AERODROME METEOROLOGICAL OBSERVATION AND FORECAST STUDY GROUP (AMOFSG)

TENTH MEETING

Montréal, 17 to 19 June 2013

Agenda Item 5: Aerodrome observations

INCONSISTENCY BETWEEN VISIBILITY AND CMV, A CONVERTED METEOROLOGICAL VISIBILITY

(Presented by Michel Leroy)

SUMMARY

Visibility is defined by the Annex 3 since 2001. The definition considers the presence of lights of 1000 cd.
The updated version of the ICAO Manual of All-Weather Operations, Doc 9365, introduces a conversion of Reported Meteorological Visibility into CMV, for Converted Meteorological Visibility, a value equivalent to a RVR, when RVR is not available. The conversion table used for that purpose is not consistent with the current definition of visibility. It is consistent with a visibility being a MO R (Meteorological Optical Range). This conversion could lead to safety problems.

Action by the AMOFSG is in paragraph 4.

1. INTRODUCTION

1.1 ICAO Annex 3 — *Meteorological Service for International Air Navigation* defines visibility for aeronautical purposes as the greater of the greatest distance at which:

a) a black object of suitable dimensions, situated near the ground, can be seen and recognized when observed against a bright background; and

b) lights in the vicinity of 1 000 candelas can be seen and identified against an unlit background.

1.2 The ICAO *Manual of All-Weather Operations* (Doc 9365), has been recently updated (currently an unedited advance version, third version 2012). This manual defines a Converted Meteorological Visibility (CMV) as: "A value (equivalent to a runway visual range (RVR)) which is derived from the reported meteorological visibility".

1.3 Straight-in approach minima are often expressed in terms of RVR. Following widely used procedures, many airline operators convert the reported meteorological visibility into an equivalent RVR value, called CMV. This conversion is applied by the pilot only for landing, when the required RVR minimum is equal or above 800 m (1/2 sm) and when the RVR is not available (a reported RVR above its 2000 m limit is considered as being not available).

1.4 This CMV concept had first been introduced in 1995 by Europe's Joint Aviation Authorities (JAA) and defined in JAR-OPS 1, subpart E. It was then adopted by a large number of States outside Europe. And it was finally introduced in Doc 9365. See an extract from this manual in Appendix A to this paper.

2. DISCUSSION

2.1 This CMV parameter is unknown in the ICAO Annexes (3, 11, …). But it seems to be widely applied by the pilots when required RVR minima are not to low (≥ 800 m). All the documents dealing with this conversion are using the same conversion table.

2.2 The conversion table of Meteorological Visibility to RVR/CMV is given in Appendix A to this paper. It considers day and night, HI approach and runway lighting or any other type of lighting, with converting factors of 1, 1.5 and 2.

2.3 This conversion table was established in 1995, before the definition of the visibility (for aeronautical purposes) in Annex 3, from 2001. It is not consistent with this definition. It is consistent with a visibility being a meteorological optical range (MOR). See details in Appendix B to this paper.

2.4 A simple example can be given to highlight this inconsistency: during night and lighting installation other than HI approach and runway lighting, the conversion factor is 1.5.

2.4.1 The intensity of HI approach and runway lighting is typically 10 000 cd.

2.4.2 Lighting installation other than HI is typically LI lighting. And LI lighting is typically close to 25 – 50 cd, lower than 1000 cd.

2.4.3 This means that a visibility taking into account lights of 1000 cd is increased by 50 per cent (multiplied by 1.5) to get an equivalent RVR for a runway with 50 cd lighting! There is no logic behind this conversion. The CMV is overestimated and could lead to safety issues!

2.5 The explanation of this inconsistency is probably the fact that the conversion table was established before 2001, the year when Annex 3 defined for the first time the term "visibility" (for aeronautical purposes). Before 2001, the only objective definition of visibility was that of the World Meteorological Organization (WMO), the MOR. And the CMV conversion table is consistent with a visibility being a MOR. But this conversion table was not updated to take into account the ICAO definition of visibility.

2.6 What to do now?

2.6.1 First, it is a pity to calculate a CMV from visibility, when the aerodrome system is designed to calculate the RVR, a CMV being calculated just because the RVR is above its upper limit.

2.6.1.1 If an operational minimum exists above the upper limit of RVR (typically 2000 m), a better solution would be to increase the RVR upper limit! When RVR was assessed only from the measurements of a transmissometer, the RVR upper limit was the limit above which the uncertainty of the measurement was considered too high. When RVR is assessed from the measurements of a forward scatter meter, this technological limit no longer exists (or its value is much higher). If the upper limit of RVR is extended to a higher limit (why not 10 km), a conversion of the reported visibility to CMV would not be necessary.

2.6.2 If the aerodrome system is not designed to calculate the RVR and the reported visibility takes into account 1000 cd lights, the higher valid conversion factor between this visibility and an equivalent RVR, for night condition and HI lighting, would be 1.3. The direct use of the reported visibility would be much easier than a CMV.

2.7 For your information, when the visibility (for aeronautic purposes) was defined by ICAO Annex 3 in 2001, France was not ready to apply this definition in all the French aerodromes due to some missing sensors (mainly background luminance sensors). Therefore, France continued to observe and report visibility as a MOR. This difference was notified to ICAO. Later, our systems were upgraded to measure the background luminance and to be able to calculate and to report the visibility, in accordance with the ICAO definition. But due to the existence of RVR/CMV conversions, it was decided to continue to observe and report visibility as a MOR.

3. CONCLUSION

3.1 The inconsistency between the ICAO definition of visibility (for aeronautical purposes) and the conversion of reported visibility to an equivalent RVR/CMV should be taken into account, by either modifying the ICAO definition of visibility (!) or modifying the ICAO *Manual of All-Weather Operations* (Doc 9365).

3.2 The CMV conversion of a visibility compliant with the ICAO Annex 3 definition could lead to a safety issue.

4. ACTION BY THE AMOFSG

1.1 The AMOFSG is invited to:

a) note the information contained in this paper; and

b) consider appropriate follow-up actions.

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APPENDIX A

APPENDIX E OF THE ICAO MANUAL OF ALL-WEATHER OPERATIONS, DOC 9365

Appendix E

Conversion of Reported Meteorological Visibility (RVR/CMV) practices for the application of an Approach Ban.

The principle of converting reported meteorological visibilities into corresponding RVR values and the exclusive use of either reported or converted RVR values for the determination of straight-in approach minima had first been introduced in 1995 by Europe's Joint Aviation Authorities (JAA) and defined in JAR-OPS 1, subpart E. In the years following the first publication of JAR-OPS 1, the JAA AOM concept was not only adopted by all European States but also by a large number of States outside Europe. As a result, the concept of converting reported meteorological visibilities into RVR values used for the establishment of an Approach Ban with straight-in approach minima has found widespread acceptance by many airline operators worldwide.

The evolution of the JAA AOM concept into a new AOM concept, based on CDFA and largely harmonized between Europe and the United States of America, made it necessary to develop a new term for reported meteorological visibilities converted into RVRs when these values exceed 2000m because, other than in the original JAA AOM concept, upper RVR values defined for straight-in approaches in the new AOM concept do not end at 2000m but at 5000m. The new term found was "Converted Meteorological Visibility" (CMV). CMV values are derived by applying the same methodology as applied for the conversion of reported meteorological visibilities into RVR values in those cases where the resulting values exceed 2000m. Since its first introduction in EU-OPS in 2008, the CMV concept has been in use by all European operators and States and by many operators and States outside Europe.

Because Runway Visual Range and meteorological visibility are established differently, a ratio can be established between the two. Effect of lighting intensities and background luminance play a role when establishing a Runway Visual Range. Table E-1 below indicates the relation between light intensity and day or night condition.

An operator must ensure that a meteorological visibility to RVR/CMV conversion is not used for takeoff, for calculating any other required RVR minimum less than 800 m (1/2 sm), or when reported RVR is available.

When converting meteorological visibility to RVR in all other circumstances than those in sub-paragraph above, an operator must ensure that Table E-1 is used:

Note: If the RVR is reported as being above the maximum value assessed by the aerodrome operator, e.g. "RVR more than 1500 metres", it is not considered to be a reported value for the purpose of this paragraph.

Table E-1. Conversion of Met visibility to RVR/CMV

Lighting elements in operation	RVR/CMV= Reported Met. Visibility x	
	Day	Night
HI approach and runway lighting	1·5	2·0
Any type of lighting installation other than above	1·0	1·5
No lighting	1·0	Not applicable

APPENDIX B

LINK BETWEEN VISIBILITY AND RVR, AS A FUNCTION OF APPROACH AND RUNWAY LIGHTING INTENSITY AND DAY/NIGHT STATE

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Two mechanisms are in force concerning visibility: the vision/identification of a distant object or mark by contrast and the distance at which a distant light is seen as a point source.

- Meteorological Optical Range (MOR) is a measure of the visibility by contrast, with a conventional contrast ratio threshold of 0.05. It is driven by the Koschmieder's law, linking MOR to σ, the extinction coefficient (MOR = 3/σ).
- The distance at which a light is seen is driven by the Allard's law. It depends on
  - the optical clarity of the atmosphere, expressed by σ (and therefore by MOR);
  - the intensity of light (I);
  - the visual threshold of illumination (E_T) of the eye that is required for a point source or small light to be visible. E_T is linked to the luminance of the background (BL) against which the light is viewed. This relation was mainly established in the 1940's and 1950's, by visual observations of lights.

So, the distance at which a light is visible can be expressed as a function of MOR, I and E_T or BL.

RVR considers the (high) intensity of lights of a runway to assess what the pilot sees. It is the maximum value between MOR and the distance at which the approach and runway lighting is seen.
Both visibility by contrast (MOR) and RVR have been objectively defined for decades (see WMO Doc n° 8 and ICAO doc. 9328).
Before the amendment 72 of Annex 3 of ICAO (2001), visibility for aeronautical purpose was not objectively defined. MOR, the parameter considered as the definition of visibility for WMO needs, may have been used by default, but was not felt to be well adapted to the conditions encountered on an aerodrome. Therefore, in 2001, the definition of visibility for aeronautical purposes (VA) was introduced in Annex 3. It is the maximum value between the visibility by contrast (MOR) and the distance at which lights of 1000 cd can be seen.
So, VA is objectively defined and can be expressed as a function of MOR, I = 1000 cd and E_T or BL.

When only based on human observations, the link between MOR, VA and RVR may deviate from the theoretical relationships between these parameters. When based on automatic measurements, by means of transmissometers or forward scatter meters and associated background luminance sensors, MOR, VA and RVR are linked by their definitions and by the Koschmeider's and Allard's laws.

This link is described in the attached file and below, for night and day conditions and several values of lighting's intensity (see file). By simplification, for RVR values between 200 and 550 m, no decrease of light intensity of the runway edge lights is used.

For night, the visual threshold of illumination E_T is taken to be 8.10^{-7} lx. For day, E_T is taken to be 10^{-4} lx (see Attachment D of Annex 3).

When RVR is not available, visibility may have to be converted to RVR, under the term "CMV", for Converted Meteorological Visibility, with this type of table:

(h) Conversion of reported meteorological visibility to RVR

1. An operator must ensure that a meteorological visibility to RVR conversion is not used for calculating take-off minima, Category II or III minima or when a reported RVR is available.

   Note: If the RVR is reported as being above the maximum value assessed by the aerodrome operator, e.g. "RVR more than 1 500 metres", it is not considered to be a reported RVR in this context and the Conversion Table may be used.

2. When converting meteorological visibility to RVR in all other circumstances than those in subparagraph (h)1. above, an operator must ensure that the following Table is used:

Table 9

Conversion of visibility to RVR

Lighting elements in operation	RVR = Reported Met. Visibility x	
	Day	Night
HI approach and runway lighting	1,5	2,0
Any type of lighting installation other than above	1,0	1,5
No lighting	1,0	Not applicable

The CMV conversion table considers the following criteria: "day/night", HI[1] lighting, Any other intensity lighting, no lighting".
In this document, HI lighting is considered to be ~10 000 cd.
"Any type of lighting installation other than above" is not defined in terms of intensity. 2 c ases are considered:

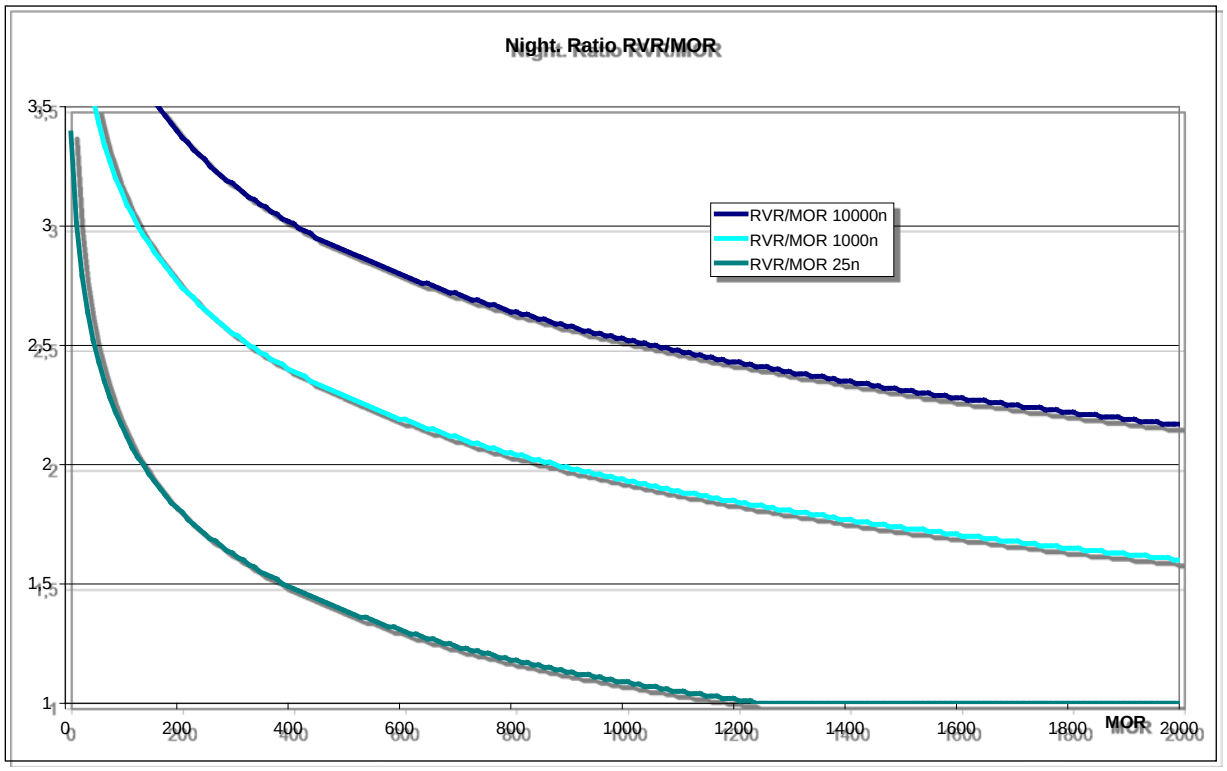
- 1000 cd, because it is the value used in the ICAO definition of visibility, thus considering that lights with an intensity of 1000 cd exist on an aerodrome.
- 25 cd, because LI[1] lighting may be as low as 25 cd.

Curves of RVR calculation with lighting values of 10 000, 1 000 and 25 cd are shown. Other lighting values are available in the attached file.

[1] HI: High Intensity; LI: Low Intensity

Night simulation

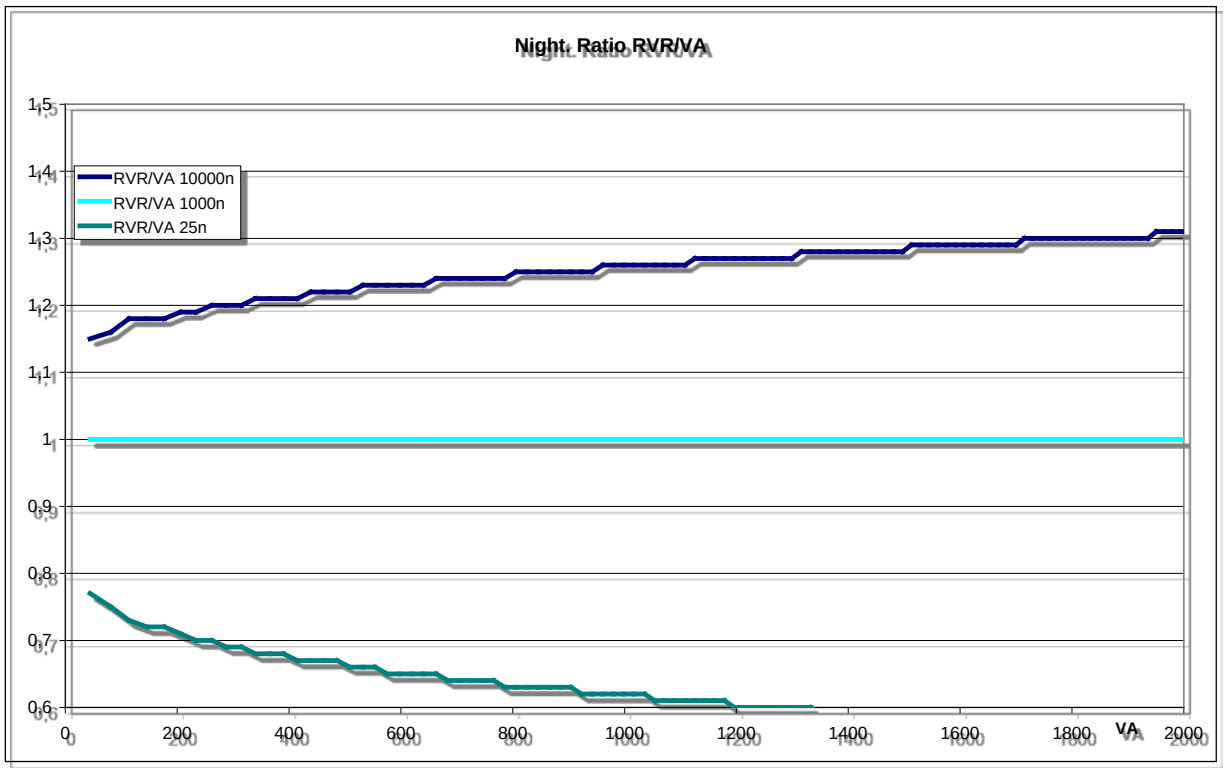
Ratio RVR/MOR



It can be seen that in night conditions and HI lighting, the ratio between RVR and MOR decreases from 3 down to 2.2, for increasing MOR values.

For low intensity lighting (25 cd), the ratio between RVR and MOR is 1.5 for MOR = 400 m and decreases down to 1 for higher MOR values. Above 1200 m, a light intensity of 25 cd is too low to give a better visibility distance than the visibility by contrast (MOR).

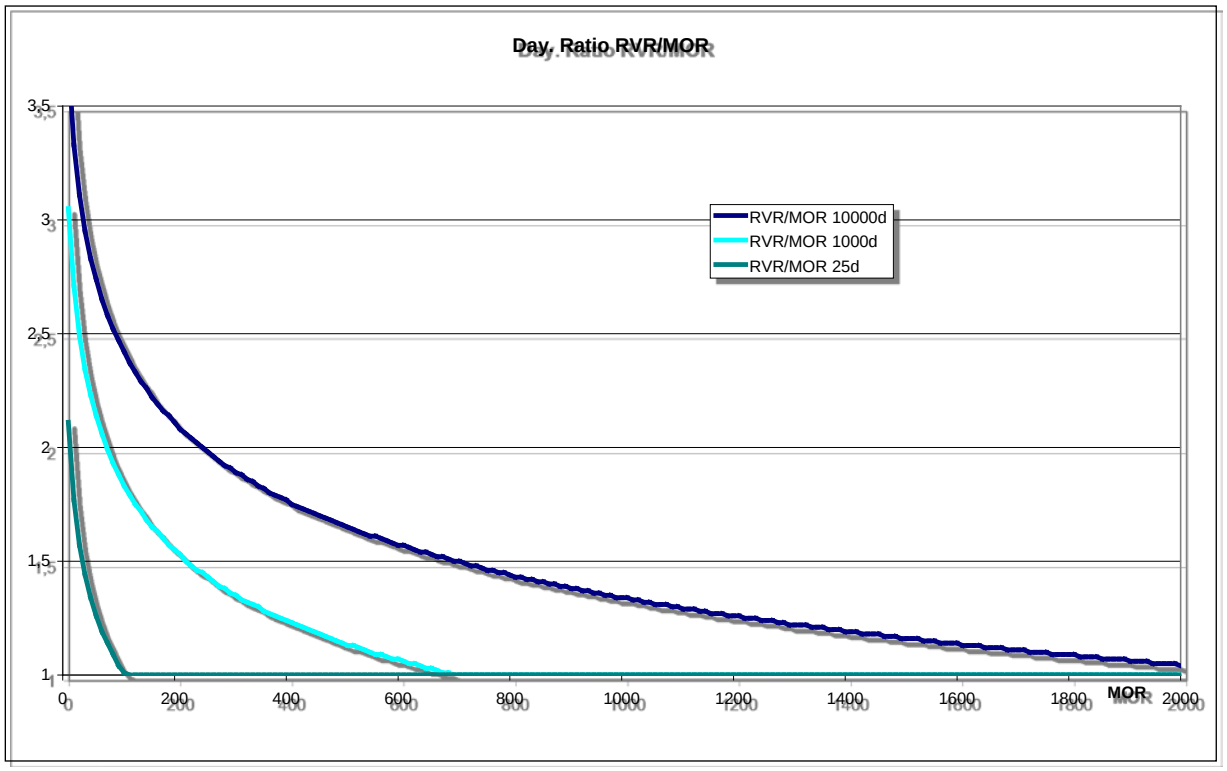
Ratio RVR/VA



When visibility is considered to be VA, the ratio between RVR and VA is much lower than when considering MOR.
In night conditions and HI lighting, the ratio between RVR and MOR increases from 1.1 to 1.3.
For low intensity lighting (25 cd), the ratio between RVR and VA is significantly lower than 1 for any VA values. Any RVR calculated with a light intensity < 1000 cd is by nature lower than VA, calculated with a conventional 1000 cd intensity.

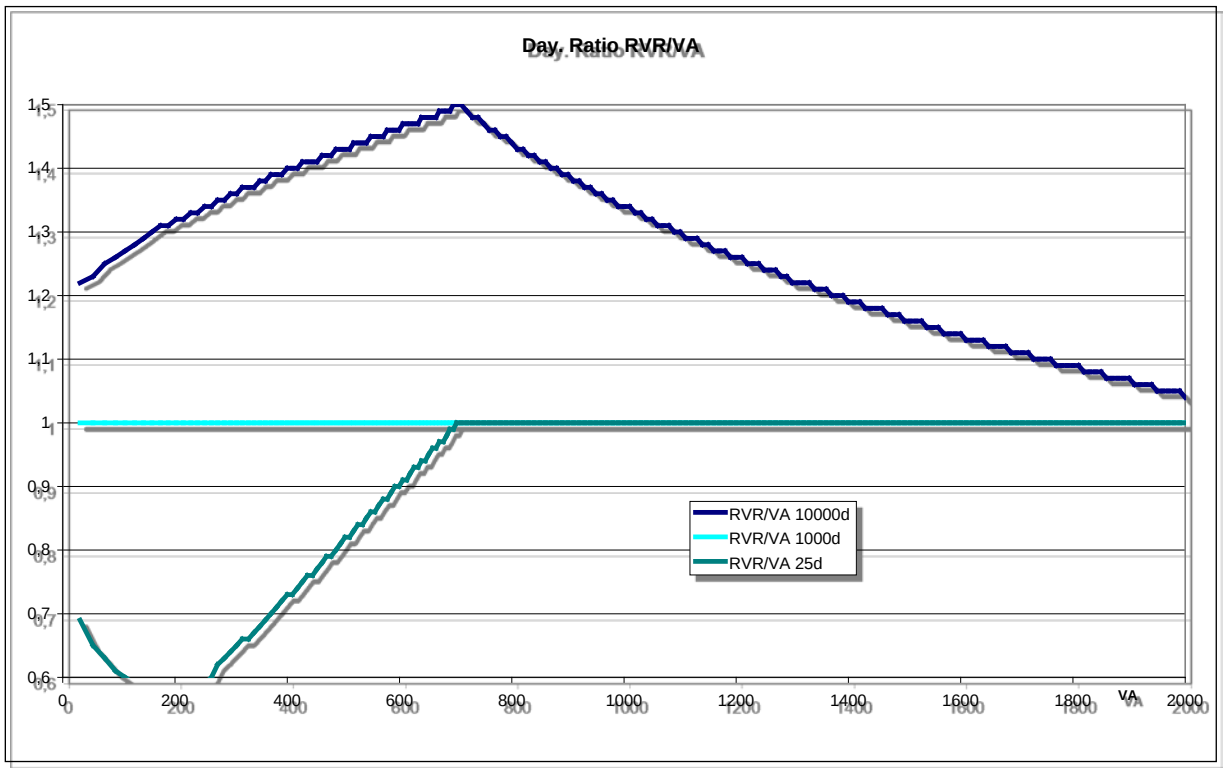
Day simulation

Ratio RVR/MOR



In day conditions and HI lighting, the ratio between RVR and MOR decreases from 2 down to 1. For low intensity lighting, the ratio between RVR and MOR is 1 for any MOR values > 100m.

Ratio RVR/VA



When visibility is considered to be VA, in day conditions and HI lighting, the ratio between RVR and VA increases up to 1.5 and then decreases down to 1. This curve shape is due to the respective influence of lighting intensity in the calculation of RVR and VA.
For low intensity lighting (25 cd), the ratio between RVR and VA is < 1 for VA > 700 m: above 120 m, RVR(25cd) = MOR and VA is > MOR. The RVR/VA ratio is 1 for any VA values > 700 m, because both RVR and VA are then equal to MOR.

Validity of a conversion of Reported Meteorological Visibility to RVR

The conversion table used to derive CMV has been established and introduced in the JAR-OBS 1 well before ICAO define the visibility for aeronautical purposes (2001).
The conversion factors of 2, 1.5 and 1 are mean values (over the visibility range) rather consistent with a visibility being a MOR.
As before 2001, the visibility (for aeronautical purpose) was not objectively defined, it is likely that the CMV conversion table was established by considering the only visibility definition which was available at that time, the MOR.

Conversion of visibility (**MOR**) to RVR		
Lighting elements in operation	RVR = Reported Met. Visibility x	
	Day	Night
HI approach and runway lighting	**1.5** -25% ----> + 50%	**2** -33% ----> - 10%
Any type of lighting installation other than above (**1000 cd ?**)	**1** = (0%)	**1.5** -66% ----> - 6%
Any type of lighting installation other than above (**25 cd ?**)	**1** = (0%)	**1.5** 0% ----> + 50%
No lighting	**1** = (0%)	

This table shows the under-estimation (negative values) or over-estimation (positive values) of CMV, compared to the theoretical link between MOR and RVR, MOR ranging from 400 m to 2000 m.

Since 2001, the term "visibility" has been defined in Annex 3, as the greatest of MOR and the distance at which lights of 1000 cd can be seen and identified:

> *Visibility*. Visibility for aeronautical purposes is the greater of:
>
> a) the greatest distance at which a black object of suitable dimensions, situated near the ground, can be seen and recognized when observed against a bright background;
>
> b) the greatest distance at which lights in the vicinity of 1 000 candelas can be seen and identified against an unlit background.
>
> *Note.— The two distances have different values in air of a given extinction coefficient, and the latter b) varies with the background illumination. The former a) is represented by the meteorological optical range (MOR).*

In this case, the link between RVR and "visibility" is changed and the converting factors of 2 and 1.5 are systematically over-estimated, as shown above and below.

Conversion of visibility (**VA**) to RVR		
Lighting elements in operation	RVR = Reported Met. Visibility x	
	Day	Night
HI approach and runway lighting	**1.5** +36% ---> 0% ---> + 36%	**2** +66% ----> +53%
Any type of lighting installation other than above (**1000 cd ?**)	**1** = (0%)	**1.5** + 50%
Any type of lighting installation other than above (**25 cd ?**)	**1** = +30% → 0%	**1.5** > + 150%
No lighting	**1** = (0%)	

This table shows the over-estimation (positive values) of CMV, compared to the theoretical link between visibility as defined by ICAO Annex 3 (VA) and RVR, VA ranging from 400 m to 2000 m.

With HI approach and runway lighting, a conversion factor of 1.3 could be used for day and night. In other conditions, the conversion factor should be 1.
With these low conversion factors, the relevance of a visibility/RVR (CMV) conversion should be considered. With the ICAO definition of visibility, it may not be relevant to convert this visibility into RVR, when RVR is not available.

— END —