

## **APPENDIX F**

### **Procedures for Determining the Weights of Selection Factors in the Weighted-Matrix Delivery Decision Approach (Tier 2)**

This appendix describes four weighting methods that combine subjective and objective approaches to arrive at weight values for the key selection factors used in Tier 2. These methods have been selected for their simplicity and effectiveness.

## **Background**

The Weighted Matrix Delivery Decision Approach (Tier 2) consists of selecting a few important issues and project goals and rating their importance in achieving project objectives. Specifically, Step 2 of the Tier 2 (see Chapter 5) requires that the user rank and weight the short-listed selection factors. While a completely subjective method can be used to assign these weights, many formal procedures have been developed in management science that facilitate this process and make it more objective. This appendix describes four such methods that combine subjective and objective methods to arrive at weight values for the key selection factors used in Tier 2. These methods have been selected for their simplicity and effectiveness. These methods will help decision-makers develop more consistent and transparent weights. The four methods described here are: (1) the Delphi Method, (2) the Rank Order Centroid Method, (3) the Ratio Method, and (4) the Pairwise Comparison Method.

### **Delphi Method**

The Delphi Method is a reliable way of obtaining the opinions of a group of experts on an issue by conducting several rounds of interrogative communications. This method was first developed in the U.S. Air Force in the 1950s, mainly for market research and sales forecasting (Chan et al. 2001).

This method is basically a communication device that is particularly useful for achieving a consensus among experts given a complex problem. The method consists of repeated solicitations of questions from a panel of experts who are anonymous. The information and ideas of each panel member are distributed among all the panel members in the next round. They can comment on others' viewpoints and can even use new information to modify their own opinions. Panel members can change their opinions based on new information more easily than in regular group meetings and open discussion. A consensus of opinions should be ultimately achieved in this way. This method will also highlight the areas where panel members have disagreements or uncertainty in a quantitative manner. The evaluation of belief statements by the panel as a group is an explicit part of the Delphi method (Chan et al. 2001).

The panel consists of a number of experts chosen based on their experience and knowledge. As mentioned previously, panel members remain anonymous to each other throughout the procedure in order to avoid the negative impacts of criticism on the innovation and creativity of panel members. The Delphi Method should be conducted by a director (facilitator) who has independent communication with each panel member. The director develops a questionnaire based on the problem at hand and sends it to each panel member. Then, the responses to the questions and all the comments are collected and evaluated by the director. The director should process the information and filter out the irrelevant content. The result of the processed information will again be distributed among the panel members. Each member receives new information and ideas and can comment on them and/or revise his own previous opinions.

In the context of the Tier 2 approach (see Chapter 5), one can use the Delphi Method for giving weights to the short-listed critical factors. The panel members should give weights to each factor as well as their reasoning. In this way, other panel members can evaluate the weights based on the reasons given and accept, modify, or reject those reasons and weights.

For example, let us assume that after application of Tier 1 by the transit agency, there still remain two or more project delivery methods as viable options. The agency has identified the following four factors to be considered in Tier 2:

- shortening the schedule,
- agency control over the project,
- project cost, and
- competition among contractors.

The facilitator should ask the panel members to weight each of the factors while giving their reasons for the weights selected. The facilitator can then use the collected weights and viewpoints and establish a weight for each factor. One possible approach could be to calculate an average weight for each factor based on responses. If there are large divergences in some responses, the facilitator should study that and comment on those cases. The outcome of this analysis should be distributed to the panel again for further consideration and modification. The facilitator will decide when to stop the process, based on the level of consensus desired.

### **Rank Order Centroid (ROC)**

This method is a simple way of giving weight to a number of items ranked according to their importance. The decision-makers usually can rank items much more easily than give weight to them. This method takes those ranks as inputs and converts them to weights for each of the items. The conversion is based on the following formula:

$$W_i = (1/M) \sum_{n=i}^M \frac{1}{n}$$

where  $M$  is the number of items and  $W_i$  is the weight for  $i^{th}$  item.

For example, if there are 4 items, the item ranked first will be weighted  $(1 + 1/2 + 1/3 + 1/4) / 4 = 0.52$ , the second will be weighted  $(1/2 + 1/3 + 1/4) / 4 = 0.27$ , the third  $(1/3 + 1/4) / 4 = 0.15$ , and the last  $(1/4) / 4 = 0.06$ . As shown in this example, the ROC is simple and easy to follow, but it gives weights which are highly dispersed (Chang 2004).

As an example, consider the same factors to be weighted (shortening schedule, agency control over the project, project cost, and competition). If they are ranked based on their importance and influence on decision as 1- shortening schedule, 2- project cost, 3- agency control over the project and 4- competition, their weights would be 0.52, 0.27, 0.15, and 0.06, respectively. These weights almost eliminate the effect of the fourth factor, i.e., competition among contractors.

## Ratio Method

The Ratio Method is another simple way of calculating weights for a number of critical factors. A decision-maker should first rank all the items according to their importance. The next step is giving weight to each item based on its rank. The lowest ranked item will be given a weight of 10. The weight of the rest of the items should be assigned as multiples of 10. The last step is normalizing these raw weights (Weber and Borcharding 1993). This process is shown in the example below. Note that the weights should not necessarily jump 10 points from one item to the next. Any increase in the weight is based on the subjective judgment of the decision-maker and reflects the difference between the importance of the items. Ranking the items in the first step helps in assigning more accurate weights.

**Table F-1 – Ratio Method Example**

Item Task	Shortening schedule	Project cost	Agency control	Competition
Ranking	1	2	3	4
Weighting	50	40	20	10
Normalizing	41.7%	33.3%	16.7%	8.3%

Normalized weights are simply calculated by dividing the raw weight of each item over the sum of the weights for all items. For example, normalized weight for the first item (shortening schedule) is calculated as  $50/(50 + 40 + 20 + 10) = 41.7\%$ . The sum of normalized weights is equal to 100% ( $41.7 + 33.3 + 16.7 + 8.3 = 100$ ).

## Pairwise Comparison

In this method, the decision-maker should compare each item with the rest of the group and give a preferential level to the item in each pairwise comparison (Chang 2004). For example, if the item at hand is as important as the second one, the preferential level would be one. If it is much more important, its level would be 10. After conducting all of the comparisons and determining the preferential levels, the numbers will be added up and normalized. The results are the weights for each item. Table F-2 can be used as a guide for giving a preferential level score to an item while comparing it with another one.

The following example shows the application of the pairwise comparison procedure. Referring to the four critical factors identified above, let us assume that shortening the schedule, project cost, and agency control of the project are the most important parameters in the project delivery selection decision. Following the pairwise comparison, the decision-maker should pick one of these factors (e.g., shortening the schedule) and compare it with the remaining factors and give a preferential level to it. For example, shortening the schedule is more important than project cost; in this case, it will be given a level of importance of 5.

The decision-maker should continue the pairwise comparison and give weights to each factor. The weights, which are based on the preferential levels given in each pairwise comparison, should be consistent to the extent possible. The consistency is measured based on the matrix of preferential levels. The interested reader can find the methods and applications of consistency measurement in Temesi (2006).

**Table F-2 – Scoring Guide for Pairwise Comparison**

SCORE	DEFINITION
10	The issue at hand is of the highest possible order of affirmation and is much more important than the other issue.
8	The issue is strongly important for the owner in choosing a delivery method and is absolutely more important compared to the other issue.
6	The issue is more important for the owner than the other one.
4	The issue is slightly more important to the owner.
2	The issue is not practically more important but yet slightly more effective while selecting a delivery method.
9,7,5,3,1	Intermediate values between two adjacent judgments.

Table F-3 shows the rest of the hypothetical weights and the normalizing process, the last step in the pairwise comparison approach.

**Table F-3 – Pairwise Comparison Example**

	Shorten the schedule (1)	Project cost (2)	Agency control (3)	Competition (4)	Total (5)	Weights (6)
Shorten the schedule	1	5	5/2	8	16.5	16.5/27.225=0.60
Project cost	1/5	1	1/2	1	2.7	2.7/27.225=0.10
Agency control	2/5	2	1	2	5.4	5.4/27.225=0.20
Competition	1/8	1	1/2	1	2.625	2.625/27.225=0.10
				Total=	27.225	

Note that Column (5) is simply the sum of the values in Columns (1) through (4). Also note that if the preferential level of factor  $i$  to factor  $j$  is  $n$ , then the preferential level of factor  $j$  to factor  $i$  is simply  $1/n$ . The weights calculated for this exercise are 0.6, 0.1, 0.2, and 0.1 which

add up to 1.0. Note that it is possible for two factors to have the same importance and weight.