ADVISORY CIRCULAR

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DETERMINATION AND REPORTING OF PAVEMENT STRENGTH USING PAVEMENT CLASSIFICATION NUMBER (PCN) METHOD

1. PURPOSE

This Advisory Circular (AC) provides guidance to Aerodrome operators on the standard method for reporting aerodrome pavement strength using the PCN Method.

2. REFERENCES

2.1 Civil Aviation (Aerodromes) Regulations
2.2 ICAO Aerodrome Design Manual- Doc 9157 Part 3-Pavements
2.3 ICAO Annex 14 – Volume 1

3. APPLICABILITY

The use of the standardized method of reporting pavement strength applies only to pavements with bearing strengths of 5 700 kg or greater. This method does not apply to the reporting of pavement strength for pavements of less than 5 700 kg bearing strength.

4. DEVELOPMENT OF A STANDARDIZED METHOD

4.1 Legislative Requirement

The UCAA as per Civil Aviation (Aerodromes) Regulations require aerodrome operators to report to Aeronautical Information Services provider, the pavement surface type and bearing strength using the Aircraft Classification Number – Pavement Classification Number (ACN-PCN) Method. This Advisory Circular (AC) provides guidance for using the standardized International Civil Aviation Organization (ICAO) method known as the Aircraft Classification Number – Pavement Classification Number (ACN-PCN) method to report aerodrome pavement strength.

4.2 Introduction

The pavement classification number (PCN) is defined as a number expressing the bearing strength of a pavement for unrestricted operations. Only when the aircraft's ACN is less than the aerodrome’s PCN is the aircraft allowed to land with its maximum landing weight.

There are two ways to determine the PCN which are **using aircraft experience method** and the **technical evaluation method**. Computer programme (COMFAA) for determining PCNs has been introduced in this guidance manual. **COMFAA** is a program which can run two modules for computing flexible and rigid **Aircraft Classification Numbers (ACN**s) and **Design of Total Pavement Thickness**. The program runs under Windows 2000, XP, and VISTA. This program is used for pavement thickness design in the procedure required for PCN determination by the technical evaluation method. The programme has an option to select the new ICAO alpha factors for flexible pavements.

Aerodrome operators should take responsibility to establish and review PCNs of all pavements for publication in the AIP as well as for forming a basis for imposing operational controls of the pavements. It is additionally noteworthy that, with the remarkable increase of aircraft loads and movements, continuous checking of the structural conditions of aerodrome pavements is important to avoid both overstressing and underutilization which will invariably result in safety and economic implications.

The ACN-PCN system is structured so a pavement with a particular PCN value can support, without weight restrictions, an aircraft that has an ACN value equal to or less than the pavement’s PCN value. This is possible because ACN and PCN values are computed using the same technical basis.

5. LIMITATIONS OF THE ACN-PCN METHOD

The ACN-PCN system is only intended as a method of reporting relative pavement strength so aerodrome operators can evaluate acceptable operations of aircrafts. It is not intended as a pavement design or pavement evaluation procedure, nor does it restrict the methodology used to design or evaluate a pavement structure.

6. DETERMINATION OF AIRCRAFT CLASSIFICATION NUMBER

6.1 DETERMINATION OF THE ACN

The aircraft manufacturer provides the official computation of an ACN value. Computation of the ACN requires detailed information on the operational characteristics of the aircraft such as maximum aircraft center of gravity, maximum ramp weight, wheel spacing, tyre pressure, and other factors.

6.2 SUBGRADE CATEGORY

The ACN-PCN method adopts four standard levels of subgrade strength for rigid pavements and four levels of subgrade strength for flexible pavements. These standard support conditions are used to represent a range of subgrade conditions as shown in Tables 1 and Table 2.

Table 1: Standard Sub-grade Support Conditions for Rigid Pavement

Subgrade Strength Category	Subgrade Support k-value pci (MN/m^3)	Represents pci (MN/m^3)	Code Designation
High	150	k >120	A
Medium	80	(60<k<120)	B
Low	40	(25<k<60)	C
Ultra Low	20	k<25	D

Table 2: Standard Sub-grade Support Conditions for Flexible Pavement

Subgrade Strength Category	Subgrade Support CBR-Value	Represents	Code Designation
High	15	CBR > 13	A
Medium	10	8<CBR<13	B
Low	6	4<CBR<8	C
Ultra Low	3	CBR<4	D

6.3 OPERATIONAL FREQUENCY

Operational frequency is defined in terms of coverages that represent a full-load application on a point in the pavement. Coverages must not be confused with other common terminology used to reference movement of aircrafts. As an aircraft moves along a pavement section it seldom travels in a perfectly straight path or along the exact same path as before. This movement is known as aircraft wander and is assumed to be modeled by a statistically normal distribution. As the aircraft moves along a taxiway or runway, it may take several trips or passes along the pavement for a specific point on the pavement to receive a full-load application. It is easy to observe the number of passes an aircraft may make on a given pavement, but the number of coverages must be mathematically derived based upon the established pass-to-coverage ratio for each aircraft.

6.4 ACN OF A RIGID PAVEMENT

For rigid pavements, the aircraft landing gear flotation requirements are determined by the Westergaard's solution for a loaded elastic plate on a Winkler foundation (interior load case), assuming a concrete working stress of 399 psi (2.75 MPa).

6.5 ACN OF A FLEXIBLE PAVEMENT

For flexible pavements, aircraft landing gear flotation requirements are determined by the California Bearing Ratio (CBR) method for each subgrade support category. The CBR method employs a Boussinesq solution for stresses and displacements in a homogeneous, isotropic elastic half-space. To standardize the ACN calculation and to remove operational frequency from the relative rating scale, the ACN-PCN method specifies that ACN values be determined at a frequency of 10,000 coverages.

6.6 ACN CALCULATION

Using the parameters defined for each type of pavement section, a mathematically derived single wheel load is calculated to define the landing gear/pavement interaction. The derived single wheel load implies equal stress to the pavement structure and eliminates the need to specify pavement thickness for comparative purposes. This is achieved by equating the thickness derived for a given aircraft landing gear to the thickness derived for a single wheel load at a standard tyre pressure of 181 psi (1.25 MPa). The ACN is defined as two times the derived single wheel load (expressed in thousands of kilograms).

6.7 VARIABLES INVOLVED IN DETERMINATION OF ACN VALUES

Because aircrafts can be operated at various weight and center of gravity combinations, ICAO adopted standard operating conditions for determining ACN values. The ACN is to be determined at the weight and center of gravity combination that creates the maximum ACN value. Tyre pressures are assumed to be those recommended by the manufacturer for the noted conditions. Aircraft manufacturers publish maximum weight and center of gravity information in their Aircraft Characteristics for Aerodrome Planning (ACAP) manuals.

7. DETERMINATION OF PCN NUMERICAL VALUE

7.1 PCN CONCEPT

In fundamental terms, the determination of a pavement rating in terms of PCN is a process of determining the ACN for the selected critical or most demanding aircraft and reporting the ACN value as the PCN for the pavement structure.

Under these conditions, any aircraft with an ACN equal to or less than the reported PCN value can safely operate on the pavement subject to any limitations on tyre pressure.

7.2 DETERMINATION OF NUMERICAL PCN VALUE

Determination of the numerical PCN value for a particular pavement can be based upon one of two procedures. The procedures are known as the “using” aircraft method and the “technical” evaluation method. ICAO procedures permit member states to determine how PCN values will be determined based upon internally developed pavement evaluation procedures. Either procedure may be used to determine a PCN, but the methodology must be reported as part of the posted rating.

7.3 Using Aircraft Experience Method to Determine PCN

a) The using aircraft experience method is a simple procedure where ACN values for all aircrafts currently permitted to use the pavement facility are determined and the largest ACN value is reported as the PCN. This method is easy to apply and does not require detailed knowledge of the pavement structure and often conservative in that it does not have to be backed by detailed analysis of operational characteristics and predicted performance of the pavement.

b) Assumptions of Using Aircraft Experience Method: An underlying assumption with the using aircraft method is that the pavement structure has the structural capacity to accommodate all aircrafts in the traffic mixture and that each aircraft is capable of operating on the pavement structure without restriction.

c) Inaccuracies of Using Aircraft Experience Method: The accuracy of this method is greatly improved when aircraft traffic information is available. Significant over- estimation of the pavement capacity can result if an excessively damaging aircraft, which uses the pavement on a very infrequent basis, is used to determine the PCN. Likewise, significant under-estimation of the pavement capacity can lead to uneconomic use of the pavement by preventing acceptable traffic from operating. Although there are no minimum limits on frequency of operation before an aircraft is considered part of the normal traffic, the reporting agency must use a rational approach to avoid overstating or understating the structural capacity of the pavement. Application of this method is discouraged on a long-term basis due to the inaccuracies that may arise.

7.4 Technical Evaluation Method to Determine PCN

a) The strength of a pavement section is difficult to estimate in a precise manner and will vary depending upon unique combination of aircraft loading conditions, frequency of operation, environment, inherent component layers and support conditions of the pavement. The technical evaluation method attempts to address these and other site-specific variables to determine reasonable pavement strength.

In general terms, for a given pavement structure and given aircraft, the allowable number of operations (traffic) will decrease as the intensity of pavement loading increases (increase in aircraft weight). It is entirely possible that two pavement structures with different cross-sections may report similar strength. However, the permissible aircraft operations will be considerably different. This discrepancy must be acknowledged by the aerodrome operator and may require operational limitations administered outside of the ACN-PCN system.

All of the factors involved in determining a pavement rating are important, and it is for this reason that pavement ratings should not be viewed in absolute terms, but rather as estimations of a representative value. A successful pavement evaluation is one that assigns a pavement strength rating that considers the effects of all variables on the pavement.

b) The accuracy of a technical evaluation is better than using aircraft experience procedure but requires a considerable increase in time and resources. Pavement evaluation may require a combination of on-site inspections, load- bearing tests and engineering judgment. It is common to think of pavement strength rating in terms of ultimate strength or immediate failure criteria.

However, pavements are rarely removed from service due to instantaneous structural failure but rather with gradual loss of structural capacity over a given period. A decrease in the serviceability of a pavement is commonly attributed to increases in surface roughness or localized distress, such as rutting or cracking. Determination of the adequacy of a pavement structure must not only consider the magnitude of pavement loads but the impact of the accumulated effect of traffic volume over the intended life of the pavement.

c) **Determination of the PCN Value:** The PCN numerical value is determined from an allowable load rating. While it is important not to confuse the PCN value with a pavement design parameter, the PCN is developed in a similar fashion. An allowable load rating is determined by applying the same principles as those used for pavement design. The process for determining the allowable load rating takes factors such as frequency of operations and permissible stress levels into account.

Allowable load ratings are often stated in terms of aircraft gear type and maximum gross aircraft weight, as these variables are used in the pavement design procedure. Missing from the stated load rating, but just as important, is frequency of operation. In determining an allowable load rating, the evaluation must address whether the allowable load rating represents the pavement strength over a reasonable frequency of operation. Once the allowable load rating is established, the determination of the PCN value is a simple process of determining the ACN of the aircraft representing the allowable load and reporting the value as the PCN.

d) **Concept of Equivalent Traffic:** The ACN-PCN method is based upon design procedures that establish one aircraft as the critical or most demanding on the pavement structure. Calculations necessary to determine the PCN can only be performed for one aircraft at a time. The ACN-PCN method does not directly address how to represent a traffic mixture as a single aircraft. To address this limitation, the equivalent aircraft concept to consolidate entire traffic mixtures into one representative aircraft can be used.

e) **Counting Aircraft Operations:** When evaluating or designing a pavement section, it is important to account for the number of times the pavement will be stressed. An aircraft may have to pass over a given section of pavement numerous times before the portion of pavement considered for evaluation receives one full stress application. While statistical procedures exist to determine the passes required for one full stress application, the evaluation of a pavement section for PCN determination must also consider how aircrafts use the pavement in question.

A conservative approach is used in pavement design procedures where it is assumed that each aircraft using the aerodrome must land and take off once per cycle. Since the arrival or landing weight of the aircraft is usually less than the departure weight, the design procedure only counts one pass at the departure weight for analysis. These departures are usually discussed in term of departures per year or annual departures.

7.5 LIMITATIONS OF THE PCN

The PCN value is for reporting relative pavement strength only and should not be used for pavement design or as a substitute for evaluation. Pavement design and evaluation are complex engineering problems that require detailed analyses. They cannot be reduced to a single number. The PCN rating system uses a continuous scale to compare pavement strength where higher values represent pavements with larger load capacity.

7.6 REPORTING THE PCN

a) The PCN system uses a coded format to maximize the amount of information contained in a minimum number of characters and to facilitate computerization. The PCN for a pavement is reported as a five-part number where the following codes are ordered and separated by forward slashes.

- Numerical PCN value
- Pavement type,
- Subgrade category,
- Allowable tyre pressure, and
- Method used to determine the PCN. (An example of a PCN code is 80/R/B/W/T).

b) **Numerical PCN Value:** The PCN numerical value is a relative indication of the load-carrying capacity of a pavement in terms of a standard single wheel load at a tyre pressure of 181 psi (1.25 MPa). The PCN value should be reported in whole numbers, rounding off any fractional parts to the nearest whole number. For pavements of diverse strengths, the controlling PCN numerical value for the weakest segment of the pavement should normally be reported as the strength of the pavement. Engineering judgment may be required here in that if the weakest segment is not in the most heavily used part of the runway, then another representative segment may be more appropriate to determine PCN.

c) **Pavement Type:** For the purpose of reporting PCN values, pavement types are considered to function as either flexible or rigid structures. Table 3 lists the pavement codes for the purposes of reporting PCN.

Table 3: Pavement Codes for Reporting PCN

Pavement Type	Pavement Code
Flexible	F
Rigid	R

d) **Flexible Pavement:** Flexible pavements support loads through bearing rather than flexural action. They comprise several layers of selected materials designed to gradually distribute loads from the surface to the layers beneath. The design ensures that load transmitted to each successive layer does not exceed the layer's load-bearing capacity.

e) **Rigid Pavement:** Rigid pavements employ a single structural layer, which is very stiff or rigid in nature, to support the pavement loads. The rigidity of the structural layer and resulting beam action enable rigid pavement to distribute loads over a large area of the subgrade. The load-carrying capacity of a rigid structure is highly dependent upon the strength of the structural layer, which relies on uniform support from the layers beneath.

f) Composite Pavement: Various combinations of pavement types and stabilized layers can result in complex pavements that could be classified as between rigid or flexible. A pavement section may comprise multiple structural elements representative of both rigid and flexible pavements.

Composite pavements are most often the result of pavement surface overlays applied at various stages in the life of the pavement structure. If a pavement is of composite construction, the pavement type should be reported as the type that most accurately reflects the structural behavior of the pavement.

The method used in computing the PCN is the best guide in determining how to report the pavement type. For example, if a runway is composed of a rigid pavement with a bituminous overlay, the usual manner of determining the load-carrying capacity is to convert the pavement to an equivalent thickness of rigid pavement. In this instance, the pavement type should be reported as a rigid structure.

A general guideline is that when the bituminous overlay reaches 75 to 100 percent of the rigid pavement thickness the pavement can be considered as a flexible pavement. It is permissible to include a note stating that the pavement is of composite construction but only the rating type, "R" or "F", is used in the assessment of the pavement load capacity.

g) Sub-grade Strength Category: As discussed in Section 6, there are four standard subgrade strengths identified for calculating and reporting ACN or PCN values. The values for rigid and flexible pavements are reported in Tables 1 and 2.

h) Allowable Tyre Pressure: Table 4 lists the allowable tyre pressure categories identified by the ACN-PCN system. The tyre pressure codes apply equally to rigid or flexible pavement sections; however, the application of the allowable tyre pressure differs substantially for rigid and flexible pavements.

Table 4: Tyre Pressure Codes for Reporting PCN

Category	Code	Tyre Pressure Range
Unlimited	W	No pressure limit
High	X	Pressure limited to 1.75 MPa
Medium	Y	Pressure limited to 1.25 MPa
Low	Z	Pressure limited to 0.50 MPa

i) Tyre Pressures on Rigid Pavements: Aircraft tyre pressure will have little effect on pavements with Portland cement concrete surfaces. Rigid pavements are inherently strong enough to resist tyre pressures higher than currently used by commercial aircrafts and can usually be rated as code W.

j) Tyre Pressures on Flexible Pavements: Tyre Pressures may be restricted on asphaltic concrete, depending upon the quality of the asphalt mixture and climatic conditions. Tyre pressure effects on an asphalt layer relate to the stability of the mixture in resisting shearing or densification. A poorly constructed asphalt pavement can be subject to rutting due to consolidation under load.

The principal concern in resisting tyre pressure effects is with stability or shear resistance of lower quality mixtures. A properly prepared and placed mixture can withstand substantial tyre pressure in excess of 218 psi (1.5 Mpa) whilst improperly prepared and placed mixtures can show distress under tyre pressures of 100 psi (0.7 MPa) or less.

Although these effects are independent of the asphalt layer thickness, pavements with well-placed asphalt of 4 to 5 inches (10.2 to 12.7 cm) in thickness can generally be rated with code X or W, while thinner pavement of poorer quality asphalt should not be rated above code Y.

k) **Method Used to Determine PCN:** Two pavement evaluation methods are recognized in the PCN system. If the evaluation represents the results of a technical study, the evaluation method should be coded T. If the evaluation is based on “using aircraft” experience, the evaluation method should be coded U. Technical evaluation implies that some form of technical study and computation were involved in the determination of the PCN.

Using aircraft evaluation means the PCN was determined by selecting the highest ACN among the aircrafts currently using the facility and not causing pavement distress. PCN values computed by the technical evaluation method should be reported to UCAA for publications in its AIP.

l) **Example PCN Reporting:** An example of a PCN code is 80/R/B/W/T—with 80 expressing the PCN numerical value, R for rigid pavement, B for medium strength subgrade, W for high allowable tyre pressure, and T for a PCN value obtained by a technical evaluation.

m) **Reporting of PCN Values:** Once a PCN value and the coded entries are determined, the PCN code should be reported to AIS, either in writing or as part of the annual update to the aerodrome records. The AIS will publish the PCN values in its Aeronautical Information Publication (AIP). An aircraft's ACN can then be compared with the published PCN to determine if the aircraft can safely operate on the aerodrome’s runways, subject to any limitation on tyre pressure.

n) The following examples shall be used to illustrate how pavement strength data are reported under the ACN-PCN method-

- If the bearing strength of a rigid pavement, resting on a medium strength subgrade, has been assessed by technical evaluation to be PCN 80 and there is no tire pressure limitation, then the reported information would be-

PCN 80 / R / B / W / T

- If the bearing strength of a composite pavement, behaving like a flexible pavement and resting on a high strength subgrade, has been assessed by using aircraft experience to be PCN 50 and the maximum tire pressure allowable is 1.25 MPa, then the reported information would be—

PCN 50 / F / A / Y / U

- If the bearing strength of a flexible pavement, resting on a medium strength subgrade, has been assessed by technical evaluation to be PCN 40 and the maximum allowable tire pressure is 0.80 MPa, then the reported information would be—

PCN 40 / F / B / 0.80 MPa /T

- If a pavement is subject to a B747-400 all-up mass limitation of 390 000 kg, then the reported information would include a note to the effect that the reported PCN is subject to a B747- 400 all-up mass limitation of 390 000 kg.

8. EQUIVALENT TRAFFIC OF AIRCRAFT COMPOSITION

8.1 General

The concept of equivalent traffic is to allow the calculation of the combined effect of multiple aircraft in the traffic mix for a given aerodrome. This combined traffic is brought together into the equivalent traffic of a critical aircraft. This is necessary in that the procedure used to calculate ACN allows only one aircraft at a time. By combining all of the aircraft in the traffic mix into an equivalent critical aircraft, calculation of a PCN that includes the effects of all traffic becomes possible.

The assessment of equivalent traffic, as described in this section, is needed only in the process of determining PCN using the technical method and may be disregarded when the ‘Using aircraft method’ is employed

In order to arrive at a technically derived PCN, it is necessary to determine the maximum allowable or commonly sustained gross weight of the critical aircraft (i.e. the allowable weight on a given landing gear configuration). This in turn requires that the pavement design and aircraft loading characteristics be examined in detail.

8.2 Equivalent Traffic Terminologies

a) In order to determine a PCN, as based on the technical evaluation method, it is necessary to define common terms used in aircraft traffic and pavement loading. The terms arrival, departure, pass, coverage, load repetition, operation, and traffic cycle are often used interchangeably when determining the effect of aircraft traffic operating on a runway. It is important not only to determine which of the aircraft movements need be counted when considering pavement stress, but how these terms apply in relation to the pavement design and evaluation process. In general, and for the purpose of this document, they are differentiated as follows:

b) **Arrival (Landing) and Departure (Takeoff):** Typically, aircraft arrive at an aerodrome with a lower amount of fuel than is used at takeoff. As a consequence, the stress loading of the wheels on the runway pavement is less when landing than at takeoff due to the lower weight. This is true even at the touchdown impact in that there is still lift on the wings, which alleviates the dynamic vertical force.

However, if the aircraft do not receive additional fuel at the aerodrome, then the landing weight will be substantially the same as the takeoff weight (neglecting the changes in passengers and cargo), and the landing operation should be counted as a takeoff for pavement stress loading cycles. In this latter scenario, there are two equal load stresses on the pavement for each traffic count (departure), rather than just one. Regardless of the method of counting load stresses, a traffic cycle is defined as one takeoff and one landing of the same aircraft, subject to a further refinement of the definition in the following text.

c) **Pass:** A pass is a one-time transaction of the aircraft over the runway pavement. It could be an arrival, a departure, a taxi operation, or all three, depending on the loading magnitude and the location of the taxiways. Figure 1 shows typical traffic patterns for runways having either parallel taxiways or central taxiways. A parallel taxiway requires that none or very little of the runway be used as part of the taxi movement. A central taxiway requires that a large portion of the runway be used during the taxi movement.

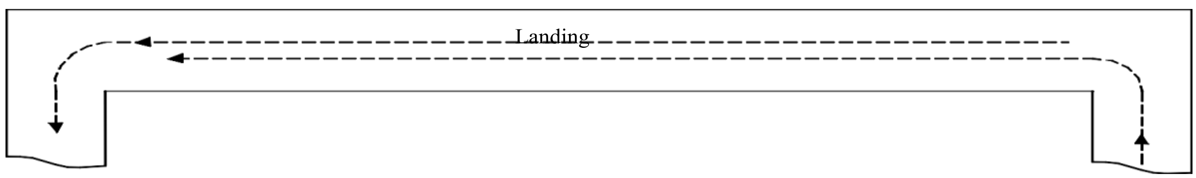

Figure 1a: Runway with Parallel Taxiway

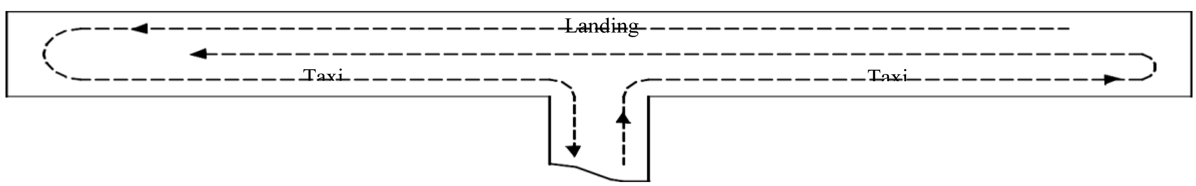

Figure 1b: Runway with Central Taxiway

Figure 1: Traffic Load Distribution Patterns

d) **Parallel Taxiway Scenario:** In the case of the parallel taxiway, as shown in Figure 1a, two possible loading situations can occur. Both of these situations assume that the passenger count and cargo payload are approximately the same for the entire landing and takeoff cycle:

If the aircraft obtains fuel at the aerodrome, then a traffic cycle consists of only one pass since the landing stress loading is considered at a reduced level, which is a fractional equivalence. For this condition only the takeoff pass is counted, and the ratio of passes to traffic cycles (P/TC) is 1.

If the aircraft does not obtain fuel at the aerodrome, then both landing and takeoff passes should be counted, and a traffic cycle consists of two passes of equal load stress. In this case, the P/TC ratio is 2.

e) **Central Taxiway Scenario:** For a central taxiway configuration, as shown in Figure 1b, there are also two possible loading situations that can occur. As was done for the parallel taxiway condition, both of these situations assume that the payload is approximately the same for the entire landing and takeoff cycle:

If the aircraft obtains fuel at the aerodrome, then both the takeoff and taxi to takeoff passes should be counted since they result in a traffic cycle consisting of two passes at the maximum load stress. The landing pass can be ignored in this case. It is recognized that only part of the runway is used during some of these operations, but it is conservative to assume that the entire runway is covered each time a pass occurs. For this situation, the P/TC ratio is 2.

If the aircraft does not obtain fuel at the aerodrome, then both the landing and takeoff passes should be counted, along with the taxi pass, and a traffic cycle consists of three passes at loads of equal magnitude. In this case, the P/TC ratio is 3.

A simplified, but less conservative, approach would be use a P/TC ratio of 1 for all situations. Since a landing and a takeoff only apply full load to perhaps the end third of the runway (opposite ends for no shift in wind direction), this less conservative approach could be used to count one pass for both landing and takeoff. However, it is recommended to conduct aerodrome runway evaluations on the conservative side, which is to assume any one of the passes covers the entire runway.

f) **Coverage:** When an aircraft moves along a runway, it seldom travels in a perfectly straight line or over the exact same wheel path as before. It will wander on the runway with a statistically normal distribution. A single coverage occurs when a unit area of the runway has been traversed by a wheel of the aircraft main gear. Due to random wander, this unit area may not be covered by the wheel every time the aircraft is on the runway. The number of passes required to statistically cover the unit area one time on the pavement is expressed by the pass to coverage (P/C).

Although the terms coverage and P/C ratio have commonly been applied to both flexible and rigid pavements, the P/C ratio has a slightly different meaning when applied to flexible pavements as opposed to rigid pavements. This is due to the manner in which flexible and rigid pavements are considered to react to various types of gear configurations. For gear configurations with wheels in tandem, such as dual tandem (2D) and triple dual tandem (3D), the ratios are different for flexible and rigid pavements, and using the same term for both types of pavements may become confusing. It is incumbent upon the user to select the proper value for flexible and rigid pavements.

The P/C ratios for gears with wheels in tandem are different for flexible and rigid pavement. This difference occurs because of the method in which the flexible and rigid pavements are assumed to handle stress. It is assumed that the flexible pavement loading pattern has a series of stress peaks, depending on the number of wheels in tandem, while a rigid pavement acts as a single deflecting plate, with only one stress peak per group of wheels.

Generally, a single- or dual-gear arrangement will provide only one load stress per pass, regardless of the pavement type, since there is only one set of wheels traversing a given place on the pavement. However, a dual tandem gear stresses a flexible pavement twice since there are two repetitions of the load on flexible pavement, and it stresses a rigid pavement once due to the effect of only one stress loading per group of wheels. Likewise, a triple dual tandem gear stresses the flexible pavement three times but only one time for rigid pavement.

g) Operation: The meaning of this term is unclear when used in pavement design or evaluation. It could mean a departure at full load or a landing at minimal load. It is often used interchangeably with pass or traffic cycle. When this description of an aircraft activity is used, additional information should be supplied. It is usually preferable to use the more precise terms described in this section.

h) Traffic Cycle and Traffic Cycle Ratio: As has been discussed, a traffic cycle can include a landing pass, a takeoff pass, a taxi pass or all three. For pavement design or evaluation, the ratio of traffic cycles to coverages (TC/C) in flexible pavement, rather than passes to coverages, is required since there could be one or more passes per traffic cycle. When only one pass on the operating surface is assumed for each traffic count, then the P/C ratio is sufficient. However, when situations are encountered where more than one pass is considered to occur during the landing to takeoff cycle, then the TC/C ratio is necessary in order to properly account for the effects of all of the traffic. These situations occur most often when there are central taxiways or fuel is not obtained at the aerodrome.

Equation 1 translates the P/C ratio to the TC/C ratio for flexible and rigid pavements by including the previously described ratio of passes to traffic cycles (P/TC):

$$\frac{TC}{C} = \frac{P}{C} \Big/ \frac{P}{TC} \qquad \text{-(Equation 1)}$$

Where;

TC = Traffic Cycles
C = Coverages
P = Passes

Determination of the TC/C ratio can best be illustrated by examples. Table 5 shows typical ratios for flexible pavement runways for situations in which fuel is not obtained at the aerodrome. Typical values of the P/C ratio are shown in this table, but different ratios can be substituted for other aircraft. Refer to Figure 1 for guidance in determining the number of passes used for each traffic count. Note that the number of traffic cycles to complete one coverage is reduced considerably for a runway with a central taxiway, as opposed to one with a parallel taxiway. The effect of this is that a runway with a central taxiway will experience more load stresses for each traffic count than one with a parallel taxiway.

Table 5: TC/C Ratio for Flexible Pavements – Additional Fuel Not Obtained

Taxiway Type	Typical Dual Gear (D)	Typical Dual Tandem Gear (2D)	Typical Triple Dual Tandem Gear (3D)
P/C	3.6	1.8	1.4
P/TC - Parallel	2	2	2

P/TC - Central	3	3	3
TC/C - Parallel	1.8	0.9	0.7
TC/C - Central	1.2	0.6	0.5

Table 6 shows the same information for a situation in which additional fuel is obtained at the aerodrome. From a comparison of these two tables, it is seen that for a runway having a central taxiway where fuel is not obtained at the aerodrome, there are more traffic cycles than for a runway in which a parallel taxiway exists and fuel is obtained at the aerodrome. For example, the typical dual gear TC/C for a central taxiway indicated in Table 5 is 1.2 compared with that of 3.6 for the parallel taxiway indicated in Table 6, resulting in three times the number of passes for each traffic count. Additionally, as the number of wheels increases, the TC/C ratio decreases, regardless of the taxiway configuration. The effect of this is that there are more loading cycles in terms of coverages per traffic count on flexible pavement with the increased number of wheels.

Table 6: TC/C Ratio for Flexible Pavements – Additional Fuel Obtained

Taxiway Type	Typical Dual Gear (D)	Typical Dual Tandem Gear (2D)	Typical Triple Dual Tandem Gear (3D)
P/C	3.6	1.8	1.4
P/TC - Parallel	1	1	1
P/TC - Central	2	2	2
TC/C - Parallel	3.6	1.8	1.4
TC/C - Central	1.8	0.9	0.7

Table 7 shows typical ratios for rigid pavements for situations in which fuel is not obtained at the aerodrome, while Table 8 shows the same information for cases in which additional fuel is obtained at the aerodrome. The same comparison as above is seen in which a different number of traffic cycles occur between the runways with differing taxiway configurations.

However, unlike the flexible pavement example, the ratio of traffic cycles to load stress is not very sensitive to gear configuration. For example, in Tables 7 and 8, both the dual and dual- tandem gears have the same TC/C ratio, while the triple dual tandem gear is only slightly different. The effect of this is that for the same taxiway type and fuel- loading situation, the level of load repetitions per traffic cycle on rigid pavement is virtually the same, regardless of the gear configuration.

Table 7: TC/C Ratio for Rigid Pavements – Additional Fuel Not Obtained

Taxiway Type	Typical Dual Gear (D)	Typical Tandem Dual Gear (2D)	Typical Triple Dual Tandem Gear (3D)
P/C	3.6	3.6	4.2
P/TC - Parallel	2	2	2
P/TC - Central	3	3	3
TC/C - Parallel	1.8	1.8	2.1

TC/C - Central	1.2	1.2	1.4

Table 8: TC/C Ratio for Rigid Pavements – Additional Fuel Obtained

Taxiway Type	Typical Dual Gear (D)	Typical Dual Tandem Gear (2D)	Typical Triple Dual Tandem Gear (3D)
P/C	3.6	3.6	4.2
P/TC - Parallel	1	1	1
P/TC - Central	2	2	2
TC/C - Parallel	3.6	3.6	4.2
TC/C - Central	1.8	1.8	2.1

8.3 Equivalent Traffic Based on Gear Type

In order to complete the equivalent traffic calculation, all other significant aircraft in the traffic mix must first be converted to a critical aircraft in terms of gear type and traffic cycles so this other traffic is accounted for in the overall pavement design life. Then, the converted gear types must be in turn converted to a critical aircraft equivalent in terms of load magnitude. The critical aircraft is an aircraft that regularly uses the pavement and that has the greatest thickness requirements, based on its individual operational characteristics.

Table 9 provides conversion factors for common gear configurations that are used to convert a given gear type to that of the critical aircraft. After this conversion, each aircraft in the traffic mix, and its corresponding traffic cycles, will be represented by the same gear configuration as the critical aircraft.

Table 9: Conversion Factors to Convert from One Landing Gear Type to Another

To Convert From Gear Type (N)	To Gear Type (M)	Multiply Traffic Cycles By
Single Wheel (S)	D	0.80
Single Wheel (S)	2D	0.51
Single Wheel (S)	3D	0.33
Dual Wheel (D)	S	1.25
Dual Wheel (D)	2D	0.64
Dual Wheel (D)	3D	0.41
Dual Tandem (2D)	S	1.95
Dual Tandem (2D)	D	1.56
Dual Tandem (2D)	3D	0.64
Triple Tandem (3D)	S	3.05
Triple Tandem (3D)	D	2.44
Triple Tandem (3D)	2D	1.56
Double Dual Tandem (2D/2D2)	D	1.56
Double Dual Tandem(2D/2D2)	2D	1.00

The general equation for this conversion is;

$$0.8^{(M-N)} \quad \text{- (Equation 2)}$$

Where;

M= the number of wheels on the critical aircraft main gear and

N= the number of wheels on the converted aircraft gear.

Tables 10 and 11 provide examples of the use of gear configuration conversion factors Table 10 shows the gear equivalencies for a dual tandem (2D) gear in a sample traffic mix, while Table 11 shows the same gear equivalencies for a dual gear (D). The equivalent traffic cycles totals are shown for comparison purposes only and are not necessary for critical aircraft calculations.

It can be seen from a comparison of these totals that the selection of the critical aircraft is very important for the overall evaluation process in that an incorrect selection leads to an erroneous number of equivalent traffic cycles. This is evident in Table 10 where the overall total of annual traffic cycles is 15,200, compared with the total equivalent dual tandem traffic cycles of 12,632, whereas in Table 11, the total equivalent dual traffic cycles is 19,720

Table 10: Equivalency Conversion to a Dual Tandem (2D) Gear Type

Aircraft	Gear Type	Annual Traffic Cycles (TC)	Conversion actor	Total Equivalent (2D) TC
727-200	D	400	0.64	256
737-300	D	6,000	0.64	3840
A319-100	D	1,200	0.64	768
B747-400	2D/2D2	3,000	1.0	3,000
B767-200ER	2D	2,000	1.0	2,000
DC8-63	2D	800	1.0	800
A300-B4	2D	1,500	1.0	1,500
B777-200	3D	300	1.56	468
		15,200		12,632

Table 11: Equivalency Conversion to a Dual Gear (D) Type

Aircraft	Gear Type	Annual Traffic Cycles (TC)	Conversion Factor	Total Equivalent (D) TC
727-200	D	400	1.0	400
737-300	D	6,000	1.0	6,000
A319-100	D	1,200	1.0	1,200
B747-400	2D/2D2	3,000	1.56	4,680
B767- 200ER	2D	2,000	1.56	3,120
DC8-63	2D	800	1.56	1,248
A300-B4	2D	1,500	1.56	2,340
B777-200	3D	300	2.44	732
		15,200		19,720

8.4 Equivalent Traffic Based on Load Magnitude

After the aircraft have been grouped into the same gear configuration, it is necessary to determine the total equivalent traffic cycles of each aircraft in terms of the critical aircraft as based on the relative load magnitude. As for the gear type conversion procedure, this step requires a previously selected critical aircraft.

When computing equivalent traffic cycles of the critical aircraft based on load magnitude, there are several simplifying rules to use:

- For the purpose of equivalent traffic cycle calculations, it is generally sufficient to use single wheel loads based on 95 percent of gross aircraft weight on the main gear.
- Since it is difficult to determine current or projected operational weights, it is recommended to use maximum taxiing gross weights of each aircraft for this calculation.

After gear types for the aircraft of the traffic mix are converted to that of the critical aircraft, the traffic cycles of each aircraft must be converted to equivalent traffic cycles of the critical aircraft. This conversion addresses the effect of wheel load magnitude and may be calculated by applying Equation 3:

$$\text{Log } R_1 = \text{Log } R_2 \text{ x} \left(\frac{W_2}{W_1}\right)^{\frac{1}{2}} \quad \text{- (Equation 3)}$$

R_1 = Equivalent traffic cycles of the critical aircraft

R_2 = Traffic cycles of a given aircraft expressed in terms of the critical aircraft landing gear

W_1 = Wheel load of the critical aircraft

W_2 = Wheel load of the aircraft in question

Example: Table 12 shows how the above calculations are combined to determine the equivalent traffic cycles of the critical aircraft. For this example, assume that the B747-400 is the critical aircraft. It can be seen that the original 3,000 annual traffic cycles of the B747-400 have increased to an equivalent 7,692 due to the combined effect of the other aircraft in the traffic mix. The R_2 column is from Table 12.

Table 12: Equivalent Traffic Cycles Based on Load Magnitude

Aircraft	Operating Weight,lb	(W_2) Single Wheel Load, lb	(R_2) (2D) TC	$\left(\frac{W_2}{W_1}\right)^{\frac{1}{2}}$ Wheel Load Ratio	(R1) Equivalent B747-400 TC
727-200	185,000	43,938	256	0.95	194
737-300	130,000	30,875	3,840	0.796	716
A319-100	145,000	34,438	768	0.841	268
B747-400	820,000	48,688 (W1)	3,000	1.000	3,000 (Critical Aircraft)
B767- 200ER	370,000	43,938	2,000	0.950	1,368

DC8-63	330,000	39,188	800	0.897	403
A300-B4	370,000	43,938	1,500	0.950	1,041
B777-200	600,000	47,500	468	0.988	434
			12,632		7,424

Note: Columns 5 and 6 values are obtained through computation of the equation 3 whilst data in column 1 and 2 are obtained from the Aircraft operation manuals. The values of column 3 are obtained from Table 10 as equivalency conversion to a Dual Tandem (2D) Gear Type.

Note that a sensitive factor in this table is the single wheel load and its ratio to the critical aircraft single wheel load. Any changes in the single wheel load magnitude are reflected in the wheel load ratio, which is used as an exponent in the calculation of equivalent traffic cycles. For example, the 727-200 equivalent traffic is shown to decrease from 256 to 194. Alternately, the B777-200 equivalent traffic decreases from 468 to 434 due to the relative magnitude of the single wheel loads.

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