SMART- Multi-criteria decision-making technique for use in planning activities

Meera Rameshkumar Patel
P. G. Student, M. E. Town & Country Planning,
Sarvajanik College of Engineering & Technology, Surat, Gujarat
Email: meerapatel567@gmail.com , Mobile: +91-9727202697

Manisha Pranav Vashi
Assistant Professor,
Faculty of Civil Engineering,
Sarvajanik College of Engineering and Technology, Surat, Gujarat
Email: manisha.vashi@scet.ac.in , Mobile: +91-9825245551

Bhasker Vijaykumar Bhatt
P. G. in charge (ME-TCP) & Assistant Professor,
Faculty of Civil Engineering,
Sarvajanik College of Engineering and Technology, Surat, Gujarat
Email: bhasker.bhatt@scet.ac.in , Mobile: +91-9825835364

ABSTRACT

Multi-Criteria Decision Making (MCDM) technique has seen an unbelievable amount of use over the last several decades. The present study explores the operation of MCDM method with the case study of nuclear dump site selection among the various choices. This study uses Simple Multi - Attribute Rating Technique (SMART) is a method of multi-criteria decision making. Each alternative consists of some criteria that have value and each criterion have a weight that illustrates how important the other criteria. The simplicity of the questions to the decision maker and the easier analysis of answers are the significant advantage of SMART.

KEYWORDS: ***SMART technique; MCDM; Decision making; Planning; Alternatives***

INTRODUCTION

Multiple criteria decision making (MCDM) commits to making judgments in the presence of various, usually conflicting, criteria. MCDM problems are common in everyday life. It argued that a local or federal government, industry, or business activity involve, in one way or the other, the evaluation of alternatives set regarding a set of decision criteria (Sons, 1998). Very frequently these criteria are conflicting with each other.

MCDM is related to structuring and solving decision and planning problems which involving multiple criteria. The intention is to support decision makers facing such problems. MCDM consists of constructing a global preference relation for a set of alternatives evaluated using various criteria and selection of the best actions from a set of choices, each of which assessed against multiple, and often different criteria (Sons, 1998).

Multi-criterion Decision-Making (MCDM) analysis has such characteristics which is entirely depends on the multiples and alternatives (Sons, 1998).

General operations of any MCDM methods

There are three operations in utilizing any decision-making technique involving numerical analysis of alternatives (Sons, 1998):

1. Determine the relevant criteria and alternatives.
2. Attaching statistical measures to the relative importance of the criteria and the impacts of the alternatives on these criteria.
3. Ranking of each alternative.

Iterative steps of MCDM are:

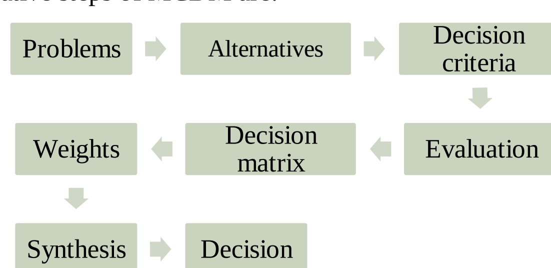

Fig.1 Iterative steps of MCDM method

DIFFERENT METHODS OF MCDM WITH ITS AREA OF APPLICATIONS

Table 1 MCDM methods with its field of application

№	Methods	Area of application
1	Multi-Attribute Utility Theory (MAUT)	Economics, finance, actuarial, water management, agriculture
2	Simple Multi-Attribute Rating Technique (SMART)	Transportation and logistics, planning, environmental, construction, military, manufacturing and assembly problems.
3	Analytic Hierarchy Process (AHP)	Performance-type problems, resource management, corporate policy and strategy, public policy, political strategy, and planning.
4	Case-Based Reasoning (CBR)	Businesses, vehicle insurance, medicine, and engineering design.
5	Data Envelopment Analysis (DEA)	Economics, medical, services, road safety, agriculture, retail, and business problems.
6	Fuzzy Set Theory	Engineering, economics, environmental, social, medical, and management.
7	Goal Programming (GP)	Production planning, scheduling, healthcare, portfolio selection, distribution systems, energy planning, water reservoir management, scheduling, wildlife management.
8	ELECTRE	Energy, environmental management, water management, and transportation problems.
9	PROMETHEE	Environmental, hydrology, water management, business and finance, chemistry, logistics and transportation, manufacturing and assembly, energy, agriculture.
10	Simple Additive Weighting (SAW)	Water management, business, and financial management.
11	TOPSIS	Supply chain management and logistics, engineering, manufacturing systems, business and marketing, environmental, human resources, and water resources management.

SIMPLE MULTI-ATTRIBUTE RATING TECHNIQUE (SMART)

SMART (Simple Multi-Attribute Rating Technique) is a compensatory method of multiple criteria decision making, developed by Edwards in 1971 (Filho, 2005). This approach was designed to provide an easy way to implement the origins of MAUT. Along the years, failures in this method had identified, and they were corrected (EDWARDS and BARRON, 1994) which creates the methods SMARTS and SMARTER, that present two different forms of fixing these flaws (Filho, 2005). In this study, the method SMART used (Filho, 2005).

The simplicity of the questions and answers are the excellent advantage of SMART. This simplicity influences directly on the understanding of the decision maker about the process used in the solution of the problem.

In the SMART method, ratings of alternatives are assigned directly, in the natural scales of the criteria (where available) (Filho, 2005). As an example, a natural scale is a range of 100 to 200 miles per hour for evaluating the criterion of the top speed of motor cars. Holding the weighting of criteria and rating of alternatives as separate as possible, the different scales of criteria need to convert to a common internal scale. In SMART, a process is done mathematically by the decision maker using a "Value Function" (Filho, 2005).

For the alternative, the decision maker is allowed to choose one of the attributes to elevate the performance of this alternative for the maximum value, like this, the decision maker attributes "100 points "for the criterion that he decided to promote first to the largest possible punctuation (Filho, 2005). After assigning "100 points" for that criterion, the decision maker passes the chosen criterion, repeating this procedure for an order of weights.

Application area of SMART method

In planning activities

- Decision for Site suitability
- Transportation planning
- Decision of Route choice
- Land-use behavior
- Develop logistics
- Resource management
- Environmental impact assessment

In general fields

- Engineering
- Agriculture
- Military
- Security
- Manufacturing and assembly problems.

Pros and cons of SMART method

Pros:

- ***Unity:*** It is a linear function which is the simplest choice of value function
- ***Applicability:*** This feature is sufficient in most of the cases of linearity
- ***Interdependence:*** The decision model is independent of the alternatives.
- ***Operations:*** All the lowest-level attributes come into considered
- ***Relevancy:*** The ratings of alternatives are not much relative therefore that changing the number of alternatives will not in itself change the decision scores of the first options.

Cons:

- ***Complexity:*** More complex as the number of criteria increase.
- ***Accuracy:*** Some poorly performing alternatives rejected in the screening phase
- ***Sensitivity:*** Not adequately address scale ranges in determining appropriate category weights.
- ***Consistency:*** It is not consistent due the subjective nature of technique

PROCESS INVOLVED IN SMART METHOD

Edwards proposed a ten step SMART method. Some of these measures include the operation of identifying objectives and organization of these objectives into a hierarchy (Olson, 1996). Steps are below (Olson, 1996):

Step 1: Identify the person or agency whose utilities are to maximize. Edwards [1977] argued that MAUT could be applied to public decisions in the same manner as was proposed for individual decision making.

Step 2: Identify the issue. Efficiency would depend on the circumstances and purpose of that decision.

Step 3: Identify the alternatives to evaluated. This move would determine the outcomes of possible actions, a data gathering process.

Step 4: Identify the relevant dimensions of value for evaluation of the alternatives. It is important to limit the dimensions of value. It accomplishes by restating and combining goals, or by omitting less important goals. Edwards argued that it not be necessary to have a complete list of targets. Fifteen were considered too many, and eight was found to be sufficiently significant. If the weight for a particular goal is quite weak, that goal need not included. There is no precise range of the number of goals appropriate for decisions.

Step 5: Rank the dimensions in the order of importance. For decisions made by one person, this move is relatively simple. The ranking is a decision task that is easier than developing, weights, for instance. This task is usually more challenging in group environments.

Step 6: Rate dimensions in importance, preserving ratios. The least important dimension would be assigned an importance of 10. The next-least-important dimension is assigned a number reflecting the ratio of relative importance to the least significant dimension. This process is continued, checking implied ratios as each new judgment made. Since this requires a growing number of comparisons, there is a very practical need to limit the number of dimensions (objectives). Edwards expected that different individuals in the group would have different relative ratings.

Step 7: Sum the importance weights, and divide each by the sum. This allows normalization of the relative importance into weights summing to 1.0.

Step 8: Measure the location of each alternative evaluated on each dimension. Dimensions classified into the groups subjective, partly subjective, and purely objective. For subjective aspects, an expert in this field would estimate the value of an alternative on a 0-100 scale, with 0 as the minimum plausible value and 100 the maximum likely value. For partly subjective dimensions, objective measures exist, but attainment values for specific alternatives must be estimated. Purely objective dimensions can be measured. Raiffa [1968] advocated identification of utility curves by dimension. Edwards [1971] proposed the simpler expedient of connecting the maximum plausible and minimum plausible values with a straight line. It argued that the straight line approach would provide an acceptably accurate approximation.

Step 9: Calculate Utilities for alternatives.

$$U_j = \sum_k . w_k u_{jk} \quad \text{Eq. (1)}$$

where U_j is the utility value of alternative j, w_k is the normalized weight for objective k, and u_{jk} is the scaled value for alternative j on dimension k.
$\sum_k . w_k = 1$.The w_k values obtained from Step 7 and the u_{jk} values generated in Step 8.

10: Decide. If a single alternative is to be selected, choose the alternative with maximum U_j. If a budget constraint existed than rank order alternatives are in the order of U_j/C_j where C_j is the cost of alternative j. Then alternatives are selected in order of highest ratio first until the budget is exhausted.

In SMART, ratings of alternatives assigned directly. In a view to keeping the weighting of the criteria and the rating of the alternatives needs to be separate as possible, the different scales of criteria need to convert into a standard internal scale. The process in this technique is done mathematically by the decision-maker using a Value Function. The simplest and most widely used form of a value function method is the additive model, which in the easiest cases can be applied using a linear scale (e.g. going from 0 to 100).

CASE STUDY

Here explained case study of nuclear dump site selection example (Olson, 1996).

Apply SMART to the nuclear dump site problem which needs to identify the best alternative among the location options of five cities namely Nome-Alaska, Newark-New Jersey, Rock springs-Wyoming, Duquesne-Pennsylvania and Gary-Indiana of the United-States. The process conducted (Olson, 1996):

Step 1: The decision maker here the planning authority is responsible for dealing with a public issue.

Step 2: The issues involved could include some cost categories, such as the cost of construction, cost of operation, and cost of incorporating adequate safety policies. Expected lives lost could come in a variety of subsets, such as the loss of lives regarding construction workers, operators of the system once it built, and of the public who not directly employed in any aspect of the facility. The catastrophic risk could include the possibility of the earthquake, the risk of flood, or other major traumatic incidents. The civic improvement provides an encompassing objective as well. There could be other objectives considered, such as providing public works to a particular area.

Step 3: Alternatives generated, along with data measuring (or if necessary, evaluating) how well each alternative would perform on each dimension considered. At this stage in Step 2, we were considering more objectives. Therefore, the following table would have been employed to include cost sub items, expected lives lost subcategories, and risk subcategories. However, the point can demonstrate by the following table.

Table 2: Alternatives with the data gathering

	Cost (billions)	**Expected Lives Lost**	**Risk**	**Civic Improv -ement**
Nome, AK	40	60	very high	low
Newark, NJ	100	140	very low	Very high
Rock Springs, WY	60	40	low	high
Duquesne , PA	60	40	medium	medium
Gary, IN	70	80	low	Very high

Step 4: The number of objectives considered in Step 2 includes some objectives that can be combined (Cost objectives, Lives Lost objective, catastrophic risk categories). There also could be objectives that are considered too unimportant to the matter at baud (providing public works to a particular constituency). Here we end up with four objectives as outlined. This step concludes by organizing the objectives retained for analysis into a hierarchy.

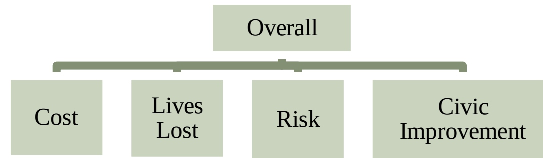

Fig. 2 Identification of objectives for selection of dump site

Step 5: Those objectives finally selected for analysis would be rank ordered by importance. In this case, we might rank them in the order:

Lives > Risk > Cost > Improvement

Step 6: This step provides an opportunity for the decision makers to **weigh the relative importance of objectives carefully.** The least important objective is **(Improvement) given a value of 10.**

Then Cost is compared with Improvement to determine the ratio of relative importance. Initial rating might give **cost a score of 60** compared to Improvements 10.

The risk is compared to Improvement and given a relative weighting of 150. The risk is compared with Cost and given a rating **3 times Cost, or 180**. These ratings are slightly different and need to be reconciled. Upon additional consideration, the score for Cost is reduced to 50, providing consistency between the three pairs of ratings.

Live is initially considered about 25 times as necessary as Improvement, seven times as important as Cost, and two times as necessary as Risk. This set of ratings provides three implied relative scores for **Lives: 350, 250, and 100.** After deliberation, the relative score for Cost to Improvement reduced to 4 to 1. Further, (Sons, 1998)the relative ratio of Lives to Risk is reduced a bit, settling on Lives being 25 times Improvement, and Risk having a score 15 times Improvement. **This yields relative scores of Lives = 250, Risk = 150, Cost = 40, and Improvement = 10.**

Step 7: These relative scores are normalized to produce a set of weights with the property that the sum of weights =1.0. Dividing each score obtained in Step 6 by the sum (450), the following weights obtained:

Lives = 55.6, Risk = 33.3, Cost = 8.9, Improvement = 2.2

Step 8: Scores for each of the alternatives on each objective developed. The minimum plausible value of each objective gives a score of 0. The best plausible attainment level gives a score of 100. For continuous variables, a straight line function can develop. For qualitatively rated measures, scores can be assigned reflecting relative performance.

Cost is measured on a continuous scale, based on cost estimates. While cost estimates on long-range projects are by their nature somewhat uncertain, they can view as providing an objective "best-guess" of relative cost. The least likely cost might be considered to be $40 billion in net present terms. The maximum plausible cost could be $100 billion. A formula converting the cost of project j into a 0-100 scale would be:

$$Score_{j,cost} = 100(100 - Cost_j)/(100 - 40)$$

$$= 100\left(100 - Cost_j\right)/60 \qquad \text{Eq. (2)}$$

Lives also measured on a continuous scale, based on estimates. As with Cost, this estimate is highly uncertain, but also should be the best estimate available. The least likely number of lives expected to lost might be 30, and the greatest number plausibly suspected to be lost to be 140. The formula converting the expected number of lives lost for any plausible project j is:

$$Score_{j,lives} = 100(140 - Lives_j)/(140 - 30)$$

$$= 100(140 - Lives_j)/110 \qquad \text{Eq. (3)}$$

The risk is a categorical variable, measured on a qualitative scale. The best possible category can give a score of 100, and the worst possible a score of 0, with all other categories given average scores considered appropriate. In this case, a "very high" rating is assigned a $Score_{j,risk}$= 0, "high" = 25, "medium"= 50, "low" = 75, and "very low" = 100.

Improvement is treated the same as Risk, only in this case high is better than low. Therefore, for the “very low” civic improvement category, $Score_{j,improve}$=0 , “low” = 25, “medium” = 50, “high” = 75 and “very high” = 100

Step 9: Utilities are calculated by the formula: $U_j = \sum_{k} w_k u_{jk}$

Table 3: Calculation of utilities

	Cost (billions)	**Expected Lives Lost**	**Risk**	**Civic Improvement**
Weight	.089	.556	.333	.022
Nome, AK	100	36.4	0	25
Newark, NJ	0	0	100	100
Rock Springs, WY	66.7	90.9	75	75
Duquesne, PA	66.7	90.9	50	50
Gary, IN	50	54.5	75	100

The resultants are the products of weights time scores (W x S).

Nome	.089(100)	+ .556(36.4)	+ .333(0)	+ .022(25)	= 29.7	Eq. (4)
Newark	.089(0)	+ .556(0)	+ .333(100)	+ .022(100)	= 35.5	Eq. (5)
Rock Spring	.089(66.7)	+ .556(90.9)	+ .333(75)	+ .022(75)	= 83.1	Eq. (6)
Duquesne	.089(66.7)	+ .556(90.9)	+ .333(50)	+ .022(50)	= 74.2	Eq. (7)
Gary	.089(50)	+ .556(54.5)	+ .333(75)	+ .022(100)	= 61.9	Eq. (8)

Step 10: The system recommends locating the nuclear dump site in Rock Springs as it scored with the highest number.

CONCLUSION

Simple Multi-Attribute Rating Technique (SMART) is a method widely used due to its simplicity. Applicability of SMART is in most of the fields like urban planning, in business, engineering, environmental studies and such so. For solving the complicated MCDM problems, SMART method would be a proper approach. The numerical example strongly recommends that it is a decision taking technique which made by one decision maker is more efficient than the group of people.

The above observations suggest that SMART method should use as decision support tool and which may not be a final answer. Finding the best solution by human hand is hard. The solution can make lightly and used as an indication of the best possible answer.

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