Information Technology Investment: Decision Making Methodology

Chapter 10

Multi-Factor Scoring Methods and the Analytic Hierarchy Process

Chapter Outline:

I. Introduction

II. What are Multi-Factor Scoring Methods?

III. What is the Analytic Hierarchy Process?

I. Introduction

This chapter continues to introduce the use of various methodologies for IT decision-making, focusing on multi-criteria techniques

The methodologies in this chapter illustrate how individual multi-criteria useful in decision-making can be weighted and considered in a model

II. What are Multi-Factor Scoring Methods?

While "price" and "cost" factors can be easily measured objectively in dollars for a comparison, factors such as "flexibility", "brand name", and "compatibility" have to subjectively be rated by some type of score (i.e., a "1" representing "poor" score up to a "9" for a "good" score)

A common unit of measurement that can be used to deal with this subjectivity is a system that converts objective and subjective factor measures into *scores*

II. What are Multi-Factor Scoring Methods?

A group of methodologies that make use of these subjectively derived scores when applied to selection-type decision making problems with differing factors, are called *multi-factor scoring methods* (MFSM's)

Multi-factor scoring methods (MFSMs) are a collection of quantitative methodologies that can be used to make a choice from a set of alternatives using a set of two or more factors as decision choice criteria

II. What are Multi-Factor Scoring Methods?

The alternatives must be mutually exclusive and discrete choices (i.e., no proportional choices of more than one alternative) like those presented in the table (i.e., Alternatives A, B, or C)

Factors (Criteria)	Alternative A Computer System	Alternative B Computer System	Alternative C Computer System
1. Flexibility			
2. Brand name			

The factors used as decision choice criteria must also be rated in some numerical fashion. Any numbered rating scale such as 1 to 9, or 1 to 100, etc. can be created and used in MFSM's.

II. What are Multi-Factor Scoring Methods?

In the table the three alternatives have been rated on a scale of 1 (i.e., a "1" represents a "poor rating" in satisfying that criteria) to 9 (i.e., a "9" represents a "good rating" in satisfying that criteria)

Factors (Criteria)	Alternative A Computer System	Alternative B Computer System	Alternative C Computer System
1. Flexibility	5	1	9
2. Brand name	5	7	2
3. Price	6	3	6
4. Delivery	5	6	7
Total Score	21	17	24

We can see in the table that for the decision factor of "Flexibility" Alternative C is rated the highest and Alternative B is rated the lowest

II. What are Multi-Factor Scoring Methods?

They can be generally categorized into two basic types: un-weighted MFSM and weighted MFSM

In *un-weighted MFSM* problems the ratings are simply summed up to achieve a score that will denote the desired choice of alternatives

Factors (Criteria)	Alternative A Computer System	Alternative B Computer System	Alternative C Computer System
1. Flexibility	5	1	9
2. Brand name	5	7	2
3. Price	6	3	6
4. Delivery	5	6	7
Total Score	21	17	24

For example, Alternative C is the best un-weighted choice

II. What are Multi-Factor Scoring Methods?

Summary of steps for the un-weighed method:

1. **Identify all alternative choices**
2. **Identify all relevant factors**
3. **Construct a MFSM table with individual columns for each alternative, rows for each factors, and final row labeled Total Score**
4. **Rate each alternative using a scale of choice (e.g., 1 to 9), where the lower value on the scale represents a less preferred value and the higher value represents a more preferred value for each factor**
5. **Place the ratings by row and column in each cell that makes up the table**
6. **Sum the ratings in each column (i.e., each alternative) to generate a total score and place these values in the Total Score row at the bottom of the table**
7. **Select the alternative with the largest total score**

II. What are Multi-Factor Scoring Methods?

In the un-weighted MFSM it is assumed that each factor is equally weighted but in some situations this is not an accurate representation of the decision environment

Weighted MFSMs **allow the decision-maker an opportunity to weight the criteria**

II. What are Multi-Factor Scoring Methods?

- **Determining a *factor weight* (i.e., a mathematical weight reflecting the importance of that factor relative to the other factors) can be done very subjectively or more objectively with other quantitative methods**

These factor weights are usually expressed as decimals (or percentages) and they must add up to 1.0 (or 100 percent) over all the factors being considered in the problem

II. What are Multi-Factor Scoring Methods?

Let's say the origin of the factor weight in the table is subjectively "guessed-at" by an IS manager who feels the factor of "Flexibility" in a computer system is five times as important as the factor "Brand name" and two and a half times as important as the "Price" and "Delivery" factors

Factors (Criteria)	Factor Weight	Alternative A System	Alternative B System	Alternative C System
1. Flexibility	0.5	5	1	9
2. Brand name	0.1	5	7	2
3. Price	0.2	6	3	6
4. Delivery	0.2	5	6	7
Total Score	1.0			

II. What are Multi-Factor Scoring Methods?

Computations for the weighted model:

Factors (Criteria)	Factor Weight	Computations for Alternative A Computer System	Computations for Alternative B Computer System	Computations for Alternative C Computer System
1. Flexibility	0.5	0.5 x 5 = 2.5	0.5 x 1 = 0.5	0.5 x 9 = 4.5
2. Brand name	0.1	0.1 x 5 = 0.5	0.1 x 7 = 0.7	0.1 x 2 = 0.2
3. Price	0.2	0.2 x 6 = 1.2	0.2 x 3 = 0.6	0.2 x 6 = 1.2
4. Delivery	0.2	0.2 x 5 = 1.0	0.2 x 6 = 1.2	0.2 x 7 = 1.4
Total Score	1.0	5.2	3.0	7.3

Again the best solution is again Alternative C

II. What are Multi-Factor Scoring Methods?

Summary of steps for the weighed method:

1. ***Identify all alternative choices***
2. ***Identify all relevant factors***
3. ***Identify, judgmentally derive, or compute factor weights for each factor***
4. ***Construct an MFSM table with individual columns for each alternative and one additional column labeled Factor Weights, rows for each factor, and final row labeled Total Score***
5. ***Rate each alternative using a scale of choice (e.g., 1 to 9), where the lower value on the scale represents a less preferred value and the higher value represents a more preferred value for each factor***

II. What are Multi-Factor Scoring Methods?

***Summary of steps for the weighed method* (Continued):**

6. Place the ratings by row and column in each cell that makes up the table

7. Place the factors weights in the Factor Weight column

8. Multiply the factors weights in the Factor Weight column times each of the ratings across each row, and place those values in each of the rating cells of the table

9. Sum these computed ratings by column (i.e., each alternative) to generate a total score and place these values in the Total Score row at the bottom of the table

10. Select the alternative with the largest total score

III. What is the Analytic Hierarchy Process?

In the previous MFSM example the weights were guessed at. Suppose we would want to compute them in a more inclusive manner, considering their relationship among the other factors?

Sensitivity Analysis of MFSM
→ Check the robustness of the solution

The *analytic hierarchy process* (AHP) can be employed to develop the factor weights and can also be used as a decision-making methodology itself

III. What is the Analytic Hierarchy Process?

The *analytic hierarchy process* utilizes pairwise comparisons to establish factor weights for decision models, establish priorities for a decision choice, and generate accurate statistics to confirm its decision analysis

AHP is a superior decision making methodology because it requires all of the factors in the decision environment to be directly compared with all other factors, providing a more inclusive consideration of the interaction and value of each factor relative to all other factors

III. What is the Analytic Hierarchy Process?

The procedure for AHP includes the following steps:

1. Establish the "decision hierarchy" by determining the overall decision, the factors and the alternatives.
2. Establish the pairwise comparisons of alternatives through a subjective judgment process and using Saaty's nine point scale.
3. Compute the factor priorities based on the values from Step 2.
4. Compute the factor weights based on the same set of procedures from Step 3.
5. Compute the overall decision priorities using a similar matrix multiplication as that of MFSM.
6. Determine consistency ratios by first computing a consistency index, and then using the random index values from the table.

III. What is the Analytic Hierarchy Process?

Let's look at an example to illustrate these steps:

1. *Establish the "decision hierarchy" by determining the overall decision, the factors and the alternatives*

In this step the decision maker must identify:

(1) the overall decision,

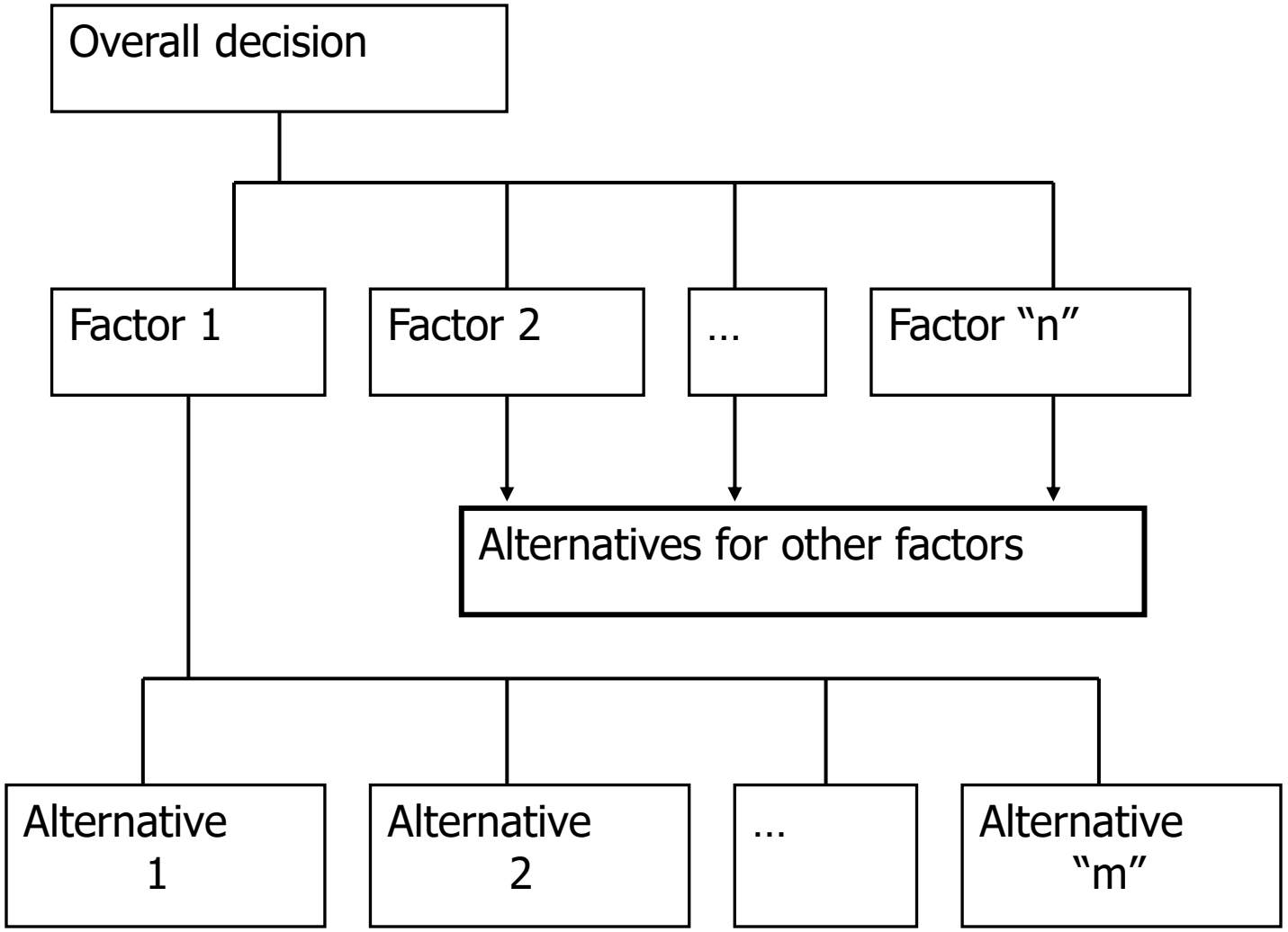
(2) the factors that must be weighted or used to make the decision, and

(3) the alternative choices from which a decision is to be made

III. What is the Analytic Hierarchy Process?

1. *Establish the "decision hierarchy" by determining the overall decision, the factors and the alternatives*

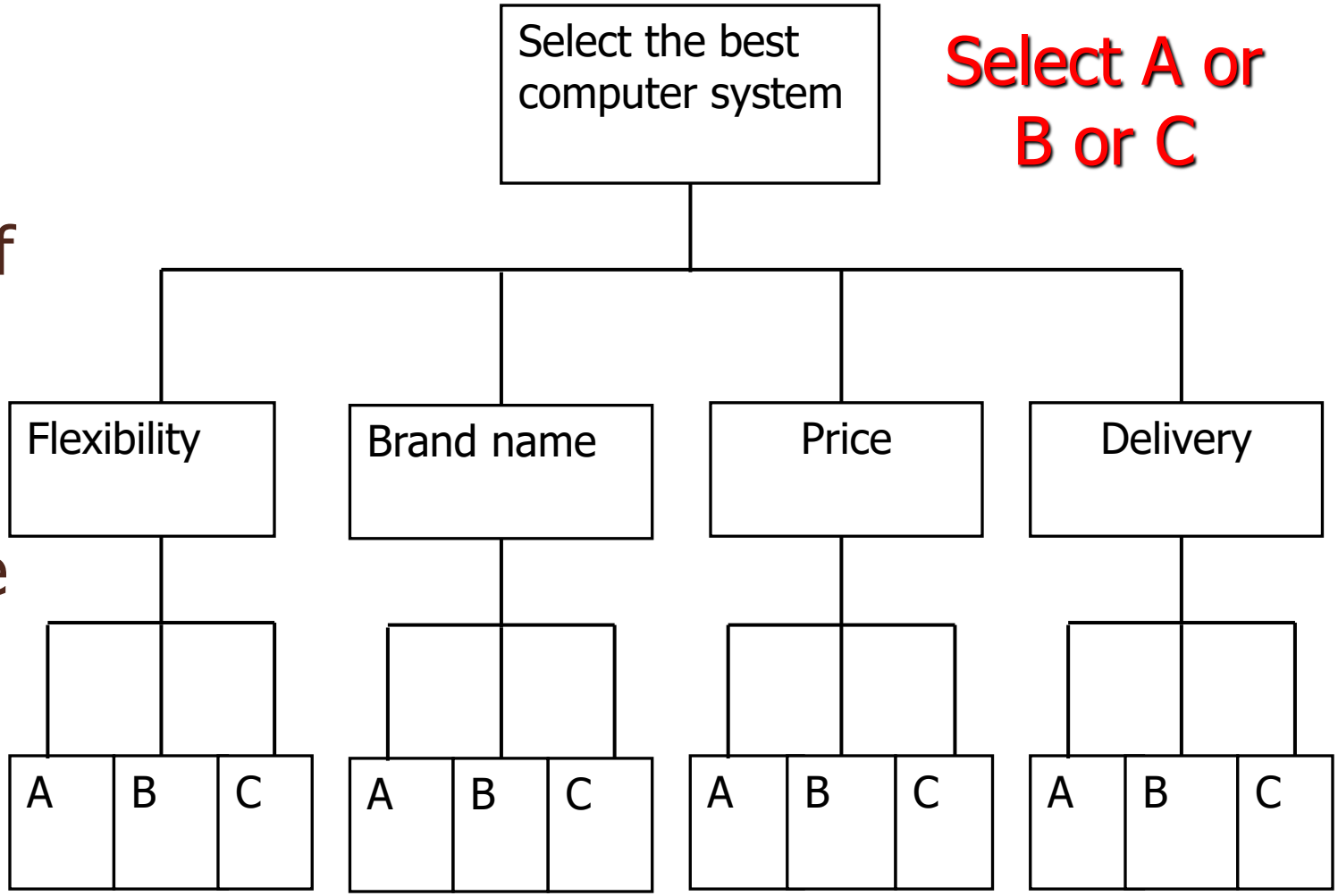
To help put these items together, an AHP decision hierarchy is used



III. What is the Analytic Hierarchy Process?

1. *Establish the "decision hierarchy" by determining the overall decision, the factors and the alternatives*

For the purposes of our example, let's assume the following problem…



III. What is the Analytic Hierarchy Process?

Step 2. Establish the pairwise comparisons of alternatives

In this step the decision maker must compare each alternative with all other alternatives, one factor at a time

Scale	Numerical rating	Reciprocal
Extremely importance	9	1/9
Very to extremely strongly importance	8	1/8
Very strongly importance	7	1/7
Strongly to very strongly importance	6	1/6
Strongly importance	5	1/5
Moderately to strongly importance	4	1/4
Moderately importance	3	1/3
Equally to moderately importance	2	1/2
Equally importance	1	1

AHP: Analytic hierarchy process

III. What is the Analytic Hierarchy Process?

Step 2. Establish the pairwise comparisons of alternatives

Set up initial table for each factor and compare each system:

Flexibility	Computer System A	Computer System B	Computer System C
Computer System A			
Computer System B			
Computer System C			

III. What is the Analytic Hierarchy Process?

Step 2. Establish the pairwise comparisons of alternatives

Place diagonal comparisons for each factor and each system:

Flexibility	Computer System A	Computer System B	Computer System C
Computer System A	1		
Computer System B		1	
Computer System C			1

These always have to be 1-for-1

III. What is the Analytic Hierarchy Process?

Step 2. Establish the pairwise comparisons of alternatives

We next need to make comparisons between differing computers. These values will go in the upper portion of the comparison table

III. What is the Analytic Hierarchy Process?

Step 2. Establish the pairwise comparisons of alternatives

First, we compare computer system A with B in regard to their flexibility. What we are rating is computer system A, with respect or relative to B. Note, we are rating computer A, not B. Lets say the decision maker thinks computer system A is a little more preferable (i.e., does a better or more satisfying job on providing flexibility with the existing system) than B. So the rating given is a "3" or "moderately preferred" rating to that of computer system A.

Flexibility	**Computer System A**	**Computer System B**	**Computer System C**
Computer System A	**1**	**3**	**9**

III. What is the Analytic Hierarchy Process?

Step 2. Establish the pairwise comparisons of alternatives

Second, we compare computer system A with C in regard to their flexibility. Lets say the decision maker thinks computer system A is a lot more preferable (i.e., does the best job of satisfying or providing flexibility with the existing system) than C. So the rating given is a "9" or "extremely preferred" rating to that of computer system A.

Flexibility	**Computer System A**	**Computer System B**	**Computer System C**
Computer System A	**1**	**3**	**9**

III. What is the Analytic Hierarchy Process?

Step 2. Establish the pairwise comparisons of alternatives

To finish the upper portion of the table we now compare computer system B with C. Lets say the decision maker thinks computer system B rating is somewhere between the previous two ratings of "3" and "9". So the rating given is a "6" or "Strongly to very strongly preferred" to computer system B.

Flexibility	**Computer System A**	**Computer System B**	**Computer System C**
Computer System A	**1**	**3**	**9**
Computer System B		**1**	**6**

III. What is the Analytic Hierarchy Process?

Step 2. Establish the pairwise comparisons of alternatives

The inverse of A-to-B (3) is the B-to-A cell is 1/3

Flexibility	Computer System A	Computer System B	Computer System C
Computer System A	1	3	9
Computer System B	1/3	1	6
Computer System C	1/9	1/6	1

III. What is the Analytic Hierarchy Process?

Step 2. Establish the pairwise comparisons of alternatives

We now have to do the same work on the other three factors (i.e., Brand name, Price, Delivery)

Brand name	**Computer System A**	**Computer System B**	**Computer System C**
Computer System A	**1**	**1**	**6**
Computer System B	**1**	**1**	**3**
Computer System C	**1/6**	**1/3**	**1**

Price	**Computer System A**	**Computer System B**	**Computer System C**
Computer System A	**1**	**1/2**	**1/8**
Computer System B	**2**	**1**	**1/5**
Computer System C	**8**	**5**	**1**

Delivery	**Computer System A**	**Computer System B**	**Computer System C**
Computer System A	**1**	**1**	**6**
Computer System B	**1**	**1**	**3**
Computer System C	**1/6**	**1/3**	**1**

III. What is the Analytic Hierarchy Process?

Step 3. Compute the factor priorities

This step is accomplished by the following sub-steps for all factors:

(1) convert values in prior tables to decimals,
(2) add column totals up,
(3) divide column totals into each value in that column,
(4) sum the resulting row values, and
(5) average the resulting row value

III. What is the Analytic Hierarchy Process?

Step 3. Compute the factor priorities

(1) convert values in prior tables to decimals,
(2) add column totals up,

Flexibility	Computer System A	Computer System B	Computer System C
Computer System A	1.0000	3.0000	9.0000
Computer System B	0.3333	1.0000	6.0000
Computer System C	0.1111	0.1667	1.0000
Column Total	1.4444	4.1667	16.0000

III. What is the Analytic Hierarchy Process?

Step 3. Compute the factor priorities

(3) divide column totals into each value in that column,

Flexibility	Computer System A	Computer System B	Computer System C
Computer System A	1.0000 / 1.4444 = 0.6923	3.0000 / 4.1667 = 0.7200	9.0000 / 16.0000 = 0.5625
Computer System B	0.3333 / 1.4444 = 0.2308	1.0000 / 4.1667 = 0.2400	6.0000 / 16.0000 = 0.3750
Computer System C	0.1111 / 1.4444 = 0.0769	0.1667 / 4.1667 = 0.0400	1.0000 / 16.0000 = 0.0625
Column Total	1.0000	1.0000	1.0000

III. What is the Analytic Hierarchy Process?

Step 3. Compute the factor priorities

(4) sum the resulting row values, and
(5) average the resulting row value

Flexibility	Priority Calculations	Resulting Priorities
Computer System A	$\frac{0.6923 + 0.7200 + 0.5625}{3} =$	0.6583 Best
Computer System B	$\frac{0.2308 + 0.2400 + 0.3750}{3} =$	0.2819 2nd Best
Computer System C	$\frac{0.0769 + 0.0400 + 0.0625}{3} =$	0.0598 3rd Best
Total		1.0000

The resulting values prioritize or rank the importance of each computer system with respect to FLEXIBILITY.

III. What is the Analytic Hierarchy Process?

Step 3. Compute the factor priorities

We now have to repeat those sub-steps on the other factors

Brand name		
Computer System A	$\frac{0.3750 + 0.4286 + 0.6000}{3}$ =	**0.4679**
Computer System B	$\frac{0.3750 + 0.4286 + 0.3000}{3}$ =	**0.3679**
Computer System C	$\frac{0.2500 + 0.1428 + 0.1000}{3}$ =	**0.1642**
Total		**1.0000**

Price		
Computer System A	$\frac{0.0909 + 0.0769 + 0.0944}{3}$ =	**0.0874**
Computer System B	$\frac{0.1818 + 0.1539 + 0.1509}{3}$ =	**0.1622**
Computer System C	$\frac{0.7273 + 0.7692 + 0.7547}{3}$ =	**0.7504**
Total		**1.0000**
Delivery		
Computer System A	$\frac{0.3750 + 0.4286 + 0.6000}{3}$ =	**0.4679**
Computer System B	$\frac{0.3750 + 0.4286 + 0.3000}{3}$ =	**0.3679**
Computer System C	$\frac{0.2500 + 0.1428 + 0.1000}{3}$ =	**0.1642**
Total		**1.0000**

III. What is the Analytic Hierarchy Process?

Step 4. Compute the factor weight priorities

We now have to repeat the previous 3 Steps but this time comparing the importance of each factor with each other factor

Factor Weights	Flexibility	Brand name	Price	Delivery
Flexibility				
Brand name				
Price				
Delivery				

III. What is the Analytic Hierarchy Process?

Step 4. Compute the factor weight priorities

We now have to repeat the previous 3 Steps but this time comparing the importance of each factor with each other factor

Factor Weights	Flexibility	Brand name	Price	Delivery
Flexibility	1			
Brand name		1		
Price			1	
Delivery				1

Factor Weights	Flexibility	Brand name	Price	Delivery
Flexibility	1	1	5	7
Brand name	1	1	3	3
Price	1/5	1/3	1	1
Delivery	1/7	1/3	1	1

Factor Weights	Flexibility	Brand name	Price	Delivery
Flexibility	1	1	5	7
Brand name		1	3	3
Price			1	1
Delivery				1

Factor Weights	Flexibility	Brand name	Price	Delivery
Flexibility	1.0000	1.0000	5.0000	7.0000
Brand name	1.0000	1.0000	3.0000	3.0000
Price	0.2000	0.3333	1.0000	1.0000
Delivery	0.1429	0.3333	1.0000	1.0000
Column Total	**2.3429**	**2.6666**	**10.0000**	**12.0000**

III. What is the Analytic Hierarchy Process?

Step 4. Compute the factor weight priorities (Continued)

Factor Weights	Flexibility	Brand name	Price	Delivery
Flexibility	1.0000=**0.4268** 2.3429	1.0000=**0.3750** 2.6666	5.0000=**0.5000** 10.0000	7.0000=**0.5834** 12.0000
Brand name	1.0000=**0.4268** 2.3429	1.0000=**0.3750** 2.6666	3.0000=**0.3000** 10.0000	3.0000=**0.2500** 12.0000
Price	0.2000=**0.0854** 2.3429	0.3333=**0.1250** 2.6666	1.0000=**0.1000** 10.0000	1.0000=**0.0833** 12.0000
Delivery	0.1429=**0.0610** 2.3429	0.3333=**0.1250** 2.6666	1.0000=**0.1000** 10.0000	1.0000=**0.0833** 12.0000
Column Total	**1.0000**	**1.0000**	**1.0000**	**1.0000**

Factor Weights	Priority Calculations	Resulting Priorities
Flexibility	$\frac{0.4268 + 0.3750 + 0.5000 + 0.5834}{4}$ =	**0.4713**
Brand name	$\frac{0.4268 + 0.3750 + 0.3000 + 0.2500}{4}$ =	**0.3380**
Price	$\frac{0.0854 + 0.1250 + 0.1000 + 0.0833}{4}$ =	**0.0984**
Delivery	$\frac{0.0610 + 0.1250 + 0.1000 + 0.0833}{4}$ =	**0.0923**
Total		**1.0000**

The Resulting Priorities are what we needed to move to the next step…

III. What is the Analytic Hierarchy Process?

Step 5. Compute the overall decision priorities

To do this, we begin by creating a table that combines the information we need for the overall decision priorities. Taking the Resulting Priority values from Step 3 and arranging them by row…

Overall Decision Priorities	Alternative	Alternative	Alternative
Factors	Computer System A	Computer System B	Computer System C
Flexibility	0.6583 x 0.4713 = **0.3102**	0.2819 x 0.4713 = **0.1329**	0.0598 x 0.4713 = **0.0282**
Brand name	0.4679 x 0.3380 = **0.1581**	0.3679 x 0.3380 = **0.1243**	0.1642 x 0.3380 = **0.0555**
Price	0.0874 x 0.0984 = **0.0086**	0.1622 x 0.0984 = **0.0160**	0.7504 x 0.0984 = **0.0738**
Delivery	0.4679 x 0.0923 = **0.0432**	0.3679 x 0.0923 = **0.0340**	0.1642 x 0.0923 = **0.0152**

III. What is the Analytic Hierarchy Process?

Step 5. Compute the overall decision priorities

We then multiplying them by the Resulting Priority values from Step 4, and summing these values, we derive the overall decision priorities

Overall Decision Priorities	Alternative	Alternative	Alternative
Factors	Computer System A	Computer System B	Computer System C
Flexibility	0.6583 x 0.4713 = **0.3102**	0.2819 x 0.4713 = **0.1329**	0.0598 x 0.4713 = **0.0282**
Brand name	0.4679 x 0.3380 = **0.1581**	0.3679 x 0.3380 = **0.1243**	0.1642 x 0.3380 = **0.0555**
Price	0.0874 x 0.0984 = **0.0086**	0.1622 x 0.0984 = **0.0160**	0.7504 x 0.0984 = **0.0738**
Delivery	0.4679 x 0.0923 = **0.0432**	0.3679 x 0.0923 = **0.0340**	0.1642 x 0.0923 = **0.0152**
Column Total	**0.5201**	**0.3072**	**0.1727**

Based on these overall priorities, which can be considered a mathematical weighting, Computer System A is the best choice

III. What is the Analytic Hierarchy Process?

Step 6. Determine consistency ratios

Investigate if the subjective ratings are consistent enough to justify using the resulting overall decision priorities

Checks itself to make sure the ratings consistently make sense for the purposes of using the AHP analysis

III. What is the Analytic Hierarchy Process?

Step 6. Determine consistency ratios

The first sub-step is to compute the *weighted sum vector* *as shown in the table below…*

Flexibility	**Computer System A**	**Computer System B**	**Computer System C**	**Weighted Sum Vector**
Computer System A	**0.6583x1.0000 +**	**0.2819x3.0000 +**	**0.0598x9.0000 =**	**2.0422**
Computer System B	**0.6583x0.3333 +**	**0.2819x1.0000 +**	**0.0598x6.0000 =**	**0.8601**
Computer System C	**0.6583x0.1111 +**	**0.2819x0.1667 +**	**0.0598x1.0000 =**	**0.1799**

You will note the Resulting Priorities from Step 3 and multiplying them by the Original Comparisons from Step 1

III. What is the Analytic Hierarchy Process?

Step 6. Determine consistency ratios

The second sub-step divide each of the weighted sum vector values by their related Resulting Priority values previously in the last table. This gives us the ***Consistency Vector***.

	Computations	Consistency Vector
Computer System A	2.0422/0.6583 =	**3.1022**
Computer System B	0.8601/0.2819 =	**3.0511**
Computer System C	0.1799/0.0598 =	**3.0084**

$$A \cdot w = \lambda \cdot w$$

III. What is the Analytic Hierarchy Process?

Step 6. Determine consistency ratios

The third sub-step we compute the *consistency index*. This index is found using the following formula:

$$CI = \frac{\lambda - n}{n - 1}$$

Where *CI* is the consistency index value, *n* is the number of items being compared (i.e., computer system A, B, and C) and λ is the average of the consistency vector values

III. What is the Analytic Hierarchy Process?

Step 6. Determine consistency ratios

The λ is the average of the consistency vector values [3.1022+3.0511+3.0084/3]=3.0539

The *consistency index*: $CI = \frac{3.0539 - 3}{3 - 1} = 0.0270$

The fourth and final sub-step involves computing the *consistency ratio* and interpreting it. This ratio is computed by a simple formula: $CR = CI/RI$

Where *CR* is the *consistency ratio* and *RI* is a random index value that is obtained from a computed set of tabled statistics. The random index is a statistic designed to identify significant variability of statistical variation in the rating measures.

III. What is the Analytic Hierarchy Process?

Step 6. Determine consistency ratios

The random index value that is obtained based on the n number of comparisons…

"n" number of comparisons	1	2	3	4	5	6	7	8	9	10
Random index	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

So the RI for our problem is 0.52

Finally, we can compute the consistency ratio as:

CR = CI /RI= 0.0270/0.52= 0.0519

III. What is the Analytic Hierarchy Process?

Step 6. Determine consistency ratios

The interpretation is that for values of CR > 0.10 there exists sufficient inconsistency that a re-evaluation of the basic factors and alternatives (that is Step 2, and all the subsequent computations in the remaining steps) should be undertaken

For values of CR ≤ 0.10 the decision maker's ratings are relatively consistent and the AHP method can be used for making a decision.