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Development of a Prompt Evaluation Method for Airfield Pavements

Prompt Evaluation and Integrated Index (IIAE) applied to the Study Case - Aeródromo Municipal de Cascais (AMC)

EXTENDED ABSTRACT

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1. Introduction

Any aerodrome, even those of reduced dimensions and usage, is a complex infrastructure that demands a management committed to its several essential areas. It is fundamental a constant concern, among many other elements, with the equipment of security, assistance, communications, the training of its operational human resources, etc. However, the maintenance of pavement conditions is a truly unavoidable issue that assures the safe usage of this kind of infrastructure.

Pavement Management Systems (PMS) appeared as a necessity to measure pavement conditions and though it is difficult to say when the idea of systematically managing pavement networks first started, it is possible that it was envisioned 2000 years ago by a roman engineer. Nevertheless the first concepts associated with management systems date from the 1950s with the experiment of AASHO Road Test (FHA, 1997).

However**,** only over 25 years ago it has become a standard procedure to apply the principles from the Airfield Pavement Management Systems to the main airports in developed countries.

The current tendency, with the increasing concern of security, is to make the use of Airfield Pavement Management Systems (APMS) mandatory (ASTM D5340-98, 1998). However, the smallest aerodromes will not have an easy job in implementing such systems developed for the most demanding world-wide airports as for many of these this would represent an unbearable cost and a commitment out of proportions.

It is the goal of this essay to demonstrate the fact that all infrastructures can have access to a credible, prompt and less expensive Airfield Pavement Management System. For that, the author proposes a brand new model of evaluation for airfield pavement conditions, supporting the APMS.

In order to fulfill the purpose of this research work, a case study carried out in the Aeródromo Municipal de Cascais, and more specifically to one of its Aprons (Alfa Apron), was also integrated in this work.

An additional experimental work was realized, *in situ*, by performing tests to the macrotexture of the analyzed pavements according to the Pavement Macrotexture Depth Using the Volumetric Method (ASTM E965-96, 2006).

During the process of presentation and development of this new method, its analysis and comparison with other published studies from the same area will emerge.

Once the first experimental test was concluded, the results were analysed and, such as possible, related with other models and methods of evaluation for pavement conditions and performances.

A small practical illustrative manual for flexible pavements is attached at the end with the intent of facilitating the consultation and use of the method at discussion, during future field works.

2. Proposed Model – Prompt Evaluation and Integrated Index (IIAE)

The intention was to launch the principles of an innovative tool that assists the technicians that perform the evaluations in gathering the data necessary to the classification of the pavements performance, in an integrated and prompted way.

The goal was to get a prompt model of evaluation, that could serve of base to future models, adopted by aerodromes' administration boards and help them to apply a management pavement system, with three main characteristics: credible and useful; less expensive; and prompt, without the necessity to restrain the operations.

Thus the Prompt Evaluation and Integrated Index (IIAE) designation, proposed by the author in the present essay, is revealed.

The concept that is intended to be introduced, despite the fact of being in an early embryonic phase, consists of the integration of valences, crossing, into the same model, two faces that were driven more and more apart with calculations and procedures automation. It was planned to integrate the known mathematical models' abilities (although in a very simple way), with the human and subjective abilities of immediate evaluation.

It is not intended to remove any worthiness to the computational models, more complete and complex, not even to compete with them. The objective is to develop a prompt alternative, the more accurate as possible but, at the same time, less demanding from a technician and human being point of view, as well as of interference with the evaluated infrastructures operations, turning all of this phase less onerous.

The great advantage of such procedure seems to be that all the aerodromes will be able to have access to this model, and to continue to channel more financial resources for the pavement intervention stage, achieving this way, a pavement conditions' improvement and consequentially improving the security, comfort and durability conditions for all of those who use and depend on these pavements.

2.1 Pavement Division Process

The division of the pavements to analyse is the first of the four main stages of application of the model IIAE. It consists in identifying pavement areas with the same physical and usage characteristics, called Zones, dividing them into quadrilaterals that establish themselves as the mesh for the analysis of the pavements.

To each quadrilateral it is given the name of “Section”, which is sequentially identified as a matrix entry.

Contrary to what happens with the common airfield pavement division for PCI (Pavement Condition Index) determination, the considered model doesn’t resort to sampling.

The necessary steps to adopt in this phase are summarized in the following order:

- To divide the pavement net for evaluation into zones;
- To verify the identified zones characteristics uniformity, according to a physical characteristic, age and type of use criteria.
- To use smaller scales plants (1: 50 or 1:100) for the observation records;
- If possible, to use pavement plants that encloses the type, nature and the year of construction of those pavements.

To the theoretical grid drawn “over” the pavement for analysis, it is given the name Grid D.

Once created the theoretical grid on the pavement area that is to be studied, it can be verified the existence of some pavement bands that exceed the dimension of any of the sections. They must be numbered individually, whenever they represent more than 25% of the quadrilateral grid (i.e section). When the opposite happens, they must integrate the adjacent (precedent) quadrilateral or section.

The definition as how to divide an aerodrome pavement Zone must be done in the first usage of the considered model, having to be followed in all future evaluations.

2.2 Pavement Direct Subjective Condition Evaluation

Once accomplished the pavement for analysis division, the pavement conditions classification procedure can be started, taking into account the essential inspections to the place.

In this stage, the evaluator covers by foot all the pavement sections for analysis, identifying them through the aerodrome plants and involving elements, classifying the pavement superficial conservation state of each one of the sections, independently, according to a five level scale: failed, poor, fair, good and excellent. Table 1 presents the correspondence and the classification criteria of this stage in detail.

Table 1 Pavement Direct Subjective Condition Evaluation

Classif (S_i)	Scale	Designation	Description
1	Failed	**Ruined Pavement**	The pavement condition restrains the operations and/or place the aircrafts safety and the one of its users at risk
2	Poor	**Pavement in poor state of performance**	Although it doesn't place the aircrafts security and the one of its users at an evident risk, it presents defects that need to be quickly repaired
3	Fair	**Pavement in normal state of performance**	It presents a deterioration condition proceeding from its use and natural ageing. Although it doesn't affect the security factor nor needs an immediate maintenance interventions, it presents anomalies that require a pressed and cared monitoring
4	Good	**Pavement in good conditions**	It presents normal conditions decurrently from the use and aging, with small anomalies that don't require special monitoring
5	Excellent	**Pavement in excellent condition**	It presents ideal conditions, of a new and well constructed pavement, without any anomaly

To the matrix that is achieved from the D Grid with a S_i classification it's given the name of "Matrix S".

As the referral of sections can sometimes be extremely difficult, the evaluator must mark with chalk, whenever necessary, the pavement quadrilaterals' vertices. As this division in sections must be identified during the evaluation stage that follows, a new D Grid must be used, where is graphically represented, in the respective section, the anomalies identified during this first evaluation (Matrix S').

2.3 Distress Manifestation Index (DMI) Evaluation

The Distress Manifestation Index - DMI is an index that classifies, in the most accurate way as possible, the degradation and fatigue condition of the pavements surface.

In these conditions, a correct identification of anomalies that deflect pavement structural problems, draining or use, becomes more pertinent than quantifying its density by pavement unit area.

In this stage, the evaluator must intently observe each pavement section, analyzing all the possible existing anomalies, classifying them according to their importance relatively to the other ones present in that section. This classification must be pointed down in a matrix designated as “Matrix A”.

The fulfillment of the Matrix A with the anomalies classification (individually), must respect the following assignments (Table 2) and criteria (Table 3):

Table 2 Designation corresponding to the anomalies classification

Classification	Designation
2	Serious anomaly that conditions the evaluation as so as the section pavement performance
1	Existing anomaly that doesn´t condition the evaluation as so as the section pavement performance
0	The anomaly doesn’t exists in the pavement section

Table 3 Anomalies Classification Criteria

<table>
<tr><th colspan="2">Criteria</th><th>Classification</th></tr>
<tr><td rowspan="5">The anomaly exists in the section</td><td>It’s the only detected anomaly</td><td rowspan="4">2</td></tr>
<tr><td>There are another type of anomalies in this section, however this is the most grievous one</td></tr>
<tr><td>There are another type of anomalies in this section, however this is one of the two most grievous *</td></tr>
<tr><td>There are another type of anomalies in this section, however this is one of the three most grievous, since the two most grievous can’t be distinguished.**</td></tr>
<tr><td>There is another anomaly more grievous in the same section</td><td>1</td></tr>
<tr><td colspan="2">The anomaly doesn’t exists in the section</td><td>0</td></tr>
</table>

* The distinction is evident between the two most grievous anomalies and the remainder ones detected in the section.

** It can happen in a maximum of 10% of the sections for analysis.

The evaluation must start by the first evaluated section in the previous stage, following the same sequence and consulting only the Matrix S’, previously filled, for the clarification of any doubts in the relative location of the evaluator.

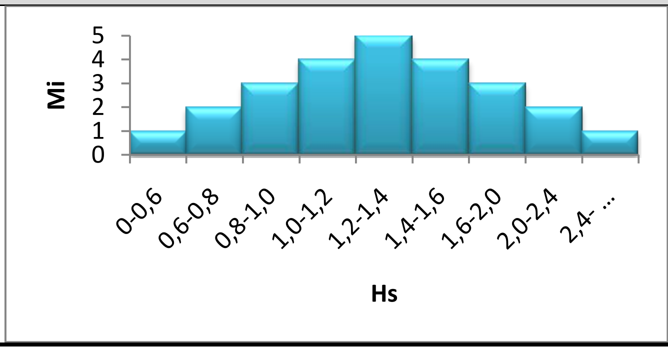
2.4 Pavement Surface Texture Integration

It is with the goal of integrating another valence, without making the evaluation process significantly difficult, that superficial texture integration is considered. This one integrates another face of pavement evaluation, the functional one, materialized by practical tests that will have to answer to the developed model original requirements, meaning that they have to be prompt and cheap.

The test that congregates such characteristics is the volumetric test that determines the pavement textures, also designated as sand spot test. This test and its results interpretation allows to foil and calibrate situations where the evaluator's inexperience could result in a less accurate evaluation.

The framing of the results proceeding from the sand spot test in the IIAE is summarized in Table 4.

Table 4 IIAE model macrotexture framing

Hs (mm)	Section Classification - M_i	Graphic
]0 ; 0,6]	1	
]0,6 ; 0,8]	2	
]0,8 ; 1,0]	3	
]1,0 ; 1,2]	4	
]1,2 ; 1,4]	5	
]1,4 ; 1,6]	4	
]1,6 ; 2,0]	3	
]2,0 ; 2,4]	2	
]2,4 ; +∞[	1	

This scale has the following fundamental aspects: the fact that 0.6 mm is the minimum value for new pavements, admitted by the EP (Estradas de Portugal S.A.) (JAE, 1998); the fact that airfield pavements show specific characteristics when high velocities are practiced, and by having to maintain good drainable conditions with small slopes (for instance, in Aprons, the slope has to alternate between 0.5 and 1.0% in parking positions, to a maximum of 1.5% in the remaining areas (ICAO, 1983)

Thus the airfield pavements should ideally have a texture designated "Thick" and "Very thick", alternating between the 0.8 mm and 1.6 mm (SPECHT, ROZEK, HIRSCH, & SANTOS, 2007).

The remaining intervals result from the realized experimental tests and published works consultation (MENEZES, 2008).

The pavement surface macro texture gauging could be carried out whenever doubts appear concerning the pavement texture under analysis and, by consequence, of the friction developed between tire and pavement.

The execution of two to three tests in each pavement zone for evaluation allows to acquire a more all-inclusive integrated classification, not only classifying the pavement structural evaluation, but also the functional one, with objective concerns of security and comfort being explicitly aimed at.

2.5 IIAE Calculus Method

The IIAE index calculus starts with the calculation of the DMIi. In order to do that it's necessary to select the variables X and Y. The Y variable corresponds to the sum of the number of anomalies in each section, classified with 2. The X variable corresponds to the sum of the number of anomalies, also in each section, classified with 1.

So far it is known that Y will take values between 0 and 3. On the other hand, X will be able to vary between 0, if a section doesn´t present any or only one anomaly and 12, value that it's considered as the permissible maximum for overlapping of anomalies in a section. This value means that it is not possible to judge more than 13 anomalies in a section, that is, if X = 12, Y will be, at least, equal to 1, and therefore it will not be possible to identify, in such reduced area, more than 13 different anomalies. It's admitting that 30% of the possible anomalies are mutually exclusive (physically) in a section, with the remainder ones.

Thus, the calculus formula for DMIi, proposed by the signatory, calibrated for the Study Case, is [1]:

$$DMI_i = 5 - \frac{0{,}5 \times X_i + 1{,}5 \times Y_i}{7/3} \quad [1]$$

The result of the IIAE for each section, that is, $IIAE_i$ or $IIAE_{i,T}$ (with the result of the sand spot test), crossing the different evaluations professed in this model, can be refined according to the following formulas proposed by the author [2] and [3]:

$$IIAE_i = (0{,}6 \times S_i + 0{,}4 \times DMI_i)/d_k \quad [2]$$

$$IIAE_{i,T} = (IIAE_i + M_i)/2 \quad [3]$$

Where the correction factor d_k is given by the Matrix B (Table 5), it must be calibrated during future applications of this innovative model.

Table 5 Matrix B for d_k correction factor

		S_i – Pavement Condition Direct Subjective Evaluation for section i				
		1	**2**	**3**	**4**	**5**
DMI_i value obtain through the equation [4]	**1**	1	1	1		
	2	1	1	1	1	
	3	1	1	1	1	
	4	2	1	1	1	1
	5				1	1

Finally, the calculus of the IIAE for each pavement Zone is the arithmetic average of the $IIAE_i$ results [4].

$$IIAE = \frac{\sum_i^n IIAE_i}{n} \qquad [4]$$

The number acquired for the IIAE is translated in the same scale that was previously introduced for the subjective evaluation (Table 1).

It is important to point out that this final number for the evaluated Zone does not translate into more than the average of all the sections' evaluations, therefore not excusing a critical observation at the $IIAE_i$ classifications map, as more or less sharp situations can occur that need detailed and differentiated attention.

3. Case Study application

The first test to the IIAE model, developed in this work, was carried out in the Alpha Apron of the Aeródromo Municipal de Cascais (AMC).

AMC is located 2 km (1.24 miles) from the centre of Tires and even though it was inaugurated on the 11th of October of 1964, the initial construction works were only concluded two years later.

Throughout the years, the aerodrome has been the target of improvement and expansion works, of which are example several hangars and other support lodgements. Currently, AMC continues to serve essentially civil aviation. The biggest percentage of flights belongs to instruction and training flights, as so as executive aviation, coil and spurt, and swift aviation for fire combat, among many other types of aircrafts. The annual number of flights has consistently grown, being nearly 40 000 in 1998, and currently around 80 000.

The Aeródromo Municipal de Cascais consists of an orientation track 17/35, with 1700m of total length and 30m width, a path of circulation on the rising side with 1000m, parallel to the track, and four more paths of circulation on the setting side, providing access to different Aprons, which are 5 in total (A, B, C, D, E).

The characteristics of the Alpha Apron of the AMC are summarized in Table 6 with the data acquired from the last evaluation report of the structural capacity of the aerodrome's pavement (FONTUL, 2007), carried out by the LNEC and the AIP provided by the NAV Portugal (NAV, 2009).

Table 6 Alpha Apron of the AMC Characteristics

Apron	A - Alpha
Designation/ Structural capacity	PCN 03/F/C/W/T
Pavement type	ASPH
Total Area	2540 m^2
Construction Year	1977
Altitude	101 m
Usage	Parking and Maintenance of small instruction and training aircrafts

From the segmentation of the platform A's pavement, 42 numbered and independent sections were obtained, with 3 small portions of pavement integrating the immediately previous sections, that is, in the sections nº 37, 44 and 51, as it can be seen in Figure 1.

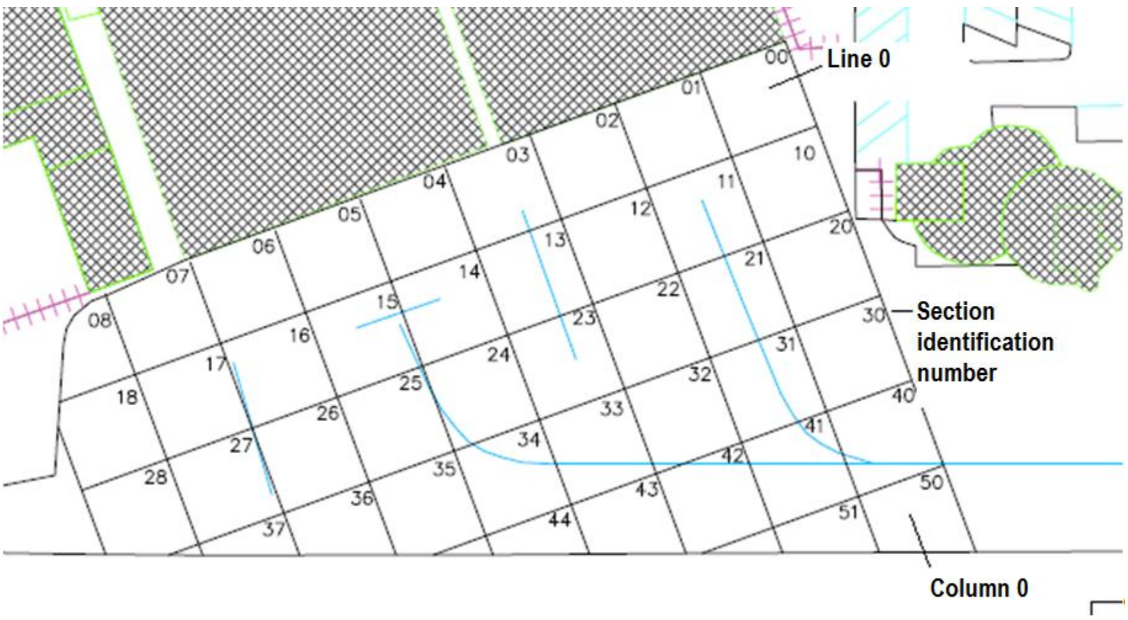


Figure 1 Grid D obtained from platform Alpha of AMC

The Matrix S acquired in the Direct Subjective Evaluation of the Pavement's Condition is represented in Figure 2.

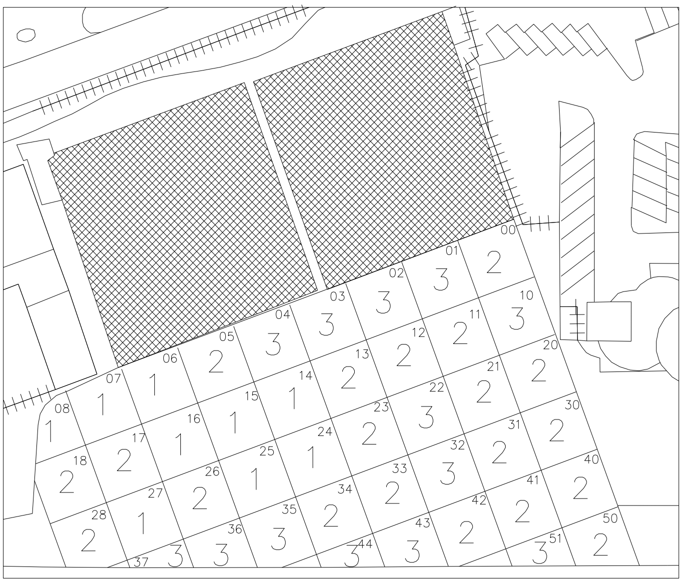


Figure 2 Matrix S obtained from platform Alpha of AMC

In the following stage, during the Distress Manifestation Index, Matrix A was created, being the results for the values of DMI_i displayed in Table 7.

Table 7 DMI_i results with most serious anomalies

8	7	6	5	4	3	2	1	0	Line/ Column
3 – A.I.1 A.IV.1	2 – A.I.1 A.II.3 A.III.6	2 – A.I.1 A.IV.1	2 – A.IV.2 A.V.1	3 – A.I.1 A.V.1	2 – A.II.2 A.III.1	3 – A.I.1 A.II.3	2 – A.III.4 A.V.1	3 – A.I.3 A.V.1	**0**
2 – A.I.1 A.IV.2	2 – A.I.1 A.V.1	1 – A.I.1 A.V.1	1 – A.I.1 A.I.3	2 – A.I.1 A.V.1	2 – A.I.1 A.V.1	3 – A.I.1 A.V.1	2 – A.I.1 A.III.1 A.V.1	3 – A.I.1 A.V.1	**1**
3 – A.III.4 A.IV.2	2 – A.II.2 A.II.3 A.III.4	2 – A.I.1 A.III.6	2 – A.I.1 A.III.4	2 – A.I.1 A.III.6 A.V.1	3 – A.I.1 A.V.1	3 – A.I.1 A.V.1	3 – A.I.1 A.V.1	3 – A.I.1 A.II.3	**2**
-	4 – A.II.2	3 – A.I.1 A.III.4	3 – A.II.1 A.III.4	3 – A.I.1 A.I.3	3 – A.I.1 A.I.3	3 – A.I.1 A.V.1	2 – A.II.3 A.III.6	3 – A.I.1 A.V.1	**3**
-	-	-	-	4 – A.I.1 A.III.4	3 – A.I.1 A.III.4	4 – A.I.1	3 – A.I.3 A.III.6	3 – A.I.1	**4**
-	-	-	-	-	-	-	4 – A.I.1 A.III.4	3 – A.I.3 A.III.4	**5**

The execution of tests done to the Alpha Apron pavement macrotexture, the Sand Spot Test, followed the LNEC procedures (PROC. 51/1/3416) but didn't meet the most recent normative (EN 13036-1, 2001) (ASTM E965-96, 2006) due to the non-availability of material to the execution of the tests (glass spheres). The execution place and the average height achieved in the tests to the platform can be checked in Figure 3.

Three previous tests were done to the main track of the aerodrome for calibration, followed by 12 tests done to the platform in question.

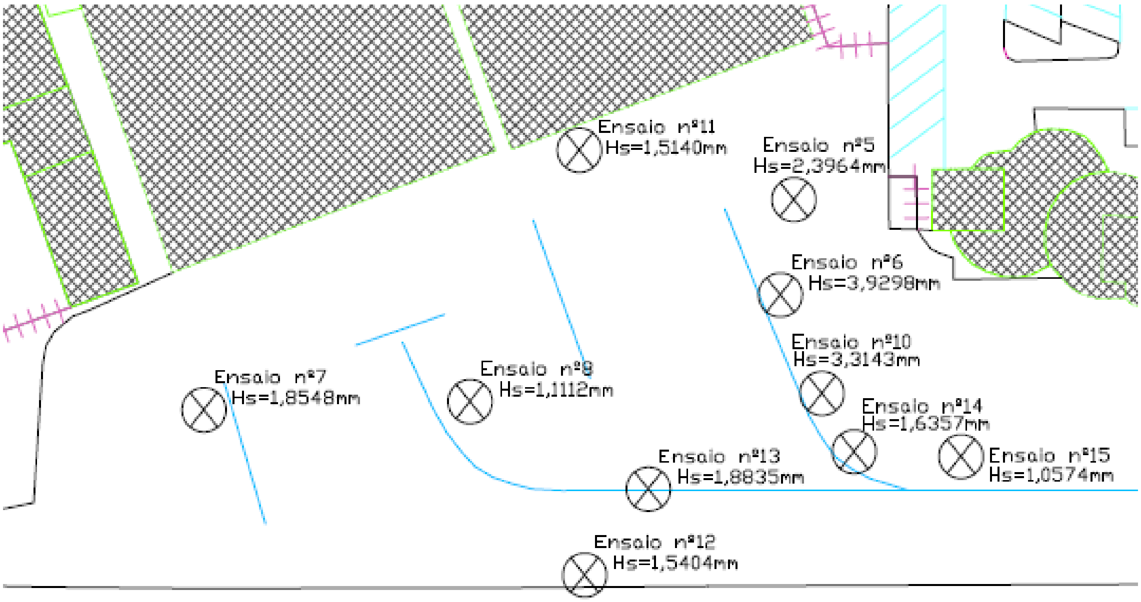


Figure 3 Execution place and results of the sand spot tests done to platform Alpha of AMC

With the results of the three evaluations executed: subjective evaluation, evaluation of the DMI and evaluation of the functional performance of the pavement (macrotexture); the number 2 for the IIAE from Alpha platform was achieved, meaning that the pavement presents a weak performance condition and that the intervention planned to be made should already been in course.

This study carried out a comparison of results, integrating or not a macrotexture evaluation component, to evaluate its relevancy and contribution to the IIAE model.

4. Pavement Manual

The manual of flexible pavements enclosed in the present work intends to be of assistance for those in the future who want to apply the IIAE model. It relates, whenever possible, to the classification of the PCI (Pavement Condition Index), one of the biggest and most known evaluation indexes for the condition of pavements (MTC, 1986).

More precisely, it describes the 18 different types of the more common anomalies in airfield pavements (Table 8), identifying for each one of them two levels of individual classification according to IIAE, meaning that it distinguishes more objectively as possible the two possible situations that can occur: the anomaly exists but it doesn't condition the evaluation of the pavement performance in this section, since there are others more grievous in the same pavement Section (anomaly classified with 1); the anomaly exists and is the only anomaly detected in the section or is one of the most grievous in the attribution of classification to the same one (anomaly classified with 2). To this individual classification of each anomaly (to carry out in each section in the application of the IIAE), the manual adds a photograph that illustrates the anomaly in cause, and of the two possible situations whenever as possible, resorting mostly to photographs caught by the author during the field work in the Aeródromo Municipal de Cascais.

Table 8 Anomalies types and codes, adapted from (U. S. Department of Transportation, 2004)

Category	Code	Type
Surface Defects	A.I.1	Raveling
	A.I.2	Flushing
	A.I.3	Polishing
	A.I.4	Jet erosion
Surface Deformation	A.II.1	Rutting
	A.II.2	Distortion
	A.II.3	Settling
	A.II.4	Frost heave
Cracks	A.III.1	Thermal
	A.III.2	Reflection
	A.III.3	Slippage
	A.III.4	Joint/Edge
	A.III.5	Block
	A.III.6	Alligator cracks
Patches and Potholes	A.IV.1	Patches
	A.IV.2	Potholes
Chemical and Mechanical Aggressions	A.V.1	Oils and other solvents spill
	A.V.2	Cleft or Impact settling

5. Conclusions

This research work proposed a unique and new model for evaluating pavements' conditions, allowing a pavement management system less expensive, more credible and of a more prompted implementation, accessible to all aerodrome administrations.

The results obtained, including the experimental results, enabled the following conclusions to be drawn:

1. It was achieved an innovative method that seems to be credible as an alternative to the traditional Pavement Management Systems (PMS) models.
2. The results from the first considered model application reveal a good method performance, and of its formulation, however not excusing future corrections in relative weights and corrective factors
3. The author's proposed calibration and formula confirmation, in this essay, only will be possible with more IIAE model applications, that are judged as indispensable to its valorisation.
4. Partially, the direct subjective pavement condition evaluation results seem to be sort of pessimists of that same condition. This may happen due to the analysed pavement distress particular conditions, that present several localized serious pathologies, but also due to the author´s relative inexperience in this activity.
5. The Distress Manifestation Index (DMI) seems to be adequate to the average pavement performance level
6. The pavement macro texture experimental tests results, show a regular level with a consequential good interaction between tire and pavement. On the other side, this evaluation leads to a slight pavement performance level increase expressed in the IIAE. Through this fact, the attributed weights to each one of the evaluation components can be discussed.
7. On the other hand, the present pavement manual (for ACC pavements) is considered an useful tool for future developments of this and other pavement condition evaluation methods, particularly of airfield pavements.

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