Chapter 5: Modeling and Analysis

- Major component
- the model base and its management
- *Caution*
  - Familiarity with major ideas
  - Basic concepts and definitions
  - Tool--the influence diagram
  - Modeling directly in spreadsheets

- **Structure of some successful models and methodologies**
  - **decision analysis**
  - **decision trees**
  - **optimization**
  - **heuristic programming**
  - **simulation**
- **New developments in modeling tools and techniques**
- **Important issues in model base management.**

5.1 Opening Vignette: Siemens Solar Industries Saves Millions by Simulation

- **Clean room contamination-control technology**
- **No experience**
- **Use simulation: a virtual laboratory**
- **Major benefit: knowledge and insight**
- **Improved the manufacturing process**

Saved SSI over $75 million each year

5.2 Modeling for MSS

- Modeling
- Key element in most DSS
- A *necessity* in a model-based DSS
- Frazee Paint Company (Appendix A
- Three model types
  1. Statistical model (regression analysis)
  2. Financial model
  3. Optimization model
- *Several models*
- *Standard*
- *Custom made*

Major Modeling Issues

- Problem identification
- Environmental analysis
- Variable identification
- Forecasting
- Multiple model use
- Model categories (or selection) [Table 5.1]
- Model management
- Knowledge-based modeling

TABLE 5.1 Categories of Models.

Category	Process and Objective	Representative Techniques
Optimization of problems with few alternatives (Section 5.7)	Find the best solution from a relatively small number of alternatives	Decision tables, decision trees
Optimization via algorithm (Section 5.8)	Find the best solution from a large or an infinite number of alternatives using a step-by-step improvement process	Linear and other mathematical programming models, network models
Optimization via analytical formula (Sections 5.8, 5.12)	Find the best solution, in one step, using a formula	Some inventory models
Simulation (Section 5.10, 5.15)	Finding "good enough" solution, or the best among those alternatives checked, using experimentation	Several types of simulation
Heuristics (Section 5.9)	Find "good enough" solution using rules	Heuristic programming, expert systems
Other models	Finding "what-if" using a formula	Financial modeling, waiting lines
Predictive models (Web Page)	Predict future for a given scenario	Forecasting models, Markov analysis

5.3 Static and Dynamic Models

- **Static Analysis**
  - Single snapshot
- **Dynamic Analysis**
  - Dynamic models
  - Evaluate scenarios that change over time
  - Are *time dependent*
  - Show *trends* and patterns over time
  - Extended static models

5.4 Treating Certainty, Uncertainty, and Risk

- Certainty Models
- Uncertainty
- Risk

5.5 Influence Diagrams

- **Graphical representations of a model to assist in model design, development and understanding**
- **Provide visual communication to the model builder or development team**
- **Serve as a framework for expressing the MSS model relationships**

Rectangle = a decision variable

Circle = uncontrollable or intermediate variable

Oval = result (outcome) variable: intermediate or final

Variables connected with arrows

Example in Figure 5.1

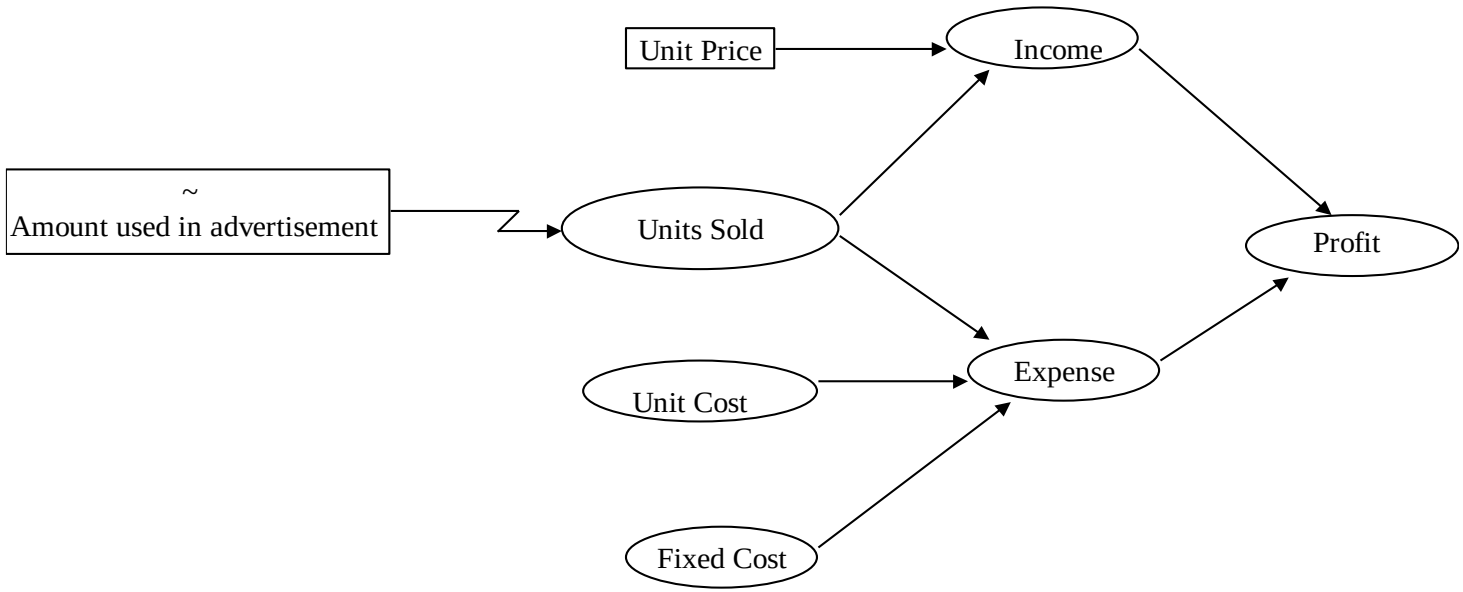

FIGURE 5.1 An Influence Diagram for the Profit Model.

5.6 MSS Modeling in Spreadsheets

- (Electronic) spreadsheet: most popular *end-user modeling tool*
- Powerful financial, statistical, mathematical, logical, date/time, string functions
- External add-in functions and solvers
- Important for analysis, planning, modeling
- Programmability (macros)

- What-if analysis
- Goal seeking
- Seamless integration
- Microsoft Excel
- Lotus 1-2-3
- Figure 5.2: Simple loan calculation model (static)
- Figure 5.3: Dynamic

5.7 Decision Analysis of Few Alternatives (Decision Tables and Trees)

- **Single Goal Situations**
  - **Decision tables**
  - **Decision trees**

Decision Tables

- **Investment Example**
- **One goal: Maximize the yield after one year**
- **Yield depends on the status of the economy**
- **(the *state of nature*)**
  - **Solid growth**
  - **Stagnation**
  - **Inflation**

1. If there is solid growth in the economy, bonds will yield 12 percent; stocks, 15 percent; and time deposits, 6.5 percent
2. If stagnation prevails, bonds will yield 6 percent; stocks, 3 percent; and time deposits, 6.5 percent
3. If inflation prevails, bonds will yield 3 percent; stocks will bring a loss of 2 percent; and time deposits will yield 6.5 percent

View problem as a two-person game

- **Payoff Table 5.2**
  - **Decision variables (the alternatives)**
  - **Uncontrollable variables (the states of the economy)**
  - **Result variables (the projected yield)**

TABLE 5.2 Investment Problem Decision Table Model.

	States of Nature (Uncontrollable Variables)		
Alternative	**Solid Growth**	**Stagnation**	**Inflation**
Bonds	**12.0%**	**6.0%**	**3.0%**
Stocks	**15.0%**	**3.0%**	**- 2.0%**
CDs	**6.5%**	**6.5%**	**6.5%**

Treating Uncertainty

- **Optimistic approach**
- **Pessimistic approach**

Treating Risk

- **Use known probabilities (Table 5.3)**
- **Risk analysis: Compute *expected values***
- **Can be dangerous**

TABLE 5.3 Decision Under Risk and Its Solution.

Alternative	Solid Growth 0.50	Stagnation 0.30	Inflation 0.20	Expected Value
Bonds	12.0%	6.0%	3.0%	8.4% (Max)
Stocks	15.0%	3.0%	- 2.0%	8.0%
CDs	6.5%	6.5%	6.5%	6.5%

- **Decision Trees**
- **Other Methods of Treating Risk**
  - **Simulation**
  - **Certainty factors**
  - **Fuzzy logic.**
- **Multiple Goals**
- **Table 5.4: Yield, safety, and liquidity**

TABLE 5.4 Multiple Goals.

Alternatives	Yield	Safety	Liquidity
Bonds	8.4%	High	High
Stocks	8.0%	Low	High
CDs	6.5%	Very High	High

TABLE 5.5 Discrete versus Continuous Probability Distributions.

	Discrete	Continuous
Daily Demand	**Probability**	
5	**0.10**	**Normally**
6	**0.15**	**distributed with**
7	**0.30**	**a mean of**
8	**0.25**	**7 and a standard**
9	**0.20**	**deviation of 1.2**

5.8 Optimization via Mathematical Programming

- **Linear programming (LP) used extensively in DSS**
- **Mathematical Programming**

  Family of tools to solve managerial problems in allocating scarce resources among various activities to optimize a measurable goal

LP Allocation Problem Characteristics

1. Limited quantity of economic resources
2. Resources are used in the production of products or services.
3. Two or more ways (solutions, programs) to use the resources
4. Each activity (product or service) yields a return in terms of the goal
5. Allocation is usually restricted by constraints

LP Allocation Model

- **Rational Economic Assumptions**
  1. **Returns from different allocations can be compared in a common unit**
  2. **Independent returns**
  3. **Total return is the sum of different activities' returns**
  4. **All data are known with certainty**
  5. **The resources are to be used in the most economical manner**
- **Optimal solution: the best, found algorithmically**

Linear Programming

- Decision variables
- Objective function
- Objective function coefficients
- Constraints
- Capacities
- Input-output (technology) coefficients

5.9 Heuristic Programming

- Cuts the search
- Gets *satisfactory* solutions more quickly and less expensively
- Finds rules to solve complex problems
- Heuristic programming finds feasible and "good enough" solutions to some complex problems
- Heuristics can be
  - Quantitative
  - Qualitative (in ES)

When to Use Heuristics

1. Inexact or limited input data
2. Complex reality
3. Reliable, exact algorithm not available
4. Simulation computation time too excessive
5. To improve the efficiency of optimization
6. To solve complex problems
7. For symbolic processing
8. For solving when quick decisions are to be made

Advantages of Heuristics

1. Simple to understand: easier to implement and explain
2. Help train people to be creative
3. Save formulation time
4. Save programming and storage requirements on the computers
5. Save computer running time (speed)
6. Frequently produce multiple acceptable solutions
7. Usually possible to develop a measure of solution quality
8. Can incorporate intelligent search
9. Can solve very complex models

Limitations of Heuristics

1. Cannot guarantee an optimal solution
2. There may be too many exceptions
3. Sequential decision choices can fail to anticipate future consequences of each choice
4. Interdependencies of subsystems can influence the whole system

- Heuristics successfully applied to vehicle routing

5.10 Simulation

- **A *technique for conducting experiments with a computer on a model of a management system***
- **Frequently used DSS tool**
- **Major Characteristics of Simulation**
  - **Simulation *imitates* reality and capture its richness**
  - **Simulation is a technique for *conducting experiments***
  - **Simulation is a *descriptive* not normative tool**
  - **Simulation is often used to solve very complex, risky problems**

Advantages of Simulation

1. Theory is straightforward
2. *Time compression*
3. Descriptive, not normative
4. Intimate knowledge of the problem forces the MSS builder to interface with the manager
5. The model is built from the manager's perspective
6. No generalized understanding is required of the manager. Each model component represents a real problem component

7. Wide variation in problem types
8. Can experiment with different variables
9. Allows for real-life problem complexities
10. Easy to obtain many performance measures directly
11. Frequently the only DSS modeling tool for handling nonstructured problems
12. Monte Carlo add-in spreadsheet packages (@Risk)

Limitations of Simulation

1. Cannot guarantee an optimal solution
2. Slow and costly construction process
3. Cannot transfer solutions and inferences to solve other problems
4. So easy to sell to managers, may miss analytical solutions
5. Software is not so user friendly

Simulation Methodology

- **Set up a model of a real system and conduct repetitive experiments**
  1. **Problem Definition**
  2. **Construction of the Simulation Model**
  3. **Testing and Validating the Model**
  4. **Design of the Experiments**
  5. **Conducting the Experiments**
  6. **Evaluating the Results**
  7. **Implementation**

Simulation Types

- **Probabilistic Simulation**
  - ***Discrete distributions***
  - ***Continuous distributions***
  - **Probabilistic simulation via Monte Carlo technique**
  - **Time Dependent versus Time Independent Simulation**
  - **Simulation Software**
  - **Visual Simulation**
  - **Object-oriented Simulation**

5.11 Multidimensional Modeling

- From a spreadsheet and analysis perspective
- 2-D to 3-D to multiple-D
- Multidimensional modeling tools: 16-D +
- Multidimensional modeling: four views of the same data (Figure 5.5)
- Tool can compare, rotate, and "slice and dice" corporate data across different management viewpoints

5.12 Visual Spreadsheets

- User can visualize the models and formulas using influence diagrams
- Not cells, but symbolic elements (Figure 5.6)
- English-like modeling

5.13 Financial and Planning Modeling

- **Special tools to build usable DSS rapidly, effectively, and efficiently**
- **The models are *algebraically* oriented**

Definition and Background of Planning Modeling

- Fourth generation programming languages
- Models written in an English-like syntax
- Models are self-documenting
- Model steps are nonprocedural
- Examples
  - Visual IFPS / Plus
  - ENCORE Plus!
  - SORITEC
  - Some are embedded in EIS and OLAP tools

- **Major differences between financial modeling-based tools and DBMS-based tools (Table 5.6)**
- **Visual IFPS/Plus model from the influence diagram model in Figure 5.1 (Figure 5.7)**
- **List of typical applications of planning models (DSS In Focus 5.6).**

TABLE 5.6 Comparison of Financial Modeling Generators with Those Based Around DBMS.

	Major Advantages (Strong Points)	Major Disadvantages (Weak Points)
Financial Modeling-based tools	Financial reporting (and consolidations with some systems) Forecasting Sensitivity analysis Usually easier to learn for financial people Many built-in financial and statistical routines	Limited sorting with older two-dimensional packages Limited data entry Limited handling of text with data Some systems are two-dimensional and require DBMS for consolidation
DBMS-based tools	Data (record)-oriented Best text handling Best sort/merge Data integrity Strong in ad hoc, unstructured queries and analysis	Cumbersome with time- series problems Cumbersome with multidimensional applications (multiple "passes" of the data required) Cumbersome in sensitivity analysis applications

***Source*: Developed by Neil Dorf, Xerox Corporation, Los Angeles, CA.**

```
COLUMNS 2000..2010
\Model to show relationships among variables
\
\ Annual Result Variable:
PROFIT = INCOME - EXPENSE
\
\ Decision Variable:
AMOUNT USED IN ADVERTISEMENT = 10000, PREVIOUS * 1.1
\
\ Intermediate Result Variables:
INCOME = UNITS SOLD * UNIT PRICE
EXPENSE = UNITS COST * UNIT PRICE + FIXED COST

\
UNITS SOLD = .5 * AMOUNT USED IN ADVERTISEMENT
\
\ Initial Data:
UNIT COST = 10, PREVIOUS * 1.05
UNIT PRICE = 20, PREVIOUS * 1.07
FIXED COST = 50000, PREVIOUS * .5, PREVIOUS * .9
\
\ To Complete the Model, we normally would take a Net Present Value
Calculation:
DISCOUNT RATE = 8%
NET PRESENT VALUE PROFIT = NPVC(INCOME, DISCOUNT RATE,
EXPENSE)
```

FIGURE 5.7 IFPS Model and Solution of the Profit Model Shown in the Influence Diagram in Figure 5.1. The model has been expanded to include expressions for the unknown initial data and for the decision variable.

DSS In Focus 5.6: Typical Applications of Planning Models

Financial forecasting	**Manpower planning**
Pro forma financial statements	**Profit planning**
Capital budgeting	**Sales forecasting**
Market decision making	**Investment analysis**
Mergers and acquisitions analysis	**Construction Scheduling**
Lease versus purchase decisions	**Tax Planning**
Production scheduling	**Energy requirements**
New venture evaluation	**Labor contract negotiation fees**
Foreign currency analysis	

5.14 Visual Modeling and Simulation

- Visual interactive modeling (VIM) (DSS In Action 5.8)
- Also called:
  - Visual interactive problem solving
  - Visual interactive modeling
  - Visual interactive simulation

- Use computer graphics to present the impact of different management decisions.
- Users perform sensitivity analysis
- Static or a dynamic (animation) systems (Example: Figure 5.8)

Visual Interactive Simulation (VIS)

- Decision makers interact with the simulated model and watch the results over time
- Visual Interactive Models and DSS
  - VIM (Case Application W5.1 on the Book's Web Site)
  - Queuing

5.15 Ready-made Quantitative Software Packages

- Preprogrammed models can expedite the programming time of the DSS builder
- Some models are building blocks of other quantitative models
  - Statistical Packages
  - Management Science Packages
  - Financial Modeling
  - Other Ready-Made Specific DSS (Applications)
  - including spreadsheet add-ins

TABLE 5.7 Representative Ready-made Specific DSS

Name of Package	Vendor	Description
AutoMod, AutoSched	AutoSimulations Bountiful, UT http://www.autosim.com	3 D walk-through animations for manufacturing and material handling; Manufacturing scheduling
Budgeting & Reporting	Helmsman Group, Inc. Plainsboro, NJ http://www.helmsmangroup.com	Financial data warehousing
FACTOR/AIM PACKAGING	Pritsker Corp. Indianapolis, IN http://www.pritsker.com	Manufacturing simulator with costing capabilities, High speed/high volume food and beverage industry simulator
MedModel, ServiceModel	ProModel Corp. Orem, UT http://www.promodel.com	Healthcare simulation, Service industry simulation
OIS	Olsen & Associates Ltd. Zürich, Switzerland http://www.olsen.ch	Directional forecasts, trading models, risk management
OptiPlan Professional, OptiCaps, OptiCalc	Advanced Planning Systems, Inc. Alpharetta, GA	Supply chain planning

PLANNING WORKBENCH	**Proasis Ltd. Chislehurst, Kent, England http://www.proasis.co.uk**	**Graphically-based planning system for the process industry**
StatPac Gold	**Stat Pac Inc. Edina, MN**	**Survey analysis package**
TRAPEZE	**Trapeze Software Group Mississauga, ON http://www.trapsoft.com**	**Planning, scheduling and operations**
TruckStops, OptiSite, BUSTOPS	**MicroAnalytics, Inc. Arlington, VA**	**Distribution management and transportation**

5.16 Model Base Management

- MBMS: capabilities similar to that of DBMS
- But, there are no comprehensive model base management packages
- Each organization uses models somewhat differently
- There are many model classes
- Some MBMS capabilities require expertise and reasoning

Desirable Capabilities of MBMS

- Control
- Flexibility
- Feedback
- Interface
- Redundancy Reduction
- Increased Consistency

MBMS Design Must Allow the DSS User to

1. Access and retrieve existing models.
2. Exercise and manipulate existing models
3. Store existing models
4. Maintain existing models
5. Construct new models with reasonable effort

- **Modeling Languages**
- **Relational MBMS**
- **Object-oriented Model Base and Its Management**
- **Models for Database and MIS Design and their Management**
- **Enterprise and Business Process Reengineering Modeling and Model Management Systems**

SUMMARY

- Models play a major role in DSS
- Models can be static or dynamic.
- Analysis is under assumed certainty, risk, or uncertainty
  - Influence diagrams
  - Electronic spreadsheets
  - Decision tables and decision trees
- Optimization tool: mathematical programming

SUMMARY (cont'd.)

- **Linear programming: economic-base**
- **Heuristic programming**
- **Simulation**
- **Simulation can deal with more complex situations**
- **Expert Choice**
- **Forecasting methods**
- **Multidimensional modeling**

SUMMARY (cont'd.)

- **Built-in quantitative models (financial, statistical)**
- **Special financial modeling languages**
- **Visual interactive modeling**
- **Visual interactive simulation (VIS)**
- **Spreadsheet modeling and results in influence diagrams**
- **MBMS are like DBMS**
- **AI techniques in MBMS**

Questions for the Opening Vignette

1. Explain how simulation was used to evaluate a nonexistent system.
2. What was learned, from using the simulation model, about running the clean room?
3. How could the time compression capability of simulation help in this situation?
4. How did the simulation results help the SSI engineers learn about their decision making problem? Were they able to focus better on the structure of the real system? How did this save development and operating costs of the real clean room?

Debate

- **Some people believe that managers do not need to know the internal structure of the model and the technical aspects of modeling. “It is like the telephone or the elevator, you just use it.” Others claim that this is not the case and the opposite is true. Debate the issue.**

Class Exercises

- **3. Everyone in the class Write your weight, height and gender on a piece of paper (no names please!).**
- **Create a regression (causal) model for height versus weight for the whole class, and one for each gender.**
- **If possible, use a statistical package and a spreadsheet and compare their ease of use.**
- **Produce a scatterplot of the three sets of data.**
- **Do the relationships appear linear?**

- **How accurate were the models (R^2)?**
- **Does weight *cause* height; does height *cause* weight; or does neither really *cause* the other? Explain?**
- **How can a regression model like this be used in building design; diet / nutrition selection? in a longitudinal study (say over 50 years) in determining whether students are getting heavier and not taller, or vice-versa?**

- **6. DSS generators are English-like and have a variety of analysis capabilities.**
  - **a. Identify the purpose and the analysis capabilities of the following IFPS program:**
- **MODEL FIRST**

```
COLUMNS 1-5
INVESTMENT = LAND + BUILDING
RETURN = SALES - COSTS
PRESENT VALUE = NPVC(RETURN, DISCOUNT RATE,
   INVESTMENT)
INTERNAL RATE OF RETURN = IRR(RETURN, INVESTMENT)
\ INPUT DATA
LAND = 200, 0
BUILDING = 100, 150, 0
SALES = 500, PREVIOUS + 100
COSTS = SUM(MATERIALS THRU LABOR)
MATERIALS = 10 + 0.20 * SALES
OVERHEAD = .10 * SALES
LABOR = 20 + 0.40 * SALES
DISCOUNT RATE = 0.20, PREVIOUS
```

- **b. Change sales to be under assumed risk, that is, replace the SALES line and insert a line following it:**
  - **9 SALES = NORRANDR(EXPECTED SALES, EXPECTED SALES/10)**
  - **EXPECTED SALES = 500, PREVIOUS + 100**
- **and use**
  - **MONTE CARLO 200**
  - **COLUMNS 5**
  - **HIST PRESENT VALUE, INTERNAL RATE OF RETURN**
  - **FREQ PRESENT VALUE, INTERNAL RATE OF RETURN**
  - **NONE**
- **What do these statements do to this new model?**

- **12. Use the Expert Choice software to select your next car. Evaluate cars on ride (from poor to great), looks (from attractive to ugly), and acceleration (seconds per first 50 yards).**
  - **Consider three final cars on your list. Develop:**
  - **a. Problem hierarchy**
  - **b. Comparison of the importance of the criteria against the goal**
  - **c. Comparison of the alternative cars for each criterion**
  - **d. An overall ranking (synthesis of leaf nodes with respect to goal)**

- **e. A sensitivity analysis.**
- **Maintain the inconsistency index lower than 0.1. If you initially had an inconsistency index greater than 0.1, what caused it to be that high? Would you really buy the car you selected? Why or why not?**
- **Also develop a spreadsheet model using estimated weights and estimates for the intangible items, each on a scale from 1-10 for each car.**
- **Compare the conclusions reached with this method to those found in using the Expert Choice Model. Which one more accurately captures your judgments and why?**

- **14. Job Selection Using Expert Choice. You are on the job market (use your imagination, if necessary). List the names of four or five different companies that have offered you a job (or from which you expect to get an offer). (As an alternative, your instructor may assign Graduate or Undergraduate Program Selection.)**

- **Write down all the factors that may influence your decision as to which job offer you will accept. Such factors may include but need not be limited to geographic location, salary, benefits, taxes, school system (if you have children), and potential for career advancement. Some of these factors (criteria, attributes) may have sub-criteria. For instance, location may be sub-divided further into climate, urban concentration, cost of living, etc.**

- **If you, in fact, do not yet have a dollar salary figure associated with a job offer, you should just guess a "reasonable" figure. Perhaps your classmates can help you in determining realistic figures.**

- **a. Model this problem in a spreadsheet (Excel) using some kind of *Weighted Average Methodology* [you set the criteria weights first] (see the current Rand-McNally *Places Rated Almanac* for an example).**
- **b. Construct an Expert Choice model for your decision problem, and use the pairwise comparisons to arrive at the "best" job opportunity.**
- **c. Compare the two approaches. Did they yield the same results? Why or why not?**

- **d. Write a short report (one or two typed pages) explaining the results including those of the Weighted Average Methodology, and for Expert Choice: each criterion, sub-criterion (if any) and alternative. Describe (briefly) which options and capabilities of Expert Choice you used in your analysis, and show the numerical results of your analysis. To this purpose, you may want to include printouts of your AHP tree, but make sure you circle and explain the parts of interest on these printouts. Discuss the nature of the tradeoffs you encountered during the evaluation process. You may want to include a (meaningful) sensitivity analysis of the results, but this is optional (for this assignment).**

- ***To think about:*** **Was the Expert Choice analysis helpful in structuring your preferences? Do you think it will be a helpful aid in your actual decision making process? Comment on all these issues in your report.**

Term Paper

- **Select a current DSS technology or methodology. Write up a 5 page report detailing the origins of the technology, what need prompted the development of the technology, and what the future holds for it over the next 2, 5 and 10 years. Use electronic sources, if possible, to identify companies providing the technology. If demo software is available, acquire it and include a sample run in your paper**