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DND AND MULTI-CRITERIA DECISION MAKING METHODS (MCDMM): UNTAPPED POTENTIAL

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ABSTRACT

Multi-criteria decision making methods (MCDMM) have been used by industry, governments and also DND, for years. These methods are in response to individual decision maker's limitations in being able to take decisions rationally when faced with more than 7 items. The application of Multi Criteria Decision Making Methods permits decision makers to consider a great array of information when making their decision. However, the use of Multi Criteria Decision Making Methods is limited in DND, which also applies to the use of decision processes in order to reach decision. As the use of intuition is bound by limited rationality, it should be obvious to use Multi Criteria Decision Making Methods in order to avoid errors. Therefore, the question would be that in view of the benefits that Multi Criteria Decision Making Methods could have for the decisions taken within DND, for what decisions and which type of Multi Criteria Decision Making Methods could be used and what are the barriers that are preventing their use? By reviewing the benefits of Multi Criteria Decision Making Methods, our human cognitive limitations, this will show that Multi Criteria Decision Making Methods can bridge the gap that is limiting decision making. It will also show the various methods that are available to DND, which would greatly improve the transparency of the decision process.

Three main categories of methods will be explained: voting, utility and outranking methods. The voting methods comprise of the Borda and Condorcet methods. For the utility methods: these are the methods that will be discussed: weight sum, weighted product, Simple Additive Weighting (SAW), AHP, Multi-Attribute Utility Theory (MAUT), Simple Multi-

Attribute Rating Technique (SMART), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Measuring Attractiveness by a Category-Based Evaluation Technique (MACBETH). Finally, the ELECTRE and PROMETHEE family of methods are discussed, for situations were a utility function cannot be determined. The recommend methods are the Borda and Condorcet methods, the SAW and MACBETH methods and some of the ELECTRE methods. Some of the software that is associated to these methods was explained, as they could be possibly added to DND software in order to make the use of Multi Criteria Decision Making Method easier.

There are many areas of the DND that could greatly benefit from the use of Multi Criteria Decision Making Method. Either through the process or by using the actual methods to determine the solution, this will lead to better decision that are more transparent and fair. By reaffirming DRDC's lead in the matter, by providing information and by mandating that complex and expensive projects use Multi Criteria Decision Making Method, this will improve the quality of the decision process within DND.

INTRODUCTION

Life is continuous string of decision that start at infancy and lasts until death. Some decisions are so insignificant that they are taken without real thought being applied while others could take days even years, before a decision is taken. This dichotomy in how much time it takes for a decision to be reached is not only evident in personal decision but also in organizational decisions. One of the culprits of this prolonged decision cycle, is the complexity of the problem or situation that is faced. But this is not the only issue that arises, as there are mistakes and even failures that occur because of difficulties in understanding the problems. History is replete with infamous failures, like the military examples of Napoleons failed invasion of Russia, the Battle of Little Big Horn or Gallipoli, the Japanese failure at the Battle of Midway or Operation Eagle Claw. Other examples ranges from the Ford Edsel, to the Three Mile Island meltdown, the Exxon Valdez, the Challenger and Columbia Crash either based on business and management bad decision. Actually, all human endeavors can be viewed as attempts at resolving problems, stretching from science, to engineering, to politics, philosophy. A problem exists, to which the practitioner of the related field might be able to provide a solution for which he follows a process in order to resolve the problem. One might ask, is this not the case in decision making, the foundation of resolving problems. Contrary to established field of study, like medicine, for example, there is no fundamental decision making process. However, this does not mean, that this field has not been studied. Through various angles, like sociology, psychology and mathematics, decision making has been studied in order to better understand its underlying components and dynamics. This has been especially through in regards to complex decisions that have posed most of the delays and failures. Operational Research and especially the Decision Making Support primary focus has been towards improving decision making. The most complex

decision including multiple inputs, possible consequences, variables and possible solution which has required its own field of research in order to find solutions. This field of research is called Multi-Criteria Decision making (also referred to as aiding or analysis) methods (Multi Criteria Decision Making Method) which attempts to resolve these complex decisions.

DND is a very complex organization that takes numerous decisions every day, on everything from mundane to extremely multifaceted problems. Many times, the problems that are faced delve into the range of "wicked problems", which are difficult or impossible to resolve and for which solutions will generate other problems. The vast majority of issues faced by DND are not limited to one resolution method. This complexity is even more magnified by the fact that parameters are either incomplete or changing and that the stake holders are numerous. However, many of the decisions on "wicked problems" are made through simple decision making methods like intuition, approximations and negotiations. Only a limited number of these complex problems us a detailed methodology to determine the problem space and even less use Multi Criteria Decision Making Methods in order to aid prioritize possible solutions. If one is ready to accept the potential consequences of the decisions, these simple methods could be acceptable. However, most decisions in DND involve the management of government's assets or the life of soldiers. Also, they include an element of negotiations with various stakeholders who have a different understanding of the problem and of the objective to achieve. In using these simple methods, mistakes will arise as humans, even less a group of them, are unable to consider all the facets (criteria) of a complex problem. To make matters worse, these simple methods, lack the transparency, the explicitness or the rigor that are now appear to be an essential requirement of all DND decisions. As decision aiding methods, the use of Multi Criteria Decision Making Methods and their associated processes is an evident way of addressing these decisional

problems. However, its current limited use points towards concerns with their use, lack a knowledge of Multi Criteria Decision Making Methods and their benefits. To this can be added a reticence from the part of decision makers in trusting scientific or technological means in supporting decision making. Finally, in the areas where Multi Criteria Decision Making Methods could be used, the current limited resources and what would be required in order to make these methods available to decision makers that could use is another limiting factor.

Therefore, the question would be that in view of the benefits that Multi Criteria Decision Making Methods could have for the decisions taken within DND, for what decisions and which type of Multi Criteria Decision Making Methods could be used and what are the barriers that are preventing their use?

An increased use of Multi Criteria Decision Making Methods inside DND could help decision makers better evaluate possible solutions to many complex problems that are faced by DND. The types of complex problems will impact the effectiveness of these methods, as they will be more difficult to use with "wicked problems" then with "tame" ones. More importantly, it is needed to explore the lack of use of these decision support methods and that through the provision of information of them, this can be hopefully remedied. More details needs to be also given on what are the potential areas of use for Multi Criteria Decision Making Methods inside DND including an insight on what resources would be needed in order to facilitate their use.

The reason for using Multi Criteria Decision Making Methods will be explained in the first chapter, where the limitation of personal decision making will be shown to be ineffective in front of complex decisions. There will also be a description of the concept of "wicked" and

"tame" problems and why the use of intuition based decision making is preferred and sometimes better when in certain situations. The second chapter will be to explain the history of Operational Research and where Multi Criteria Decision Making Methods fit in that history. Its relatively young history has however seen some major developments over the last 40 years, leading to an ever increasing use of its method in government and industry. It must be noted, that most of these methods are based on some advanced mathematical theories, which require the support of qualified personnel or Multi Criteria Decision Making Methods software to simplify resolution of problems. This chapter will also include some indications of why these methods should be used in DND and some basic principles of Multi Criteria Decision Making Methods, as this will permit a general understanding of the principles and to comprehend the differences between the various methods. This will lead to, in the third chapter, to a description of the Multi Criteria Decision Making Methods that are and could be used in DND. These will be divided in three groups: voting, utility and outranking methods. To this, examples in business and organizations will be given to indicate its potential usefulness in similar situations in DND. Finally, some examples of the software that are used to implement these methods will be given. The last chapter will discuss the current use of Multi Criteria Decision Making Method in DND and will give some possible areas where these areas where these methods could be applied. This will be followed by a recommended way forward in order to make the use of Multi Criteria Decision Making Method more widespread within DND.

Chapter 1

DECISION MAKING IN COMPLEX SITUATION

Life would be simple if problems that people faced had limited complexity, like choosing which color outfit to wear on a specific day (a situation which, for some people, is not even a simple decision). However, the reality of today's world is that decisions are nowhere this simple, even in our day to day lives. Decisions have been taken since the dawn of time, from day to day mundane decisions to decisions on how to administer countries or how to wage war. Decision makers have used various means in order to understand the situation and reach a decision, from a simple discussion of the issue to peering over a map. These examples of collection of information face some serious limitations and are ultimately flawed when faced with complex decisions. Some problems are easier than others, with parameters that are defined and are fixed, whereas other problems can equate to a moving targets. This is why it is necessary to explain the type of problem spaces, which can be described as "tame" or "wicked". Regardless of the type of problem, decisions can result in failure. Why this occur can be partly explained through a description of decision, how it is affected by the complexity of the situation and the limits of human cognitive abilities. This will show that decision makers are unable to make rational decisions when faced with complex problems, thus leading to grave failures. However, not all decisions can be taken in a deliberate manner, and intuition is used, what one can call intuition based decision making, which feels like a natural way for decision makers. However, at other times, Multi Criteria Decision Making Methods are a tool that can solve some of the problems that have been identified. To understand what Multi Criteria Decision Making Method are, there needs to be an explanation of where it comes from and some key concepts related to these

methods. More importantly, it must be understood that these tools are part of an overall process that is made to answer some of the limitations of decision makers.

What to wear this morning? What route to take to go to work? What to eat lunch? These are all questions that people face on a daily basis and seem mundane, however they are quite complex. One can easily get lost in the multiple options and the various factors that could influence these decisions, especially, if one was to consider every aspect. Just considering what to wear to work, there might be a dozen of options available. The factors could be numerous, like the weather, an event at work, a specific impression on wants to give, an activity you have after work, only to name a few. Most people are able to make these decisions and pick an option by not eliminating some of the possible options. This is a learned mechanism, as we have worked out that we cannot consider all the options at the same time, as was clearly identified by Dr. George Miller:

> I would propose to call this limit the span of absolute judgment, and I maintain that for unidimensional judgments this span is usually somewhere in the neighborhood of seven. We are not completely at the mercy of this limited span, however, because we have a variety of techniques for getting around it and increasing the accuracy of our judgments. The three most important of these devices are (a) to make relative rather than absolute judgments.; or, if that is not possible, (b) to increase the number of dimensions along which the stimuli can differ; or (c) to arrange the task in such a way that we make a sequence of several absolute judgments in a row[1].

This is not the only treatise that identifies limitations in human's cognitive reasoning (ability to consider items), even though it's perhaps one of the most famous, as it is the bases for the span of control concept (ie number of subordinates one can have). Herbert Simon, further limits the rational ability of decision makers in his paper "A behavioral model of rational choice" where he introduces the concept of bounded rationality: "Broadly stated, the task is to replace the global

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[1] George A. Miller, "The Magical Number Seven, Plus Or Minus Two: Some Limits on our Capacity for Processing Information." *Psychological Review* 63, no. 2 (1956), 91.

rationality of economic man with a kind of rational behavior that is compatible with the access to information and the computational capacities that are actually possessed by organism, including man, in the kinds of environments in which such organisms exist."[2] In order words, the decision maker is not only limited by his own, cognitive abilities, but also by the information he has and the environment in which he takes the decision. Furthermore, Dorner identified in his book, "The logic of failure", a very cynical description of the decision makers reactions involved in one of his studies, which he equates to reactions of real word decision makers:

- acted without prior analysis of the situation
- failed to anticipate side effects and long-term repercussions
- assumed that the absence of immediately obvious negative effects meant that correct measures had been taken
- let over involvement in "projects" blind them to emerging needs and changes in the situation
- were prone to cynical reactions[3]

He continued to identify that decision makers use a reductive ability, reducing the problem to smaller parts in order to more easily deal with it. Another method that he identified was "deconditionalization", where a decision based on a previous successful decision that was closely related to the current problem, without considering the current context[4]. This was also identified by Simon, where the decision maker, will simplify the real world in order to able to make a choice, which then conflicts with the rational model (economic man) and what occurs in reality[5]. A study done by Bakken and all. found that, when they looked at how military officers reacted on how they considered feedback processes, which in most cases used intuition and was

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[2] Herbert A. Simon, "A Behavioral Model of Rational Choice," *The Quarterly Journal of Economics* (1955), 99.
[3] Dietrich Dörner, *The Logic of Failure: Recognizing and Avoiding Error in Complex Situations* Basic Books, 1996), 18.
[4] Ibid.
[5] Simon, *A Behavioral Model of Rational Choice*, 114

9 times out of 10 wrong[6]. Even more telling is the fact that intuition is related to an emotional recognition of known patterns which is then tied to reasoning. This concept is well known in neurobiology and has led Simon to postulate the following limitations as where resumed by Pomerol:

> -l'impossibilité de donner des probabilités à tous les événements et même tout simplement d'énumérer tous les événements possibles avec leurs combinaisons ;
>
> -le fait que les préférences du décideur ne sont pas rationnelles au sens de la maximisation d'une fonction d'utilité et qu'en fait elles sont multicritères et aussi changeantes, ce qui entraîne l'impossibilité d'avoir une fonction d'utilité globale pour le choix ;
>
> -les décisions s'étalent dans le temps et, dans les organisations, forment un processus temporel dans lequel les sous-décisions ne sont pas indépendantes entre elles, mais peuvent être prises à des moments et des niveaux différents avec des critères non identiques; de plus on ne peut séparer préférences, actions et buts ("Closely related to the idea that actions generate their goals is the fact that action is itself an important goal in lives of many people" (March et Simon, 1993, p. 15)); le fait que les sous-décisions sont prises de manière locale sur des critères partiels s'oppose évidemment et, j'ajouterai, mathématiquement, à toute optimisation globale (Simon, 1983, p. 18);
>
> -l'information est fondamentale et conditionne très fortement la décision; ceci est particulièrement évident lorsqu'on constate le nombre (petit) d'actions qu'un individu est capable d'étudier réellement. L'attention joue aussi un rôle considérable pour cadrer le problème et conditionner la décision subséquente. L'attention est une ressource rare, l'homme ne peut fixer son attention que sur un tout petit nombre de problèmes à la fois, voir un seul quand il est très préoccupé[7].

Based on this, it is therefore evident that decision makers are unable to take rational decision. However, all is not lost, as indicated by Kenney that stipulates that out of 10,000 decisions he surmises that only 50 really need to be administered by Multi Criteria Decision Making Methods as they are the most complex. All the other decisions, in his example are either too mundane or can easily be solved by clear thinking[8]. It must be noted that so far, we have only dealt with individual decision making. When looking at group decision making, the added dynamic only

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[6] Jan Noyes, Yvonne Masakowski and Malcolm Cook, *Decision Making in Complex Environments*Ashgate Publishing, Ltd., 2012), 206.

[7] Jean-Charles Pomerol, "La Décision Humaine: Reconnaissance Plus Raisonnement," *Nous* 2 (2004), 8.

[8] Ralph L. Keeney, "Making Better Decision Makers," *Decision Analysis* 1, no. 4 (2004), 196.

adds to the complexity and makes the problematic of reaching a decision even more difficult. As was indicated before, most decisions are of little consequence but this is rarely the case in DND. It is surprising to note that in decision making inside industry, a very high failure rate was recorded by Nutt that his study of 356 decisions from medium and large organization in US and Canada, has found that half have failed. The main roots of these failures were identified as being: "managers who impose solutions, limit the search for alternatives, and use power to implement their plans. Managers who make the need for action clear at the outset, set objectives, carry out an unrestricted search for solutions, and get key people to participate are more apt to be successful"[9]. This clearly identifies that the decision-making process is political, involving many stakeholders. Also, these precepts would seem self-evident to any manager and should therefore not be the basis of failures of decisions. Some of these decisions are more difficult to take, because of the type of problem that they aim to solve. As was identified, most problems are complex, however some of them have defined parameters, while other are moving targets. The distinction between these "tame" and "wicked" problems must be defined, as they will impact which Multi Criteria Decision Making Methods can be used, if any to propose an order for the possible solutions.

Wicked Problems

All decisions are associated to complex problems, as they will always test the limits of people rationality. However, there is varying level of complexities for these problems, where

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[9] Paul C. Nutt, "Surprising but True: Half the Decisions in Organizations Fail," *The Academy of Management Executive* 13, no. 4 (1999), 75.

some are vary scientific in nature, with parameters that do not change and that are known. Others problems, have more fluid structures and the impacts of the decisions can essentially change the problem itself. "Tame" problems was seen by Rittel and Webber as "the problems that scientists and engineers have usually focused on"[10], which are problems that are almost mathematical in nature, for which the outcome is clear and it is known if the problem can be solved. In comparison, wicked problems "have neither of these clarifying traits; and they include nearly all public issues – whether the question concerns the location of a freeway, the adjustment of a tax rate, the modification of school curricula, or the confrontation of crime"[11]. They identified ten distinguishing properties to wicked problems, namely:

1. They have no definitive formulation: It is impossible to gather all the information to solve the problem and it depends on ones point of view of the problem

2. They have no stopping rule: some type of situation will continue after the solution is implemented, therefore it is ongoing

3. There solutions are not true or false but good or bad: it is impossible to find the ultimate solution, only a good enough one.

4. There is no immediate or ultimate test of a solution: the results are unexpected and complex, therefore no way to test to 100%

5. Each solutions is unique and there is no opportunity to learn from past mistakes: there is no way to prevent impacts from decision or reverse them

6. There is no enumerable set of potential solutions: all possible solutions to a wicked problem cannot be determines

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[10] Horst WJ Rittel and Melvin M. Webber, "Dilemmas in a General Theory of Planning," *Policy Sciences* 4, no. 2 (1973), 160.
[11] Ibid.

7. Each problem is unique: it impossible to replicate the problems as the environment affecting is always changing.

8. Every problem is a symptom of another problem: there are interrelations between problems

9. There are numerous ways to explain a wicked problem, which choice will determine the possible solutions: the definition given to the problem will shape the solution set.

10. The planner (the ones solving the wicked problem) has no right to be wrong: essential, the decision maker is responsible for the results

These characteristics show the level of complexity of wicked problems and can tend to make one think that trying to use Multi Criteria Decision Making Methods is more difficult would be more difficult. It must be noted that it is however not impossible as examples will be given that are akin to the ones given before in Rittel and Webber. As will be shown later, Multi Criteria Decision Making Methods were used for the selection of airline hub or for the location of a logistics center. Ultimately, the decision on the definition of the problem and the acceptance of the limitation of the model, would permit the use of Multi Criteria Decision Making Methods which would need to be revisited if the parameters change. These two types of problems also align themselves on the two types of decision making in the military identified by Bryant, Robert and McCann, namely the analytical and intuitive approach to decision making. In the analytical approach "have emphasized explicitly computable processes to take in information, code it symbolically, manipulate these symbolic representations, and generate some output"[12] which is extremely well defined and closely related to the "tamed" type of problem. Whereas the intuitive approach "are based on descriptive, rather than normative, models of the strategies employed by

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experienced decision makers in coping with real problems"[13] which is more in line with "wicked" problems. They identified that both approaches are used in the military, however in combat and in the core training that all military personnel receive, a large emphasis is put on intuitive decision making, which could explain the familiarity of military leaders with this type of decision making. Also, this analytical approach that was identified by Bryant and all, requires more information of a quantitative nature and is more exhaustive. As they identified, the more the method is on the analytical side, the more time, information and computational (human or actual computer) is needed.[14] Based solely on these criteria, it can be easily understood why the analytical approach to decision making would not be used. There are many decision, especially in the midst of operations, where time is not available in order to use a long decision process. Also, many times, the information is so limited, that one could not even draw up a model or come up with sufficient solutions in order to proper evaluate them. Finally, the availability of the tools and expertise required in order to properly do a long decision process, let alone using and Multi Criteria Decision Making Method is not an option. However, it must be noted that most Multi-criteria decision making methods also include a framework for the whole decision process associated to the actual mathematical method. These are an essential part and in itself is possibly the most important part of Multi Criteria Decision Making Methods.

Decision making is not limited to the evaluation of CoA and the selection of the best one. It is a process that involves many steps, the number and designation of them, varies based on which theory one adheres to. Possibly one of the best known decision making processes, which has been used by decision makers, from industry and military alike, is the OODA loop from Mr John Boyd. His simple loop of Observe, Orient, Decide and Act with built in feedback

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[13] Ibid.
[14] Ibid.

mechanisms has been the foundation of many theories[15]. Most Multi Criteria Decision Making

Methods include as part of their theory decision process that is substantially equivalent. In order

to make them work, these methods first need an agreement between stakeholders on what the

problem is, which in itself can be an impossible task. There is also a requirement for information

about the problem, its structure and what the linkages in the data are. As was identified, the

involvement of the stakeholders and of the key individuals that have the information required for

the specific problem is primordial in order to cover all bases. After a solution set is provided by

the Multi Criteria Decision Making Method used, there is a review phase where some of the

components of the structure or linkages in the data are adjusted in order to achieve a better

solution set. Also, most methods discuss the requirement to draw a plan for the application of the

solution and to return to adjust the model based on the lesson learned in the application. These

general steps are defined in different ways, as for example Valerie Belton, who recognizes three

phases: problem identification and structuring, model building and use and the development of

an action plan[16]. It must be noted that all these phases including the involvement of the decision

maker, especially in the problem identification, structuring and model building. Finally, the

development of an action is a central responsibility of the decision maker also. In the British

government department of communities and local government book on multi criteria analysis

they define the steps as follow:

> 1. Establish the decision context. What are the aims of the MCA, and who are the decision makers and other key players?
>
> 2. Identify the options.
>
> 3. Identify the objectives and criteria that reflect the value associated with the consequences of each option.

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[15] John R. Boyd, "The Essence of Winning and Losing," *Unpublished Lecture Notes* (1996), 4.

[16] Valerie Belton and Theodor Stewart, *Multiple Criteria Decision Analysis: An Integrated Approach*Springer, 2002), 6.

4. Describe the expected performance of each option against the criteria. (If the analysis is to include steps 5 and 6, also 'score' the options, i.e. assess the value associated with the consequences of each option.)

5. 'Weighting'. Assign weights for each of the criteria to reflect their relative importance to the decision.

6. Combine the weights and scores for each of the options to derive and overall value.

7. Examine the results.

8. Conduct a sensitivity analysis of the results to changes in scores or weights[17].

This description of the process is more detailed than the previous one where its step 1 and 2 are related to problem structuring and where all the following steps are related to the model building. The other steps are not mentioned as they are covered earlier in the book in the overall decision process, which lists the following steps: Identifying objectives, Identifying options for achieving the objectives, identifying the criteria to be used to compare the options, Analysis of the options, Making choices, and Feedback[18]. Another point of view of the Multi Criteria Decision Making Method process is given by Tsoukias, which is very close to the previous examples: "a representation of the problem situation; a problem formulation; an evaluation model; a final recommendation."[19] The interesting fact with these processes, is that some of the failings that were identified in decisions failures by in organizations in Canada and the US by Nutt, would be answered by these steps.

As with the OODA loop, Multi Criteria Decision Making Methods advocate that they are learning process, that the solution generation is only a small part of decision making and that Multi Criteria Decision Making Methods are only a tool. As was defined by Roy, "DA aims at establishing, on recognized scientific bases, with reference to working hypotheses, formulations

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[17] JS Dodgson et al., *Multi-Criteria Analysis: A Manual*Department for Communities and Local Government: London, 2009).

[18] Ibid.

[19] Alexis Tsoukiàs, "On the Concept of Decision Aiding Process: An Operational Perspective," *Annals of Operations Research* 154, no. 1 (2007), 10.

of propositions … … which are then submitted to the judgment of a decision maker and/or the various actors involved in the decision making process[20]. The solution provided should never be seen as the silver bullet but be more seen as what it is, one of many tools available to decision makers. These facts and the steps alluded to before are surprisingly closely related to the OODA loop or other similar processes like the CAF OPP. At the end of the day, one important fact remains, that a decision process needs to be used as this is the only way to guarantee that all important factors are properly considered. The effort of taking the time, will pay large dividends and could possibly prevent certain problems of arising or at very least these problems could be anticipated. However, as most of the problems that are faced by DND have at least 2 options with at least 5 criteria, it is clear that rational decisions cannot be reached. This is where Multi Criteria Decision Making Methods and especially their problem resolution will provide the added support to provide better solution that are transparent and auditable.

Chapter 2

Multi Criteria Decision Making Method and why they should be used in DND

Decision making is not an easy task, which gets even more complicated when one is faced to a complex problem. As was laid out in the previous section, there is a very real requirement for using some sort of decision process in trying to resolve complex problems. However, just using a decision process will not be sufficient when faced with problems that includes multiple options and criteria. This is where Multi Criteria Decision Making Methods

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[20] Bernard Roy, "Paradigms and Challenges," in *Multiple Criteria Decision Analysis: State of the Art Surveys*Springer, 2005), 5.

can provide the added support in order to fully comprehend the situation and consider all the relevant options. To first step will be to explain the origin Multi Criteria Decision Making Methods as it fits inside the field of Operational Research. From this, we will build on the knowledge by explaining the basic theory that supports Multi Criteria Decision Making Methods, especially on the problem resolution side. This will lead us to the next section, where we will look at some of the most popular models being used in organizations in order to support management.

Complex problems have always existed but the 20th century saw the rise of an ever more complicated world. This was even more the case during the two Great Wars, so much so that the experience of the First World War caused a surge in the research in relation to complex systems. This occurred at the same time as there was many advances in management, mathematics and engineering, which in turn influenced the overall research on systems, which included decision making. This would lead to in the years before World War II, to the creation of the field of study called Operational Research (OR), which attempted to improve processes in the face of the complexity that existed during World War II. As was indicated before, Operational Research was the marriage of many disciplines that were attempting to improve efficiency of human processes in order to find an optimal state. Its range of involvement stretches from complex mathematical modelling and optimization to the analysis of policy. One of the areas of research in OR, is Multi-Criteria Decision Making, which looks at much on how to structure a decision model as how to solve the model.

> One of the principal aims of Multi-Criteria Decision Analysis (MCDA) approaches is to help decision makers organize and synthesize such information in a way which leads them to feel comfortable and confident about making a decision, minimizing the potential

post-decision regret by being satisfied that all criteria or factors have been taken into account.[21]

As can be seen, it is as much the answer that is reached as it is the process to gather the information, opinions of DMs and the structure that is given to that information that is important. This is what makes the use of Multi Criteria Decision Making Methods so critical, as they provide a structure to complex problems and provide invaluable tools in order to reach a decision. They try to recreate human decision process, through the use of rules and mathematics, in such a way as to ensure that all important factors are included and considered in the decisions or solutions that are provided. In a way, it tries to eliminate or limit the impact of the usual way decision makers take decisions. They take these decisions through intuition, associations or simply disregarding some of the aspects, which permits to reach a decision rapidly, even if it's not the right one. As was explained before, for most of our day to day decisions, Decision Makers can get away with not considering all the options, as they can accept the consequences. However, as it is rarely the case in most management decisions, one way to mitigate bad consequences of decisions is to take better ones or at least understand how the decision is reached.

Taking decisions for complex problems can be a daunting task, this is where Multi Criteria Decision Making Methods can provide some help. However, before explaining the various options that are available, one must first understand the field of Multi Criteria Decision Making Methods, for which there are certain basic foundational pieces. As was indicated before, the process involves three phases, problem identification and structuring, model building and use, and the development of an action plan[22]. The first phase is fact finding, understanding the problem space, determining the criteria and finding the possible solutions. From the information

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[21] Belton and Stewart, *Multiple Criteria Decision Analysis: An Integrated Approach*, 2
[22] Ibid.

that is collected in this phase, one can then build the model and resolve it in the next phase. This is followed by a development of an action plan based on the solution that was derived. It must be noted, that sometimes that the solutions are unknown or are infinite, these are known as multi-criteria design problems or multi objective decision making, where the alternatives are found through the use of complex mathematics, which involves its own Multi Criteria Decision Making Methods. It might seem impossible for some to consider of infinite, however, if we consider the problem of getting to work, one can easily see an infinite number of solutions, including going to work using a helicopter or even circumnavigating the world. However, these are what we would call throw away CoAs. Also, some solutions are barely differentiable between each other. The problems rarely occur in practices, as most decision Makers determine what acceptable solutions are not considering the outliers. In these types of setting, which Multi Criteria Decision Making Method calls multi-criteria evaluations problems or multi attribute Decision Making (MADM), there is much research that has been devoted on how to determine the objectives/ solutions and most methods devote some time in explaining on how to reach determine the solution set. In the majority of cases in DND, the solution set is known, therefore it will be assumed that the methods that will be of use for DND will be of the deterministic nature.

The type of Multi Criteria Decision Making Methods that can be used can also be impacted by another factor, the units of the criteria selected. The selection of criteria can lead to a variety of different measures that can go from the most common criteria of cost to more qualitative ones like: "how happy does the option makes you feel". The first criteria, is called a cardinal criteria, as it will return a number. The other criteria is ordinal, as it will a verbal value within a preset range that will then be transformed into a number. The type and the possible combinations of criteria will determine what methods can be used. Also, you can end up having

only cardinal criteria, however if the various units of the criteria that are being involved could be different (ie: $ and kg), this could preclude certain methods. A further category that can be assigned is where Multi Criteria Decision Making Methods can be either deterministic, stochastic or fuzzy. The last two are related to considering unknowns, in particular in some of the variables of the problems. Again, most of the problems in DND, the solutions will be assumed to be known and the same will be true for the criteria of the problem. Ultimately, this adds a level of complexity that will determine which methods that can be used.

This leaves one final concept that must explained as it also limits the number of methods that can be used. The concept of preferences in Multi-Criteria Decision Making is of prime importance, as it is where the Decision Maker classifies the problem based on his preferences. This is the fundamental precept of MCDM, as preferences are where the Decision Maker consider each individual piece of the deconstructed problem, instead of deciding on the overall problem, in order to determine the overall priority of the options. This is the beauty of using Multi Criteria Decision Making Methods, since the decision maker does not have to consider the whole problem and try make a decision, which was stated before as being impossible. It builds on their ability to clearly decide on small concepts and marries all those decisions into one final decision. If the decision are being made by a group, each individual piece of preference can be negotiated between the participating Decision Makers. The primacy of preferences is essential as it maintains the place of the decision maker in the Multi Criteria Decision Making Method process.

Multi Criteria Decision Making Methods processes that use sometimes very complex mathematical theorem in order to resolve the preferences of decision makers and determine or prioritize options. Without going into the actual mathematics of Multi Criteria Decision Making

Methods, it was necessary to explain that this field of study originated from Operational Research. As was seen, this field of research is a marriage of many different fields in mathematics, management, sociology, psychology, to name of few. Its main focus is to help decision makers in taking a decision, without prescribing the decision and even sometimes the journey to reach the decision is the value that Multi Criteria Decision Making Method provide. A few theoretical concepts were also discussed in order to permit an understanding of the various Multi Criteria Decision Making Methods that could be used by DND. In particular, that Multi Criteria Decision Making Method are a decision process that rests on phases that are closely related to the OODA loop, which in this case are called: problem identification and structuring, model building and use, and the development of an action plan. Between the various methods, there are differentiations that are possible, either on fact that there is a limited or unlimited number of objectives, the type of criteria units, and the fact that the value of the criteria can be known or random. Finally, the most important concept, is the consideration of preferences, which are central and requires the input of decision makers. It is therefore evident that Multi Criteria Decision Making Methods are in no way simple procedures that can be implemented by anyone. Most of them require the involvement of trained technicians or scientists, even if there is software that has been developed to simplify this work. This therefore leads us to the description of the various methods that could be of use within DND and that have been successfully applied in multiple organizations.

MOST COMMON Multi Criteria Decision Making Method USED IN INDUSTRY AND GOVERNMENT AND EXAMPLES

MCDM can be found in various forms going from very simple like the Benjamin Franklin process of comparing pros and cons lists to select the winner or to complex mathematical dilemmas that takes computers days to solve. The increasing complexity of the methods are further hindered by the quantity of information that is available, the number of decisions makers and the impacts of the decisions. It is clear that there is not on MCDM method that can answer all problems, as some of these methods are tailored to live within certain types of problems. As was discussed before, most problems have an infinite number of possible solutions, from the optimal to totally unrealistic solutions. These unbounded problems will not be covered, as their theories are complex and do not represent the reality of DND, where almost all problems have a limited solution set. These discrete problems can be solved in a variety of ways, from voting methods to complex methods that consider numerous criteria for each option. Therefore, there exists numerous options to decision makers in which method they want to use. A limited description of some of these methods, will be provide in the hopes of providing an understanding of their mechanisms. The first group of methods that will be considered are voting methods, in particular the Borda Count that is used by DND. This will be followed by the utility methods, which are based on expected utility and are among the most used types of Multi Criteria Decision Making Methods. Finally, the descriptions of method will be closed out by the outranking methods. This will be followed by a short listing of some of the more prominent software that permit the application of these methods.

Even by limiting the field of methods to discrete methods, this still leaves a huge number of means by which decision makers can receive help in their decision making. In order to provide some sense into this vast array of methods, they will be divided in three groups: voting, utility and outranking methods. Voting methods involve the casting of a vote for the preferred candidate, as one would in an election. The methods that will be discussed are more complex in order to provide a ranking between all the options. In particular, the Borda Count and the Condorcet voting methods are described as they are in use in DND. The software MARCUS that uses these voting methods in consort with the Kendall tau-x rank coefficients is the most common means by which DRDC provides decision support to DND. The next two groups of methods differ from the voting methods, as they will consider criteria for each of the options, albeit in different ways. The utility methods comprises of the most popular methods. They are based on the concept that each criteria can be translated into a utility value, which then translate into an overall value for each option. These can be extremely simple like a like a simple weight some model, where all the criteria have the same units (ie cost) or more complex like the Analytic Hierarchy Process (AHP) or MACBETH that consider any type of criteria. After explaining the concept of utility, the following methods will be covered:

weight sum, weighted product, Simple Additive Weighting (SAW), AHP, Multi-Attribute Utility Theory (MAUT), Simple Multi-Attribute Rating Technique (SMART), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Measuring Attractiveness by a Category-Based Evaluation Technique (MACBETH).

All these techniques are based on the premise of utility and vary based on the complexity or lack of information of the problem. But they can only be used if a utility function can be derived, which is not always the case. This is where the outranking methods come into play, as they only

deal in wanting to know if an alternative outranks another but not needing all alternatives to be comparable. The results are weaker, but permits the application to problems that were not solvable by utility methods. These methods were invented by researchers in France and Belgium, which lead to them being termed as the French School of Multi Criteria Decision Making Methods. The two groups of methods that will be investigated are the ELECTRE (ELimination and Choice Expressing Reality) and PROMETHEE (Preference Ranking Organization METHod for Enrichment of Evaluations) family of methods. The description will give a good understanding of the breadth of methods that exist and that could be used by DND decision makers in order to reach informed transparent decisions.

Borda, Condorcet and Simple Rankings

The most well-known and common decision aiding method is the fundamental right of every citizen in a democracy and that is the right to vote for their government. Voting is used for all sorts of elections, national, regional, municipal or any type of organizational leadership positions. It can be as simple as having every allegeable voter cast one vote for the option of his choice or having each voter ranking all the options. Voting is not limited to election of officials, it can also be used to select a preferred option or of individual criteria. The two most common and robust methods of using voting as MCDMs is the Borda and Condorcet Counts.

One method that is used by DND in ranking its options is the Borda Count, which is a preferential voting system. Each member of the decision maker group ranks all the options by order of preference which receive points based on their order, with the best option getting the most points. However, it must be noted that the Borda count has its problem, as it can be affected by tactical voting. As was explained by Emond: "The problem with Borda's method stems from a failure to recognize that a ranking system cannot measure the degrees of intensity of preference

held by the rankers[23]. Another voting method that is used in DND is the one invented by Condorcet, which is a pairwise comparison of each option against each other. An option gets a point for every time it is preferred to the other option, with the winner being the one with the most votes. Ambiguity can exist, as sometimes there is no candidate that has the overall preference of the voters, this is what is called circular ambiguity.[24] As was indicated before, other voting mechanisms do exist and could be used in order to determine a ranking between alternatives for a group of decision makers.

In DND, DRDC uses the MARCUS (Multicriteria Analysis and Ranking Consensus Unified System) software in order to solve complex problems. It is a decision support software that takes inputs based on votes from the decision makers and provides a ranked order of options through a mathematical program of branch and bound through multiple iterations. MARCUS uses the Kendall-tau x correlation coefficient in order to determine the best solution, where as indicated by Emond: "The solution concept which we will use for the general m rankings problem is to find a solution or consensus ranking which has maximum weighted average tau-x rank correlation with the m input rankings"[25]. These methods are solely based on the judgements of the decision maker on either the options or the criteria for the options. They do not consider the impact of the data from the problem, apart from the preferences that are expressed by the decision maker. In order to see the available data directly inputted from the problem into the model, one must turn to the various utility theories based methods.

Expected Utility

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[23] *"Developments in the Analysis of Rankings in Operational Research," ORD Project Report PR2000/13).Defence R&D Canada, Centre for Operational Research and Analysis.Directorate of Operational Research Corporate, Air & Maritime (2006).*
[24] Ibid.
[25] Ibid.

As was identified earlier, one of the basis of Multi Criteria Decision Making Method is the concept of preferences. This concept was central in the voting theories, but is also central in the utility theories. These are based on the expected utility theory, where the decision maker must determine the outcomes and the probability of the outcomes. In other words, if the decision maker thinks he has 50% chance of winning $100, the expected utility is $50. This utility can be graphed and give a utility function that varies over time (the more money one has the less value it holds, which is in itself a paradox). The expected utility theory was seen to be bound by four rules, as described by von Neumann and Morgenstern which can be described as follows:

1. Completeness: In a lottery with 2 items a and b: either a is preferred or b is preferred or the decision maker is indifferent
2. Transitivity: In a choice of a, b and c: If a is preferred to b and b is preferred to c then a is preferred to c
3. Continuity: In a choice of a, b and c, where a is less or equal to b who is less or equal to c, there exists a probability where that will identify a tipping point from option b as worse or better then.
4. Independence: If a decision maker is indifferent between two outcomes, then he will be indifferent if the results have equal chance of occurring[26].

These are the basis which permit the use of utility theory, however, there are circumstances where these are broken, forcing one to use other methods. However, it remains a common method, from a common use is the decision matrix, a table with alternatives and valued criteria. This method is widely used in DND, for example, in business cases analysis and in the Operational Planning Process Course of Action comparison, as it is a simple methodology. Depending on the complexity of the problem, simple utility methods, like the Weighted Sum Model can be used or a bit more complex methods like the Simple Multi-Attribute Rating Technique can be used.

Weighted Sum Model

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[26] John Von Neumann and Oskar Morgenstern, *Theory of Games and Economic Behavior (60th Anniversary Commemorative Edition)*Princeton university press, 2007), 26.

The search for a method that would account for more complexity in a problem, while staying simple, is exactly what Peter Fishburn was seeking, when he created the Weighted Sum model (WSM). In this method, each criteria is assigned a weight and for each option a score with the individual scores are multiplied by its assigned weight and the product for each option is added together. This method works well for single-dimension problems, however it fails when faced with multi-dimensions, as its basis is the addition of utilities[27]. However, the cases where the criteria are limited to only one type of unit of measure, are very limited within DND, which will force the use of other methods.

Weighted Product Model

One of the methods, that is not limited to only being used in situation with only one unit of measure, is the Weighted Product Model (WPM). The main difference, of this alternative to WSM, is that multiplication of factors is used, instead of addition. The advantage of this method is that it a dimensionless analysis, as it eliminates units of measure through its calculations. This permits it to be used for multi-dimensional, one of the limitations of the previous model, WSM. This method is a bit more complex, however, it is still relatively simple, which should make it acceptable for most problems met by decision makers in DND.

Simple Additive Weighting

The Simple Additive Weighting (SAW) method, also known as weighted linear combination is a popular method that is multi-dimensional like WSM, deriving normalized values for each criteria inside a decision matrix. As was stated Afshari and el. "The advantage of this method is that it is a proportional linear transformation of the raw data which means that the relative order of

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[27] Evangelos Triantaphyllou, *Multi-Criteria Decision Making Methods: A Comparative Study*, Vol. 44 (Dordrecht ; Boston, Mass.: Kluwer Academic Publishers, 2000), 7.

magnitude of the standardized scores remains equal"[28]. It was used by them for a personnel

selection problem using a DMs ranked evaluation of each criteria. Another example was its use

in the selection of the best option for where to locate a future airport hub in Europe. In this study

by Janic and Reggiani, they used a large number of quantitative criteria, like the Population of

airport catchment area (million), Per Capita Income (ECU/inhabitant) or Airport capacity

(aircraft/hour)[29] This cardinal method (uses real data) is therefore well placed in order to fulfill

the requirements of decisions inside DND, as many of the problem that are faced include data of

this kind. As this is not always possible or there is a requirement to have more descriptive type of

criteria, this is where the other more complex types of utility method must step in.

Multi-Attribute Utility Theory

When faced with many real world problem, one can quickly find himself faced with a

decision model that includes a wide range of criteria, including descriptive ones. One of the

methods that expends on the basic utility theory is the Multi-Attribute Utility theory (MAUT). It

permits the inclusion of risk preference and uncertainty, which are definite advantages compared

to other methods. This accurate method is also time consuming and resource intensive, as it

requires large amount of data, in order to work properly. It is also daunting for the decision

maker, as it needs to record his preferences at every step of the process. However, its strengths

has led to its use in many studies, many times in combination with other methods. It has been

used on problems like the selection of locations for facilities, risk preferences, policies for

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[28] Alireza Afshari, Majid Mojahed and Rosnah Mohd Yusuff, "Simple Additive Weighting Approach to Personnel Selection Problem," *International Journal of Innovation, Management and Technology* 1, no. 5 (2010), 511.

[29] Milan Janic and Aura Reggiani, "An Application of the Multiple Criteria Decision Making (MCDM) Analysis to the Selection of a New Hub Airport," *European Journal of Transport and Infrastructure Research EJTIR, 2 (2)* (2002), 126.

emergency response in disasters[30]. In order to address some of the limitations specified above, especially in regards to complexity other methods have expended on its strength, as for example, the Simple Multi-Attribute Rating Technique.

Simple Multi-Attribute Rating Technique

MAUT was judged as a very accurate utility model, however its complexity made it difficult to use, especially in regards to the amount of data that was required. A model that stems from multi-attribute utility theory is the Simple Multi-Attribute Rating Technique (SMART) which was developed by Edwards (1971). It uses direct rating and ratio weighting in order to construct utility functions and assess weights for each of the criteria to reflect its relative importance to select the best alternative. "The advantage of this method is that attributes are preferentially independent i.e. the decision maker's preference (or feelings) regarding the value of one attribute are not influenced in any way by the values of the other attributes"[31]. It is a very simple method that can be easily implemented by the decision maker, as the mechanisms in order to determine the weights and values of criteria that are required for this model, are more straightforward in their application then other models. Also, the calculations that are used are only a step above a simple weighted criteria method that are usually used in option analysis in DND. This leads us to more complicated utility methods, that have however been widely used throughout the world, none more than the models proposed by Saaty, namely the Analytic Hierarchy Process and the Analytic Network Process.

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[30] Mark Velasquez and Patrick T. Hester, "An Analysis of Multi-Criteria Decision Making Methods," *International Journal of Operations Research* 10, no. 2 (2013), 57.

[31] Fentahun Moges Kasie, "Combining Simple Multiple Attribute Rating Technique and Analytical Hierarchy Process for Designing Multi-Criteria Performance Measurement Framework," *Global Journal of Researches in Engineering* 13, no. 1 (2013), 20.

Analytic Hierarchy Process

In regards to the real world use of Multi Criteria Decision Making Methods, the Analytic

Hierarchy Process (AHP) is possibly the best known method. This is partly due to how well this

method has been advertised and the software and organizations that have made it their business.

As with most Multi Criteria Decision Making Methods, it breaks down a complex problem into

manageable chunks, which are organized into a system of hierarchies. In essence it comprises of

three steps: decomposition of the problem, comparative judgment, and synthesis of priorities.

> "*Decomposition of the problem* deals with a hierarchical schematic representation of the
> overall objective and the decision alternatives. *Comparative judgment* includes the
> formation of the pairwise matrices and their comparison at two levels: i) the level at
> which all alternatives are compared with respect to each criterion, and ii) the level at
> which the criteria are compared with respect to the overall objective"[32].

The comparative judgment is what is seen as the strength of AHP, in which all the criteria are

compared between themselves (pairwise comparisons), which is one way this methods receives

some of its acceptance. Furthermore, as it draws on Decision Makers preference of the

determined criteria for each alternative, it is not limited by ordinal values, as it translates

qualitative into quantitative. This makes AHP, are relatively easy method to use, which might

explain its popularity and its wide usage: "The AHP has been proposed in recent literature as an

emerging solution approach to large, dynamic and complex real-world MCDM problems and

organizational resources"[33].

Its vast popularity has therefore attracted much review by academics, which have

identified varied areas of problems in its processes. One of the biggest problem that is seen with

AHP, is the arbitrary nature of the 1-9 scale, which is seen as being inconsistent with itself. As

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[32] Janic and Reggiani, *An Application of the Multiple Criteria Decision Making (MCDM) Analysis to the Selection of a New Hub Airport*, 120

[33] G. Kannan, "Fuzzy Approach for the Selection of Third Party Reverse Logistics Provider," *Asia Pacific Journal of Marketing and Logistics* 21, no. 3 (2009), 404.

the scale is too restrictive, when many pairwise comparisons are done, there will be circumstances where the comparison cannot be exactly transitive between three criteria. Here is an example :" A may be scored 3 in relation to B and B similarly scored 5 relative to C. But the 1–9 scale means that a consistent ranking of A relative to C (requiring a score of 15) is impossible."[34] Another big problem, is the possibility of having rank reversal of the alternatives, when a new option is introduced or one is removed from the problem, as identified by Belton and Gear[35]. It is for these reasons, that DRDC does not support this method, as is clearly stated in Dr Emond study[36]. Some Multi Criteria Decision Making Methods have been created to correct the problems, one example is with Belton and Gear, who recommended what they called Revised AHP, which proposed normalizing the data thus preventing the rank reversal. Ultimately, Saaty created a new method, called Analytic Network Process that is even more robust and more tied to real world examples

The AHP method makes the assumption that all the criteria are independent of each other, which is not the reality in real world problems. Most times, there is interdependence between the criteria and the alternatives, which basically means that consideration to feedback between all elements. This is what the Analytic Network Process (ANP) was made to answer, by taking into consideration the feedback loops between all the elements of the system. This permits the model to be modified by the data that is provided. An example would be the price of an automobile that could be extremely important, however, if all the options have a similar price, the feedback loop, would lessen the importance of that criteria. Its principal areas of use is in complex problems that involve interdependent criteria, that often oppose itself, like using

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[34] Dodgson et al., *Multi-Criteria Analysis: A Manual*, 130
[35] Valerie Belton and Tony Gear, "On a Short-Coming of Saaty's Method of Analytic Hierarchies," *Omega* 11, no. 3 (1983), 228-230.
[36] Emond, *Developments in the Analysis of Rankings in Operational Research*, 6.

Benefits, opportunities, costs and risks as criteria. Some examples of use as were by Saaty like the forecasting of the next financial crisis or what should Ford have done in regards to its problems with the Explorer. Other examples are even more interesting, like how to stabilize social security or what to do with the US energy sector. Even more surprising was its use for an analysis of the most hopeful outcome in the Middle East Conflict, the conflict between China and Taiwan or what should be the response to North Korea Nuclear threat[37].

The AHP and ANP methods of Saaty have shown some merit, but have also suffered some wide range criticisms, because of some of their limitations and the errors that they generate. They are methods for which much has been written and for which there is a lot of support through companies that provide Decision support using these methods or with software that is available to use to do the work internally. Therefore, these methods should not be a primary choice but are certainly an option that is available for use. There are however more utility method that are available, which could provide options that avoid some of the issues of AHP.

Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

The main intent of all the previous methods is to determine the best possible solution. However, sometimes, there are decision making situation, where the ideal situation is known, but is unacceptable and a compromise option is required. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) can determine a compromise solution. It can use cardinal type criteria or can use verbal evaluation criteria that are translated into cardinal values. It will then it normalizes the criteria as part of its solution process, thus permitting the criteria with

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[37] Thomas L. Saaty and Luis G. Vargas, *Decision Making with the Analytic Network Process: Economic, Political, Social and Technological Applications with Benefits, Opportunities, Costs and Risks*, Vol. 95 (New York: Springer, 2006), 278.

differing units and even permitting the use of negative criteria. Therefore, as this method is very specific in it use, it is not necessarily the best choice for DND. This brings us to the last type of utility methods that would be one of the better methods that should be used by DND.

MACBETH

Many of the utility methods would be adequate solutions for resolving some of DND complex problems. These methods still have constraints and one possible technique that would fulfill this requirement would be the Measuring Attractiveness by a Category-Based Evaluation Technique is (MACBETH), which uses the same process as AHP, or a pairwise comparison of criteria. As was the case with AHP, MACBETH can uses qualitative or quantitative criteria as part of its model, thus permitting the use of any type of cardinal or ordinal criteria.

The first step in the MACBETH method, is to extract from an individual or group, a set of verbal pairwise comparison judgments of qualitative difference in attractiveness. The other stage uses these judgments to make a multicriteria evaluation model, the measure the relative attractiveness of the options[38]. It is this final step that marks the difference with AHP, which permits the preservation of the judgments of the decision maker in regards to the preferred order of the options. As was the case with AHP and was hinted to previously, its application is extremely wide, as can be expected based on its comparative nature. This ranges from agriculture and Performance measurement up to Human resource management & job selection[39]. The flexibility of this method and its ease of use, make it the perfect candidate for solving complex problems within DND.

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[38] E. COSTA BANA, DE CORTE JEAN-MARIE and JEAN-CLAUDE VANSNICK, "MACBETH," *International Journal of Information Technology & Decision Making* 11, no. 02 (03/01; 2015/03, 2012), 380.
[39] Ibid.

As was seen so far, utility and all it supporting methodologies, are useful methods if one considers that they can determine the utility functions for all criteria. We looked at come very simple models like the Weighted sum method and the weighted product method. Other models included the Multi Attribute utility theory and its extension into the Simple Multi-Attribute Rating Technique, which were valid models that are routinely used but still were challenging. This lead us the Analytic Hierarchy Process and the Analytic Network process which have been widely used but face some theoretical challenges. Ultimately MACBETH, which we have seen as being the best suited method on the utility side to support DND in taking its complex decisions. This method should satisfy most of the decisions within DND, however there are other problems, where different MDCMMs must be used as it is not possible to derive a utility function.

Outranking methods

As was identified before, Multi Criteria Decision Making Methods that are the concern of this paper are interested with the evaluation by a decision maker or a group of a limited number of alternatives through a limited number of criteria. Up to this point, the methods that have been covered were based on the concept of aggregation of the value function, the "American school" which: "is inspired by the work of Keeney and Raiffa on multi-attribute value functions and multi-attribute utility theory."[40] There is another group of methods to counter this philosophy, the French school. These methods are based on the outranking of alternatives between themselves, not based on a value of the alternatives but on the outranking relation between the alternatives. The outranking can be explained as follows: "An alternative *a* is said to outrank another alternative b if, taking account of all available information regarding the problem and the

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[40] FA Lootsma, "The French and the American School in Multi-Criteria Decision Analysis," *RAIRO.Recherche Opérationnelle* 24, no. 3 (1990), 264.

decision's maker preferences, there is a strong enough argument to support a conclusion that a is at least as good as *b* and no strong argument to the contrary"[41]. The most popular methods are grouped under the ELECTRE, by Roy and PROMETHEE by Brans family of methods, which originated from the limitations of the utility based methods, which did not work in all circumstances. These outranking methods are weaker then utility based methods, but have the benefit of providing sufficient information in order to provide some conclusions to be drawn.

The ELECTRE family includes several methods that vary in the complexity in regards to the quantity of information they require. It comprises of two main procedures that are the construction of outranking relationships and an exploitation procedure. Also, there are four types of preference relationships that are seen to exist as part of the ELECTRE procedures: indifference, the fact that there can be a strict or a weak preference between the options. It was first presented in the ELECTRE I method which was further refined in successive ELECTRE II, III, IV, TRI and more in how they were structured, the data they used or in the outputs they provided. ELECTRE I main focus is to indicate a group of preferred options making it a rather simple method that does not have significant application in the real world. ELECTRE II adds the benefit of rankings the options, through two outranking relations. ELECTRE III introduces the notion of indifference into the equation, as was indicated by Mrs Belton:

> "ELECTRE III permits more sophisticated modelling of preferences on individual criteria than does ELECTRE II, which does however call for more work in modelling preferences with respect to each individual criterion before progressing to the building and exploitation of the outranking relation"[42].

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[41] Belton and Stewart, *Multiple Criteria Decision Analysis: An Integrated Approach*
[42] Ibid.

There are other variants of outranking ELECTRE, like ELECTRE III TRI and ELECTRE IV, to name a few. Of these the ELECTRE TRI method is of particular interest, as it is directed towards classification problems, where alternatives are allocated into categories. The original method was based on three categories: acceptable, unacceptable and indeterminate, which has been expanded for use in more than three categories.

The final outranking method that will be discussed is the Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE) which was developed by Brans and co-workers. As for all the methods, the various alternatives are assessed against a set of criteria. One of the major difference is that the preference for each criteria is assigned a preference function. Again, there are many variants, with PROMETHEE I giving a partial preorder and PROMETHEE II giving a complete preorder, PROMETHEE III provides and interval order emphasizing indifference and PROMETHEE IV deals with continuous sets of possible alternatives[43]. These are acceptable methods, even if there are not as widely used as the ELECTRE family of methods.

This brings us to the end of the outranking methods that attempt to break from the models that were based on utility. As was indicated, the utility theory has difficulties dealing with situations where a utility curve is not easily identifiable. The outranking methods, even if they are not as precise, at least permit to draw a solution set for problems for which it would have been difficult with the utility methods. Of these, the latest ELECTRE methods, in particular ELECTRE III and ELECTRE TRI. Again, this would depend on the type of problem and what needs to be achieved.

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[43] G. H. Tzeng and Jih-Jeng Huang, *Multiple Attribute Decision Making: Methods and Appliations* (Boca Raton, FL: CRC Press, 2011).

MCDM have numerous methods that can be applied to problems, with new methods being created each year. Not all of them are appropriate for all circumstances, as some are more theoretical in nature or are for very complex situations. Therefore, only certain methods are applicable for use within DND based on the type of problems that it faces. This is why only certain methods were explained, in order to focus on some of the most common and relevant that could benefit DND if they were used. The voting methods, which some are already in use, like the Borda and Condorcet methods, are well suited when one seeks to just draw direct preferences for options, without looking at any criteria. It can also be used for voting on criteria to be then added together to determine a ranking between options. From the utility types, a few models would be of use, depending on the problem being analyzed. When faced with only quantitative data, the Simple Additive weighting method would be recommended. However, the MACBETH method is highly recommended, as it can combine both cardinal and ordinal data, to give a ranking of options. When faced with an options to which we cannot determine a value function, the outranking methods permit to create a ranking of the options to point towards an acceptable solution. Primarily, these are the ELECTRE family of methods, primarily ELECTRE TRE and ELECTRE III. These are only recommendations and a review of these methods by DRDC in order to determine if some of these methods would need to be conducted before going ahead with their use.

Software

Most of these methods can be applied through the use of software, some of which are already within DND. As was indicated before, DND uses software called MARCUS, in order to administer the voting results from decision makers. Almost all the methods described before, have their own software, with prices ranging from very expensive to totally free. Any exploration

of these methods, might involve the purchase of some of these software in order to properly understand the methods and rapidly implement their use.

One of the most popular and written about MCDM is AHP, therefore it is not surprising that is has many different software, in particular: Criterium DecisionPlus, Decision Lens, Expert Choice and Logical Decisions. Criterium Decision Plus from Info Harvest and Logical Decisions supports as much AHP and SMART. Decision Lens and Expert Choice are decision support companies which software is based on. MakeItRational is another AHP based software that is web-based and easy to use. VISA Decisions is another Multi-Attribute Value Theory software. The MACBETH method has the haply named M-MACBETH software which was created by the inventors of the method, Costa and De Corte. The ELECTRE methods are covered by a series of software that are provided from LAMSADE (Laboratoire d'Analyse et Modelisation de Systemes pour l'Aide a la DEcision). Visual PROMETHEE supports the PROMETHEE method and gives a straight forward windows interface, which is also done by D-Sight software which also uses MAUT.

As with all the other software, it is sufficiently complicated that it would be of limited use to anyone who does not understand the method. Some of these software have some interesting feature with a few of them free academic versions. Ultimately, it is recommended that these various software be explored to determine their value in support of DND complex decision making. It is interesting to note that in reviewing some of this sites, the list of their stated clients is very vast. They cover every field of business and many government agency. Most military organizations in the US and many other ones in the World can be found listed as one of the user of these software. It is even the case for DND, which is listed as one of the clients of D-Sight.

Chapter 4

USE OF Multi Criteria Decision Making Methods IN DND

Decision makers are usually in organizations in which the decisions that have to be taken are rarely simple. There are usually many options and an inordinate amount of factors that can influence the decision. The approximations that are used in everyone daily routine decisions are used but the impacts are never small. From the outset, the decisions impacts, at the very least the organization and the wrong decision could be very damaging. If one looks at DND, nothing in this organization is simple, making all decisions complex. One of the problems that is faced in that organization is how problems are perceived and how they can be resolved. However, it's the consequences that are involved in all the decisions in DND that are of a bigger concern. If one looks at situations relating to capital projects or operations, consequences of making the wrong decision could cost millions of dollars or even lives[44]. This is not to say that the military does not already use MCDM.

If one looks on the decision process side, all military personnel are trained on Mission planning or what is also called Situation, Mission, Execution, Administration, Communications (SIMEAC), which is a very efficient decision making process. Another example is the Operational Planning Process (OPP) which closely resembles some of the processes that are laid out as part of the Multi Criteria Decision Making Methods that exist today. Even, the capability planning process and its embedded business case analysis are closely related to Multi Criteria Decision Making Methods process. On the mathematical side of Multi Criteria Decision Making Methods, the PER ranking process, especially the ranking process based on the dot evaluation, is equivalent to a Weighted Sum model, which will be discussed later. Even more basic example is the Course of Action (COA) evaluation, which is done as part of OPP, which is a simple

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[44] Belton and Stewart, *Multiple Criteria Decision Analysis: An Integrated Approach*, p.2

summation of criteria evaluation with sometimes a weight added to one of the criteria. There has

also been some complete use of Multi Criteria Decision Making Methods, especially by Defense

Research Development Canada (DRDC), which is the leader in defence and security science and

technology. These included the use of Condorcet, Borda and other different additive weights

methods, even developing software in order to facilitate use of Multi Criteria Decision Making

Methods[45]. However, the use of decision processes in DND is weak, being limited to a few

established processes or to situation where time, resources permit and the willingness to use

them is present.

Part of the problem of limited use of Multi Criteria Decision Making Methods is rooted

in the perception of the problems and how they can be resolved. As was discussed before, Multi

Criteria Decision Making Methods can be used for wicked problems, but only with great

difficulty and with the understanding that the results can be contradictory in view of the

complexity of the problem. If the Decision makers can agree on the definition of the problems,

the criteria to use and can align their preferences properly, it is possible to use some of the Multi

Criteria Decision Making Methods, like MACBETH or ELECTRE TRI to order the possible

solutions. However, it is a generalize feeling that all the problem that are faced by DND are of a

wicked nature and are too complex to be codified. Therefore intuition is a more relevant means

of taking a decision. But as was explained before, intuition has its limits, especially when

considering problems created by bounded rationality. Even more concerning, is that these wicked

problems, involve multiple actors and a large amount of information. This then faces the

limitations of "bounded awareness" as described by Chugh and Bazerman, "as the fact that

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[45] Emond, *Developments in the Analysis of Rankings in Operational Research*, 41

humans regularly fail to see and use stimuli and information easily available to them."[46]. They also identified that this bounded awareness affected negotiations, where people were out of focus with the rules of the negotiations and the decisions of others. This shows that on top of being limited by the information available, Decision Makers also disregard some of the keys factors that are at their disposal.[47] Hammond, Kenney and Raiffa have gone as far as identifying all the traps that we face as decision makers take decision, usually in using heuristics. From the anchoring trap all the way to the estimating and forecasting traps, these are all realities that affect decision makers, in which awareness is the greatest defense.[48] Therefore, the risks of errors by decision makers must be controlled by more detailed process, through the use of decision process and even possibly Multi Criteria Decision Making Methods. There is however a concern, with the use of these methods, in regards to the information and the records it produces. It represents a very transparent methodology, which would be pleasing to auditors and to all those that whish full accountability. As was identified before, Multi Criteria Decision Making Methods are not made for every decision and the resources and time required for their use, could prove detrimental to certain processes inside DND. Therefore, its application would need to be monitored and a proper understanding of its limitation must be sought. But this an increase us of Multi Criteria Decision Making Methods does not mean that they are not currently in use within DND.

As was stated before, DND already uses Multi Criteria Decision Making Methods, especially through DRDC, in fields like options analysis, project management, and priority

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[46] Dolly Chugh and Max H. Bazerman, "Bounded Awareness: What You Fail to See can Hurt You," *Mind & Society* 6, no. 1 (2007), 2.

[47] Ibid.

[48] John S. Hammond, Ralph L. Keeney and Howard Raiffa, "The Hidden Traps in Decision Making," *Harvard Business Review* 76, no. 5 (1998), 10.

setting within Investment Plan (IP). In industry and government, it has found use to answer many different problems. These range from choosing where to build a hospital, to where to build an airport, which fund to invest in or which supplier to choose. Just one method, MACBETH, who is based on the pairwise comparison of criteria has been applied to a wide range of field going from Agriculture, Manufacturing & Services, Medical, Environment or even Personnel Management[49].

As was indicated before, DND has been using MCDA in many different areas, an example of which is the initial PER evaluation, the business case and the OPP process. However, the main user of Multi Criteria Decision Making Methods, which is used to support decision making in many areas is DRDC, in particular CORA. This suburbanization of DRDC is affiliated with most of the Level 1 within NDHQ, providing operational research support within those organizations, with Multi Criteria Decision Making Methods being a subset of OR. Their support has targeted area like senior leadership and providing decision support to committees. It has also been used in capital projects in order to support some of the complex decisions that were taken. One such example is the work that was done with the CSC project where different methods were used in order to look at the various options. A Borda count was used to rank the criteria, with the summation of the weights giving a best option. To this a sensitivity analysis was done in order to determine the strength of the results[50]. Another area where is has been highly involved is in supporting the prioritization of expenditures based on the budget in the work that was done to support the Investment Plan (IP). This is a prime example, where numerous projects had to be sorted in order to determine where the funding line would impact the projects. Finally, it was

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[49] BANA, DE CORTE and VANSNICK, *MACBETH*, 381

[50] BL Kaluzny and RHAD Shaw, "Sensitivity Analysis of Additive Weighted Scoring Methods: How to Fool Your Friends (again)," (2009), 8.

recently used in the work related to the Strategic review, where the expenses of the department were oriented in order to realize the savings that the government was seeking. Therefore, there has been some use of Multi Criteria Decision Making Methods in DND, however it is in no way widespread.

As was discussed before, most decision that are taken in DND are of a complex nature, however not all of possible consequences that require more than the ability of all decision makers. There is a threshold where these problems grow to a level of complexity either because of their size or that multiple decision makers are involved, that makes it unreasonable for a decision maker to reach an optimal solution. Also certain complex problems consequences reach a threshold, where mistakes would cause sizable issues. These could be of a financial nature, like an unacceptable cost or of a more tangible nature, ie the loss of material or, even worse, injury or loss of life. In these situation, a decision must still be taken however, the requirement for demonstration that clear consideration of all possible facets of the problem is essential. By following a Multi Criteria Decision Making Methods, there is a clear and transparent accounting of all the data and a traceable process to explain why a certain decision was taken. The lack of transparency in decision making in procurement has been brought up many times by the OAG, especially since the introduction of the Federal Accountability Act of 2006. The same can be said of other sectors, where decisions have been called on, but no accounting can be given of why a particular decision. More importantly, the details of why a decision was reached, in particular of what criteria and how they were evaluated is not present or does not even exist. Therefore, for certain problems faced by DND, Multi Criteria Decision Making Method should be used.

Not all complex problems require the use of a Multi Criteria Decision Making Method, as this would slow down the decision process to a standstill. A criteria should be established of

which problems could warrant the use of a Multi Criteria Decision Making Method. Also, for audit purpose, another threshold should be establish requiring the consideration and an explanation for why one was not used. DRDC teams (CORA teams already exist in most level 1) should then be approached in order to investigate the use of an MCDM.M As was indicated previously, CORA has a resident software that could be made available to decision makers staffs in order to help in the decision making process. This used in tandem with the use of problem exploration process would go a great way in helping provide the required transparency and intellectual rigor that is currently lacking in current decision making processes. Also, the various methods and some of the associated software that were previously discussed should also be investigated because of the way some of them can incorporate actual as part of their criteria.

It is recommend that DRDC investigates some of the other methods in order to determine if there could be a benefit to their use by decision makers. Of prime importance would be methods that can actually draw on the existing data that is available in certain problems. MACBETH could be a good candidate, based on its relative ease of use and the fact that it can incorporate actual data. The availability of its windows based software could permit its rapid deployment to DND, even if the complexity of the model creation might require support from DRDC in order to permit its use. If the complex problems does not permit the creation of a utility function by the Decision maker or if the use of method that is now tied to actual data is required, the methods from the ELECTRE or PROMOTHEE family, should be used. The introduction of all these methods would give flexibility to the decision makers to use a method that would fit his needs and the information that they have available. It would also demonstrate to outside agencies the seriousness in providing transparency and traceability of our Decision process.

Possible areas of application

As was discussed before, complex problems exist everywhere and are not to procurement issues and decision making by senior executives. There are many areas within DND where these methods could be used or coupled with existing processes in order to improve on decision making results. Listing all of them would be impossible, therefore the possible areas of application will be limited to certain key possible areas of application. These will be operational planning, risk evaluation, budget allocation and personnel policy.

The Operational Planning Process (OPP), is a very long in complicated process which one of the mean purposes is to draw as much information about the problem, understand it, find possible course of actions in order to reach stated objectives all the while considering all the possible facets of the problem. This process follows the same process that has been identified as the foundation of all the MCDM methods or the structuring the problem. However, when they arrive at the end of the process, having amassed a vast amount of qualitative and quantitative information and having well understood the problem and its possible solution, a simple decision matrix in order to determine which the best CoA is. The translation of this data, based on the data available into one of the methods would be highly recommended, as it would make use of the vast array of information that is collected in the process. As this is a well-established, some of the collection of information could be automated or pre-loaded in order to expedite the use of the Multi Criteria Decision Making Method. Also, of note, the other methods that are used are a war game of the CoA against enemy CoAs and the result of a risk matrix. These war games which are supposed to account for situations that arise in reaction to actions by each side, could benefit from automation. Currently, only one action and one opposing reaction are possible, which

would not be the case with automation where many possible action and reactions could be tested. However, this is not part of Multi Criteria Decision Making Methods and more part of simulation theory. The other evaluation means of CoA, the risk matrix, is however something to which Multi Criteria Decision Making Methods could be applied.

In DND, risk matrixes have been used in OPP but also in other decision making scenarios, like capability planning and business planning. Theses risk matrixes like at risks associated to certain actions to determine the individual impact of each risk item and aggregate into one overall risk figure. Most of the risk evaluation are done based on intuitive judgement with the underlying complexity that commanders are risk adverse, therefore one must attain, at the end a low level of risk. Risks are in fact criteria and there is always the option of not doing the action, therefore on could easily us an MCDM for risk analysis, which would provide some transparency to solving risk matrixes.

As was indicated above, risk matrixes are part of the business planning process in order to determine the risk associated with doing of not doing a business process. However, the determination of the budget allocation, as part of business planning could also benefit from Multi Criteria Decision Making Methods. In the same way that projects were sorted as part of using Multi Criteria Decision Making Method for the IP, this could be done for all the business lines within a budget. As they are more requirements for funds then actual funds themselves, each component of the budget could be prioritized by applying a Multi Criteria Decision Making Method to determine which are funded. Criteria could easily be found that would influence the order, like its priority, the necessity for the item to be funded (civilian salaries) or the impact of not funding the item. Much of the data needed in order to apply and Multi Criteria Decision

Making Method is already available through the business planning process again making this a great candidate.

Finally, another area where the use of Multi Criteria Decision Making Method would be beneficial is in personnel policy development. These policy are always aimed to answer complex problem, that involve many actors and the possible impacts are wide ranging. Just the fact of going through the problem structuring process would be highly beneficial in understanding the full scope of the problem. More importantly, information captured as part of the process would provide invaluable insight on what were the factors that led to the decision. Also, the use of a Multi Criteria Decision Making Method would plainly indicate how a certain decision was reached, which would again give confidence in the solution selected.

These are only but a few examples of where Multi Criteria Decision Making Methods could be used, which are by no means the only ones. Their application and the process in order to be able to used should be advocated for all complex problems. For problems of high dollar value, of potential damaging impact to the department or where loss of equipment or life is possible, there use should be an obligation. This will guarantee that all facets of the problem are understood and that the process is transparent, unbiased and is auditable. This should permit DND to fulfill its accountability requirements to the Government and the people of Canada, all the while ensuring that the best possible decisions are being taken in the most efficient way possible. Therefore, it is essential that Multi Criteria Decision Making Methods be known by all decision makers and that there use becomes a requirement in certain circumstances. Also, DRDC needs to be ready to answer the requests of decision makers as it has always done. It should investigate all possible Multi Criteria Decision Making Method to see where they could be applied in all types of decisions. Finally, it should work at making Multi Criteria Decision

Making Method accessible through its provision in DWAN and providing education on how to use them for simpler complex problems. Multi Criteria Decision Making Methods will not provide the silver bullet answer to decision makers, as it has its own limitations and problems. However, it is a crucial tool that can help the decision maker contend with his limited cognition ability and therefore take better decisions.

CONCLUSION

Decision making is a complex endeavor, which becomes almost impossible to achieve, when faced with complex problems. There is a clear limitation in decision makers that are unable to take rational decision when faced with too many factors. The human brain is unable to rationalize more than 7 things at a time, which makes almost any decision impossible to take. Therefore, one is then force to approximate, take short cuts, and disregard certain facts in order to take a decision, which could lead to undesirable consequence. In organizations, like DND, these consequences could mean severe wastage or even the loss of life. This is where Multi Criteria Decision Making Methods step in by providing decision aiding tools in order to take better decisions. There are first of all a process, where just by following it, the decision maker will improve his awareness of the problem, consider a valid group and be able to understand all the components of each option. More importantly, the preferences of the decision makers, over the various solutions and their related criteria, make the solution a result the decision of the stakeholders. This ability to consider all the information and preferences, will give to the

decision maker, at the very least, invaluable information about the problem and the resulting decision.

There are too many methods to consider, with many not being applicable in DND, either being too abstract or theoretical for its needs. From the voting, utility and outranking groups of methods, the Borda and Condorcet, SMART and MACBETH and the ELECTRE III and ELECTRE TRE, where retained as method that should be explored. Some of the other methods that were presented could be useful, however some are complex like MAUT and others have been known to have certain issues, like rank reversal like for AHP. The ones that were identified as being the best received this status because of their flexibility and their potential applicability to situations that exist in DND. Ultimately, the use of these methods would provide greater options for use and possibly more accuracy and transparency into how the solution was achieved. Of interest, is that the utility and outranking have several software that could be used in order to simplify the task for users.

DND has been using Multi Criteria Decision Making Methods for years, especially through DRDC and one of its sections called CORA, who has done many studies on Multi Criteria Decision Making Methods. Some of the work was related to Capability Planning or towards the department's finances. It was also used in capital projects, especially when reviewing the various options in order to fulfill the requirements. But there are other areas where Multi Criteria Decision Making Methods could be used. OPP or the various risk assessments matrixes, already contain sufficient information, in order to apply Multi Criteria Decision Making Methods. This would be much more beneficial, than the current approximations (usually by simple criteria waiting or by codifying by colors) that are used in order to achieve a decision.

DND has a great amount of information and data stored in databases either in the financial system or in other systems that could be used in order to provide some very rational decisions.

Ultimately, there should be greater emphasis in the use of Multi Criteria Decision Making Methods in order to provide better tools to decision makers. The first step would be to request from DRDC to review the various to determine their applicability to various DND problems. This would be done at the same time as a review of the software applicable to those methods to determine which could be used by DND in order to simplify usability by decision makers and their staffs. There would need to be a communication strategy coupled with a support cell, in order to help users work through the Multi Criteria Decision Making Methods process and associated software. More complex problems should remain the purview of DRDC who should remain the champion of these methods. Finally, the use of Multi Criteria Decision Making Methods should be mandated, under the direction of DRDC, for projects or policy items of a certain value. This would ensure that transparency major government decisions is maintained and would also improve the quality of the decisions.

It should be clear that Multi Criteria Decision Making Methods have great benefit for decision makers, at the very least the fact of going through their associated processes will improve the quality of decisions. The use of these tools, will bring to light information and factors that will educate the decision. It will also bring to light the preferences of the decision maker, which might revisit some of his considerations based on the impacts of his decisions. It will also consider all the information, making the resulting solution robust and transparent, as it will be based on the considerations of all. DND has tracked lessons learned for many of its actions over the years, which means a comparison could be made of the results based of Multi Criteria Decision Making Methods work and similar situation from the past. This would validate

the positive impact of the use of these methods. DRDC should also continue to explore this emergent field, as there are new methods or variants of old ones that arise all the time.

Taking decisions is not an easy endeavor that should never be taken lightly, regardless of the situation or its complexity. Possibly the most important part, is that all decision should be taken with due consideration of all information. All the possible stakeholders should be consulted and all possible consequences should be envisioned. This in itself would be a huge development over current practices. Once all this information is collected, making that extra step to use Multi Criteria Decision Making Methods determine the best solution, should be extremely easy, considering the software that will be at the disposal of decision makers. This will lead to better, more efficient and transparent decision that will increase DND efficiency.

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