# SRA_Ch2: Spatial Risk factors and MCDA

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2.1 Multi-criteria decision-aiding methods

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# 2.1 Multi-criteria decision-aiding methods

"**Although MCDA may be applied in a great range of settings, it generally consists of four, possibly iterative steps (that is, the progress of work may go backwards and forwards at times) (Figure 2.1) ([Bigaret et al., 2017](#))**"
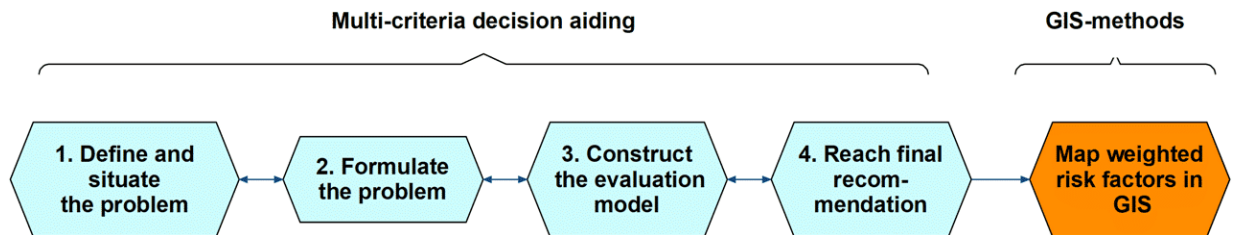


Figure 2.1: Stages in MCDA-GIS risk assessment mapping

*Step 1*

### Define and situate the problem

- Identify the stakeholders or actors

- Define the goals of the process and how the final decision should be reached

*Step 2*

**Formulate the problem**

- decision problem

- Define the relationships between the decision alternatives and the final outcome required from the MCDA process

- Decide how to manage the multiple DM's and their different perspectives (a focus group discussion usually in SRA)

*Step 3*

**Construct the evaluation model**

- Choosing the appropriate mathematical model to

  - Reflect the perspectives of the DM's

  - Resolve the problem with a multi-criteria aggregation algorithm

  - Make a decision

*Step 4*

**Reach the final recommendation**

- Presentation of the recommendation to the key DM who either validates the recommendation, asks for supporting analyses, or revisits previous steps to refine the solution.

CONTINUE

## 2.2 Define or situate the problem

"This step is self-explanatory and specific for each SRA. The stakeholders or actors are the subject experts and key stakeholders involved in the MCDA process, who in turn are guided by the needs of the DM's, the experts, or end users related to the problem at hand. Although this step appears simple and self-evident, as with defining a research question before undertaking an epidemiological study, it is critical that the problem and aim of the SRA are described in sufficient detail to guide the remaining steps and reach a successful outcome."

CONTINUE

# 2.3 Formulate the problem

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**The decision alternatives are the risk factors to be considered, and they may be considered for SRA if spatial features are available to describe them or are in some way related to them.**

"**A causal path model is an effective way in SRA to describe the relationships between the risk factors and the occurrence of disease, and also the relationships between risk factors. This model is important as it helps define which risk factors will be most important in the SRA model, and importantly, which factors should not be used because they will obscure the effect of other important factors (see next section). A path model is constructed during the discussion between the subject experts, typically in a facilitated focus group. The role of the facilitator is to ensure that all the opinions of all the participants are heard and contribute to the creation of the path model.**"

"Thought needs to be given to whether the available disease data is more appropriate for modelling incursion or spread of disease, or both. If disease data have defined the index case for an incursion, and epidemiologically linked cases are distinguished from the index case, then these data may be best used for modelling incursion. However, if disease data do not define the index case from the cases that followed, as is often the case, then these type of data are in fact describing both incursion and spread, and therefore these types of occurrence can't be separated and are best modelled combined. This distinction is not always relevant as often both incursion and spread share the same risk factors, but it is useful nonetheless to understand what in fact is being modelled."

**Create a path model to aid in selecting risk factors for SRA**

"This step can be carried out on large sheets of paper with felt-tipped pens to record the opinions of the participants, or possibly with computer software and a shared screen. The steps in the creating a path model are:"

*Step 1*

**Record the risk factors for the selected animal disease**

- Divide these in two ways

    - Factors relating to incursion or spread (some factors may be included in each category)

    - Factors that have or don't have a geographic characteristic that can be mapped

*Step 2*

**Decide which type of disease occurrence to create a model for- incursion or spread, or both incursion and spread combined**

- You may decide this on the basis of the disease and data available or the needs of the DM's

**3. Draw an hypothesised causal path diagram with single direction arrows that depict the direction of the causal path**

- Join the risk factors to
    - Disease occurrence
    - Other risk factors where they are causally linked

**Eliminate factors that**

- Intervene between other risk factors and disease occurrence
- Are highly correlated with other risk factors
- Don't have spatial data to represent them

**5. Agree within the focus group on a limited number of risk factors to model (no more than 4 - 5 for our purposes)**

CONTINUE

" As an example, preliminary and final path models for the occurrence of FMD in Myanmar are shown in Figures 2.2 and 2.3 "
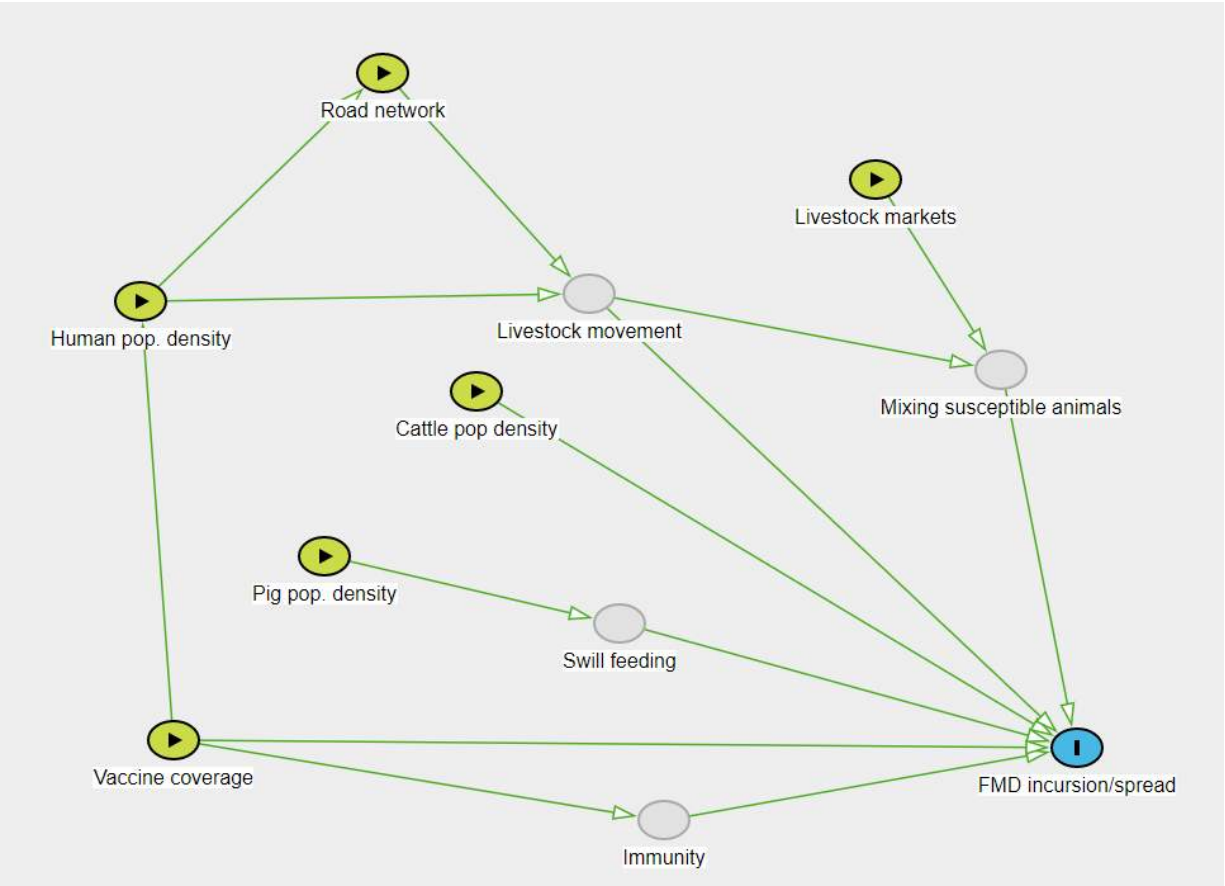
Figure 2.2: Preliminary path model for the occurrence of FMD in Myanmar (blue oval = outcome variable, green ovals = observable risk factors for which spatial data available, grey ovals = unobservable risk factors for which no spatial data available)
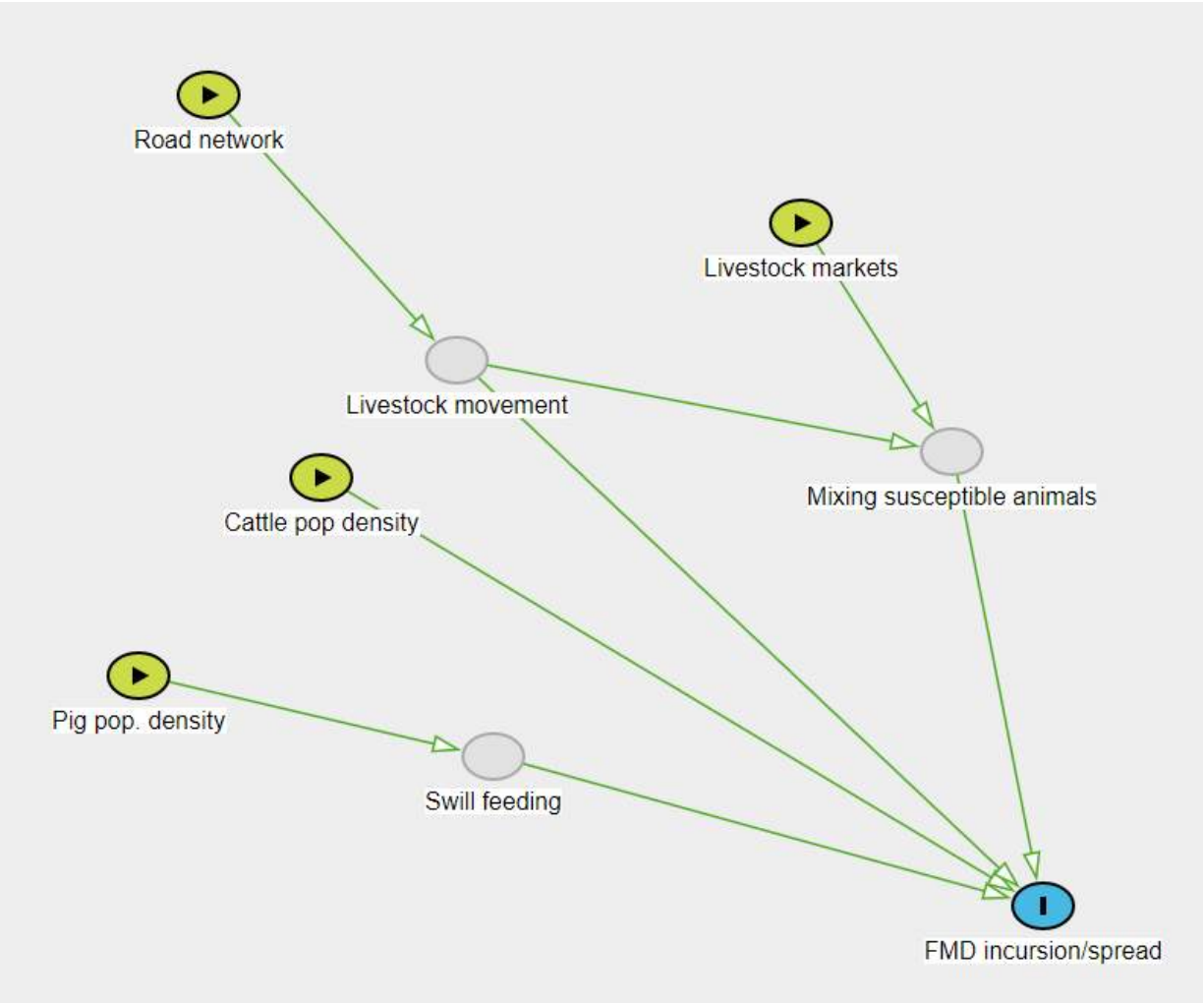
Figure 2.3: Final path model for the occurrence of FMD in Myanmar (blue oval = outcome variable, green ovals = observable risk factors for which spatial data available, grey ovals = unobservable risk factors for which no spatial data available)

CONTINUE

# 2.4 Construct the evaluation model

"**Because of the diverse range of situations in which MCDA can be applied, there is a correspondingly wide range of algorithms available. These approaches and the algorithms they use fall broadly into two different categories: 'outranking' and 'value-based'.**"

**CONTINUE**

Outranking methods compare any two alternatives pairwise on the basis of their evaluation of a set of criteria (risk factors in our SRA example), according to a majority rule. For example, for two alternatives and, if for the DM there are enough arguments in favour of the statement "is as least as good as" (or whatever the type of comparison used), then outranks. Furthermore, a weight is associated with each criterion used to evaluate the statement, which allows these partial arguments to have more or less importance in the majority rule. In the context of SRA, the weighted

risk factor measurements are aggregated to produce an overall score for each risk factor. A 'concordance index' (index of agreement between DMs) then aggregates these partial arguments via a weighted sum to calculate a credibility degree of the outranking. Finally, the results are examined for their validity and sensitivity to changes in the scores. Value-based methods won't be considered in this course as they are not appropriate for spatial risk assessment.

**CONTINUE**

"For the purposes of this course, we will use only one approach, but the reader should be aware that a range of techniques are available, and that each have their own strengths and limitations."

**CONTINUE**

# 2.5 The REMBRANDT technique

The REMBRANDT acronym (short for Ratio Estimation in Magnitude or deci-Bells to Rate Alternatives which are Non-Dominated) uses pairwise comparisons analysed on a multiplicative scale Barfod M. B. and Leleur (2014). REMBRANDT overcomes several drawbacks of other analytic hierarchy processes (AHP) methods because ratings are estimated on a logarithmic scale (c.f. a linear 1 - 9 scale) and the geometric means of the ratings avoid the problem of rank reversal (where relative rankings change after a factor is added or removed).

CONTINUE

"The scores that might be assigned to the relative importance of each risk factor compared with another is shown in Table 2.1. The values of the scores is on an interval scale and the difference between values is what is important."

## Table 2.1: Scoring system for relative importance when comparing risk factors in REMBRANDT MCDA method

| Comparison | Value |
|---|---|
| Overwhelmingly not more important | -8 |
| Very strongly not more important | -6 |
| Strongly not more important | -4 |
| Moderately not more important | -2 |
| Equally important | 0 |
| Moderately more important | 2 |
| Strongly more important | 4 |
| Very strongly more important | 6 |
| Overwhelmingly more important | 8 |

"Because not all risk factors carry the same weight, it is necessary to define the relative importance of criteria through "weights" which serve as scaling factors. These weights are then "normalised", for example, to sum to one, to aid their interpretation and prepare them for use in the GIS tasks of SRA"

CONTINUE

# 2.6 How to use a Microsoft Excel spreadsheet to set up a REMBRANDT evaluation model

"You have been provided with an Excel spreadsheet named "MCDATemplate.xlsx". Use it as a template which you can customise for the MCDA project you are working on. The spreadsheet organises the information needed to create a questionnaire and uses actual results from the 2019 course in Myanmar where 14 participants were asked to rank the relative importance of five risk factors.

It is important for you to understand that this spreadsheet is only partly automated to help in this process. You will need to edit this template to use it with different numbers of risk factors and different numbers of questionnaire participants."

**CONTINUE**

"To edit the spreadsheet, you will need some knowledge

of how to use Excel, particularly about the use of functions. At each step in the process, the places in the worksheet that may need editing will be made clear to you. In fact, you will be asked to edit the existing template for this very purpose in Exercise 2.1 and 2.2 below to gain experience about how this is done."

CONTINUE

"In the following sections, you will be shown how to use this spreadsheet to set up your evaluation model, print questionnaires to provide to your focus group participants from whom you wish to gather their opinions on the relative importance of different risk factors, and then enter the results from the questionnaires and calculate the spatial weights for the next step in the SRA process.

I suggest that you learn about the MCDATemplate.xlsx spreadsheet and how to use it by opening and viewing it while reading through the notes along with screenshots, and then repeat the process to view the video that accompanies each worksheet. Follow the steps in the ordered sequence through the named worksheets."

> ⓘ **The worksheet cells that require the user to insert values are indicated with yellow shading. Some cells have notes inserted for further explanation, indicated by red triangles in the upper right corner of the cell- hover your cursor over the cell to make these comments visible.**

## 2.7.1 "SetUp" worksheet

Complete the model setup by adding information, particularly to your needs. You will need to complete four sections related to

1. Your own risk factor codes, abbreviations and descriptions. The worksheet is already populated with five hypothetical risk factors coded A to E, abbreviated as AAA to EEE and similarly described aaaaaa to eeeeee. The abbreviations are printed in the questionnaire, not the full descriptions, to shorten the questions and make the document manageable

2. The country you are considering together with a code and abbreviation for it,

3. The disease situation you are considering- "incursion" or "spread" or both "incursion and spread", and

4. The disease you are interested in. These pieces of information are included in the questionnaire to clarify the meaning of the questions. Complete each of these sections and then print out the abbreviations

and descriptions of the risk factors using the Page Setup - Sheet - Print Preview - Print button and give one copy to each participant along with the questionnaire so that they are clear about what the abbreviations in the questionnaire mean

"**How to edit this worksheet?**

- If you need to adjust the number of risk factors you want to evaluate in your MCDA, you need to start the process in this worksheet

- Add more rows in the upper matrix of "FactorCode", "FactorAbbreviation", "FactorDescription" below the existing rows for more factors, or delete existing rows for fewer factors

**Click ▶ to play the video**
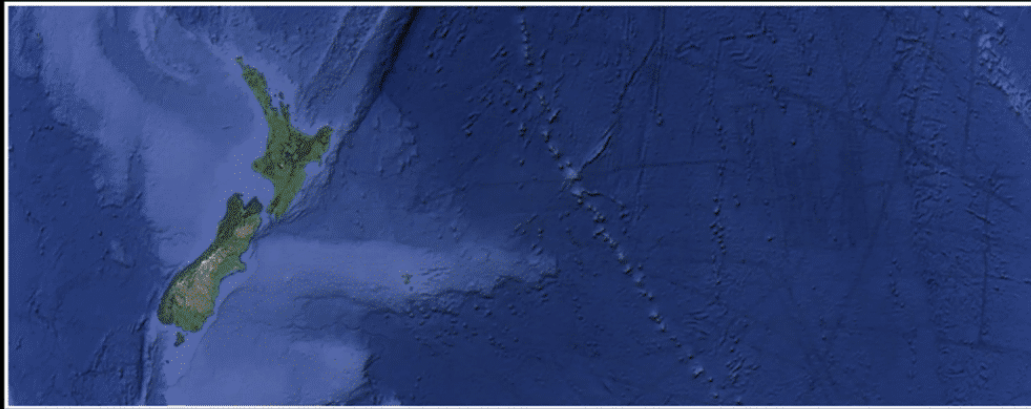
CONTINUE

## 2.7.2 "ComparisonValues" worksheet

- There is no need to edit this worksheet (no yellow cells)

- It is provided only to remind the person recording the answers provided by the participants to the questionnaire into the Results-5Factors worksheet of the value to assign to their answer

- That is, when a comparison is circled by the participant, for example "extremely less important", that answer is assigned a value of -8 and that

value is entered into the spreadsheet for that participant and question.

- Print this worksheet out for the person entering the results from the questionnaires into the "Results-5Factors" worksheet to check they are entering the correct values for the answers supplied

CONTINUE

### 2.7.3 "QuestionComparisons" worksheet

- Again, there is no need to edit this worksheet if you want to investigate 4, 5 or 6 risk factors in your MCDA analysis (though of course you could theoretically have as many or few risk factors to investigate as you decide)

- For this demonstration, we are working with 5 risk factors, but the additional matrices of comparisons are to show you how you might accommodate 4 or 6 risk factors instead

- The purpose of this worksheet is to show you a way that the questions are constructed by using a unique combination of comparisons between risk factors

- Each question to be asked in the questionnaire involves the unique comparison of two risk factors chosen in a consultation process to investigate

- Each question has a number in the cell intersecting the comparison, for example, Cell C4 has the value "1", indicating that Question 1 asks for a comparison between risk factor in the row first ("BBB" in cell B4) with the risk factor in the first column ("AAA" in Cell C2)

- The REMBRANDT method does not consider the order in which the comparison is asked i.e. the comparison between factor AAA vs. BBB is considered the same as asking the comparison of BBB vs. AAA

- The effect of this is that the cells above the diagonal are also greyed out because these are merely the reverse comparisons of those below the diagonal which have already captured the information of the relative comparisons

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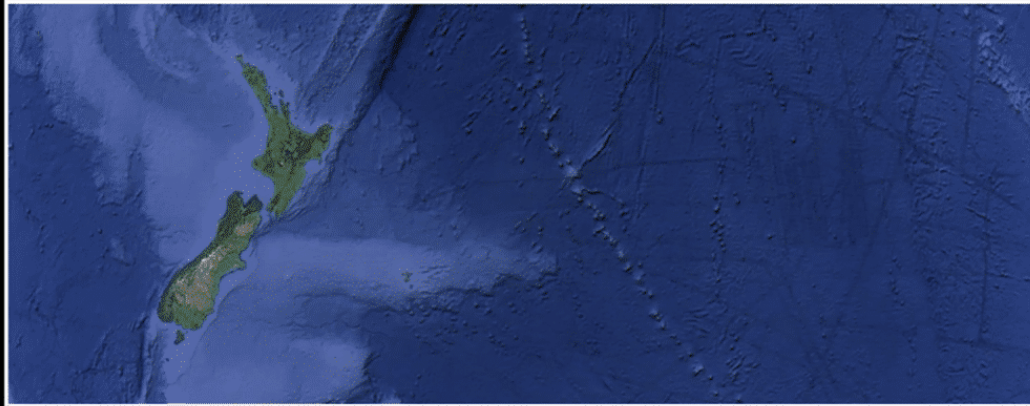


**CONTINUE**

## 2.7.4 "Questions-5Factors" worksheet

- The main aim of this worksheet is to create the questions for the questionnaire you will ask the focus group participants to answer

- It brings together the information about the country, disease, disease situation and comparisons between risk factors that you have previously defined, and creates questions about comparisons between the importance of one risk factor compared with another

- This worksheet should be printed out to provide the focus group participants with a paper questionnaire for them to complete by hand

- Setting up the printing can be tricky- try to lay out the printed questionnaire similarly to the way it appears in the spreadsheet view, with one row for the question, followed by 9 rows for each possible answer

- Add a sequential whole number for each questionnaire as the Questionnaire ID, starting from 1, so that you can keep track of the different pages for each participant when they are printed out, and staple all the pages for each participant together

- In the questionnaire header is a field to describe the role of the participant- I have suggested "Manager", "Field worker", "Other", but you should edit this to capture the important information about most participants roles. Ask the participants to circle the role that best describes what they do
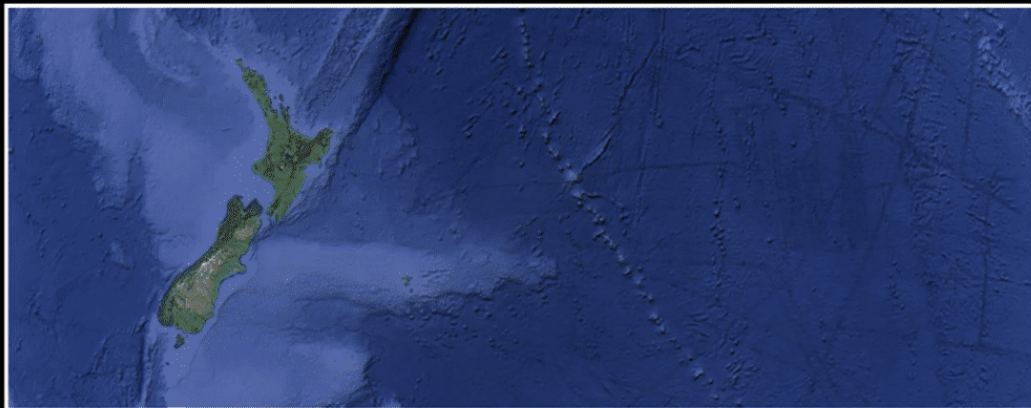


# "How to edit this worksheet?

- As the worksheet name suggests, it is designed for use with 5 risk factors and therefore 10 questions

- If you have a different number of risk factors and questions, you will need to

- Delete (if you need fewer) or add (if you need more) questions by correspondingly deleting the bold-typed question and corresponding answers or adding new questions and answers

- Deleting questions is straightforward if the preceding worksheets have not been corrupted

- Adding questions requires that the function in the bold question cells need to be edited

- This is where it helps to have some knowledge of how Excel functions work (revise the basics of functions if you are not confident with them)

- The function that creates the question concatenates (or joins together) words or values from previous worksheet cells to create a sentence

- You will need to edit the "QuestionComparisons!…" references to create the correct questions by referring to the worksheet of the same name, identifying the question matrix that you need (4 risk factors, 5 risk factors etc.) and follow the pattern as shown in the function from the previous questions

Click ▶ to play the video

## 2.7.5 "Results-5Factors" worksheet

- This worksheet is for the entry of results of the questionnaire

- As you can tell by the name of the worksheet, it is set up to enter results of a particular questionnaire with 5 risk factors (which requires 10 questions) and for 14 participants.

> ⓘ **To understand how to use this worksheet, and if needed edit it for an MCDA analysis with a different number of questions or participants, it is necessary to understand how the worksheet was set up:**

" **How to edit this worksheet?**

- Column A header is named "Questionnaire ID"

- A series of repeated numbers were created in the Questionnaire ID column, starting from 1 repeated the same number of times as the number of questions (with 5 risk factors there are 10 questions), and then this process is repeated for each subsequent Questionnaire ID, the same number of times as there

are participants (in this case, 14).

- Therefore if you have a different number of participants for your questionnaire, this column will need to be edited accordingly

- Column B header is named "Question"

- A series of ascending numbers from 1 to the number of questions (in this case 10) were repeated down the column to record the results of each question for each participant, the same number of times as there were participants (14 in this case)

- Therefore if you have a different number of questions for your questionnaire, this column will need to be edited accordingly

- Column C header is named "Value"

- For each completed questionnaire, code the circled answers from the paper questionnaire with the corresponding value with a pen on the sheet (keep the "ComparisonValues" worksheet open or printed out to check the answers are coded correctly)

- Enter the values you have just coded on the completed questionnaires in order of Questionnaire ID into the "Value" column

- It helps to filter this worksheet by the column names to ensure that the values are entered accurately for each participant

- The cells in this column are empty until you enter results from the completed questionnaires, therefore if you have a different number of participants or questions for your questionnaire, this column will need to be edited

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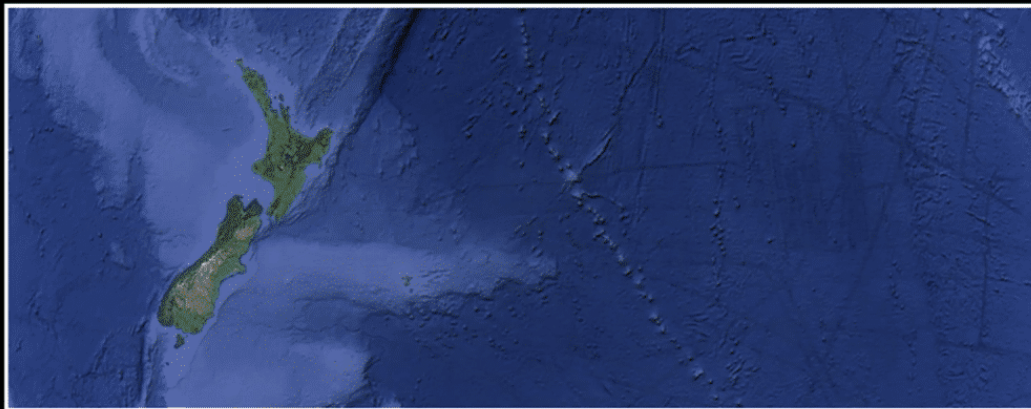


CONTINUE

## 2.7.6 "ResultsSummary" worksheet

There is nothing to do with this worksheet if your questionnaire has 10 questions and 14 participants. Just check that each question has a corresponding median value calculated by the function in the cell.

"**How to edit this worksheet?**

- If you need to create a questionnaire with a different number of risk factors or participants, then you will need to edit this worksheet

- There are two columns in this worksheet

  - "Question" which identifies the question number- if you have more or fewer questions then edit this column accordingly, but keep the question numbers in ascending numerical order (there are no functions in this column)

  - "Median" which contains a function that calculates the median value of all the responses to that particular question

    - The function lists the values of each participant (14 in this case)

    - The easiest way to check that you have the correct references to the cells you want is to go to the "Results-5Factors" worksheet, and filter the 3 columns by "Question", then click in each "Value" cell down the filtered column- the cell reference is "C" followed by the row

number read off the the left of the rows,
e.g. "C2" for Questionnaire ID = 1, Question = 1

- When this is correctly set up you can simply copy the function down the remaining column of the "Median" column and the function will update with an increment of 1 row number for each additional row, which will calculate the correct median

**Click ▶ to play the video**

**CONTINUE**
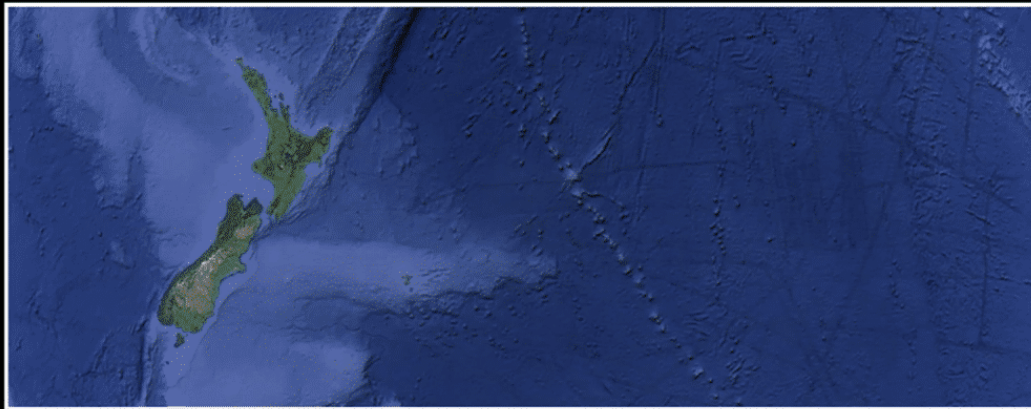
## 2.7.7 "ResultsMatrix" worksheet

This worksheet does not require any values to be entered if you considered exactly 5 risk factors. The number of participants is not important in this worksheet as the median values from any number of participants are aggregated in the function and carried forward from the previous worksheet.

"**How to edit this worksheet?**

- If you have a different number of risk factors for your MCDA, then this worksheet will need to be edited:

  - "Raw scores" matrix at the top of the worksheet

    - Increase or decrease the number of rows and columns (the number of each need to be equal) by adding additional capital letters for the risk factor codes to the matrix header and row indexes, or deleting the cells not required

    - Ensure the diagonal of the matrix is populated with zero values

    - The values above the diagonal are the inverse of the mirrored values below the diagonal, and therefore have the simple formula multiplying the mirrored value by -1

    - The values below the diagonal are populated by values calculated by functions that

reference the median values for each question calculated in the "ResultsSummary" worksheet
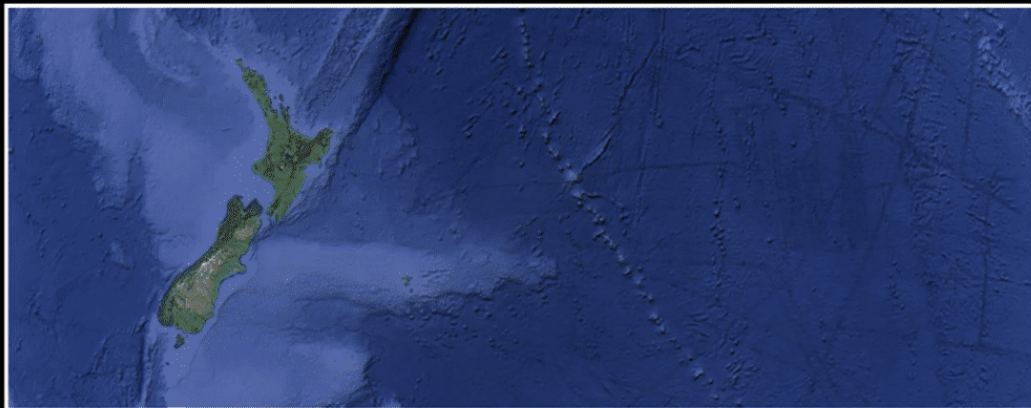
- Note how the referenced value corresponds with the same order of the questions in the "QuestionsComparisons" worksheet

- Add or delete new versions of the formula into the cells required to complete the matrix whilst checking that the correct values are referenced

- "Transformed scores for each comparison, geometric means & weights for each risk factor"

  - This matrix is set up initially with 1 row and 1 column for each risk factor (5 rows and 5 columns in this case)

  - A function in each of these 5 x 5 cells transforms the raw scores from the corresponding cells in the "Raw scores" matrix

  - If more or fewer risk factors are used, then additional rows and columns will be needed to be added to or deleted from this matrix, as with the "Raw scores" matrix

  - Copy the formulas into the newly-created cells in the lower matrix and ensure they reference the appropriate cells in the upper matrix

- Add additional rows to the lower matrix and copy the formula down into the newly required cells in the "GeoMean" column

- Repeat this exercise for the "Weight" column

- As a check, the total of the weights in the "Weight" column should equal 1

Click ▶ to play the video



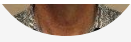"Use the skills and understanding you have gained through

reading through the teaching material and watching the videos to create an Excel spreadsheet for a particular MCDA analysis:

1. Save the spreadsheet "MCDAExercise.xlsx" you have been provided with a new name to use in this exercise so that you have the original to go back to if you corrupt the one you are working with

2. Create an evaluation model in your newly created spreadsheet that requires four (4) and not five (5) questions

3. Complete the worksheets in the order given above to create spatial weights for each risk factor

- Because for the purposes of this exercise you will not actually ask any participants to complete the questionnaire, just use the results in the existing "Results" worksheet but delete the values for the answers of questions that wouldn't be asked for a 4 risk factor questionnaire

**CONTINUE**

"Use the skills and understanding you have gained through

reading through the teaching material and watching the videos to create an Excel spreadsheet for a particular MCDA analysis:

1. Save the spreadsheet "MCDAExercise.xlsx" you have been provided with a new name to use in this exercise so that you have the original to go back to if you corrupt the one you are working with

2. Create an evaluation model in your newly created spreadsheet that requires four (4) and not five (5) questions

3. Complete the worksheets in the order given above to create spatial weights for each risk factor

- Because for the purposes of this exercise you will not actually ask any participants to complete the questionnaire, just use the results in the existing "Results" worksheet but delete the values for the answers of questions that wouldn't be asked for a 4 risk factor questionnaire

**CONTINUE**

"Extend your skills and understanding by adding an extra

question to the questionnaire. This will require copying some functions and checking to see that they are correctly referenced.

1. Save the spreadsheet "MCDAExercise.xlsx" you have been provided with a new name to use in this exercise so that you have the original to go back to if you corrupt the one you are working with

2. Create an evaluation model in your newly created spreadsheet that requires six (6) and not five (5) questions

3. Complete the worksheets in the order given above to create spatial weights for each risk factor. In this case, just copy down the required number of answers to enable the spatial weights to be calculated for each risk factors

I don't provide a solution for this exercise, but if you have completed Exercise ??, it should be evident whether you have correctly built the evaluation model."

CONTINUE

## 2.7 Reach the final MCDA recommendation

"This final step in MCDA involves communicating the results of the REMBRANDT analysis of the questionnaire results to and gaining a consensus among the group of experts that these calculated spatial weights represent their opinions as a whole (even though individual opinions may differ)."

CONTINUE

# Exercises 2.1 and 2.2: Modify the excel Spreadsheet

"This final step in MCDA involves communicating the results of the REMBRANDT analysis of the questionnaire results to and gaining a consensus among the group of experts that these calculated spatial weights represent their opinions as a whole (even though individual opinions may differ)."

**CONTINUE**

## Exercise 2.1 (Modify the Excel spreadsheet to accommodate a fewer number of risk factors for SRA)

"Use the skills and understanding you have gained through reading through the teaching material and watching the videos to create an Excel spreadsheet for a particular MCDA analysis:

1. Save the spreadsheet "MCDAExercise.xlsx" you have been provided with a new name to use in this exercise so that you

have the original to go back to if you corrupt the one you are working with

2. Create an evaluation model in your newly created spreadsheet that requires four (4) and not five (5) questions

3. Complete the worksheets in the order given above to create spatial weights for each risk factor

   - Because for the purposes of this exercise you will not actually ask any participants to complete the questionnaire, just use the results in the existing "Results" worksheet but delete the values for the answers of questions that wouldn't be asked for a 4 risk factor questionnaire
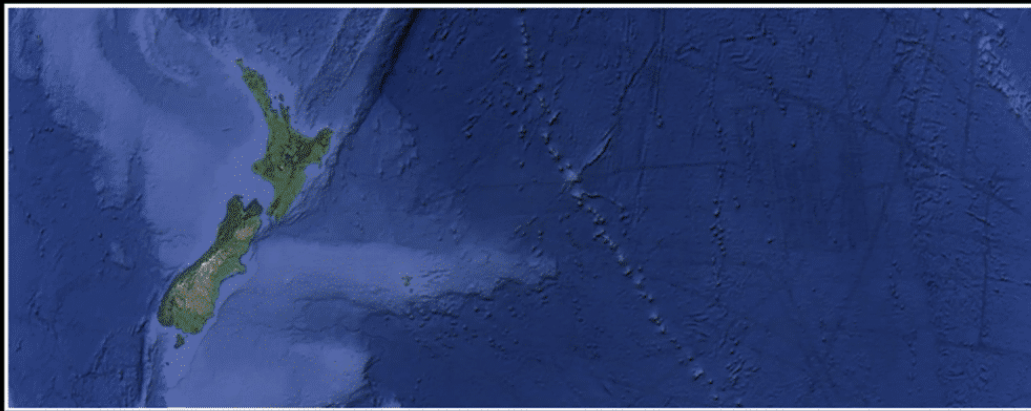
**CONTINUE**

Have you completed exercise 2.1 using Microsoft Excel Spreadsheet

○ Yes

○ No

**SUBMIT**

**Click ▶ to play the video**



CONTINUE

### Exercise 2.2 (Extension exercise- modify the Excel spreadsheet to accommodate a greater number of risk factors for SRA)

"Extend your skills and understanding by adding an extra question to the questionnaire. This will require copying some functions and checking to see that they are correctly referenced.

1. Save the spreadsheet "MCDAExercise.xlsx" you have been provided with a new name to use in this exercise so that you have the original to go back to if you corrupt the one you are working with

2. Create an evaluation model in your newly created spreadsheet that requires six (6) and not five (5) questions

3. Complete the worksheets in the order given above to create spatial weights for each risk factor. In this case, just copy down the required number of answers to enable the spatial weights to be calculated for each risk factors

No solution is provided for this exercise, but if you have completed Exercise 2.1, it should be evident whether you have correctly built the evaluation model."

**CONTINUE**

## Congratulations - end of lesson reached

## References

1. Bigaret, S., R.E. Hodgett, P. Meyer, T. Mironova, and A.-L. Olteanu. 2017. Supporting the multi-criteria decision aiding process: R and the MCDA package. EURO Journal on Decision Processes 5:169–194. doi:10.1007/s40070-016-0061-9.

2. Barfod M. B., and S. Leleur. 2014. Multi-criteria decision analysis for use in transport decision making. Lyngby: Technical University of Denmark, Transport.