



A User Guide for MARCUS

The Single Analyst Method

Paul Massel
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Abstract

MARCUS is a multi-criteria decision aid that has been developed and applied extensively within DRDC CORA. It can be used to assist with a variety of multi-criteria decision making efforts or for defence decision making problems that involve ranking or prioritization of any number of options. In practical terms MARCUS exists in both a web-based version and a Single Analyst version. Experience has shown that, over time, the Single Analyst version is used with much greater frequency. This user guide has been developed so that a MARCUS Facilitator should, in all but the most complicated cases, be able to input a vote, conduct a MARCUS analysis, and then understand the results using the current version of MARCUS, MARCUS 12, without reference to reach back support from within DRDC CORA.

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1 INTRODUCTION

MARCUS is a multi-criteria analysis tool that can be used in a number of prioritization and decision making problems. It was developed and is maintained by DRDC CORA Operational Research Defence Scientists, [Refs 1 & 2], and has been used in a variety of group prioritization and decision making situations in DND for the better part of the past ten years.

In practical terms the MARCUS application presently exists in two forms: a distributed web-based version on the DWAN and a Single Analyst version: the former has been documented in an earlier report [Ref 3], and the latter was initially described in a second report [Ref 4]. However, so that a Defence Scientist can make use of the MARCUS methodology in an un-aided fashion, this first attempt at a MARCUS User Guide, [Ref 4], is in need of some updating and adaptation. The purpose of this Technical Note is to serve as a stand alone user guide for the Single Analyst version of MARCUS and to offer some insights and observations on using either version of MARCUS in the aid of offering sound advice to decision makers.

2 USING THE MARCUS SINGLE ANALYST VERSION

The MARCUS Single Analyst version is semi-user friendly program that needs to be initiated with the correct inputs and needs some explanation to understand the outputs. The actual principles and algorithms upon which MARCUS has been built have been previously documented at [Ref 1, 2, & 5] and are not the subject of this paper. To use the MARCUS tool to analyze a multi-criteria problem the vote taker or MARCUS Facilitator needs to first gather and format the results of the 'vote' or ranking data into an Input file; then submit to the MARCUS algorithm; and then find and understand the results as recorded in the Output file.

The current stable, self compiling, version of MARCUS is called MARCUS12.exe and can be found in either on the CORA shared drives of the DWAN or the DRENET at:

DWAN	W:\CORT\MARCUS
------	----------------

DRENET	R:\CORT\MARCUS12
--------	------------------

The following steps should successfully guide the MARCUS Facilitator through the steps of using MARCUS when dealing with the majority of ranking and prioritization efforts. Exceptional problems and circumstances may require the MARCUS Facilitator to consult with the experts who developed and maintained this application in DRDC CORA.

2.1 STEP 1 - Create the Input File

The MARCUS12 version reads an input file that is a .txt or notepad file. You can copy the data from your vote from an excel file into a txt file and make a few corrections so that it the data is in the correct order to be read and understood by MARCUS12. This may seem a bit obtuse at first but obviously it is important to get right. The structure of the txt file is as follows – comments in italics are explanations:

```

5 Options      <--- number of options (columns)
4 Rankers      <--- number of rankers/criteria (rows)

  1 2 3 4 5  <- numerical representation of the options
1 -1 -1 -1 -1 -1 <- ranks of the options for the 1st criterion - 2nd - nth number in the row
1 5 3 2 4 1 <- ranks of the options for the 2nd criterion- 2nd - nth number in the row
1 -5 -5 -5 -5 1 <--- ...etc..
1 5 3 -1 -1 4

```

↖ weights of criterion – first number in the row

9999 <---- starting Objective Function value (can be left at 9999 all the time)

- Note 1: Votes that are ties are recorded using the same number and can either be left as is or have a negative '-' sign associated with it¹.
- Note 2: Missing information (ie an incomplete vote or one or more missing votes)² can be represented with a rank of 0 or as a set of weak ties, for a more detailed explanation see Annex A.
- Note 3: Although weights are often expressed as a decimal, you will need to convert a decimal weight into a whole number value before running MARCUS12
- Note 4 : In theory, there are no restrictions on the number of options and rankers that can be used on the input file. However, votes with large numbers of rankers or options or both may push the computational limits of a given computing system or may take a long time to run to completion. When faced with such a problem supporting programs such as Breaks or Slice should be considered for use, Ref 5.

Three examples of this process of taking a table of results and converting them to an input file that should serve as explanations of this process are offered below.

Example 1: An example of 1 voter, 3 options, and 10 equally weighted criteria with ties. First the voter table followed by the input file.

¹ MARCUS allows for and deals with ties in the input voting data and the ability to deal with tied votes is a key component of MARCUS methodology. The user should have a good understanding of the issues behind ties: a brief discussion of which is offered in Annex A and a more complete explanation can be found in Refs 1, 2, & 5.

² Incomplete votes can occur when voters lack enough information to make a rank determination or when an option has not been included in a particular criteria or perhaps has failed to meet a minimum cut of point for a given criteria: a brief discussion on the subtleties of incomplete votes is offered in Annex A.

Table 1: Table of Votes for Example 1

Weight	Option A	Option B	Option C
1	1	1	2
1	1	2	3
1	1	1	2
1	2	2	1
1	3	2	1
1	3	2	1
1	2	2	1
1	2	2	1
1	3	2	1
1	3	1	2

3 options
10 rankers

	1	2	3
1	-1	-1	2
1	1	2	3
1	-1	-1	2
1	-2	-2	1
1	3	2	1
1	3	2	1
1	-2	-2	1
1	-2	-2	1
1	3	2	1
1	3	1	2

9999

Figure 1: Input file for Example 1

Example 2: An example of 1 voter, 3 options, and 10 weighted criteria with ties. First the voter table followed by the input file.

Table 2: Table of Votes for Example 2

Criteria	Weight	Option A	Option B	Option C
1	0.167	1	1	2
2	0.167	1	2	3
3	0.125	1	1	2
4	0.125	2	2	1
5	0.083	3	2	1
6	0.083	3	2	1
7	0.083	2	2	1
8	0.083	2	2	1
9	0.042	3	2	1
10	0.042	3	1	2

3 options			
10 rankers			
	1	2	3
167	-1	-1	2
167	1	2	3
125	-1	-1	2
125	-2	-2	1
83	3	2	1
83	3	2	1
83	-2	-2	1
83	-2	-2	1
42	3	2	1
42	3	1	2
9999			

Figure 2: Input Vote for Example 2

Example 3: Is the most complicated one. This is an example of 3 voters, 5 options, and 5 weighted criteria with ties and some missing votes. First the voter table followed by the input file.

Table 3: Table of Votes for Example 3

	Weight	Option 1	Option 2	Option 3	Option 4	Option 5
Voter 1	2	2	4	1	5	2
	2	3	4	2	5	1
	3	2	3	1	4	5
	1	3	5	1	2	4
	2	1	5	2	1	4
Voter 2	2	5	2	1		3
	2	5	3	1	2	4
	3	1	3	5	2	4
	1	4	1	3	5	2
	2	5	3	4	1	2
Voter 3	2	4	2	3	2	1
	2	5	1	3	4	2
	3	5	3	2	2	1
	1	5	3	2	2	1
	2		2	3	3	1

5 options
15 rankers

	1	2	3	4	5
2	-2	4	1	5	-2
2	3	4	2	5	1
3	2	3	1	4	5
1	3	5	1	2	4
2	1	5	2	1	4
2	5	2	1	0	3
2	5	3	1	2	4
3	1	3	5	2	4
1	4	1	3	5	2
2	5	3	4	1	2
2	4	2	3	5	1
2	5	1	3	4	2
3	5	3	4	2	1
1	5	3	4	2	1
2	0	2	-3	-3	1

99999

Figure 3: Input Vote for Example 3

2.2 STEP 2 – Save the Input File

Name and save the input file in the same folder that holds the MARCUS12 application or executable file (MARCUS12.exe). One can copy the MARCUS12 application into another file or onto another system or run it in its current location in either of the network drives, but when the MARCUS12 application is executed it will prompt the MARCUS Facilitator for the name of the input file and that input file needs to be in the same folder as the MARCUS12 application that is running.

2.3 STEP 3 – Run MARCUS12

A double click on the file 'MARCUS12.exe' will open the application in an MS-DOS window. Or alternatively you can copy MARCUS12.exe and the input file which you have just created into the folder that you are working in.

You will then be prompted for the input file: type the file input name along with the extension (ie test.txt) and then press enter. MARCUS will run and unless you have a very large problem should generate an answer in very short order. If you have a very large problem then you may need to consider running Slice, an application that is also maintained in the MARCUS folder and is described in Ref 5.

If you are prompted with a line that reads:

```
Run Solutions? Y or N
```

this means that the first run analysis of MARCUS has generated more than one equally valid solution. Typing in 'Y' returns these equally valid solutions to MARCUS12 which then determines the centroid of the valid solutions and outputs a result file.

In some instances, a centroid won't be found. This will occur when you are repeatedly presented with the prompt 'Run Solutions? Y or N' and means that there are two very similar solutions. If this happens respond 'N' to the 'Run Solutions?' Prompt.

When MARCUS12 has finished running it will write its output to 'MARCUS12.out', to 'MARCUS12.tmp' and to 'solution.vis' and then close the MS-DOS window.

2.4 STEP 4 – Finding and Interpreting the Results

The results file is copied into the TestVote folder in a file called 'MARCUS12.TMP'. This file should open as a txt file and will look something like this.

MAXIMUM TAU-X SOLUTIONS

0 1. 5 3 2 -4 1

Chart Values : 2 6 8

Figure 4: Example of a MARCUS12.TMP Output File

The final solution is contained in the row of numbers. The explanation for each of these numbers is as follows:

1st number in the row is the final Objective Function Value that was obtained;

2nd number is the counter for results that have the same final Objective Function Value;

3rd and subsequent number or the option number in the ranked order from left to right and first to last: so for this solution Opt 5 is 1st, Opt 3 is 2nd, Opts 2 and 4 are tied for 3rd, and Opt 1 is last.

The values recorded under the label of 'Chart Values' are used in the MARCUS Sensitivity graph that can be generated by following the instructions in STEP 5.

IMPORTANT – Each time you run MARCUS, it will overwrite the MARCUS12.tmp, the MARCUS12.out, and the solution.vis files. Therefore, if you wish to retain the results of a given MARCUS run you must rename these files to something else.

2.5 STEP 5 Building the Sensitivity Chart

The MARCUS Sensitivity Chart is a helpful visualization of the vote results and offers a visual depiction of how close or alternatively how certain the combined ranking is. The details behind the MARCUS Sensitivity Chart are contained in Ref 6. To build a MARCUS Sensitivity Chart use the following steps:

- In the MARCUS Sensitivity Chart folder find and open the MARCUS Sensitivity Chart.xls and enable the Macros when asked to;
- Clear the chart and check that the pathway in cell B1 points to the 'solution.vis' file you just modified;
- Now run the chart.

At this point you should now have both the results of your MARCUS analysis and a useful Sensitivity Chart for displaying these results.

3 MARCUS – WEB BASED vs SINGLE ANALYST VERSION

While the Single Analyst version has been in use since the early days of MARCUS efforts to develop a more user friendly distributed web-based version resulted in a web accessible and enabled version of MARCUS. This web version has the advantage of allowing a vote to be collected by anyone who has access to a DWAN networked computer which in essence means that a vote could be collected in a truly distributed sense in terms of time and space. In principle, and from the point of view of collecting the input from a voting group this would seem to have a certain appeal, but to date there has been very little use if any made of this Web based version of MARCUS. This version still exists but is maintained at a minimal level and has not in any measure of utilization earned back the resources that were committed to its development.

In comparison, the Single Analyst version is in frequent use on a year in year out basis both in support of various prioritization questions that arise from time to time and in a number of group or committee meeting situations where people meet, consider options, cast a vote, and understand and work with the results. This perhaps goes to the larger question of why not make this version of MARCUS a more 'user friendly' application and here the author offers three perspectives.

First off, there is a certain level of knowledge and understanding that underlies the use of this analytical approach particularly when dealing with the subtleties of votes that are tied or votes with incomplete data. And by extension, when MARCUS is used in a group decision making effort, a certain portion of the underlying confidence the group will have with the MARCUS application will be dependant upon how confident and knowledgeable the MARCUS facilitator is with these and other aspects of the tool and approach. In this context, using the Web Based version of MARCUS in a convincing fashion with a voting group that is not familiar or readily accepting of the process may be more challenging and problematic then in a face to face meeting.

A second reason is that people still like to meet to resolve issues and address problems and this dynamic human interface is a key component of the group consensus problem. The pace and direction of change in the use and application of information technology points towards a more distributed world but that has not yet taken firm hold in the day to day decision making processes of a large and organizationally complex department such as the Department of National Defence.

A third perspective is that the time and resources that might be spent in creating a more seamless interface to the MARCUS application will only increase the overhead of maintaining and trouble shooting the interface; will only bring marginal benefit to the MARCUS Facilitator; and, therefore, is assessed not to be worthy of pursuing at this time.

4 CONCLUSION

MARCUS is a relatively easy to use and powerful decision making aid that can be used in a wide variety of multi criteria or ranking and prioritization problems. This Technical Note should be able to guide any knowledgeable MARCUS facilitator through the steps of running MARCUS in the Single Analyst version. It describes the steps that need to be followed to correctly build the input file for a MARCUS run and then how to obtain and interpret the output. It also offers some insights into the practicalities and subtleties of using the Web-Based version versus the Single Analyst version, and into issues surrounding tied and incomplete votes.

References

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Annex A Ties and Incomplete Votes in MARCUS

A.1 Strong and Weak Ties

When dealing with tied votes, there are two perspectives that need to be understood: ties from the voter's perspective and from the MARCUS Facilitator's perspective.

A.1.1 Ties From the Voter's Perspective

From the voter's perspective ties can either be considered to be strong or weak.

Strong ties indicate that two or more options are ranked equally, that the ranker found it difficult to rank one above the other for this criteria. Strong ties are a positive statement of voter preference. In the input file or matrix for MARCUS strong ties are given the same rank and left as positive.

Alternatively, weak ties indicate that the voter either had little or no information with which to rank one option with respect to another or that the voter was indifferent to the tied options and would rather let another criteria sway the decision. In the MARCUS input file, weak ties are given the same rank and the second and subsequent weakly tied options are assigned a negative value.

In practice, situations that result in weak ties are much more common than those that give rise to the use of a strong tie by a voter. Clearly, from a practical point of view, when conducting a vote, it is of value to understand what the voter means when he or she decides to rank two or more options as tied. And to be true to these inputs both strong and weak ties can be used accordingly when setting up the input file, even to the point of having some tied votes as weak ties and some as strong ties entered in the same input file.

A.1.2 Ties From the MARCUS Facilitator's Perspective

From the perspective of the MARCUS Facilitator, it is useful to point out that recording all ties in a vote as strong ties in MARCUS will result in a solution that offers a complete rank order of the options, and, alternatively recording all ties in a vote as weak ties in MARCUS will result in a solution that best finds the top ranked option or options and offers greater discrimination between options. In other words votes with strong ties tend to have many tied options in the resultant analysis and votes with weak ties tend to have more differentiation between options in the resultant analysis. So depending upon the objective of the vote (ie if one is trying to obtain the most differentiation between options in a prioritization effort) and the nature of the voters and what they understood a tied vote to mean (either strong or weak) then it may be desirable to input all ties as weak ties in MARCUS.

This all speaks to the need for the MARCUS Facilitator to be ahead of the decision making group in terms of what are the decision making group's needs and to best advise the group on when, why and how two or more options should be scored as tied.

A.2 Incomplete Votes

Care must be taken when dealing with incomplete votes. An incomplete vote can occur when a voter chooses not to rank one or more of the options under consideration; when certain options might not meet a minimum standard for a given criteria; or when a voter might be given a long list of items and be asked to only rank his or her top 10 options.

One method of dealing with an incomplete vote is by inserting a 0 for each incomplete vote as per the examples offered in section 2 of this document. This essentially tells MARCUS that the voter has no preference for where this option should be ranked according to this criteria and will let the other voters determine its rank and would be an appropriate interpretation of the situation when a voter chooses not to rank one or more of the options under consideration.

However, when some options have not been included because of a minimum cut off rule or because they are part of a large list and were not selected in someone's top 10 then they may be better considered to be not an incomplete vote but rather a sub-set of options that are in a weak tie for the lowest ranking and should be scored accordingly in the input file using the weak tie format.

A.3 A Final Word on Ties and Incomplete Votes

For a range of multi-criteria decision, ranking, and prioritization problems, MARCUS has been shown to be remarkably flexible and adaptable. This is in part because the MARCUS Facilitator can offer the voters the option of not ranking all the options or using ties in the ranking process, and in part because the developer of MARCUS has been equally supportive of exploring and adapting the use of MARCUS in novel and different decision making contexts. With the above instructions and guidelines it is anticipated that the informed MARCUS Facilitator should be able to be able to apply the MARCUS methodology as an aid to decision making for many if not most situations that he or she should encounter.

List of symbols/abbreviations/acronyms/initialisms

CORA	Centre for Operational Research
DND	Department of National Defence
DRDC	Defence Research & Development Canada
DRDKIM	Director Research and Development Knowledge and Information Management
DRENET	Defence Research Network
DWAN	Defence Wide Area Network
MARCUS	Multi-Criteria Analysis and Ranking Consensus Unified Solution
R&D	Research & Development

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- 2 Author – 2 hard copies
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MARCUS is a multi-criteria decision aid that has been developed and applied extensively within DRDC CORA. It can be used to assist with a variety of multi-criteria decision making efforts or for defence decision making problems that involve ranking or prioritization of any number of options. In practical terms MARCUS exists in both a web-based version and a Single Analyst version. Experience has shown that, over time, the Single Analyst version is used with much greater frequency. This user guide has been developed so that a MARCUS Facilitator should, in all but the most complicated cases, be able to input a vote, conduct a MARCUS analysis, and then understand the results using the current version of MARCUS, MARCUS 12, without reference to reach back support from within DRDC CORA.

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MARCUS, ranking, prioritization, multi-criteria decision making, multi-criteria analysis

