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An Application of Damage Cost Allocation for Airport Services in Ireland

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SYNOPSIS

This paper describes a procedure developed for the estimation of marginal damage costs for airfield pavements in order to establish off-peak airport charges at Irish airports. The Commission for Aviation Regulation has regulated Irish airports with more than one million passengers per annum since 2001. The Irish government in order to separate the ownership and regulatory functions that had both been vested with the Minister for Transport established the Commission. The three main international airports are owned and operated by the publicly owned Aer Rianta. The relationships between the airport authority and its main customers had become increasingly hostile and confrontational on issues including landing charges in the previous five years.

PMS Pavement Management Services Ltd was engaged by the Commission to develop a methodology for off-peak marginal costs based on damage caused to airport facilities. The procedure developed uses the ICAO Aircraft Classification Number (ACN) to determine and allocate damage costs among different aircraft types for charges in off-peak periods. A total of 18 aircraft damage categories were determined for aircraft using Dublin Airport, based on a combination of ACN and Maximum Take-Off Weight (MTOW). The predicted maintenance and rehabilitation costs for the airport pavement infrastructure were allocated among the damage categories. An equivalent cost per tonne for 5 aircraft cost categories was subsequently developed to simplify the administration of the system by the airport authorities. The system has replaced the previous charging system based on MTOW only, and is in operation since 2001.

The charging mechanism more closely reflects the actual damage induced by different aircraft, and is encouraging airline operators to consider alternative aircraft types and gear configurations that induce lower damage for similar MTOW. Some modifications have been incorporated into the charging scheme based on a 2 year review of the system in 2003. Ultimately it is intended to require aircraft operators to certify ACN values rather than MTOW on an ongoing basis at Dublin Airport.

INTRODUCTION

The Commission for Aviation Regulation was established in Ireland in 2000 to regulate, among other aspects, landing charges at Dublin, Shannon and Cork airports. The three international airports are owned and operated by Aer Rianta, a state-owned body. There was considerable discussion and controversy prior to the establishment of the Commission for Aviation Regulation on the appropriate charging levels and mechanisms to operate at the airports. Airline operators were seeking lower charges and alleging inefficiencies in the airport management while Aer Rianta were seeking higher charges primarily on the basis of improving airport services.

The Commission sought a fair mechanism for determination of a charging structure that would reflect the marginal cost associated with an additional aircraft movement. In particular, the Commission wanted to determine different charges for peak and off-peak movements to encourage more efficient use of the existing airport infrastructure. PMS Pavement Management Services Ltd was engaged by the Commission to develop a methodology for off-peak marginal costs based on damage caused to airport facilities. This paper outlines the approach put forward and reports on its application by the Commission for the Irish airports. The paper is structured as follows. In the next section, background details on the ownership structure, traffic profiles and evolution of the current regulatory procedures for Irish airports are set out. The second section details the process for computing peak-period airport charges, describes the traditional approach to calculation of off-peak charges and outlines the difficulties associated with this approach.

The new procedure put forward for the determination of off-peak charges is then presented. This is based on the ICAO Aircraft Classification Number (ACN) to determine and allocate damage costs among different aircraft types for the off-peak charges. Some comparisons of the ACN-based charges with the standard

Maximum Take-Off Weight (MTOW) approach are presented for illustrative purposes. This section also outlines how the Commission implemented the new procedure at Irish airports. The paper concludes by highlighting two main issues associated with the future implementation of the procedures.

OWNERSHIP AND REGULATION OF IRISH AIRPORTS

The Irish Republic is served by a network of three larger publicly owned airports and by six privately owned 'regional airports'. The three larger airports at Dublin, Shannon and Cork are owned and operated by the semi-state company Aer Rianta. In 1937, Aer Rianta was incorporated as a holding company for Aer Lingus (the Irish national airline, which was founded in 1936), with the Irish Minister for Finance holding all of the share capital of the company. In addition to its role as a holding company for Aer Lingus, Aer Rianta functioned as an airport management company for Dublin Airport (which was established in 1941) and statutory responsibility for this function was granted in 1950 (see note 1). In 1966 the roles of the airport authority and airline were separated, with Aer Rianta retaining its role as agent of the Government in the management of Dublin Airport. These responsibilities were extended to Cork and Shannon Airports in 1969.

Under the 1998 Air Navigation and Transport (Amendment) Act, the assets of the three airports were transferred to Aer Rianta. A single Aer Rianta Board of Management directed aeronautical and non-aeronautical activities at the three airports until mid-2003. Three separate boards were established by the Minister for Transport and will manage the airports separately from mid-2004.

The three Aer Rianta airports handle roughly 97% of all air traffic within and between the Irish Republic. Dublin Airport has the largest proportion of the traffic as Table 1 indicates. The growth rates in air traffic at the airports are also indicated in the table. The rapid growth at the three airports during the late 1990s accompanied the rapid economic growth of the period. Rising consumer incomes, increased demand for intra-European and North American passenger and freight services for business activities and tourism fuelled the increase in traffic along with the supply of low-fare/low-cost air service provision principally provided by Ryanair.

Table 1 Passenger traffic and traffic growth rates at Cork, Shannon and Dublin airports, 1995-2002

Year	Cork Airport		Shannon Airport		Dublin Airport	
	Passenger Traffic	Annual Traffic Growth Rate (%)	Passenger Traffic	Annual Traffic Growth Rate (%)	Passenger Traffic	Annual Traffic Growth Rate (%)
1995	971,319		1,573,770		8,024,894	
1996	1,124,320	16	1,700,174	8	9,091,296	13
1997	1,191,261	6	1,822,089	7	10,333,202	14
1998	1,315,224	10	1,840,008	1	11,641,100	13
1999	1,501,946	14	2,187,272	19	12,802,031	10
2000	1,680,160	12	2,408,252	10	13,843,528	8
2001	1,769,493	5	2,404,145	0	14,339,037	4
2002	1,868,585	6	2,353,658	-2	15,084,667	5

Sources: Aer Rianta and Airports Council International

Ireland's island status, geography, population density and dispersed settlement pattern have given rise to a heavy dependence on road and air transport. Ireland was ranked number one in the EU15 in 1999 in terms of per capita intra-European enplanements (revenue passengers boarding aircraft) and total air passengers per capita (Reynolds-Feighan, 2003). Dublin Airport is unusual in a European context in having a full service carrier, Aer Lingus, and a low-cost carrier, Ryanair, based at the airport. The presence of the low-cost operator has been critical in driving cross-channel and intra-European passenger growth in the past decade (Barrett, 1997). The Ryanair presence has also had a significant impact on the operations and performance of Aer Lingus, so much so that Aer Lingus has now adopted a low-cost/low-fares strategy and expanded European and North Atlantic operations in 2002/2003. A key factor in the success of low-cost/low-fares operations is the availability of low airport charges, since this accounts for a more significant share of the low- cost operator's costs (AEA, 2000)

Regulation of Irish airport charges

The Minister for Transport regulated charges at the airports until 2001. Airlines operating from the Aer Rianta airports, particularly Dublin Airport, had been vocal publicly about the relatively high level of charges for the services provided. A debate raged in the media between the airport authority and Ryanair; the airline froze new route development plans in protest at the charges and management of the airport, arguing that the lack of transparency and consultation in the setting of charges was symptomatic of the poor relations between the airport authority and its customers. The government in line with international practice sought to establish an independent regulator for the Irish airports.

The Commission for Aviation Regulation (CAR) was established under the Aviation Regulation Act, 2001 on 27th February 2001. The Act required the Commission to make a determination specifying the maximum levels of airport charges that may be levied by an airport authority at any Irish airport with more than one million passengers in the previous year, no later than 6 months from its establishment.

The Commission has imposed a price-cap economic regulation regime for airport charges, in common with the three London BAA airports, Manchester and Hamburg. This form of regulation forces the operator to charge with a certain limit set out in the CPI-X formula, where CPI is the consumer price index and X represents some productivity factor. This form of regulation is generally applied when the firm is inefficient. The Commission applied a 'single-till' approach, essentially taking into account non-aeronautical revenues of the airport in the setting of maximum airport charges (see Reynolds-Feighan and Feighan (1997) for a detailed discussion on 'single-till' versus 'dual-till' approaches). Furthermore, in order to reduce the ability of Aer Rianta to use Dublin Airport revenues to cross-subsidise its other airports, an aggregate price cap for Aer Rianta was set in addition to a separate price cap for Dublin.

CALCULATION OF PEAK AND OFF-PEAK CHARGES

The demand for airport services shows daily, weekly and monthly variability. To determine the peak and off-peak periods for an airport, the pattern of aircraft movements during a representative day must be analysed. The day that is representative of the peak is the 90% busiest day, if days were ranked from the busiest to the least busy for the previous year. In the case of Dublin airport, this amounted to adoption of the standard 30th busiest day (ICAO, 1987), in order to avoid choosing the busiest of the busy days. Because of the seasonal nature of annual traffic at the airport, the 15th busiest days in the summer half –year (1st May-31st October) and the winter half-year (1st November – 30th April) were selected. Since Fridays are the busiest days of the week, the 15th busiest Friday was selected for the two periods. Aircraft movement distributions are reported in 15-minute intervals for these representative days. Where the number of movements exceeds the capacity limit of the system (11 movements per 15-minute interval for Dublin), the excess is spread into adjacent periods with spare capacity. The off-peak periods are defined as 15-minute intervals when the forecasted number of aircraft movements does not exceed 6, and periods must be at least an hour in length to be counted.

Peak period charges: The peak period charges were set for the three airports by computing the maximum yield per passenger. The yield was calculated as the sum of the following four revenue elements: (i) the company's return on its assets (the regulatory asset base) (ii) depreciation of assets (iii) operating cost expenses (iv) the tax liability, minus the gross commercial revenues (on aeronautical and non-aeronautical services). The difference is divided by the forecasted number of passengers to give the maximum per passenger yield. Maximum charges are permitted to rise each year using the CPI-X formula (CAR, 2001a). Passenger peak-hour Dublin arrivals and departures for 2000 along with forecast volumes for 5-year periods up to 2020 are given in Table 2, broken down by aircraft type.

Off-peak charges: Peak–period demand will lead to congestion if demand exceeds capacity for one or more intervals. Over time, growth in traffic will lead to increased congestion that may be relieved by capacity expansion (see for example Reynolds-Feighan and Button, 1999). If lower off-peak charges pertain, this provides an incentive to airline operators operating in the peak period to shift into an off-peak hour. This shift may result in that hour becoming a peak hour, or it may result in the hour from which the operator shifted becoming an off-peak hour. The price differential gives rise to the shifting or spreading of the peak. Off-peak users should not be required to pay capacity expansion costs as they do not impose these costs on society. It is the peak-period users that generate the demand for increased capacity and these users should pay these costs. The off-peak charges are calculated on the basis of the short-run marginal costs, including external costs, as this approach maximises welfare. As was argued in Reynolds-Feighan and Feighan (1997), the more typical weight-based approach to calculating landing and other charges does not relate directly to the costs that users impose on airport facilities and other users.

During peak times, the marginal cost of an additional aircraft movement comprises the cost of damage to pavements together with the costs of delay that the additional aircraft movement imposes on other flights. At off-peak times, congestion costs are absent so that the damage costs alone constitute the marginal cost of use. No account is taken of other related costs, for example, ground-based navigation aids and the provision of rescue and fire fighting services. These costs are fixed, common or overhead costs and do not vary with an additional aircraft movement. Damage costs alone constitute the marginal cost of use. In setting off-peak charges according to marginal cost, the Commission aimed to provide an incentive to Aer Rianta, the airport authority, to introduce a peak/off-peak differential in landing charges.

Table 2 Peak-hour operations summary for indicative intervals, Dublin Airport, 2000-2020

Arrivals - International & Domestic Operations - All Piers Dublin Airport								
	Two engine narrow body jet	Two-engine wide body jet	Three-engine narrow body Jet	Three-engine wide body jet	Four-engine narrow body jet	Four-engine wide body jet	Turboprops with more than 20 seats	Total
2000	16	1	1		1		3	22
2005	17	2	1		1		4	25
2010	18	2	2		1		4	27
2015	18	3	2		1		4	28
2020	19	3	3		2		4	31
Time interval: 10:30-11:30								
Departures - International & Domestic Operations - All Piers Dublin Airport								
	Two engine narrow body jet	Two-engine wide body jet	Three-engine narrow body Jet	Three-engine wide body jet	Four-engine narrow body jet	Four-engine wide body jet	Turboprops with more than 20 seats	Total
2000	18				4		2	24
2005	19				4		3	26
2010	20	1			5		4	30
2015	21	1			6		5	33
2020	22	1			6		6	35
Time interval: 5:45-6:45								
Combined Peak Analysis								
	Two engine narrow body jet	Two-engine wide body jet	Three-engine narrow body Jet	Three-engine wide body jet	Four-engine narrow body jet	Four-engine wide body jet	Turboprops with more than 20 seats	Total
2000	25	3	1	1	4		5	39
2005	28	4	1	1	5		6	45
2010	32	4	2	1	5		6	50
2015	36	5	2	2	6		8	59
2020	40	5	3	2	7		8	65
Time interval: 10:30-11:30 leading to 10.45-11.45								

Source: Infrastructure Management Group Inc. estimates for the Commission for Aviation Regulation (2001b)

REPAIR AND MAINTENANCE COSTS OF PAVEMENTS

Runway, taxiway and apron pavements sustain damage from the pressure imposed by the combined weight and speed of an aircraft when landing or taking off and from the weight of the aircraft when taxiing and when parked on the apron. The resulting distresses and joint damage require “routine” repair and maintenance.

In allocating costs, the CAR chose as a starting point the total annual operating expenditures on repair and maintenance of the pavements of the runways, taxiways and aprons. The costs involved were primarily labour costs, covering maintenance operatives and management as well as material costs.

Routine maintenance and repair expenditures do not, however, capture all of the damage costs caused by an additional aircraft movement. There is also damage caused to the basic structure of the runways, taxiways and aprons that leads eventually to their reconstruction. To represent the total structural damage costs, the annualised cost of Aer Rianta’s planned airfield upgrade projects over the next ten years at Dublin Airport was calculated, including projected apron reconstruction and runway and taxiway overlay projects.

The costs were annualised by calculating a Net Present Value (NPV) of the projects over the 10 year period, and calculating an Equivalent Uniform Annual Cost (EUAC). The relevant rate of interest used in the calculations was equal to Aer Rianta's cost of capital at 7%.

Damage allocation – appropriate parameter

Different aircraft types exert different amounts of damage on runway, taxiway and apron pavements, and a methodology for allocating the total marginal damage cost across these aircraft types was necessary. Internationally, and historically at Dublin Airport, the charging basis for landings and take-offs has been the aircraft's Maximum Take Off Weight (MTOW). A fixed cost per tonne is charged, with heavier aircraft paying more on a straight-line basis. A view was taken that aircraft weight is only one of several factors that contribute to pavement damage. It has been previously suggested (Alexander and Hall 1991, Reynolds-Feighan and Feighan, 1997) that Aircraft Classification Number (ACN) is a suitable and available tool for damage cost allocation.

ICAO Aerodrome Design Manual, Part 3 (ICAO, 1983) defines the ACN as "a number expressing the relative effect of an aircraft on a pavement for a specified standard subgrade strength" and describes their use as "a standard procedure for evaluation of the load rating of aircraft." In layman's terms, an ACN is an ICAO rating based on the equivalent damage caused by, among other things, different weights, landing gear (or undercarriage) and tyre pressures of aircraft. In general, a higher ACN indicates a more damaging aircraft and, for the same load, more wheels and lower tyre pressures usually result in a lower ACN.

The ICAO PCN (Pavement Classification Number) is defined as "A number expressing the bearing strength of a pavement for unrestricted operations" (ICAO, 1983). It is important to stress that the PCN definition does not refer to unlimited operations. Unrestricted is generally taken to mean that coverages (movements) of an aircraft are not restricted within the design life of the pavement. There is also damage to the basic structure of the runways, taxiways and aprons that eventually lead to their reconstruction. Recognition of this gradual loss of structural load-carrying capacity over time is the fundamental principle underpinning pavement design. On concrete pavements, the chief structural failure mechanism is through fatigue cracking of the concrete induced by many repetitions of the loading and unloading cycle as aircraft move towards, over and away from the point of loading.

In "A Guide to Airfield Pavement Design and Evaluation" (PSA, 1989), the primary resource used in pavement design and evaluation on civil airfields in the United Kingdom, it is stated in relation to the PCN definition; "The term 'unrestricted use' of a pavement is not specifically defined. However, it is a pavement design parameter which should reflect current and forecast use over an appropriate design life before major maintenance is required". Inherent within the PCN definition is an acknowledgement that the structural life of the pavement will be consumed over a design period, and the pavement will then require further structural maintenance and/or rehabilitation to continue to serve its function. Accordingly, the PCN is a relevant and appropriate parameter in conjunction with the ACN of the aircraft types using the facility to allocate long-term structural costs and ongoing routine maintenance costs arising from the damage effects induced in the pavements.

Subsequent to the adoption of damage-related off-peak landing charges at Dublin Airport, there was a significant amount of controversy on the switch from weight-based to ACN-based charges. Objections were raised by certain aircraft operators on the basis that the approach taken was unique, and not in accord with standard international practice. The Commission's view was that the approach is different but it is one based on the principle of cost reflectiveness. It uses an internationally recognized (ICAO standard) damage classification system to determine the damage caused by different aircraft types, such that landing and take-off charges reflect more accurately the differing marginal damage costs imposed by these types. In doing so, it recognizes that aircraft weight is not the only determinant of the damage imposed by aircraft on pavements. The Commission's approach ensures that more damaging aircraft pay more and less damaging aircraft pay less; it removes the arbitrariness of simply allocating costs according to aircraft weight and makes charges more cost-reflective.

ACN-based charging vs. MTOW-based charging

Before outlining the details of the approach taken to ACN-based charging, it is timely to examine the effects that the change from MTOW-based to ACN-based charging can have. Table 3 shows comparisons of 2 sets of 2 aircraft – the B757-200 and B727-200, and the B747-200 and L1011 aircraft.

The B757-200 is heavier than the B727-200, but induces less damage as represented by its relatively low ACN. The relatively low B757 ACN in turn is due to a Dual Tandem gear configuration rather than the Dual gear configuration on the B727. Under the former weight-based charging regime, the carrier operating the

B757-200 would have had to pay IR£219.90 per movement (IR£2.02 per tonne), nearly eleven times what the damage-based charging regime suggests. The B727-200, although of similar weight, exerts a great deal more damage than the B757-200, which is, in turn, reflected in the much higher charge per movement under the ACN-based system. It can be seen that the B727-200 was actually better off under the old regime, and paid even less than the B757. This is an example of less damaging aircraft subsidising more damaging ones under that regime. It is clearly inequitable to charge more for aircraft that induce less damage, even if they are heavier.

The B747-200 is heavier than the L1011, but exerts the same amount of damage as represented by the common ACN of 66. However, under the former weight-based charging regime, the carrier would have had to pay almost twice the amount as would be chargeable for the L1011. Under the new regime, both aircraft pay approximately the same charge per movement but are charged different per tonne rates in order to compensate for their differing weights when continuing to charge on a per tonne basis. The aircraft do not pay exactly the same amount under the ACN-based system due to grouping and aggregation issues that are discussed later in this paper.

Table 3 Comparison of A.C.N. based charging versus MTOW-based charging for a sample of aircraft types (Hogan et al 2002)

Aircraft	Charge/Tonne	MTOW	A.C.N.	A.C.N. Cost	MTOW Cost
B727-200	€ 2.69	95.04	63	€ 256.12	€ 243.76
B757-200	€ 0.25	108.86	38	€ 27.30	€ 279.22
L1011	€ 1.26	211.375	66	€ 266.56	€ 542.15
B747-200	€ 0.80	377.84	66	€ 301.73	€ 969.11

Summary of Methodology

1. Marginal costs are the basis for off-peak charges
2. Relevant marginal costs are damage costs, made up of routine maintenance costs and structural damage costs.
3. ACN is the most appropriate way of allocating damage costs among aircraft types
4. ACN was used to allocate damage costs based on Y2000 aircraft figures among aircraft types.
5. A grouping of aircraft types into aircraft damage categories with similar ACN and MTOW values was used to facilitate calculation of cost per tonne for the airport authority and to allow easy and logical inclusion of future aircraft types or variants.
6. Costs per landing for each aircraft damage category were derived, and could form the basis of charging.
7. To facilitate the airport authority administratively, the costs per landing were converted to costs per landing per tonne. These costs were grouped into 5 cost categories.

The first three steps followed have already been discussed in this paper. Details of the remaining steps followed are outlined below.

Allocation of Damage Costs

In an ideal world, Aer Rianta would be able to allocate damage costs precisely according to the incremental amounts imposed by each individual aircraft type. However, such a charging structure would place an undue burden on Aer Rianta, the airport authority, through excessive complexity and accuracy. In addition, Aer Rianta would need to have an administrative system in place to require the aircraft operators to report the ACN of all the aircraft that they are operating, similar to the reporting of MTOW by the operators. In practical terms, records of all aircraft type and type variant movements were not readily available from the airport authority coding system in place in 2000.

The total number of aircraft departures at Dublin Airport in 2000 was 72,824. These departures were grouped into c. 100 aircraft types and significant variants. The ACN value for each aircraft type and variant was obtained from a variety of sources including ICAO published data and aircraft manufacturer data. The most recent year was selected for which all aircraft movements (number and aircraft type) are available – year 2000 in this case.

The ACN value varies significantly depending upon whether the runway pavement is rigid (concrete) or flexible (bitumen). The value also varies according to ground conditions. ICAO defines four subgrade categories, based on k, the modulus of subgrade reaction, as follows:

A: High: Values: > 120 MPa/m, Characteristic Value: 150 MPa/m
B: Medium: Range, 60 to 120 MPa/m, Characteristic Value: 80 MPa/m

C: Low: Range, 25 to 60 MPa/m, Characteristic Value: 40 MPa/m
D: Ultra Low: Range, < 25 MPa/m, Characteristic Value: 20 MPa/m

The following assumptions were made for the calculations:

1. The appropriate representative subgrade classification to use for Dublin Airport is C (low strength). The subgrade classification at Dublin airport varies between B (medium) and D (very low). Runway 10/28 (the main runway), associated taxiways and new aprons would generally be B, most other taxiways and aprons have a C classification, while older runways have a D classification.

2. Calculations were done for both rigid and flexible pavements; newer pavements such as runway 10/28, its associated taxiways and aprons are rigid. Most of the other pavements are termed composite (originally rigid, subsequently overlaid with bituminous layers). It was recommended that if the Commission wished only to use one allocation, it should be the rigid damage allocation, as this is representative of the majority of pavements at Dublin Airport. This approach was adopted to simplify the process.

A design aircraft with an ACN close to the highest ACN of any aircraft using the airport regularly was selected, and the damage induced by all other aircraft relative to this standard aircraft was calculated. The relative damage was calculated using a 4^{th} power transform, i.e. the damage induced by aircraft A relative to aircraft B is to the ratio of the ACN of aircraft A to ACN of aircraft B raised to the 4^{th} power. The ICAO rigid pavement calculations are based on an Equivalent Single Wheel concept. A reasonable, consistent and simple transform from load to damage was required, and the 4^{th} power transform is appropriate in this situation. This is the consistent basis for allocation of damage costs based on relative damage induced by each aircraft.

3. Multiplying this relative damage factor per movement of each aircraft type by the actual number of movements of each aircraft type in the design year (2000) gives the equivalent number of movements of the design aircraft for each aircraft type. The proportion of damage attributable to each aircraft type is then simply the equivalent number of movements of the design aircraft for each aircraft type divided by the total equivalent number of movements of the design aircraft summed over all aircraft types. This proportion of damage can then be used to allocate a similar proportion of the damage costs to each aircraft type.

Grouping of Aircraft Types into Damage Categories

An issue then arises as to whether the charges should be left at this disaggregate level, with a specific charge for each of the aircraft types and variants. The alternative is a more aggregated approach, where similar aircraft types are grouped into aircraft damage categories. The disaggregate level approach is simpler and more accurate in cost allocation, but it has disadvantages. These can be summarized thus:

1. Grouping into categories means there are more movements in each category, which improves the generalization of the cost allocation beyond the 2000 data figures.
2. At the disaggregate level, small changes in numbers of aircraft for the critical aircraft types could lead to significant differences in cost allocation. Aggregation improves the robustness of the calculations.
3. It is not possible (theoretically at least) to include new aircraft types into the disaggregate damage allocation as a. they have not flown in 2000, b. estimates of their annual use will be estimates, not recorded figures as in 2000 and c. they may be substituting for aircraft included in 2000 and these aircraft should strictly be removed before the calculations are redone. With aggregation, it is possible to include “or similar” based on the ACN and MTOW ranges used in deriving the groupings.

So in summary, while it was computationally more exact to keep all the aircraft types disaggregated, there were practical and computational problems associated with it which required the category approach to be followed. Accordingly, based on the most recent year for which all aircraft movements (number and aircraft type) are available (calendar year 2000), it was decided to group similar aircraft according to, in the first instance, the damage that they impose (that is, according to ACN numbers) and, in the second instance, the weight of the aircraft. The implication is that the aircraft types within each of the aircraft damage categories induce a similar amount of damage per landing as well as per tonne. The added benefit of this system of damage categorisation is the flexibility for new aircraft types of variants to be added to existing aircraft categories. Finally, but importantly, the grouping scheme produces a system that is more easily administered by the airport authority. Table 4 shows the damage category-grouping scheme adopted at Dublin Airport in 2001.

Table 4 Aircraft damage categorisation and corresponding ACN and MTOW ranges (Hogan et al 2002)

		A.C.N.		MTOW	
Aircraft Damage Category	***Aircraft Types***	***Minimum***	***Maximum***	***Minimum***	***Maximum***
1	< 10 Tonnes	2	7		
2	10 – 20 Tonnes	7	12		
3	20 – 30 Tonnes	12	12		
4	CRJ; FK70; BAe146; BA11; RJ85; TU134	16	28	34	47
5	FK100; RJ100; B717; B737-200, 500	31	35	44	53
6	TU154; B757	32	38	100	110
7	B737-300, 600; DC9	36	39	55	57
8	A319; AN12; B737-400, 700, 800	41	46	61	71
9	A320; B727; MD80	48	49	68	79
10	A321; MD90	52	58	79	83
11	A300; A310	52	58	142	150
12	B747-100, -200	59	66	340	378
13	B767-200, 300; DC8	61	63	152	176
14	B727-200	63	63	95	95
15	A330; B777; L1011	63	66	211	234
16	A340; DC10	67	68	260	264
17	B747-400	75	75	362	363
18	MD11	79	79	273	274

The proportion of damage attributable to each aircraft damage category is the sum of the equivalent number of departures of the design aircraft for all aircraft in each of those damage categories divided by the total equivalent number of departures of the design aircraft summed over all aircraft types. The resulting proportions are shown in Table 5.

Table 5 Proportion of damage to rigid pavements attributable to each of the 19 aircraft damage categories

Aircraft Damage Category	***Aircraft Types***	***% Damage to Rigid Pavements***
1	< 10 Tonnes or similar	0.00
2	10 – 20 Tonnes or similar	0.04
3	20 – 30 Tonnes or similar	0.02
4	CRJ; FK70; BAe146; BA11; RJ85; TU134 or similar	2.08
5	FK100; RJ100; B717; B737-200, 500 or similar	11.98
6	TU154; B757 or similar	1.09
7	B737-300, 600; DC9 or similar	1.25
8	A319; AN12; B737-400, 700, 800 or similar	10.62
9	A320; B727; MD80 or similar	7.69
10	A321; MD90 or similar	36.74
11	A300; A310 or similar	1.00
12	B747-100, -200 or similar	0.14
13	B767-200, 300; DC8 or similar	4.71
14	B727-200 or similar	2.38
15	A330; B777; L1011 or similar	17.83
16	A340; DC10 or similar	0.32
17	B747-400 or similar	0.01
18	MD11 or similar	2.15
		100.00

These damage proportions per category are then used to allocate a similar proportion of the damage costs to each aircraft damage category (column 3 of Table 6). Dividing these amounts by the number of departures of aircraft within the damage categories gave an average marginal damage cost per landing of aircraft within each of those categories (column 5 of table 6).

Table 6 Allocation of total marginal damage cost to aircraft damage categories, number of departures and average marginal damage cost per landing of aircraft within those damage categories (Hogan et al, 2002)

Category	Aircraft Types	Damage Costs	Departures	Cost per Departure
1	< 10 Tonnes or similar	€ 93	1993	€ 0.05
2	10 – 20 Tonnes or similar	€ 2,712	7852	€ 0.34
3	20 – 30 Tonnes or similar	€ 1,375	2040	€ 0.67
4	CRJ; FK70; BAe146; BA11; RJ85; TU134 or similar	€ 149,020	12479	€ 11.94
5	FK100; RJ100; B717; B737-200, 500 or similar	€ 859,439	25484	€ 33.72
6	TU154; B757 or similar	€ 78,557	1179	€ 66.64
7	B737-300, 600; DC9 or similar	€ 89,571	1457	€ 61.48
8	A319; AN12; B737-400, 700, 800 or similar	€ 762,351	5289	€ 144.14
9	A320; B727; MD80 or similar	€ 551,802	3064	€ 180.09
10	A321; MD90 or similar	€ 2,636,644	8247	€ 319.71
11	A300; A310 or similar	€ 71,672	279	€ 256.89
12	B747-100, -200 or similar	€ 9,992	18	€ 555.07
13	B767-200, 300; DC8 or similar	€ 338,181	751	€ 450.31
14	B727-200 or similar	€ 170,575	333	€ 512.24
15	A330; B777; L1011 or similar	€ 1,279,149	2202	€ 580.91
16	A340; DC10 or similar	€ 23,319	34	€ 685.85
17	B747-400 or similar	€ 1,028	10	€ 1,028.86
18	MD11 or similar	€ 154,518	122	€ 1,266.54
		€ 7,179,998	72,833	

Cost per Tonne Charge Based on Damage

Although Table 6, in itself, provides a relatively simple and more practical charging schedule than charging according to the incremental damage imposed by individual aircraft types, the Commission wished to minimise the administrative burden on Aer Rianta by converting it into a per tonne charging schedule consistent with current practice. The CAR developed a per tonne charging schedule (Hogan et al 2002) that would be based on MTOW, but whose per tonne rates would still vary according to damage derived from the ACN values. For each aircraft type, the appropriate marginal damage cost per landing calculated in step 3 was divided by the MTOW tonnage of that aircraft to give a marginal cost per landing per tonne for each type and variant. Using the pragmatic approach of searching for significant increments in marginal costs per tonne, the following bands were considered to be the most suitable for the purpose of categorizing aircraft according to the cost that they impose (Table 7).

Table 7 Cost per tonne bands used for classification of aircraft into aircraft cost categories

Aircraft Cost Category	***Cost per Tonne band***
1	< €0.84
2	€0.84 - €2.11
3	€2.12 - €3.38
4	€3.39 - €4.65
5	> €4.65

A weighted marginal damage cost per departure per tonne was then calculated for each of the 18 categories shown in Table 5. These were found by dividing the sum of the cost of the departures of all aircraft types within each aircraft cost category [Σ(marginal damage cost per departure x number of departures)] by the sum of the total MTOW weights of those departures [Σ(MTOW x departures)]. The resulting marginal cost per departure per tonne was then assigned to one of the 5 aircraft cost categories. Accordingly, a final tariff schedule was derived for all aircraft types and variants at Dublin Airport, assigning each aircraft type to one of the 5 cost categories shown in Table 7.

DISCUSSION AND FUTURE DEVELOPMENTS

A 2-year review of the entire charging structure adopted by the CAR was carried out in 2003, including a review of the operation of the off-peak charging structure described above. Some issues and discrepancies had arisen over the 2-year period of operation, and they can be summarised into two main categories below.

Source of ACN value

There was major difficulty sourcing representative ACN values to use in the system in 1999/2000; Dublin Airport movements encompass a very wide range of aircraft types and variants. ICAO publish representative ACN values for a variety of aircraft, but these can (and have been in certain cases) superceded over time by changes in Maximum Ramp Weight, tyre pressures, gear configuration and location etc. In addition, they have not been updated to include new aircraft types and variants of existing aircraft types.

Obviously, the simplest and most acceptable solution is to get the aircraft manufacturer to state the ACN value and associated MRW (Maximum Ramp Weight), tyre pressures etc. for all of the aircraft types and variations. Information is available from the major aircraft manufacturers, but not in a consistent format. There are significant difficulties in obtaining ACN values for less common aircraft. There is also an issue when manufacturers have gone out of business or have been taken over by another manufacturer, and clearly there are difficulties when aircraft are no longer manufactured. Aircraft can have a life of up to 50 years, and there is an ongoing difficulty in deriving ACN values for older aircraft. In addition, there can be disputes between aircraft manufacturers as to the “true” ACN value to use for a particular aircraft type, particularly when another manufacturer has a similar product on offer.

Transport Canada have developed software based on the ICAO-specified procedures for ACN calculation for flexible and rigid pavements, and have published ACN values for a very comprehensive range of aircraft (Transport Canada, 2003). ICAO's "Aerodrome Design Manual - Part 3, Pavements" (ICAO, 1983) specifies the procedures to be used for the calculation of aircraft ACN. Appendix 2 of that document contains the source code for two computer programs - one to compute rigid pavement ACN and another to compute flexible pavement ACN. The Transport Canada software is based on the source code shown.

Because of the methods used to develop the software (i.e. developed from the ICAO "mother" source code), there is a high degree of confidence in the authenticity of the ACN values generated (Denyes, 2003). Calculations were carried out using the Transport Canada software for a wide range of aircraft types and loading conditions as laid out in ICAO's "Aerodrome Design Manual - Part 3, Pavements", and the resulting ACN values from the Transport Canada software give identical results to the published ICAO results.

Transport Canada have then used the programs to calculate ACN values for a very wide range of aircraft types and variants, with the latest published edition dated to May 2003. It has been recommended to the CAR in 2003 that the Transport Canada values should be used as the objective standard listing of ACN values for use in the damage cost allocation, and this recommendation is being accepted.

Difficulties with Charging Mechanisms

The ACN values generated are very sensitive to the input of aircraft loading conditions, primarily operating weight, weight distribution on gear (i.e. percentage of operating weight on the main gear leg used for the evaluation), gear wheel spacings, location of centre of gravity of the aircraft, and tyre pressure. Relatively small differences in input values can produce differences of 3-4 ACN units or more.

In addition, a key problem is that there may be many variations within an aircraft type. These variations give rise to many of the disputes about the “true” value of ACN to use, as it is possible to legitimately select different representative ACN values for a particular aircraft type depending on the variation chosen as being representative. As an example, in the 2000/2001 CAR calculations for the A319-100, a representative value used of 42 was chosen. The Airbus published values for the A319-100 in 2003 show 3 values of 39, 44 and 48. The differences between variations are primarily attributable to differences in MTOW and tyre pressures.

Another example is the Boeing 747-400. For rigid pavements, subgrade category C (Low), as is the case at Dublin Airport, there are 3 variations, with values of 67, 75 and 82. There is a single representative value published by ICAO (75), and a single representative value published by Boeing (75). 75 is also the value used by the CAR in the cost calculations in 2000/2001. The range between lowest and highest variations, 15 points, is extremely wide.

A final example is the case of the Airbus A321. First, there are two variations, A321-100, and A321-200. For rigid pavements, category C, there are 3 values shown by Airbus in 2003 for the A321-100, namely 52, 57 and 59 depending primarily on MRW and tyre pressure. For the A321-200, there are 4 values shown by Airbus, namely 56, 57, 62 and 65. Thus there is a range within each aircraft variation of 7 ACN points for the 321-100, and 9 ACN points for the A321-200, and a range of 13 ACN points within the A321 designation from 52 up to 65.

The same type of variations and ranges apply for very many aircraft types using Dublin Airport. It has been suggested to the CAR by a major aircraft manufacturer in the course of development of the off-peak charges that a consistent approach to choosing a single "representative" value for each aircraft type is to choose the lowest ACN variant. Thus, for the B747-400, the representative value would be 67, based on a very low MRW variant. However, as already noted, Boeing's own published "representative" value for the B747-400 is 75, as is the ICAO published value. The advantage of this approach is that it is simple. However, it has the following disadvantages:

1. From an engineering design viewpoint, the approach should err on the conservative side rather than on the liberal side. Assuming all movements to be at the lowest possible variant ACN when, in all likelihood, substantial numbers of movements are occurring with higher ACN values would lead to premature failure and a failure to recover full damage costs if the costings are explicitly linked to ACN values.
2. The lowest possible ACN variant may be a relatively uncommon or seldom used variant, with the ACN value being low because of unusually low tyre pressures or gear configurations.

It should be stressed that this difficulty is not unique to the ACN concept. If MTOW was being used, the same difficulty of assigning a "representative" value of MTOW when there are variants with substantially different MTOW occurs.

Historically, the weight-based charging was based on <u>most common</u> variant of aircraft type using the airport, but to a lesser extent, the disadvantages outlined above still apply. The approach taken by Transport Canada is to use loading values that represent the worst case (or critical) loading scenario. Also, in the interests of simplicity and keeping the size of the ACN table down to a manageable size, they have grouped variations of certain aircraft models (e.g. cargo, stretched versions) together where the differences loading conditions are deemed to be relatively minimal.

Calculations of a new off-peak tariff scheme are currently being undertaken using comprehensive movement data from 2002. The airport authority has improved the recording scheme, and MTOW data is available by aircraft movement. Provisionally, the Transport Canada ACN values are being used, and the ACN value for the recorded aircraft types and variants are being interpolated between the maximum and minimum values to more exactly reflect the recorded takeoff weights.

It is not current practice for airlines to declare ACN values at Dublin Airport. Airlines declare weights through a twice-yearly certification scheme. Over time, the CAR has indicated its preference to move to a "pure" ACN system where all aircraft will report ACN values rather than MTOW values, and a cost structure directly related to ACN will be produced. This will eliminate any of the discrepancies in charging produced by the current aggregation into damage categories and cost per tonne categories, and will allow incorporation of any new aircraft types and variants purely on the basis of ACN alone.

ENDNOTES

1. Section 23 of the Government of Ireland Air Navigation and Transport Act, 1950

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