Contents

Chapter 2

The Scoring Method for Category 1 Decision Problems

This is Chapter 2 of "Junior Level Web-Book for Optimization Models for decision Making" by Katta G. Murty.

2.1 Category 1 Decision Making Problems, Multi-Characteristic Decision Making

As defined in Chapter 1, a Category 1 decision problem is one in which there are only a finite (typically small) number of discrete alternatives for the decision, and each of them is fully known in complete detail. In other words, the important property of these problems is that we do not need a model of the form (1.3.2), (1.3.3), (1.3.4) to identify the set of all possible alternatives for the decision.

These are the most common decision problems encountered by decision makers, so they are very important; however, very few OR books discuss these problems. Some examples of this category of decision problems are discussed in Section 1.1, here are a few more examples.

- A grocery store chain is considering locations for opening a new store in a city. There are five different sites in the city where the new store could be located. They need to select one of these sites for locating the new store.

- A city has decided to build a new airport. Adequate land is available at four different sites, one of which has to be selected for building the new airport.

- On a smaller scale, location of other public service facilities (like fire stations, clinics, restaurants etc.) have similar features. There may be several sites available, one of which has to be selected for the location.

In these problems, there are usually several **characteristics** (also called attributes) of each alternative which need to be considered in making the decision. We need to find the best alternative taking all the characteristics into consideration. Problems of this type are also known as **Multi-Characteristic Decision Making (MCDM) Problems**.

For example to decide whether to use a cast iron engine block or an aluminium engine block in a new car model, some of the important characteristics are: production costs, effect on gas mileage, expected repair and maintenance costs that customer will incur, engine life, effect on market share, profit per car, influence on the reputation of the company as a technology leader, etc.

To decide on the site to set up the new airport, some of the characteristics to consider are: environmental effects and population size affected by them, impacts of noise pollution, public safety effects, feasibility and expense of expanding transit facilities to and from the city, etc.

Some of the characteristics like distance, price, weight, production cost, power consumption, miles per gallon, etc. can be evaluated quantitatively on a numerical scale. But some others like the friendliness or beauty of a person, surface quality of a surface, etc. have to be evaluated as **ratings** on a scale of 0 to 100 say, where 100 might denote the ideal best, and 0 the worst (or vice versa). Sometimes ratings are given in letters or descriptive words such as "high", "low" etc., but these can be converted into ratings on a 0 to 100 scale. The rating given to an alternative may be subjective, i.e., it may depend on the person giving the rating. That's why when there are several decision makers involved, it is necessary for them to come to a concensus on the ratings given.

When the evaluation (quantitative measurement, or a rating) for a chartacteristic follows "the higher the better" rule, that characteristic is known as a **profit characteristic**. If the evaluation follows "the lower the better" rule, then that characteristic is known as a **cost characteristic**. A profit characteristic can be made into a cost characteristic and vice versa by multiplying its evaluation by -1.

For a cost (profit) characteristic, the decreasing (increasing) direction is the direction of improvement. That's why when there is a cost characteristic and a profit characteristic in a problem, we will say that they are in **opposite directions**. A pair of cost characteristics, or a pair of profit characteristics in a problem are in the **same directions**.

2.2 Transformations Needed to Apply the Scoring Method, and Other Important Considerations

The scoring method is based on aggregating the evaluations of the various characteristics for an alternative into a **value** or **combined score** for the alternative. We list below the transformations of data needed to apply this method, and other important points to consider.

1. **Put all characteristics in the same direction:** Express all the characteristics either as cost characteristics (smaller the evaluation, the better), or all of them as profit characteristics (higher the evaluation, the better). A cost characteristic can be converted into a profit characteristic by multiplying its evaluations by -1, and vice versa.

2. **Evaluate using a common unit:** Select a common unit for evaluating all the characteristics, and convert the evaluations of all of them into these units using reasonable assumptions. This is a very important and often difficult part of applying the scoring

method. We will illustrate using some of the important characteristics of new automobiles that customers consider when investigating them to buy one.

> **Price:** First consider the characteristic: the price of the automobile, a cost characteristic. Suppose the single payment purchase price of an automobile is \$20,000. If the unit for measuring this characteristic is selected as: "lifetime cost expressed in \$", the evaluation of this characteristic for this automobile is 20,000. On the other hand if the unit for measuring this characteristic is selected as "annual (or yearly) cost expressed in \$", the evaluation of this characteristic requires an estimate of the lifetime of this automobile, or how long the customer intends to use it. There is likely to be quite a bit of uncertainty in this, and the customer has to use human judgement and rational thinking to come up with a reasonable estimate (in other words this is not something that can be tackled by elegant mathematical techniques only). If the customer expects to use this car for 10 years, then the evaluation of this characteristic in these units is $20{,}000/10 = 2000$.
>
> **Fuel consumption:** Now consider the characteristic: fuel consumption of the automobile. It is usually measured in terms of MPG (miles per gallon) which is an efficiency measure, i.e., a profit measure. To transform this into a cost measure in terms of "annual cost expressed in \$", we need an estimate of how many miles the customer expects to drive in this car that year, and what the average price of gas will be during the year. Here again human judgement and rational thinking have to be used to come up with reasonable estimates. Suppose the customer expects to drive about 10,000 miles in this car and the average price of gas is expected to be \$2/gallon that year. Then the evaluation of this characteristic in units of annual cost in \$ is

$2 \times 10{,}000/(\text{MPG})$.

If the unit for measurement of this characteristic is "lifetime cost in $", then the same formula holds with the exception that 2$/gallon; and 10,000 miles expected to be driven this year, have to be replaced by the average price of gas over the lifetime of the car; and the expected miles the car will be driven over its lifetime respectively.

Looks: Now consider the characteristic: the looks of the automobile (i.e., how well or sexy it looks). By its very nature there is no numerical measurement for it, and its evaluation is highly subjective. So, we have to use a rating scheme for evaluating it.

Suppose we decide to classify the available automobiles into two classes "distinctive (D)" and "ordinary (O)" according to this characteristic, where D is preferrred over O by the customer.

Most customers may be willing to sacrifice their appetite for a car with the ideal look, if they can get an equally reliable car of less than ideal looks at a price discount. In evaluating the looks of one of the available automobiles, this discount in price from the ideal that will make them accept the looks of this automobile can be used as the evaluation of this characteristic for this automobile in terms of lifetime cost of its looks in $. To get an evaluation in terms of annual cost of its looks in $, we can allocate the lifetime cost proportionately over the number of years in the estimate of the lifetime.

Also the unit for measurement must be on the same platform for all the characteristics. For example, if one characteristic is measured in cost $/year, then all characteristics should be measured in cost $/year. Measuring one in cost $/year, and another in cost $/lifetime would be wrong.

3. Put all ratings in the same direction and same range: The points mentioned in 1 and 2 above apply to characteristics evaluated as ratings too. When characteristics are evaluated by ratings, the range of ratings used for evaluating all the characteristics should be the same. That is, if the range used for rating one is 0 to 100, it should be the same for all the characteristics.

If characteristic 1 is evaluated as a rating between 0−100 with "the larger the better mode" (so characteristic 1 is a profit), and characteristic 2 is evaluated as a rating between 0−10 with "the smaller the better mode" (so characteristic 2 is a cost), it is necessary to convert them into the same direction as all the other characteristics and equalize their range by scaling appropriately. If all the characteristics are being converted into cost characteristics (the smaller the better), and the range for all the characteristics evaluated as ratings is selected as 0−50, then replace the ratings x of characteristic 1 with $(100 - x)/2$; and the ratings y of characteristic 2 with 5y. Other choices are handled similarly.

4. **How to convert quantitative measurements into ratings?:** One way is to assign ratings in proportion to the measurements, which leads to the following scheme.

On a rating scale of 0 to 100 in higher the better mode, suppose the decision makers decide that the best and worst alternatives available WRT this characteristic get ratings of 80, 10 respectively. Arrange all the other alternatives from best to worst WRT this characteristic, and rate them proportionately according to their numerical measurement of this characteristic.

As an example consider a cost characteristic whose numerical measurements for alternatives 1 to 5 are respectively 50, 10, 25, 40, 20. So, in decreasing order of desirability WRT this characteristic, the alternatives are 2, 5, 3, 4, 1. Suppose the ratings assigned to 2 (the best) and 1 (the worst) are 80, 10 respectively. Then the rating for alternative 5, 3, 4 in this order are respectively

$$80 - \{\ (80 - 10)(20 - 10)/(50 - 10)\} = 62.5$$

$$80 - \{\ (80 - 10)(25 - 10)/(50 - 10)\} = 53.25$$

$$80 - \{\ (80 - 10)(40 - 10)/(50 - 10)\} = 27.5.$$

5. **Too much variation in values of a characteristic:** If there is too much variation in the quantitative measurements of a characteristic for the various alternatives, the results from applying the scoring method may not be too meaningful.

   For example, in deciding to buy a house, the prices of houses considered may vary from $100,000 to several million $. In this case this characteristic may dominate all others, and comparisons by the scoring method may not be too meaningful.

   One thing to do in this case is for the decision maker(s) to determine a reasonable but narrower range of values of this characteristic that they are willing to consider, and restrict the attention to only those alternatives within this range. The same thing is repeated with other characteristics having the same feature. Then use the scoring method to compare only alternatives within selected ranges for each of these characteristics.

6. **Should we scale so that maximum measurement for each characteristic is 1?:** It is nice to have the range of quantitative measurements of the various characteristics to be more or less the same.

   When the ranges for different characteristics are vastly different, the conclusions of the scoring method based on aggregating the evaluations of all the characteristics into a combined score may not be meaningful.

   For example, if the quantitative measurements for characteristic 1 for the various alternatives are between 1000 to 1500; and those for characteristic 2 are between 10 to 20, unless some scaling is done to equalize the ranges, characteristic 2 might have no influence in determining the best alternative. This amounts to essentially ignoring characteristic 2 in the decision making.

   But scaling distorts the true meaning in the measurements, which may not be what the decision maker(s) want.

If one of these characteristics is not that important for the decision making, it may be desirable to drop it from further consideration. Or, if both of them are very important, one of them can be considered carefully by itself, and the subset of alternatives with acceptable values for it can be identified. Then alternatives outside this subset and this characteristic can be dropped from further consideration and the scoring method applied to determine the best alternatives in this subset using only the data on the other characteristics.

So, scaling to equalize the ranges of measurements of the various characteristics is not a good idea, and it should never be carried out without consulting the decision makers.

7. **Is it better to convert all evaluations into ratings?:** This may be OK if most of the characteristics are evaluated using ratings, and a few of the not so important ones are quantitatively measured on numerical scales.

   However, converting a quantitative measurement into a rating usually involves some sort of scaling (proportionate or otherwise). This scaling may mask the information contained in the original quantitative measurements.

   As an example, suppose the prices of alternatives 1 to 4 are $80, 960, 240, 480 respectively. Here alternatives 1, 2 are the best and worst. On a scale of 0 to 100 in higher the better mode, suppose we assign a rating of 80 to alternative 1, and 14 to alternative 2. Then the ratings of alternatives 1 to 4 using the proportionate scheme are 80, 14, 68, 50. It is not easy to visualize the order of magnitude differences in the prices of alternatives using these ratings.

   So, when most of the characteristics are evaluated by quantitative measurements, as far as possible, they should not be converted into ratings in applying the scoring method.

8. **Determining weights for characteristics to reflect their importance:** After all the above transformations are carried out, all the remaining evaluations will be in a reasonable range.

Practically all approaches to multiple criteria decision making explicitly or implicitly make use of the relative importance of criteria, i.e., positive weights to reflect their relative importance to the decision problem. The higher the weight of a characteristic, the more important it is. Typically the weights are normalized so that their sum is 1. So, the weight w_i shows the importance of the i-th characteristic relative to a unit of value. They represent tradeoffs between characteristics.

Suppose there are n alternatives under consideration, and m characteristics evaluated for each alternative. For $i = 1$ to m, $j = 1$ to n, let a_{ij} be the evaluation of the i-th characteristic for the j-th alternative. The simplest and most commonly used **aggregation rule** to determine the **combined score** v_j of the j-th alternative is defined by the additive model which gives

$$v_j = \sum_{i=1}^{m} w_i a_{ij}$$

where the w_i are the weights of the characteristics. This model assumes that the preferences and strength of preferences for outcomes on one characteristic can be evaluated independently from the outcome levels of the other characteristics. All simple rating and weighing techniques for MCDM are based on this assumption which we adopt.

Numerous procedures have been proposed in the literature for the determination of the weights, but none of them offer a convincing axiomatic foundation for the meaning of weights. So, the most popular technique for determining the weights is the simple one that calls for the decision makers to determine them through a concensus.

2.3 Summary of the Scoring Method

The method is based on the additive aggregation rule described in Section 2.2. Here are the various steps.

The Scoring Method

BEGIN

Step 1. Alternatives, characteristics: Determine all the available alternatives for the decision, and all of the characteristics on which each of them have to be evaluated

Step 2. Evaluation: Put all characteristics in the same direction, and get evaluations of all of them for all the alternatives using a common unit and paying careful attention to the points mentioned in Section 2.2. Determine the weights indicating the importance of the various characteristics.

Step 3. Compute the combined scores: Let a_{ij} be the evaluation of the i-th characteristic for the j-th alternative, i = 1 to m, j = 1 to n; and w_i the weight of the i-th characteristic. Compute the combined score of the j-th alternative v_j

$$v_j = \sum_{i=1}^{m} w_i a_{ij}$$

Step 4. Select the best alternative: It is the one corresponding to the lowest (highest) combined score if all the characteristics are cost (profit) characteristics. Terminate.

END

2.4 Numerical Examples

Example 2.4.1: A person who is in the market to buy a car, is investigating 7 different cars. Price (in $1000 units), comfort (rating, E preferrred to A preferred to W), fuel expenses (given in terms of MPG), and looks (rating, D preferred to O) are the characteristics on which the decision will be based. Data on evaluations is given below.

Characteristic	car							Weight
	1	2	3	4	5	6	7	
Price ($ 1000 units)	15	13.5	12.5	13	12	12	11	5
Comfort	E	E	A	A	A	W	W	4
MPG	20	17	22	24	18	25	28	3
Looks	D	D	D	O	D	D	O	3

E = Excellent, A = Average, W = Weak, D = Distinctive, O = Ordinary

We convert all evaluations into units of "cost in $1000 units over the lifetime of the car" using the arguments given in Section 2.2. For

Car	Value of characteristic for car				Total score
	Price	Comfort	Fuel expenses	Looks	
1	15	2	10	2	119.0
2	13.5	2	11.8	2	116.9
3	12.5	5	9.1	2	115.8
4	13	5	8.3	5	115.9
5	12	5	11.1	2	119.3
6	12	8	8.0	2	114.0
7	11	8	7.1	5	105.3
Weight of characteristic	5	4	3	3	

converting MPG we estimate a lifetime of 10 years, lifetime mileage of 100,000, and average price of $2/gallon for gas over the life of the car. So, an MPG of 20 leads to lifetime fuel cost of $2 \times 100,000/20 = \$10,000$ or 10 in $1000 units. The other MPG figures are converted in the same way.

For converting the letter ratings of comfort, we use the savings in price from the ideal that would make the car acceptable to the customer. This leads to W = 8, A = 5, E = 2 in our units.

For converting the letter ratings of looks, the same argument leads to O = 5, D = 2 in our units.

The results are summarized in the above table.

Since "the smaller the better", car 7 with the smallest total score of 105.3 is the best buy.

Example 2.4.2: A person is trying to get a new motorcycle for inexpensive commuting and participating in pleasure driving in group outings. There are 6 important characteristics of a motorcycle to consider. These are:

> PRICE (Purchase price in $ to be paid at time of purchase),
>
> FUEL EXPENSES (measured in terms of MPG),
>
> RELIABILITY (evaluated as a rating, 1 = low reliability (high annual maintenance and repair costs, about $300/year on an average), 2 = medium reliability (medium annual maintenance and repair costs, about $200/year), 3 = high reliability (low annual maintenance costs of about $120/year)),
>
> R. V. (resale value after a few years of use, measured as a % of original purchase price).
>
> SOUND (Quality of sound when running evaluated as a rating, E = excellent (most desirable & sexy sound); VG = very good, G = good, in decreasing order of desirability; P = poor (least quality sound, like a sewing machine)),
>
> IMAGE (public perception about the vehicle in society, evaluated as a rating: T (top), H (high), M (medium), L (low) in decreasing order of desirability).

The person is considering 5 different models of motorcycles. They are: HD Fatboy (Harley Davidson), Indian, Honda N (Nitehawk), Suzuki, and BMW. Here is the data on the various models. The weight for each characteristic is also given. It is on a scale from 1 to 10, the higher the weight the more importance the person attaches to that characteristic.

Model	Evaluation of characteristic					
	*1	2	3	4	5	6
HD Fatboy	$15,000	50	1	110%	E	T
Indian	14,000	40	1	150%	VG	H
Honda N.	3,000	80	3	70%	P	M
Suzuki	2,000	70	2	50%	P	L
BMW	16,000	45	3	80%	G	H
Weight for characteristic	10	2	8	4	5	6

*1 = Price, 2 = MPG, 3 = Reliability,
4 = R.V., 5 = Sound, 6 = Image

First we need to convert all characteristics into the same direction, and all evaluations into common units.

Since most of the characteristics are given in terms of measurements in $, we will convert all characteristic evaluations into "lifetime costs in $ units". We will multiply profit characteristic measurements by −1 to convert them into costs.

PRICE: Paid at time of purchase, once in the lifetime of this motorcycle with our person, given in $, a lifetime cost.

FUEL EXPENSES: As measured, the MPG is a profit characteristic, we convert it into cost in terms of lifetime fuel cost. Average lifetime usage of a motor cycle is 100,000 miles in our country. Reasonable to assume that our person will have the same usage. Various methods can be used to estimate avarage cost/gallon of fuel over lifetime of this motorcycle. Suppose it is $2. Lifetime fuel costs obtained from these estimates are given in following table.

RELIABILITY: As it is given, it is a rating which is a "profit characteristic". We convert it into a cost characteristic in terms of lifetime repair costs. The average person keeps a motorcycle for 10 years. We will assume our person will do the same. Lifetime repair costs computed from this estimate are given in table below.

RV: As given, it is a % of original price,a "profit" occuring once at the end of the life. The % are not comparable among models because purchase prices are different. We convert into a cost by measuring it as negative resale value in $.

SOUND: A highly subjective characteristic. We will measure this by amount of compensation in $ that our person accepts for suffering low quality sound over the lifetime use of this motorcycle. Assume person's estimates are:E = 0$, VG = 1000$, G = 2000$, P = 4000$.

IMAGE: Similar to “sound”. Let estimates be: T = 0$, H = 1500$, M = 3000$, L = 5000$.

The results are summarized in the following table.

Model	Lifetime cost measurements of:						Total
	*1	2	3	4	5	6	Score
HD	15,000	4,000	3,000	−16500	0	0	116,000
IND	14,000	5,000	3,000	−21, 000	1,000	1500	104,000
Honda	3,000	2500	1200	−2100	4,000	3,000	85,000
Suzuki	2,000	2857	2,000	−1, 000	4,000	5,000	87,714
BMW	16,000	4111	1200	−12, 800	2,000	1500	232,022
Weight	10	2	8	4	5	6	

*1 = Price, 2 = Fuel expenses, 3 = Reliability
4 = RV, 5 = Sound, 6 = Image

Honda with the lowest score is the best buy for the person. Suzuki is a close second.

Example 2.4.3: A girl named Rita is in college pursuing a masters

Data for Example 3

Characteristic	Rating for *A	B	C	D	Type	Range	Weight
Ability to support	8	6	4	5	Profit	0–10	6
Friendliness	70	40	60	80	Profit	0–100	7
Honesty	4	5	3	6	cost	0–10	10
Respect for women	50	60	40	30	Cost	0–100	9
Handsomeness	4	7	6	8	Profit	0–10	5
Interest in appearance	7	3	4	9	Profit	0–10	6
Degree of reciprocity	6	8	5	6	Profit	0–10	8

*A = Bill, B = Raj, C = Tom, D = Dick

degree in engineering. She has been dating 4 boys off and on over the last 3 years, and has come to know each of them very well. The table given above contains her ratings of each boy on characteristics that she considers important. A different scale was used for each characteristic. The range used for each, and whether the characteristic is rated as a cost or profit are indicated in the table. For cost [profit] type the desirability of the boy increases as the rating decreases [increases] from the upper bound of the range to the lower bound [lower bound of the range to the upper bound]. Also given is a weight between 1 to 10 for each characteristic, which measures how important she considers it to be (higher weight means more important). She needs to decide which boy she should go steady with. Who among the four boys would be her best choice?

Characteristic	Rating for *A	B	C	D	Weight
Ability to support	40	30	20	25	6
Friendliness	35	20	30	40	7
Honesty	30	25	35	20	10
Respect for women	25	20	30	35	9
Handsomeness	20	35	30	40	5
Interest in appearance	35	15	20	45	6
Degree of reciprocity	30	40	25	30	8
Combined score	1560	1335	1420	1655	

*A = Bill, B = Raj, C = Tom, D = Dick

We convert all characteristics into profit characteristics by converting their ratings into "the higher the better" mode with 0−50 as the range for each as discussed in Section 2.2. The table given above shows these trasformed ratings and the combined score for each boy.

So, boy D (Dick) with the highest combined score of 1655 is the best choice for Rita to go steady.

2.5 Caution: Shortcomings of the Scoring Method

The scoring method that we discussed here is a very simple method for combining the measurements of various characteristics into a single composite numerical score to compare the different alternatives. It provides meaningful results that are satisfactory when all the measurement data is in a comparable range, and the weights truely reflect the importance attached to the various characteristics by the DMs after very careful consideration.

However, people often apply this method without checking whether all the data are in a comparable range, not devoting enough care in eliciting reasonable values for the weights from the DMs, not using logical conversion factors for converting measurements of different chartacteristics into a common unit, and scaling data to put all the data elements in a common range when it is not appropriate. Under these circumstances, this scoring method may lead to results that appear strange and misleading. Illustrative examples due to R. Ravindran are presented next.

So, before submiting the results of the scoring method to the DMs, it is always a good idea to check whether they are reasonable by looking through the data on the measurements for different characteristics.

Example 2.5.1: Spouse Selection Problem: A woman has dated three men named John, Ram, Bob, and got to know all of them well. She has rated the three men on five different characteristics considered important for this decision, which are:

Ch 1: Handsomeness and beauty

Ch 2: Sense of humor

Ch 3: Cooking skills

Ch 4: Friendliness

Ch 5: Willingness to help in housekeeping.

On each of these characteristics, each of these men is given a rating between 1 and 10, where 10 represents "the best and most desirable", and 1 represents "the worst of the lot". So, the ratings are profit ratings that follow "the higher the better" rule.

The woman has an obsession for Ch 1, she considers it the most important among the characteristics; that's why she has given it the highest weight. All other characteristics, considered of secondary importance by her, are given much smaller but all equal weights. Here is all the data:

Ratings for various characteristics

Man	Ch 1	Ch 2	Ch 3	Ch 4	Ch 5	Combined score
John	10	1	1	1	1	94
Ram	1	10	10	10	10	49
Bob	5	5	5	5	5	65
Weight	9	1	1	1	1	

John is stunningly handsome, but is very poor in all other aspects. Ram is actually somewhat ugly, but is superb in all other aspects. Bob is average in all respects.

With the weights assigned here for the various charateristics, John gets the highest combined score of 94.

If the woman selects John as her spouse, she will be very happy momentarily because of her obsession for his beauty. But his beauty may not last long, or the woman's obsession for beauty may wear out after some time, then she may find living with John miserable because he is very poor in all other respects.

John happens to get the highest combined score only because beauty in which he presently excels is given a disproportionately high weight, which may not be truely representative of its importance in spouse selection. If the weights are selected after careful consideration, the scoring method may have produced a different result that may offer a happier outcome for the long term.

This example sounds a caution that careful attention should be paid to all the points mentioned in earlier sections before applying the scoring method on a problem. Also, in some situations like in this example, it may be necessary to make the decision manually rather than rely solely on the combined score to make the choice.

Example 2.5.2: Consider the following modification of the spouse selection problem discussed in Example 2.5.1. The woman has decided to add one more characteristic,

Ch 6: Interesting hobbies

for evaluating the three men. This characteristic is also given a rating between 1 to 10, with 10 indicating the best and most desirable, and 1 indicating the worst of the lot.

Also, she has decided to change the weights given to the various characteristics. She is still very much obsessed with beauty, and so wants to keep its weight as the highest at 9. She still considers all other characteristics to be of secondary importance, but has decided to give each of them a weight of 2. Here is all the data:

Ratings for various characteristics

Man	Ch 1	Ch 2	Ch 3	Ch 4	Ch 5	Ch 6
John	10	1	1	1	1	1
Ram	1	10	10	10	10	10
Bob	5	5	5	5	5	5
Weight	9	2	2	2	2	2

Notice that John, the best person for the most important Ch 1, is again very poor in Ch 6. Ram, the worst person for Ch 1, is also the best for Ch 6. Bob is again average on Ch 6 also. So, the properties of the three men remain exactly the same on the new characteristic, Ch 6 also, as discussed in Example 1.

The combined scores of John, Ram, Bob are now 100, 109, and 95. So, Ram, the ugliest person among the three men considered, is the choice for the woman based on the combined score, even though beauty is still considered the most important characteristic and is assigned a very heavy weight.

Why did the scale now tip in favor of the worst person for the most important characteristic? It happens because too many characteristics that are considered unimportant are included in the computation of the combined score. Even with a low weight of 2, their cumulative impact tips the scale in favor of Ram. This points out the importance of not taking characteristics into consideration unless they are of some consequence.

2.6 Exercises

2.1. A TV Rental agency is planning to buy a batch of new 27" color TVs. They are investigating 6 different brands. There are several important characteristics to consider in making the choice. Information about these is summarized in the following table.

Characteristic	Value for brand						Importance
	1	2	3	4	5	6	
Price (HK$)	4600	5300	4000	4400	5000	3800	9
Life (years)	7	10	6	8	8	6	6
Salvage (HK$)	250	100	150	150	200	75	3
Weight (lbs)	30	40	25	35	35	25	8
Image	80	85	75	80	90	70	8
No. PIP	1	3	0	2	2	0	5
Yearly repair(HK$)	400	250	500	350	240	500	7

1 = Sony, 2= Panasonic, 3 = LG, 4 = Sharp,
5 = Toshiba, 6 = Gold Star

Salvage value is the money that can be obtained by selling parts and recycling the material when the unit is to be disposed of at the end of its useful life.

The weight per unit is given in lbs., their customers have a distinct preference for lighter units.

Image quality is measured as a score on a scale of 0 to 100 (100 is the very best quality, 0 is the worst).

The PIP (Picture-in-picture) feature is available in some brands. Among these, some allow only one PIP, others allow more. Some customers like the PIP option, the more the better.

The importance that the agency attaches to a characteristic is given on a scale of 0 to 10 (10 means the characteristic has highest importance, 0 means it has no importance).

Using this information, help the agency to select the brand it should buy.

2.2. An American in Hong Kong: An IOE student spent a year as an exchange student at HKUST in Hong Kong, during which time she developed very close friendships with several students there. She planned to treat all these friends to a sumptuous lunch at one of the many fine restaurants on HKUST campus after her final exams.

The restaurants she is considering are: GFCR (Ground floor Chinese Restaurant), LG1AR (American style restaurant on LG1 floor), CS (Coffee Shop style restaurant), LG1C (Cafeteria style restaurant on LG1 floor), LG7SR (Singapore style restaurant on LG7 floor), LG5CR (Cantonese style restaurant on LG5 floor); the top 6 restaurants on that campus.

She considers 5 criteria to be important for selecting the restaurant to go to. These are: CC (Comfort and Class), V (Variety of available dishes), FT (Food Taste), P (Price) and S (Speed of service).

Of these characteristics CC, V, FT are rated with scores: D (Distinctive), E (Excellent), A (Average), O (Ordinary), W (Weak) in decreasing order of merit [i.e., “D” is the best, and “W” is the least meritorious].

Price P is given in terms of expected charge (in HK $) per head for the food she is planning to order. Speed of service S is given in terms of expected no. of minutes for the food to be served. For both these characteristics, *the smaller the value, the better.*

Here is all the data on the restaurants. The *weight* measures the importance she attaches to the characteristics; the higher the weight, the more important the characteristic.

Characteristic	Rating for restaurant						Weight
	1	2	3	4	5	6	
CC	D	D	E	A	W	O	5
V	D	E	E	O	O	E	4
FT	D	O	A	E	W	E	4
P (HK $)	108	123	83	85	65	75	3
S (mts.)	25	20	15	15	10	20	2

1 = GFCR, 2 = LG1AR, 3 = LG1C, 4 = CS,
5 = LG5CR, 6 = LG7SR

Determine where she should hold her lunch. Any assumptions you make should be stated clearly with justification.

2.3: Personnel selection is a very important issue in private organizations to assure that the people hired are the right people for the

Criterion	Rating of candidate by executive							
	P_1				P_2			
	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4
C_1	VG	G	F	F	G	F	G	F
C_2	F	G	P	G	F	VG	G	VG
C_3	F	G	F	F	G	VG	F	G
C_4	G	VG	F	F	F	G	F	F
C_5	G	G	F	F	F	F	G	F
C_6	VG	VG	F	F	G	VG	G	G

Criterion	Ratings for P_3			
	D_1	D_2	D_3	D_4
C_1	G	VG	F	G
C_2	G	VG	F	G
C_3	VG	G	G	G
C_4	F	F	F	F
C_5	G	F	G	G
C_6	G	G	G	VG

jobs. A company is interviewing candidates P_1, P_2, P_3 for an important position. Interviews are conducted by senior executives D_1, D_2, D_3, D_4. Selection criteria to be considered are:

> C_1 (emotional steadiness), C_2 (leadership), C_2 (self-confidence), C_4 (oral communication skill), C_5 (personality), C_6 (past experience).

Evaluations are provided as ratings, VP (very poor), P (poor), F (fair), G (good), VG (very good).

Weights representing the importance of the criteria C_1 to C_6 are 0.85, 0.80, 0.40, 0.45, 0.93, 0.85 respectively (the higher the weight, the more important the criterion).

Ratings data is given above. Analyze this data and develop a single final score for each candidate. Who is the best candidate for the position?

2.4. Evaluation of Junior Colleges of Technology (JCT) in Taiwan: The primary role of colleges is to pursue and transmit

JCT	Evaluation under the heading								
	Instructors			Curric.		Equip.		Admini.	
	A	B	C	D	E	F	G	H	I
Taipei	2	1.5	2.6	2.8	1.8	25.2	16.5	0.7	0.6
Nantai	2	0.7	2.3	2.2	4	9	16.5	0.4	1.3
Orient.	1.9	0.3	2	2.3	0.7	23.8	13	0.6	0.9
Chinyi	2	0.6	2	2	0.5	11.5	18	0.1	0.9
Mingchi	2	2.3	2.4	3.1	11.6	13.1	16	0.3	0
Vannung	1.9	0.3	2.2	2.3	1.5	11.6	15	0.1	1
Lienho	1.8	1	2.1	2.1	1	8	14	0.2	1
St.M&J	1.9	0.1	2	1.9	1.4	11.3	16	0.4	0.1
Lunghwa	1.9	0.4	2.1	2.3	1.2	10.8	14	0.3	0.6
Shuteh	1.8	0.3	2.2	1.6	0.9	8.3	11.5	0.6	0.2
Tungfan	1.6	0	2.1	1.5	0.9	16.3	13	0.4	0

A = Degrees, B = Publications, C = Positions, D = IS ratio, E = Companies, F= Expenditures, G = Past score, H = $>$ 1 month, I = $<$ 1 month knowledge. They educate students to be useful to society, conduct advanced research to enhance welfare of society, and host activities to bring social benefits to their local communities. Taiwanese government wants to evaluate the quality of their JCTs. Performance measures are evaluated under 4 headings: instructors, curriculum, equipment, and administration.

Under the heading instructors, the characteristics evaluated are: average terminal degree (evaluated by average taken over all the faculty in the JCT of 1 (bachelors degree), 2 (masters degree), 3 (doctorate degree)); average number of refereed papers published (limited to those published in the last three years); average position (evaluated by average of 1 (assistant professor), 2 (associate professor), 3 (full professor)).

Under the heading curriculum, the characteristics evaluated are: I-S ratio (instructor-student ratio, number of instructors per 100 students), and number of cooperating companies per 100 students (JCTs are expected to establish collaborative training programs for students in companies).

Under the heading equipment, the characteristics evaluated are: average annual expenditures on equipment averaged per year over the last three years per 100 students in $1000 units, and the past score (same evaluation 3 years ago to measure status 3 years ago).

Under the heading administration, two characteristics are evaluated. According to the government's evaluation handbook JCTs are expected to encourage their instructors to attend workshops and conferences, and work for higher degrees. This handbook differentiates these activities into 2 types: those longer than 1 month, and those shorter than 1 month. The characteristics evaluated under this heading are the average number per instructor of these activities financially supported in the last 3 years.

Data on these evaluations at 11 JCTs in Taiwan for the departments of IEM (Industrial Engineering and Management) for the year 1990 are given above.

Under each heading separately, develop a combined score as a percentage, for each JCT using reasonable assumptions and justifying them.

Now using weights of 0.3, 0.25, 0.25, 0.2 for the 4 headings respectively, compute the total score for each JCT by combining the above scores over the headings. Using it, rank the JCTs in decreasing order of overall performance. (Adopted from: C. Kao, "Evaluation of Junior Colleges of Technology: The Taiwan Case", Eupopean Journal of Operational Research, 72(1994)43-51).

2.5. Hot City: Competition among US metropolitan areas for

Area	x_{ij} on attribute j								
	**1	2	3	4	5	6	7	8	9
*A	30	218	60	299	21	79	68	52	128
B	87	253	34	189	64	6	46	76	206
C	320	264	11	151	57	82	10	87	114
D	38	116	139	270	34	70	73	255	133
E	263	282	17	124	94	68	21	40	224
F	16	275	76	305	39	55	55	55	273
G	134	185	62	226	142	111	41	103	203
H	275	193	184	320	43	94	118	42	21
I	65	86	72	237	106	149	81	256	245
J	186	174	132	285	130	241	42	68	40
K	103	271	135	286	86	166	70	72	176

*The metroplitan areas are: A = Albuquerque (NM), B = Providence (RI), C = St. Paul (MN), D = Charlotte (NC), E = Milwaukee (WI), F = Portland (OR), G = Columbus (OH), H = Orlando (FL), I = Birmingham (AL), J = Fort Worth (TX), K = Sacramento (CA).

** The attributes are: 1 = Climate/terrain, 2 = Housing, 3 = Health care/environment, 4 = Lack of crime, 5 = Transportation, 6 = Education, 7 = The arts, 8 = Recreation, 9 = Economic conditions.

attracting new business is intense. *Fortune, Newsweek* and other magazines occasionally recommend their most desirable cities to their readers. Rand McNally ranks 329 US metro areas according to 9 attributes and publishes it in its *Places Rated Almanac.* For metro area i, the rating x_{ij} on attribute j is its rank for the respective attribute, i.e., 1 indicates the best and 329 the worst.

A European company wants to choose one of the following metropolitan areas to set up a branch office. They view the 9 attributes used by Rand McNally as being the important ones to consider in their selection process, out of concern for the well being of their future employees. The ratings of each of these metro areas under consideration, for all of the 9 attributes, are given in the table above.

In the selection process these 11 areas will be compared against each other, rather than against all other metro areas. This implies a need to rescale the attribute ratings to reflect the nature of the population. Rescaled attribute ratings, denoted by u_{ij} can be computed by the following equation for $i = 1$ to 11, $j = 1$ to 9.

$$v_{ij} = \frac{x_{ij} - \min\{x_{ij} : i = 1, \ldots, 11\}}{\max\{x_{ij} : i = 1, \ldots, 11\} - \min\{x_{ij} : i = 1, \ldots, 11\}}$$

Then all u_{ij} are between 0 and 1, and for each attribute j alternative i with the smaller u_{ij} is better. We use the u_{ij}s for making our selection.

The weights assigned to the attributes in order 1 to 9 are (the higher the weight, the more important the attribute): 0.073, 0.101, 0.122, 0.145, 0.095, 0.093, 0.135, 0.129, 0.107. Determine the best location for the branch office of the company. (Adopted from: E S Soofi, and J J Retzer, "Adjustment of Importance Weights in Multiattribute Value Models by Minimum Discrimination Information", *European Journal of Operational Research* 60(1992)99-108).

2.6: Buying a new car: Santa needs to decide which new compact car to buy, based on evaluations of four attributes: PP = purchase price (measured in \$1000 units), CMPG = miles per gallon in city driving, HMPG = miles per gallon in highway driving, and MC = Maintainance cost. The characteristic MC is evaluated as an MCF (MC Factor) where 1.0 represents average MC in an year. The average MC in years 1 to 5 in the life of a new car are: \$110, 190, 240, 280, 300 respectively.

She plans to use the car for a period of 5 years, and estimates that it will be driven 6,000 miles in the city, and 6,000 miles on the highway per year. At present gas costs \$2.20/gallon, and is expected to go up an average of \$0.50/gallon/year.

She has chosen 6 models from the list of 29 models classified in the compact cars category by the *Consumer Reports*. This selection is based on non-dominance of an alternative to every other alternative in the consideration set (comparability), non-duplication (such as Ford Tempo and Mercury Topaz), and the availability of complete data for the analysis. The following table shows the data on the attribute evaluations for each of the 6 models under consideration, extracted from Consumers Reports.

Model	Evaluation for attribute			
	PP	CMPG	HMPG	MCF
Ford Tempo	9.0	17	32	0.825
Toyota Camry	11.5	19	44	0.825
Honda Accord	11.7	19	40	1.000
Buick Skylark	11.1	16	36	1.000
Mazda 626	11.3	16	35	1.000
Nissan Stanza	12.2	16	34	1.000
Weight*	0.355	0.326	0.274	0.045

*Higher the weight, more important the attribute

Find the best buy for her. (From E. S. Soofi, and J. J. Retzer, "Adjustment of Importance Weights in Multiattribute value Models by Minimum Discrimination Information", *European Journal of Operational Research*, 60(1992)99-108.)

2.7: Place yourself in the position of being in the job market looking for a job involving computer systems. Seven opportunities are available. For each of them, data on some factors (i.e., characteristics called factors here) that most people feel are important is given below. These factors are:

> Work, Location, Pay/year,Potential, Risk, Workload (all jobs require 5 days work/week).

1. Data processing specialist; bank in College Station, TX; $48,000; Slow promotion potential; low risk of job loss; 8 AM to 5 PM, 48 weeks/year.

2. Computer consultant; on campus in local community; $54,000; slow promotion potential; low risk of job loss; 8 AM to 5 PM, 48 weeks/year.

3. Freelance computer consultant; Brazos County; MAY average $100/hour, range 10 to 100 hours/month with average possibly 50 hours/month; probably 11 months/year.

4. Beginning information systems analyst in a Big 8 firm; Dallas, TX; $63,000, and lots of paid overtime; moderate promotion potential; high risk of job loss; 7 AM to 6 PM, 50 weeks/year.

5. Software sales in a small international firm; Houston, TX; $65,000; high promotion potential; moderate risk of job loss; 9 AM to 6 PM and lots of unpaid overtime, 50 weeks/year.

6. Beginning information systems analyst in a major firm; Fresno, CA; $75,000; moderate promotion potential; moderate risk of job loss; 9 AM to 6 PM, 50 weeks/year, and overtime paid.

7. Maintenance programming in oil company; New Orleans, LA; $70,000; slow promotion potential; moderate risk of job loss; 8 AM to 5 PM, 50 weeks/year, and overtime paid.

Develop rankings for the various factors for each job; and develop importance weights for them using your preferences and your judgement. Using these find which offer is the most attractive. (Adopted from D. L. Olson and V. K. Dorai, "Implementation of the Control Method of Solymosi and Dombi", *European Journal of Operational Research*, 60(1992)117-129.)

2.8: The annual construction program in a large hydroelectric company spans a broad range of initiatives - construction of new buildings, installation of power lines, upgrading of generating stations, etc. These initiatives address many different needs and must be evaluated along several dimensions. These include:

> **(a)** installation cost measured in $million units, **(b)** operating cost - estimate of yearly ongoing cost of maintaining or operating the structure, also measured in $million units, (the following characteristics (c) to (f) are qualitative in

nature for which the evaluation consists only of a rank ordering of preferences as explained later) **(c)** environmental impact - overall contribution to the detraction from the environment (air qulity, ground water damage etc.), **(d)** contribution to new energy supply, **(e)** impact on existing or ongoing initiatives - either positive or negative, **(f)** senior management support.

For each of characteristics (c) to (f), each program is given a rank between 1 to 5 with the following meaning:

Ranking	Implication about the importance of the project
1	Extremely important
2	Very important
3	Average importance
4	Minor importance
5	Not important

Project	Evaluation for criterion					
	(a)	(b)	(c)	(d)	(e)	(f)
P_1	90	6.8	1	1	3	4
P_2	95	6.3	1	3	4	4
P_3	97.7	5.7	4	4	2	3
P_4	83	5.4	5	1	1	1
P_5	88	7.2	2	5	2	2
P_6	68	7.7	3	4	3	5
P_7	88	4.5	4	5	5	5
P_8	81	1.8	2	2	3	2
P_9	93.9	5.9	3	1	5	1
P_{10}	95	5.5	4	1	2	4
Weight	0.12	0.08	0.2	0.15	0.35	

Verify that all the evaluations are costs (i.e., the smaller the evaluation, the better the project). There are 10 projects to consider in a constrained budget situation. Data on the evaluations is given in the above tableau. This tableau also contains the weight for each characteristic, which reflects the priority set by the utility on it (the higher the weight, the more important the characteristic).

Prioritize the 10 projects for the company for the purpose of isolating a best or most desirable subset, justifying your assumptions clearly. (From w. D. Cook, and M. Kress, "A Multiple-Criteria Composite Index Model for Quantitative and Qualitative Data", *European Journal of Operational Research*, 78(1994)367-379.)

2.9: An Indian company that provides cars with drivers for customers is investigating 5 different car models, MB, LE, IN, LI, and CA to add another mid-size car to their fleet. They want to compare various models on 4 characteristics: purchase price, expected repair expenses, expected gas expenses, and expected loss of business due to car being in workshop for repairs; each measured on a per year basis. The weights of these chartacteristics are 10, 6, 8, 5 (the higher the weight, the more inportant the characteristic).

The expected number of years the car will be kept in service is 3. The expected mileage per year is 42,000 miles. The avaerage cost of gas/gallon during the lifetime of the car is expected to be \$3. The estimated loss of business per day the car is in workshop for repair or maintainance is \$110.

Table gives following data: A = purchase price in units of \$1000, B = expected repair expenses per year in units of \$1000, C = number of days car expected to be in workshop for repairs and maintainance per year, and D = MPG.

Model	Data for model			
	A	B	C	D
MB	35	5	10	16
LE	50	3.5	8	22
IN	40	4	9	20
LI	32	10	15	13
CA	43	13	18	11

Determine the best model to buy.

2.10: The setting of this exercise is *Mahabharata*, the great Indian epic that is dated earlier than 5000 BC. It is about a beautiful princess Satyabhama who is trying to select a prince to marry.

Trait	Score on trait of				Weight
	Krishna	Sisupala	Jarasandha	Rukmi	
1. Easygoing nature, friendly disposition	80	70	60	50	10
2. Being a lively and animated companion	90	95	70	65	8
3. Sharing her concern about destruction of nature	40	30	20	45	10
4. Willingness to limit family size to two children	50	30	60	25	10
5. Archery skill	60	70	80	70	7
6. Skill in negotiating deals with opposing parties	80	75	70	60	6
7. Concern for people, particularly those of other tribes etc.	60	45	45	45	5
8. Willingness to let females to join in wars	60	40	40	40	8

Satya was very progressive for her time. While most of her girl friends looked forward to getting married and having lots of children and a large family, she considered that not suitable as a goal for women. Of course she was not opposed to having one or a maximum of two children, but she felt very strongly that women should develop a passionate interest in something more worthwhile than bringing up a lot of children. Even in those days she was quite concerned that the human population growth was contributing to the destruction of nature. She used to go hiking in the forest on the outskirts of her father's capital city, and she particularly admired a rare flowering bush called *Parijata* in that forest. Every morning it used to blossom forth with what appeared to be a million flowers with very bright orange stems and a heavenly fragrance. To her great grief that Parijata bush was devastated in a recent spate of house building as the city expanded, and she was very concerned that it may have become extinct.

She learned horse riding, and driving chariots, and became an expert at these skills; quite unusual for a woman in those days. She learned to launch arrows using a bow with deadly accuracy, and could compete with the best archers in her kingdom. Fighting little wars was almost daily work for kings in those days, and she made up her mind that after marriage she would join her husband in any wars that he may have to fight.

In those days in India, marriages for princesses used to be organized through a function called *swayamvara* (which literally means "self-chosen"). All the eligible princes would be invited to a gala party. There would be sumptuous meals followed by dancing where the princess dances and chats with each visiting prince. There would be contests in archery etc. where the various suitors display their skills. During this entire process the princess is gathering information about each suitor and weighing her choices. When her decision is finalized, she would come out with a garland of flowers with which she would adorn the prince of her choice, and then the wedding would be celebrated.

At Satya's swayamvaram there were four suitors, Krishna, Sisupala, Jarasandha, and Rukmi. The personality traits that she considered important in her future husband are listed in the left hand column in the above table. She scored each suitor on each trait on a scale of 0 to 100 (the higher the score, the more desirable the suitor is on that trait). In the rightmost column of the table we provide the weight for each trait which measures the relative importance she attached to that trait (again, the higher the weight, the more important she considered that trait to be).

Help Satya choose her fiance from among the four suitors.

2.11: For the fall campaign the democratic presidential candidate has to decide how to allocate the campaign's advertising budget among the four media: TV, radio, newspapers and magazines, and billboards. The expenses have already been worked out by the campaign manager, and the choice for him/her narrowed to two levels, low (L), or high (H), in each media. If the candidate chooses the high level for TV advertising, the budget would only permit low level advertising in each of the other three media. On the other hand if the candidate chooses the low level for TV advertising, the budget would permit advertising at the high level in two of the other three media and at the low level in the remaining.

Medium	Advertizing level	Estimated number of people (millions) in age group who are influenced					
		20-30 years		30-60 years		60 and up	
		P	N	P	N	P	N
TV	L	5	1	12	3	5	2
	H	9	1.5	20	4	8	3
Radio	L	2.5	0.9	6	1	1.8	0.6
	H	5	0.4	12	1.8	4	0.8
Newspapers and magazines	L	1.6	0.2	4	0.4	1.5	0.3
	H	3	0.1	8	0.6	3	0.2
Billboards	L	0.7	0.2	2	0.2	0.5	0.1
	H	1.2	0.3	4	0.3	0.7	0.2

P = positively influenced, N = negatively influenced

The candidate's statistical advisers came up with estimates in the table given above for the reach of the various media.

Each person who is positively (negatively) influenced by the advertisements is expected to discuss and positively (negatively) influence an additional 0.5 (0.3) persons in the same age group through personal conversations. Only 25% of the people in the age group 20-30 years, 50% of the people in the age group 30-60 years, and 70% of the people in the age group 60 years and up, are expected to vote; the corresponding fractions are the weights for the three age groups in developing a combined score for each alternative. The overall score for any alternative is the weighted average over the different age groups of (the number of positively influenced people − the number of negatively influenced people) summed over all the media. Determine the best advertising strategy for the candidate.

2.12: A telephone company is considering 7 information systems (IS) projects, IS_1 to IS_7, with the aim of selecting a subset of them, yielding the maximum benefit, for implementation. There are many criteria to consider in making the selection. These criteria are grouped into four groups. They are:

1. **Tangible benefits:**

    1.1. **Cost savings:** Includes cost savings or increased revenues as a result of implementing the particular project. Estimated in $/month.

    1.2. **Return on investment:** Measured as a percentage over some period.

2. **Intangible benefits:** All these are measured by a score between 1 to 7, the lower the better; i.e., 1 denotes highest benefit, 7 denotes little or no benefit.

    2.1. **Customer satisfaction:** Evaluates increased customer satisfaction that will result if project is implemented.

    2.2. **Quality of information:** Evaluates improved quality of information if the project is implemented.

    2.3. **Multiple uses of information:** Evaluates improved use of available information if the project is implemented.

2.4. Setting tone for future business: Evaluates improved business opportunities that may appear if the project is implemented.

3. Policy issues-risk factors: This is an assessment of any negative impacts that may araise if the project is implemented. Scored as a factor betyween 0 to 1, the lower the better.

4. Resources needed:

4.1. User hours: Evaluates computer staff software development time needed if the project is implemented. Measured in man-hours.

4.2. Ongoing costs: Evaluates operational costs that need to be incurred if the project is completed. Measured in $/month.

4.3. Developmental hours: Evaluates the man-hours of management developmental time needed if the project is implemented. Measured in man-hours.

4.4. Computer time needed: Evaluates computer time needed to implement the project. Measured in hours of computer time.

Data on these evaluations for these various projects is given below. Here, all the evaluations of characteristics 2.1 to 2.4 for each project are combined into a single score for characteristic 2 (intangible benefits), this score lying between 1 to 7 with 1 denoting very high benefits, and 7 denoting little or no benefit from implementing the project.

Charac.	Evaluation for project						
	IS_1	IS_2	IS_3	IS_4	IS_5	IS_6	IS_7
1.1	147,500	9,083	5,000	558,330	480,000	8,834	5,000
1.2	193	5	7	54	183	2	1
2	3	2	6	4	1	6	6
3	0.55	0.50	0.025	0.60	0.70	0.15	0.75
4.1	160	500	0	910	260	2600	155
4.2	8,355	0	4,000	183,080	5,088	0	140,000
4.3	980	3,275	1,200	1,460	4,600	640	930
4.4	6	3	3	37	8	3	4

All the characteristics are considered to be of the same importance, so the weights for all of them are 1.

It is required to rank the projects in order of desirability for selecting the ones to implement. Do this using the scoring method, stating all your assumptions very clearly. From M. J. Schniederjans and R. Santhanam, "A Multi-objective Constrained Resource Information System Project Selection Method", *European Journal of Operational Research*, 70(1993)244-253.)

Additional exercises for this chapter are available in Chapter 13 at the end.

Index

For each entry we provide the section number where it appears.