R2 = Annual number of aircraft
- W1 = Wheel loads from critical aircraft
- W2 = Wheel load of each type of aircraft

Equivalent Annual Departure was calculated with the most critical planned aircraft, namely the B777. All aircraft loads other than B777 would be converted to B777 so that the number of aircraft arrivals other than B777 would be smaller compared to B777. The following is a **Table 7** showing the Equivalent Annual Departure in 2019.

The following are equivalent annual departure values for 2019, 2024, 2029, 2034 and 2039 as aircraft traffic

data that will be analyzed using FAARFIELD and COMFAA. Based on the following **Table 8**, the B777 is the most critical aircraft with the highest number of arrivals, while the ATR42 is the aircraft with the smallest load so that it will produce a small number of arrivals because it has been converted to the most critical aircraft, the B777.

a. Balikpapan Sepinggan Airport Payment Runway Layering System Data

The airport runway pavement layer data was used to see whether the existing pavement layer can withstand aircraft loads according to the existing traffic at Balikpapan Sepinggan Airport. There are 2 different segments on the Balikpapan Sepinggan Airport runway. Segment 1 and segment 2 differ in thickness on the aggregate (0-40 mm). In segment 1 the thickness is 48cm and in segment 2 the thickness is 46cm. The following are **Picture 7** and **8** of the pavement structure on the runway.

Table 8. Equivalent annual departure in 2019, 2024, 2029, 2034 and 2039

Aircraft Type	2019	2024	2029	2034	2039
A320	48	85	111	121	128
A332	1729	3098	3976	4264	5398
ATR42	17	18	20	21	24
ATR72	22	25	26	28	31
B733	175	214	243	291	338
B735	164	194	232	271	323
B738	389	389	476	620	729
B739	488	505	617	805	937
B777	5475	7300	9125	12775	17520
CRJX	85	76	83	101	130

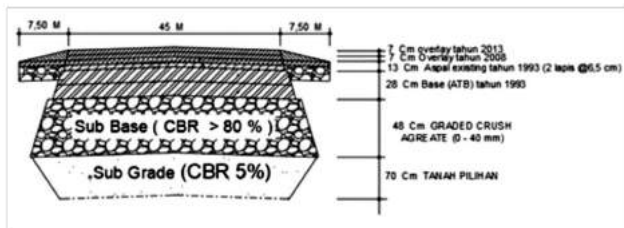


Figure 7. Existing pavement segment 1 thickness
(Source: PT. Angkasa Pura I, 2019)

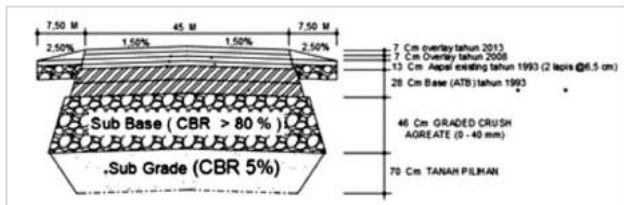


Figure 8 Existing pavement segment 2 thickness
(Source: PT. Angkasa Pura I, 2019)

In COMFAA, an analysis was carried out in accordance with traffic in 2019, 2024, 2029, 2034 and 2039. In segment 1, it was assumed that half of the runway length (sta 0 + 000 - 1 + 250) had a surface (P-401 / P-403) thickness under the existing condition of 55 cm and 33 cm after being corrected, and the subbase (P-209) in the existing condition had a thickness of 48 cm and 18 cm after being corrected. In segment 2, it was assumed that half of the runway length (sta 1 + 250 - 2 + 500) had a surface (P-401 / P-403) thickness under the existing condition of 55 cm and 33 cm after being corrected, and the subbase (P-209) in the existing condition had a thickness of 46 cm and 17 cm after being corrected. The following is a recap of the results of COMFAA running.

b. Pavement condition index (PCI) in 2013, 2014 and 2015

PCI in 2013, 2014 and 2015 were obtained based on the work report of the consultancy service on Balikpapan Sultan Aji Muhammad Sulaiman Sepinggan Airport recovery and maintenance master plan which can be seen in the **Table 11**.

c. Balikpapan City Unit Price Data

Balikpapan City unit price data was used to calculate the cost of runway pavement maintenance. The planned

Table 9. Recapitulation of PCN & ACN values based on COMFAA in segment 1

No	Type	PCN					ACN
		2019	2024	2029	2034	2039	
1	A320	24,1	23,7	23,4	23	22,7	47,3
2	A332	31,3	30,8	30,5	30	29,6	72,7
3	ATR42	14,5	14,5	14,5	14,5	14,5	7,4
4	ATR72	14,5	14,5	14,5	14,5	14,5	10,1
5	B733	22,2	21,9	21,7	21,4	21,1	38,8
6	B735	21,8	21,5	21,3	21	20,8	57,4
7	B738	24,5	24	23,7	23,3	22,9	50
8	B739	25,5	25	24,6	24,2	23,7	56
9	B777	34,3	33,8	33,5	33	32,6	89,3
10	CRJX	18,4	18,3	18,2	18,1	17,9	24,3

Table 10. Recapitulation of PCN & ACN values based on COMFAA in Segment 2

No	Type	PCN					ACN
		2019	2024	2029	2034	2039	
1	A320	23,5	23,1	22,8	22,4	22,1	47,3
2	A332	30,4	29,9	29,6	29,1	28,7	72,7
3	ATR42	14,0	14,0	14,0	14,0	14,0	7,4
4	ATR72	14,0	14,0	14,0	14,0	14,0	10,1
5	B733	21,6	21,3	21,1	20,8	20,5	38,8
6	B735	21,3	21,0	20,8	20,5	20,2	57,4
7	B738	23,8	23,4	23,1	22,7	22,3	50
8	B739	24,7	24,3	23,9	23,5	23,1	56
9	B777	33,2	32,7	32,4	32	31,6	89,3
10	CRJX	18,0	17,9	17,8	17,6	17,5	24,3

Table 11. PCI in 2013, 2014 and 2015

Year	PCI
2013	100
2014	94
2015	84

(source: PT. Angkasa Pura I, 2016)

budget would be calculated based on the type of damage, damage volume, and unit price in Balikpapan. The budget plan was calculated with several scenarios so that the maintenance plan with the most optimum costs would be obtained. The following is a **Table 12** of work type and unit price based on Balikpapan's unit cost of activity.

4.4 Projection of runway pavement damage level

Projection of PCI on Balikpapan Sepinggan Airport's runway PCI value projection on the Balikpapan Sepinggan Airport runway was also carried out on the annual number of passengers. The following is a **Picture 9** of the decrease in PCI with the annual number of passengers.

Based on the graph above, the smaller the PCI, the higher the damage severity in the Balikpapan Sepinggan Airport's runway pavement. The PCI on the graph above generated an exponential equation model with $y=281,61e^{-3E-04x}$ and $R^2 = 0,9938$. Based on the equation, a forecast would be conducted if no maintenance was done on the Balikpapan Sepinggan Airport runway.

Table 12. Asphalt work and asphalt pavement scrape

Type of Work	Price	Unit
Asphalt Work	Rp 3.566.620	m ³
Asphalt Pavement Scrape with Tools	Rp 149.469	m ³

(Source: Balikpapan's unit cost of activity, 2018)

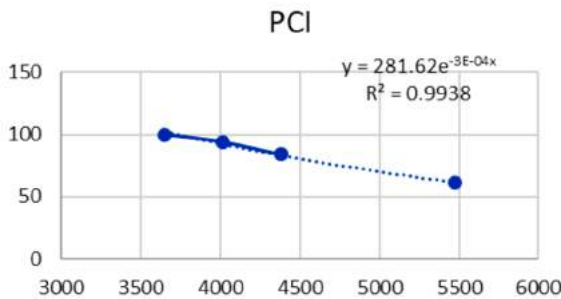


Figure 9. Graph of Decrease in PCI Based on Critical Aircraft

The decrease in PCI value based on the annual number of passengers until the planned year, 2039, can be seen in the following **Figure 10**.

The following is a graph of the decrease in PCI based on the number of annual critical aircraft until the planned year, 2039, where the critical aircraft planned until the planned year is the B777-300 ER.

The graph above shows the effect of the PCI predicted from the previous exponential equation with a scenario of no improvement until the planned year, 2039. PCI between 41-55 is categorized as poor, and the type of treatment undertaken is major rehabilitation. In 2020, the Balikpapan Sepinggan Airport runway pavement must be maintained so that it can return the PCI to 100. Based on the decrease in PCI until the planned year, an evaluation using COMFAA was conducted in accordance with the traffic that has been analyzed in previous calculations to determine the PCN on the runway pavement structure if no maintenance was carried out until the planned year (2039). The evaluation was conducted using COMFAA in accordance with the layering system in segment 1 and segment 2 at the Balikpapan Sepinggan Airport runway.

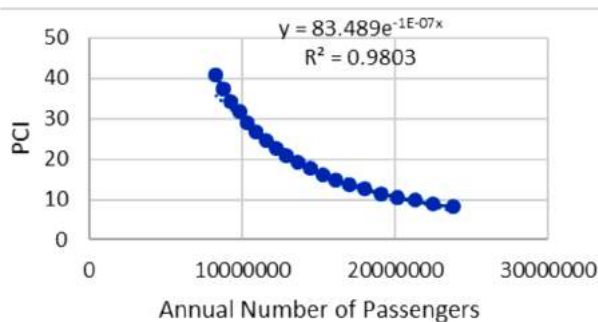


Figure 10. Graph of projection of decrease in PCI until the planned year (2039) based on the annual number of passenger

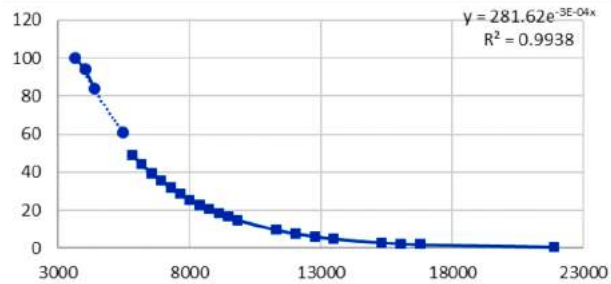


Figure 11. Graph of projection of decrease in PCI until the planned year (2039) based on the annual critical aircraft

The **Table 13** shows the decrease in PCI in 2019, 2024, 2029, 2034 and 2039 if no maintenance is performed. The decrease in PCI will affect the PCN with the most critical aircraft, which is B777, on the structure of the pavement on the runway. If the PCI decreases, the PCN value will also decrease so maintenance is needed to control the condition in the runway pavement structure so that the PCN value is not less than the most critical aircraft's ACN.

Table 13. Estimation of the effect of decrease in PCI value on PCN value

Year	PCI	PCN (B777) Seg.1	PCN (B777) Seg.2	ACN B-777
2019	61%	34,4	33,2	89,3
2024	32%	10,5	9,9	89,3
2029	18%	5,3	4,8	89,3
2034	6%	3,3	2,9	89,3
2039	0%	0	0	89,3

5. Data Analysis

5.1 Best scenario criteria

The determination of the damage handling type scenario in runway pavement depends on the value of PCI, the damage type, and the existing runway pavement thickness' strength. The handling of runway pavement damage must be in accordance with the severity of the damage and the type of pavement damage. The purpose of this scenario determination was to obtain the most optimum cost for maintenance in terms of the type of damage handling in the runway pavement. Besides, runway maintenance at the Balikpapan Sepinggan Airport aims to keep the runway from experiencing structural damage such as corrugation, rutting, and depression because these damage types will substantially decrease the value of PCI. The following is a guide Figure available in FAA AC 150-5380 - 6C year 2014 for maintenance recommendations based on the damage type that occurs.

5.2 Damage handling type strategy in runway pavement

Based on the PCI method, there are several references for decision making in the maintenance of damage to runway pavement taken from the FAA. Based on the

primary data survey conducted in the existing year of 2019, there were several types of damage that were quite dominant in the Balikpapan Sepinggan Airport runway, namely corrugation, patching, depression, rutting, and raveling. Based on those damage types, the one that was quite influential on the decrease in the PCI on the Balikpapan Sepinggan Airport runway was the corrugated damage type. Based on maintenance guidelines provided by the FAA for damage types such as corrugation, depression, and rutting, which are in the category of surface irregularities caused by traffic and pavement age, the suggestion for improvement to be carried out is to remove and replace the damaged area. Based on the decrease in PCI in 2020 which is 49 (poor), it is recommended that a major rehabilitation is done to restore the condition of the pavement structure to 100 based on the FAA 150-5380-7B. So, based on the recommendations given by the FAA, several scenarios were planned. The following is a scenario of the handling types that can be done for the maintenance of the Balikpapan Sepinggan Airport runway:

1. Additional pavement layers on the entire pavement (overlay) in 2020, done every 7 years and patching in the following years.
2. Inlay – scrape and fill in 2020, done every 7 years and patching in the following years.
3. Inlay – scrape and fill in 2020, done every 5 years and patching in the following years.
4. Inlay – scrape and fill of 7cm in 2020, done every 5 years and patching in the following years.

5.3 Overlay thickness requirement calculation results

Based on the analysis using FAARFIELD and COMFAA software for overlay handling scenarios, segment 1 requires 11 cm of thickness and segment 2 requires 12 cm of thickness. The theoretical PCN for the most critical aircraft which is the B777-300 ER in segment 1 is 119.4 and in segment 2 is 138.3 where the ACN value for B777-300 ER aircraft is 89.3. There is a fourth scenario where an overlay with 7 cm of thickness is planned, the theoretical PCN for B777 - 300 ER critical aircraft with a 7cm overlay is 65.1, where the ACN value is 89.3 so that the 7cm of thickness has not been able to withstand the aircraft traffic loads until the planned year, which is 2039.

The following is the volume of overlay work on the Balikpapan Sepinggan Airport runway.

Table 14. Volume of overlay work on the Balikpapan Sepinggan airport runway

Work Type	Stationing	Thickness	Length	Width	Volume
		m	m	m	m ³
P-401/P-403 (overlay)	0+000 - 1+250	0.11	1250	45	6187.5
P-401/P-403 (overlay)	1+250 - 2+500	0.12	1250	45	6750
Total					12937.5

5.4 Inlay - scrape and fill requirements analysis

The requirements for inlay scrape and fill can be done when the thickness of the additional layer continues to increase. The increasing thickness of the pavement layer will increase the risk of a depression in the base and subbase. Scrape requirements were calculated based on the existing pavement layer scrape on the surface layer. Fill requirements were calculated beforehand with FAARFIELD. The following is the calculation of the volume of inlay-scrape and fill work.

Volume = Length x Width x Thickness

Cost = Total Volume x Unit Price (/m³)

The **Table 15** and **16** below is a calculation for the volume of scrape and fill work. The scrape and fill were carried out along 2500m which were then divided into 2 segments, namely, segment 1 with the assumption of 0+000 - 1+250 and segment 2 with the assumption of 1+250 - 2+500. The scrape and fill work was planned with 3 alternatives namely 11cm, 12cm and 7cm.

5.5 Patching requirements analysis

Based on the data from PT. Angkasa Pura I, the volume of patching each year was taken from the highest volume, which was 8.13 m³ for minor improvement plans in the Balikpapan Sepinggan Airport runway area. The following is a Table of the calculation of patching cost for one year.

Total Cost = Volume x Unit Price (/m³)

The **Table 17** below is a calculation of the volume of fill work. The fill work unit price is the same as the asphalt, which is Rp3.566.620 per m³. The total cost required for scrape work for one year is Rp 29.003.130.

5.6 Maintenance cost of handling scenarios analysis

The volume calculation in the previous sub-chapter would be multiplied by an analysis of the unit price in Balikpapan. The unit price used would be converted into work volume so that it could be multiplied by the calculated volume. During the 20-year maintenance period the costs to be incurred would increase according to inflation and growth rate in Balikpapan, which is 3.56%. The following are the results of the calculation of the total cost for each scenario.

5.7 Total cost of each scenario

The calculation of the total cost for each scenario was based on the volume of work multiplied by an analysis of the unit price in Balikpapan. The unit price used would be converted into work volume so that it could be multiplied by the calculated volume. During the 20-year maintenance period the costs to be incurred would increase according to inflation and growth rate in Balikpapan, which is 3.56%. The following is the total planned maintenance costs for optimizing the maintenance of the pavement structure on the runway.

Based on total cost, scenario 4 is the smallest. Based on the maintenance suggested by FAA AC 150-5380 - 6C

Table 15. Work volume of Inlay-scrape and fill and total cost (11 cm and 12 cm)

Work Type	Stationing	Thickness	Length	Width	Volume	Total		Cost
		m	m	m	m ³	m ³		
Asphalt Pavement Scrape	0+000 - 1+250	0,11	1250	45	6187,5	12937,5		Rp 1.933.758.163
Asphalt Pavement Scrape	1+250 - 2+500	0,12	1250	45	6750			
Fill P-401/P-403 (overlay)	0+000 - 1+250	0,11	1250	45	6187,5	12937,5		Rp 46.143.152.201
Fill P-401/P-403 (overlay)	1+250 - 2+500	0,12	1250	45	6750			
Total Cost							Rp 48.076.910.364	

Table 16. Work volume of Inlay-scrape and fill and total cost (7 cm)

Work Type	Stationing	Thickness	Length	Width	Volume	Total		Cost
		m	m	m	m ³	m ³		
Asphalt Pavement Scrape	1+250 - 2+500	0,07	1250	45	3937,5	Rp 588.535.093		
Fill P-401/P-403 (overlay)	0+000 - 1+250	0,07	1250	45	3937,5	Rp 14.043.568.061		
Total Cost							Rp 14.632.103.154	

Table 17. Estimated total patching costs for 1 year

Work	Volume	Unit	Total Cost
Patching	8,13	m ³	Rp 29.003.130

Table 18. Total cost of each scenario

Scenario	Total Cost
1	Rp 187,548,005,020.65
2	Rp 195,376,834,091.62
3	Rp 264,569,600,686.22
4	Rp 81,004,986,829.35

according to the damage types that exist in the Balikpapan Sepinggan Airport runway, the suggested improvement is to remove and replace the damaged area which is more suitable to scenario 2 and scenario 3. So, scenario 4 is not recommended to be done.

6. Conclusions and Recommendations

6.1 Conclusions

1. Based on the primary data survey conducted in 2019 to assess the pavement conditions in the Balikpapan Sepinggan Airport runway using the PCI method, the PCI value for the flexible pavement on the runway is 61 (fair), and if nothing is done in 2020, the PCI value will continue to fall to 49 (poor), so maintenance needs to be done.
2. Based on the decrease in PCI that has been analyzed, scenario 2 is a scenario that is in accordance with FAA AC 150-5380 - 6C according to the damage types in the Balikpapan Sepinggan Airport runway. The recommended improvement is to remove and replace the damaged area. Scenario 2 has a smaller total cost than a similar scenario, scenario 3, which is Rp195,377,000,000 with the maintenance of inlay-scrape and fill once every 7 years with a minor improvement of patching in the following years.

6.2 Recommendations

Recommendations that can be given for this study are:

1. A further test of the Balikpapan Sepinggan Airport runway may be conducted to find out the layering condition other than the surface by using HWD (Heavy Weight Deflectometer) so that it can calculate the PCN in more detail per 10 meters.
2. Analysis of annual costs until the planned year of 2039 for 20 years in this study uses the inflation

rate of Balikpapan in 2019 and it needs to be updated annually.

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