

AVALANCHE FORECASTING MATRIX

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ABSTRACT: The Avalanche Forecasting Matrix (Matrix) is an avalanche forecasting classification model created to improve communication between avalanche forecasters and operational management in a meso-scale or micro-scale avalanche program. The Matrix's function is designed to assist forecasters in conveying avalanche-specific information to an audience not familiar with snow science terms or avalanche related topics. To do this, the Matrix numerically and graphically expresses avalanche forecaster concerns about a range of avalanche/weather parameters contributing to avalanche danger (hazard) for a specific forecast period. Such a situation may occur where avalanche forecaster(s) need to clearly demonstrate avalanche-related concerns to operational management quickly and unambiguously. The Matrix is based on forecasting components of "Snow Avalanches," the 1961 USDA Avalanche Handbook, and the current International Avalanche Danger Scale.

Keywords: Avalanche forecasting, contributory factor analysis, avalanche danger rating

1. INTRODUCTION

The Avalanche Forecasting Matrix (Matrix) is a simple avalanche forecasting model designed to numerically and graphically represent singular and distributional data (Hägeli, 1999) for a specific avalanche forecasting area.

The main objectives in creating the Matrix are twofold: First, to assist field oriented avalanche forecasters in communicating avalanche forecast information to operational management-management that is sometimes far removed from a forecast area and/or unfamiliar with avalanche related information. Second, is to provide operations management a quantitatively oriented avalanche forecast that allows for monitoring trends in the forecasted avalanche danger and a numerically defined "avalanche danger rating."

The idea of the Matrix was developed during the winter of 2007-08 by avalanche forecasters working for Chugach Adventure Guides (CAG) in a contracted railroad avalanche safety program (program) (Hamre, 2006). As such the Matrix is a "brand new" in-house forecasting tool that, thus far, has only been tested on a trial basis.

2. BACKGROUND

The concept of the Matrix is founded from "analysis of contributory factors" (ACF) discussed in Chapter 5 of "Snow Avalanches," the 1961 USDA Avalanche Handbook No. 194. Specifically, "Contributory, Factors" are described in section 5.1 and "Factor Analysis" methods are explained in section 5.11 (LaChapelle, 1961).

ACF is a foundational pillar of modern avalanche forecasting and provides the backbone for today's avalanche forecasting techniques and numerous forecasting models.

Contributory factors, as listed in the 1961 Avalanche Handbook, consist of ten (10) snow, weather, and terrain factors (**Table1**).

All ten contributory factors are accompanied by a detailed qualitative and/or quantitative description and are noted to be "interrelated."

It is also noted that the 10 contributory factors relate directly to "hazard forecasting" of "direct action dry slab avalanches." All factors utilized in ACF "...have been selected empirically on the basis of experience and snow, storm, and avalanche records over the years."

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1. Old Snow Depth	2. Condition of the Base	3. New Snow Depth	4. New Snow Type	5. New Snow Density
6. Snowfall Intensity	7. Precipitation Intensity	8. Settlement	9. Wind	10. Temperature

Table 1. Original 10 contributory factors listed in the 1961 Avalanche Handbook

1. Recent Avalanche Activity	2. Existing Snowpack Height	3. Existing Snowpack Instability	4. Existing Snow Surface	5. Height of Storm Snow
6. Precipitation Intensity	7. Snowfall Intensity	8. Rainfall Intensity	9. New Snow Density	10. Prev. & Current Wind Loading
11. Air Temperature Trend	12. New Snow Settlement Rate	13. Weather Forecast		

Table 2. Matrix “Avalanche Danger Factors”

One avalanche forecasting method described for use of the ACF is to have a program's avalanche forecaster(s) assign each factor a numeric value between zero (0) and ten (10). A score of 0 indicates a “minimum contribution to avalanche formation,” and a score of 10 indicates a “strong disposition toward avalanching.” The cumulative score, between 0 and 100, is then summed and the degree of avalanche hazard development is expressed as a summed total and termed the “Hazard Factor.”

An ACF Hazard Factor score of 40 to 60 would indicate a “borderline situation in which limited avalanche activity may occur whereas a hazard factor score greater than 75 would be a “definite warning or impending hazard.”

3. THE MATRIX

3.1 *Matrix Design*

The Matrix is created in Microsoft Excel where numeric and graphic representation of “Avalanche Danger Factors” (factors), are displayed on a single spreadsheet (**Figure 1**). Some ACF headings have been included for Matrix factors while other factor titles have been re-worked to better represent the Matrix model. Also, four (4) factors were added to the ACF's original contributory factors list and one original ACF factor, “Terrain Roughness and Vegetation,” was removed (**Table 2**).

The “Terrain Roughness and Vegetation” factor was not utilized in the Matrix, as terrain existing in the program forecasting area is already identified as capable of producing dangerous avalanche conditions.

Added Matrix factors include:

- Rainfall Amount
- Weather Forecast
- Recent Avalanche Activity
- Existing Snow Surface

In total, the Matrix incorporates 13 qualitative and quantitative factors related to existing and/or forecasted snow and weather conditions.

(**Table 2**). Positioning of individual factors in the list was/is arbitrary.

Similar to ACF, the Matrix's 13 factors are scored with a possible “Score” (score) of each factor ranging between zero (0) and (10). The greater the associated number with a particular factor, the greater the forecaster(s) concern is regarding that factor. For example, individual factor scores of 0-3 would represent low concern, 4-7 moderate concern, and 8-10 significant concern in relation to a factor's influence on potential avalanche activity.

Individual factors scored are displayed concurrently on a bar graph and as a result, numeric emphasis on a particular factor can be easily identified recognized, and quantitatively compared (**Figure 1**).

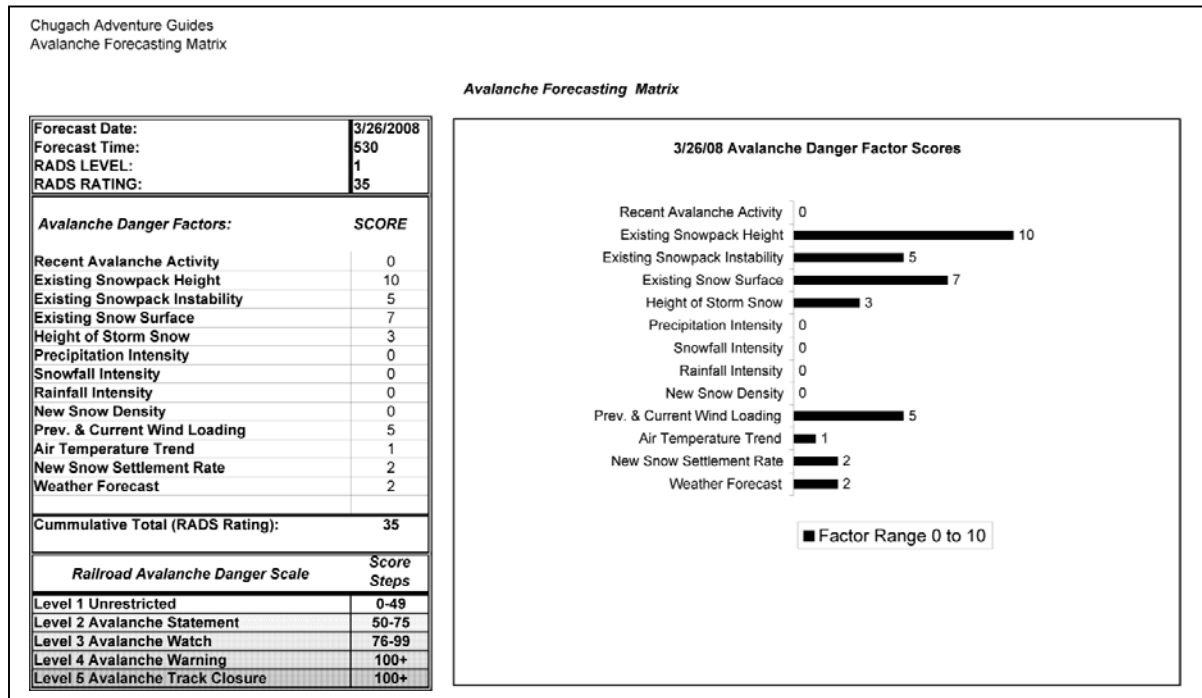


Figure 1. Example trial run of the Matrix incorporated into the RADS 3/26/08

RADS LEVEL	DESCRIPTION	SCORE STEPS
LEVEL 1 UNRESTRICTED <i>*(GREEN shading with black font)</i>	Avalanche activity above the rail and/or in the Canyon is possible. Avalanche activity that does occur is NOT EXPECTED to affect rail operations.	0-49
LEVEL 2 AVALANCHE STATEMENT <i>*(BLUE shading with black font)</i>	Avalanche activity above the rail and/or in the Canyon may be occurring. Resulting avalanche debris reaching the rail grade is POSSIBLE.	50-75
LEVEL 3 AVALANCHE WATCH <i>*(ORANGE shading with black font)</i>	Large magnitude avalanche activity above the rail and/or in the Canyon IS EXPECTED. Resulting avalanche debris reaching the rail grade or Canyon floor is LIKELY.	76-100
LEVEL 4 AVALANCHE WARNING <i>*(RED shading with black font)</i>	Large magnitude avalanche activity above the rail or in the Canyon has OCCURED. Resulting avalanche debris has been deposited near the rail grade and/or Canyon floor. Additional avalanche debris reaching the rail or Canyon floor is EXPECTED.	100+
LEVEL 5 AVALANCHE TRACK CLOSURE <i>*(BLACK shading with RED font)</i>	Large magnitude avalanche activity is OCCURRING above the rail and/or in the Canyon. Numerous avalanches have deposited avalanche debris on or near the rail. Additional large magnitude avalanches reaching the rail grade/ Canyon floor are EXPECTED.	100+

Table 3. Example RADS avalanche danger scale, description of conditions, and Matrix score steps

3.2 Practical Application

To test practical application of the Matrix, several program trial runs of the Matrix model were conducted in the latter part of the 2007-08 winter season. To do this, the Matrix was integrated with what is called the "Railroad Avalanche Danger Scale" (RADS). The RADS is an in-house, program oriented avalanche danger rating scale and formatted after the International Avalanche Danger Scale (Dennis, 1996).

3.3 Matrix Factor Scoring

During practical trial runs, input variables used for scoring each of the 13 factors in the Matrix relied on quality *Class I, II, and III* singular and distributional data (Hägeli, 1999), (McClung, 2006). Methods for collecting data followed standards developed by the American Avalanche Association (Green, 2004).

3.4 Numeric Based Avalanche Danger Rating

Once individual factor scores were established during trial runs, a numerically based avalanche danger rating "RADS RATING" was calculated by summing all factor scores.

The summated RADS rating represents the forecasted avalanche danger and can range between 0 and 130 points. The greater the cumulative factor score value, the greater the forecasted avalanche danger. The 3/26/08 trial run RADS rating shown in "**Figure 1**" has a value of "35."

3.5 Matrix-RADS Levels

Once a RADS rating is established, it can be classified in one (1) of five (5) numerically based avalanche danger levels, "RADS Level." Each RADS level is inclusive of avalanche danger level titles/ colors, conditional descriptors, and corresponding numeric "Score Steps" (**Table 3**).

In the 3/26/08 trial run, the RADS level is "Level 1 Unrestricted" with a RADS rating of 35. The associated Score Step for Level 1 encompasses RADS scores between "0" and "49" (**Figure 1**).

Creating score steps for each RADS level delineates numeric thresholds for each level of forecasted avalanche danger while allowing viewers of the Matrix to numerically evaluate

increasing or decreasing forecasted avalanche danger.

The numeric high-low score step range for each RADS level is derived from numeric ranges discussed for "hazard factors" in the ACF. Because there are more specific levels of identified avalanche danger in the RADS than ACF, the range for each RADS level has been further dissected. Numeric ratings associated with Level 4 and 5 are "100+" indicating that large magnitude avalanche activity is occurring and/or has already affected railroad operations.

Matrix score steps for RADS levels were chosen randomly and adjusted periodically during the 2007-08 model trial runs. Continued adjustments to the score steps will be made on an as-needed basis in the 2008-09 season.

4. CONCLUSIONS

Trial runs of the Matrix have shown that the Matrix model has potential as an avalanche forecasting communication/ education tool. That is, it preformed well in numerically displaying avalanche forecaster concerns and conveying those concerns to operations management in an unambiguous format.

However, trial runs also revealed critical limitations associated with the Matrix. First, the Matrix is highly exposed to avalanche forecaster(s) subjectivity. This is particularly true when "unknowns" enter the picture, like weather forecasts, and the program forecaster(s) does/do not know how to score a particular factor- there is no established score for "I don't know." Secondly, and in line with the first limitation, to utilize the Matrix with any accuracy requires as much quality singular and distributional data as is available. Sometimes, especially when it is needed most, like in the middle of a serious storm cycle, this information can be very difficult to obtain.

As such, it appears to this author that the Matrix, to be utilized efficiently, must be incorporated as a "sub-component" of a text based avalanche forecast where deficiencies of a particular Matrix run can be documented and clarified.

Additional in-house trial runs of the Matrix are scheduled for the 2008-09 winter season to prove or discredit its practical abilities for program needs.

Hopefully, the Matrix model, through this poster, peer review, and additional practically applied trial runs can prove its worthiness and/or be improved as a “simple” avalanche forecasting model.

5. ACKNOWLEDGEMENTS

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