Modeling and Analysis

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Modeling and Analysis

Learning objectives:

- Understand the basic concepts of ***management support system*** (***MSS***) modeling
- Describe how ***MSS*** models interact with data and user
- Understand some different well-known model classes
- Understand how to structure decision making with a few alternatives
- Describe how spreadsheets can be used for ***MSS*** modeling and solution
- Explain the basic concepts of optimization, simulation, and heuristics, and when to use them
- Describe how to structure a linear programming model
- Understand how search methods are used to solve ***MSS*** models
- Explain the differences among algorithms, blind search, and heuristics
- Describe how to handle multiple goals
- Explain what is meant by sensitivity analysis, what-if analysis, and goal seeking
- Describe the key issues of model management

Management support system modeling

Modeling is a key element in most DSS and a necessity in a model-based ***DSS***. There are many classes of models, and there are often many specialized techniques for solving each one. ***Simulation*** is a common modeling approach, but there are several others:

- A ***general model***, based on an **algorithm** (for example to make transportation-cost estimates). This model is programmed directly into the ***DSS***.
- A ***demand-forecasting model*** (statistics based).
- A ***distribution*** center location ***model***. This model uses aggregated data (a special modeling technique) and is solved with a standard linear/integer optimization package.
- A ***transportation model*** (i.e. a specialization of a linear programming model) to determine the best shipping option from sources to distribution centers (fed to it from the previous model) and hence to customers. This model is solved using commercial software and is loosely integrated with the distribution location model. The ***DSS*** must interface with commercial software and integrate the model.
- A *financial* and *risk* ***simulation model*** that takes into consideration some qualitative factors that require important human judgment.
- A ***geographical information system*** (*GIS*; effectively a graphical model of the data) for a user interface.

Some major modeling issues

1. Identification of the problem and Environmental Analysis

An important aspect of the environmental analysis is environmental scanning and analysis, which is the monitoring, scanning, and interpretation of collected information. No decision is made in a vacuum. It is important to analyze the scope of the domain and the forces and dynamics of the environment. A decision maker needs to identify the organizational culture and the corporate decision-making process. It is entirely possible that environmental factors have created the current problem. The problem must be understood, and everyone involved should share the same frame of understanding because the problem will ultimately be represented by the model in one form or another. Otherwise, the model will not help the decision maker.

2. Variable identification

Identification of a model's variables is critical, as are relationships of the variables. Influence diagrams, which are graphical models of mathematical models, can facilitate the identification process. A more general form of an influence diagram, a cognitive map, can help a decision maker develop a better understanding of a problem, especially of variables and their interactions.

3. Forecasting – Predictive Analytics

Forecasting is predicting the future. This form of predictive analytics is esential for construction and manipulating models because when a decision is implemented, the results usually occur in the future. Whereas DSS are typically designed to determine what will be, traditional MIS report what is or what was. There is no point in running a what-if (sensitivity) analysis on the past because decisions made then have no impact in the future. Forecasting is getting easier as software vendors automate many of the complications of developing such models. Forecasting system that incorporates its predictive analytics technology, ideally for retailers. This software iss more automated than most other forecasting packages.

4. Multiple Models

A DSS can include several models which represents a different part of the decision-making problem (for example P&G supply-chain DSS includes a location model to locate distribution center, a product-strategy model, a demand-forecasting model, a cost generation model, a financial- and risk-simulation model, and even a GIS model).

5. Model Categories

There are seven groups of DSS models. Each category can be applied to either a static or a dynamic model, which can be constructed under assumed environments of certainty, uncertainty, or risk. To expedite model construction, we can use special decision analysis systems that have modeling languages and capabilities embedded in them. These includes spreadsheets, data mining systems, OLAP systems, and even fourth-generation languages (formerly financial planning languages).

… 5. Model Categories

Category	Process and Objectives	Representative Techniques
Optimization of problems with few alternatives	Find the best solution from a small number of alternatives	Decision tables, decision tree
Optimization via algorithm	Find the best solution from a large number of alternatives, using a step-by-step improvement process	Linear programming models, network models
Optimization via an analytic formula	Find the best solution in one step, using a formula	Some inventory models
Simulation	Finding a good enough solution or the best among the alternatives checked, using experimentation	Several types of simulation
Heuristics	Find a good enough solution, using rules	Heuristic programming, expert systems
Predictive models	Predict the future for a given scenario	Forecasting models, Markov analysis
Other models	Solve a what-if case, using a formula	Financial modeling, waiting lines

6. Model Management

Models, like data, must be managed to maintain their integrity and thus their applicability. Such management is done with the aid of the ***model base management systems*** (MBMS), which are analogous to ***database management systems*** (DBMS) .

7. Knowledge-Based Modeling

DSS uses mostly quantitative models, whereas expert systems use qualitative, knowledge-based models in their applications. Some knowledge is necessary to construct solvable (and therefore usable) models. We defer the description of knowledge-based models until later chapters.

8. Current Trends in Modeling

One recent trend in modeling involves the development of model libraries and solution technique libraries. Some of these codes can be run directly on the owner's web server for free, and others can be downloaded and run on an individual's PC, Unix machine, or server. The availability of these codes means that powerful optimization and simulation package are available to decision makers who may have only experienced these tools from the perspective of classroom problems.

There is a clear trend toward developing and using Web tools and software to access and even run software to perform modeling, optimization, simulation, and so on. This has, in many ways, simplified the application of many models to real-world problems. Another trend, involves the lack of understanding of what models and their solutions can do in the real world.

There is a continuing trend toward making MSS models completely transparent to decision maker. For example, multidimensional analysis (modeling) involves data analysis in several dimensions.

There is also a trend to model a model to help in its analysis. An influence diagram is a graphical representation of a model; that is, it is a model of a model. Some influence diagram software packages are capable of generating and solving the resultant model.

Static and Dynamic Models

Dss models can be classified as ***static*** or ***dynamic***:

Static Analysis:

A ***static model*** takes a single snapshot of a situation. During this snapshot, everything occurs in a single interval. For example, a decision about whether to make or buy a product is static in nature.

Dynamic Analysis:

Dynamic models represent scenarios that change over time. For example, a 5-years profit-and-loss projections in which the input data (costs, prices, and quantities) change from year to year. ***Dynamic models*** are ***time dependent***. ***Dynamic models*** use, represent, or generate trends and patters over time, show averages per periods, moving averages, and comparative analyses. When a static model is constructed to describe a given situation, it can be expanded to represent the dynamic nature of the problem.

Certainty, Uncertainty, and Risk

Decision making process involves evaluating and comparing alternatives. During the process, it is necessary to predict the future outcome of each proposed alternative. Decision situation are often classified on the basis of what the decision maker knows or believes about the forecasted result. We customarily classify this knowledge into three categories, ranging from complete knowledge to total ignorance:

- Certainty
- Risk
- Uncertainty

When we are develop models, any of these conditions can occur, and different kind of models are appropriate for each case.

Increasing knowledge ←

Complete knowledge certainly	Risk	Ignorance, total uncertainly

→ Decreasing knowledge

Decision making under certainty

In decision making under certainty, it is assumed that complete knowledge is available – the decision maker knows exactly what the outcome of *each course of action* will be (a deterministic environment).

The decision maker is viewed as a perfect predictor on the future.

Certainly models are relatively easy to develop and solve, and they can yield optimal solution.

Decision making under uncertainty

In decision making under uncertainty, the decision maker considers situations in which several outcomes are possible for each course of action. The decision maker does not know, or cannot estimate, the probability of occurrence of the possible outcomes.

The problem, in this case, is more difficult because there is insufficient information – modeling involves assessment of the decision maker's attitude toward risk.

Decision making under risk

In decision made under risk (*a probabilistic or stochastic decision-making situation*), is one in which the decision maker must consider several possible outcomes for each alternative, each with a given probability of occurrence.

The decision maker can asses the degree of risk associated with each alternative (**calculated** risk).

Risk analysis is a decision-making method that analyzes the risk (based on assumed known probabilities) associated with different alternatives.

Risk analysis can be performed by calculating the expected value of each alternative and ***selecting*** the one with the ***best expected value***.

Management Support Systems Modeling with Spreadsheets

Models can be developed and implemented in a variety of programming languages and systems: from third-, fourth-, and fifth-generation to computer aided software engineering (CASE) systems and other systems that automatically generate usable software. We focus primarily on spreadsheets, model languages, and transparent data analysis tools – the most popular *end-user modeling tool*.

Spreadsheets include extensive statistical, forecasting, and other modeling and database management capabilities, functions, and routines (***Solver, What's Best, Braincel, NeuralTools, Evolver, @Risk***).

Loan Calculation Model	
Loan Amount	$150,000
Interest Rate	8.00%
Number of Years	30
Number of Month	360
Interest Rate/Month	0.67%
Monthly Loan Payment	-$1,100.65

Dynamic Model

		$100.00		
Month	Normal Paym.	Prepay Amount	Total Payment	Principale Owed
0				$150,000
1	$1,100.65	$100.00	$1,200.65	$149,799.35
2	$1,100.65	$100.00	$1,200.65	$149,597.37
3	$1,100.65	$100.00	$1,200.65	$149,394.04
4	$1,100.65	$100.00	$1,200.65	$149,189.35
5	$1,100.65	$100.00	$1,200.65	$148,983.30

5. Decision Tables

Decision tables organize information and knowledge in a systematic, tabular manner to prepare it for analysis.

<u>Example.</u>

An investment company is considering investing in one of three alternatives: *bonds*, *stocks*, or *certificates of deposit* (*CDs*). The company is interested in one goal: maximizing the yield on the investment after one year. If it were interested in other goals, such as safety or liquidity, the problem would be classified as one of *multi-criteria decision analysis*.

The yield depends on the state of the economy sometime in the future (called the *state of nature*), which can be in solid growth, stagnation, or inflation. Experts estimated the following annual yields:

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

The problem is to select the one best investment alternative. These are assumed to be discrete alternatives.

The investment decision-making problem can be viewed as a *two-person game*. the investor makes a choice (a move), and then a state of nature occurs (makes a move). The next table shows the payoff of a mathematical model. The table includes *decision variables* (*the alternatives*), *uncontrollable variables*, and result variables (the project yields).

Investment Problem Decision Table Model			
	State of Nature (Uncontrollable Variables)		
Alternative	*Solid Growth*	*Stagnation*	*Inflation*
Bonds (Obligat.)	12.0%	6.0%	3.0%
Stocks (Actiuni)	15.0%	3.0%	-2.0%
CDs (Cert. Dep.)	6.5%	6.5%	6.5%

Treating Uncertainty

There are several methods of handling uncertainty:

- The *optimistic approach* assumes that the best possible outcome of each alternative will occur and then selects the best of the best (*Stocks*).
- The *pessimistic approach* assumes that the worst possible outcome for each alternative will occur and selects the best of these (*CDs*).
- Another approach simply assumes that ***all states of nature are equally possible***.
- The problem can be treated under assumed certainty or risk.

Alternative	*Solid Growth*	*Stagnation*	*Inflation*
Bonds (Obligat.)	12.0%	6.0%	3.0%
Stocks (Actiuni)	15.0%	3.0%	-2.0%
CDs (Cert. Dep.)	6.5%	6.5%	6.5%

Treating Risk

The most common method for solving this risk analysis problem is to select the alternative with the greatest expected value.

Assume that the experts estimate the chance of *solid growth* at 50%, the chance of *stagnation* at 30%, and the chance of *inflation* at 20%. The decision table is then rewritten with the known probabilities (see next table). An ***expected value*** is computed by multiplying the results (*outcomes*) by their respective probabilities and adding them. For example, *investing in bonds* yields an expected return of 12(0,5)+6(0.3)+3(0.2)=8.4%. (This approach can be a dangerous strategy!)

Decision Under Risk and its Solution

Alternative	*Solid Growth* 50.0%	*Stagnation* 30.0%	*Inflation* 20.0%	*Expected Value*
Bonds	12.0%	6.0%	3.0%	8.4%
Stocks	15.0%	3.0%	-2.0%	8.0%
CDs	6.5%	6.5%	6.5%	6.5%

6. Decision Trees

An alternative representation of the *decision table* is a ***decision tree*** (see *Mind Tools*).

A decision tree shows the relationships of the problem graphically and can handle complex situations in a compact form.

A decision tree can be cumbersome (*ancombrant*) if there are many alternatives or states of nature.

Tree Age Pro and *Precision Tree* include powerful, intuitive, and sophisticated decision tree analysis systems.

These vendors also provide excellent examples of decision tree used in practice (psychwww.com/mtsite/dectree.html **?**).

A simplified investment case of multiple goals (a decision situation in which alternatives are evaluated with several, sometimes conflicting, goal) is shown in next table.

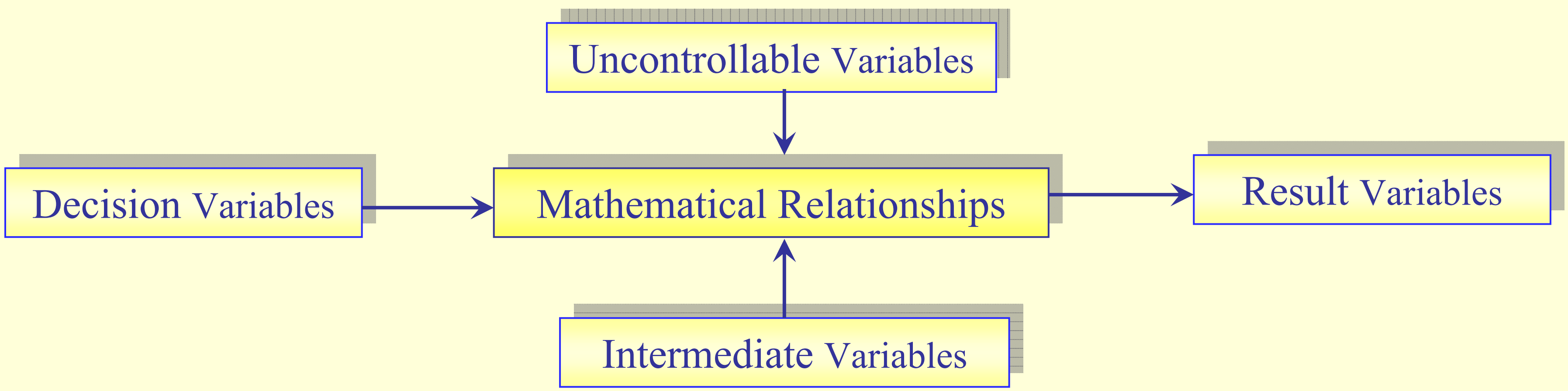
Multiple Goals			
Alternative	*Yield*	*Safety*	*Liquidity*
Bonds	8.4%	High	High
Stocks	8.0%	Low	High
CDs	6.5%	Very High	High

The three **goals** (**criteria**) are ***yield, safety, liquidity***. This situation is under assumed certainty; that is, only one possible consequence is projected for each alternative; the more complex cases of risk or uncertainty could be considered. some of the results are qualitative (e.g. *low*, *high*) rather than numeric.

7. The structure of Mathematical Models for Decision Support

The Components of decision Support Mathematical Models

All models are made up of four components: result, decision, uncontrollable, and intermediate result variables:



Mathematical Relationships link these components together. The modeling process involves identifying the variables and relationships among them. Solving a model determines the values of these and the result variables.

Result (Outcome) Variables

Result (outcome) variables reflect the level of effectiveness of a system; that is, they indicate how well the system performs or attains its goal.

Result variables (outputs) are considered *dependent variables*.

Intermediate result variables are sometimes used in modeling to identify intermediate outcomes.

In the case of a *dependent variable*, another event must occur first before the event described by the variable can occur.

Result variables depend on the occurrence of the *decision variables* and the *uncontrollable variables*.

… The Components of decision Support Mathematical Models

… Result (Outcome) Variables

Examples of the Components of Models			
Area	***Decision Variables***	***Result Variables***	***Uncontrollable Variables and Parameters***
Financial investment	Investment alternatives and amounts	Total profit, risk Rate of return of investment Earnings per share Liquidity level	Inflation rate Prime rate Competition
Marketing	Advertising budget Where to advertise	Market share Customer satisfaction	Customer's income Competitor's actions
Manufacturing	What and how much to produce Inventory levels Compensation programs	Total cost Quality level Employee satisfaction	Machine capacity Technology Materials prices
Accounting	Use of computers Audit schedule	Data processing cost Error rate	Computer technology Tax rates Legal requirements
Transportation	Shipments schedules Use smart cards	Total transport cost Payment float time	Delivery distance Regulations
Services	Staffing levels	Customer satisfaction	Demand for services

Decision Variables

Decision variables describe alternative courses of action.

The decision maker controls the decision variables.

For example, for an investment problem, the amount to invest in bonds is a decision variable.

In a scheduling problem, the decision variables are people, times, and schedule.

Other examples are listed in the next table.

… Decision Variables

Examples of the Components of Models			
Area	***Decision Variables***	***Result Variables***	***Uncontrollable Variables and Parameters***
Financial investment	Investment alternatives and amounts	Total profit, risk Rate of return of investment Earnings per share Liquidity level	Inflation rate Prime rate Competition
Marketing	Advertising budget Where to advertise	Market share Customer satisfaction	Customer's income Competitor's actions
Manufacturing	What and how much to produce Inventory levels Compensation programs	Total cost Quality level Employee satisfaction	Machine capacity Technology Materials prices
Accounting	Use of computers Audit schedule	Data processing cost Error rate	Computer technology Tax rates Legal requirements
Transportation	Shipments schedules Use smart cards	Total transport cost Payment float time	Delivery distance Regulations
Services	Staffing levels	Customer satisfaction	Demand for services

Uncontrollable Variables, or Parameters

In any decision-making situation, there are factors that affect the result variables but are not under the control of the decision maker. Either these factors can be fixed, in which case they are called uncontrollable variables, or parameters, or they can vary, in which case they are called *variables*.

Examples of factors are the prime interest rate, a city's building code, tax regulations, and utilities costs. Most of these factors are uncontrollable because they are in and determined by elements of the system environment in which the decision maker works. Some of these variables limit the decision maker and therefore form what are called the constrains of the problem.

… Decision Variables

Examples of the Components of Models			
Area	***Decision Variables***	***Result Variables***	***Uncontrollable Variables and Parameters***
Financial investment	Investment alternatives and amounts	Total profit, risk Rate of return of investment Earnings per share Liquidity level	Inflation rate Prime rate Competition
Marketing	Advertising budget Where to advertise	Market share Customer satisfaction	Customer's income Competitor's actions
Manu-facturing	What and how much to produce Inventory levels Compensation programs	Total cost Quality level Employee satisfaction	Machine capacity Technology Materials prices
Accounting	Use of computers Audit schedule	Data processing cost Error rate	Computer technology Tax rates Legal requirements
Transpor-tation	Shipments schedules Use smart cards	Total transport cost Payment float time	Delivery distance Regulations
Services	Staffing levels	Customer satisfaction	Demand for services

Intermediate Result Variables

Intermediate result variable reflect intermediate outcomes in mathematical models.

For example, in determining machine scheduling, spoilage is an intermediate result variable, and total profit is the result variable (i.e., spoilage is one determinant of total profit).

Another example is employee salaries. This constitutes a decision variable for management. It determines employee satisfaction (i.e., intermediate outcome), which in turn determines the productivity level (i.e., final result).

The structure of MSS Mathematical Models

The component of a quantitative model are linked together by mathematical (algebraic) expressions – equations or inequalities.

A very simple financial model is

$$P = R – C$$

where P = profit, R = revenue, and C = cost. This equation describes the relationship among the variables.

Another well-known financial model is the simple present-value cash flow model, where P = present value, F = a future single payment in dollars, i = interest rate (percent-age), and n = number of years. With this model it is possible to determine the present value of a payment of \$100,000 to be made five years from today, at a 10% (0.1) interest rate, as follows:

$$P = 100{,}000 / (1+0.1)^5 = \$62{,}092$$

8. Mathematical Programming Optimization

Linear programming (**LP**) is the best-know technique in family of optimization tools called ***mathematical programming***. In **LP**, all relationships among the variables are linear.

Mathematical Programming

Mathematical programming is a family of tools designed to help solve managerial problems in which the decision maker must allocate scarce resources among competing activities to optimize a measurable goal.

Linear Programming

Every **LP** problem is composed of:

- ***decision variable*** - whose values are unknown and are searched for,
- an ***objective function*** - a linear mathematical function that relates the decision variables to the goal, measures goal attainment, and is to be optimized,
- ***objective function coefficients*** -unit profit or cost coefficients indicating the contribution to the objective of one unit of a decision variable,
- ***constraints*** - expressed in the form of linear inequalities or equalities that limit resources or requirements; these relate the variables through linear relationships,
- ***capacities*** - which describe the upper and sometimes lower limits on the constraints and variables, and
- ***input/output (technology) coefficients*** - which indicate resource utilization for a decision variable.

An example of modeling in LP:

- The ***decision variables*** :

$$X_1 = \text{units of CC-7}$$

$$X_2 = \text{units of CC-8}$$

- The ***result variable*** :

$$\text{Total profit} = Z$$

- The ***objective*** is to maximize :

$$Z = 8{,}000X_1 + 12{,}000X_2$$

- The ***uncontrollable variables*** (***constraints***) :

Labor constrain: $300X_1 + 500X_2 \leq 200{,}000$

Budget constrain: $10{,}000X_1 + 15{,}000X_2 \leq 8{,}000{,}000$

Marketing requirement for CC-7: $X_1 \geq 100$

Marketing requirement for CC-8: $X_2 \geq 200$

The **Mathematical Model** is:

Decision Variables

X_1= units of CC-7

X_2= units of CC-8

→

Mathematical Relationships

Maximize Z (profit)

subject to constraints

→

Result Variables

Total profit = Z

$Z = 8{,}000X_1+12{,}000X_2$

↓

Constraints (Uncontrollable)

$300X_1+500X_2 \le 200{,}000$

$100X_1+1{,}5000X_2 \le 8{,}000{,}000$

$X_1 \ge 100$

$X_2 \ge 200$

The **Excel *Solver* Solution** is:

	X_1	X_2		
Decision Variables:	**333.33**	**200.00**		
Total Profit:	8.00	12.00	**5,066.67**	
Labor:	0.30	0.50	200.00	200.00
Budget:	10.00	15.00	6,333.33	8,000.00
X1 lower:	1.00	0.00	333.33	100.00
X2 lower:	0.00	1.00	200.00	200.00

The Excel *Solver* Answer Report is:

Microsoft Excel 11.0 Answer Report

Worksheet: [PL.xls]PL

Report Created: 12/13/2009 7:57:12 PM

Target Cell (Max)

Cell	Name	Original Value	Final Value
$E$7	Total Profit	5,066.67	5,066.67

Adjustable Cells

Cell	Name	Original Value	Final Value
$C$6	Decision Variables: X1	333.33	333.33
$D$6	Decision Variables: X2	200.00	200.00

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$E$8	Labor:	200.00	$E$8<=$F$8	Binding	0
$E$9	Budget:	6,333.33	$E$9<=$F$9	Not Binding	1666.666667
$E$10	X1 lower:	333.33	$E$10>=$F$10	Not Binding	233.33
$E$11	X2 lower:	200.00	$E$11>=$F$11	Binding	0.00

The Excel *Solver* Sensitivity Report is:

Microsoft Excel 11.0 Sensitivity Report

Worksheet: [PL.xls]PL

Report Created: 12/13/2009 7:57:12 PM

Adjustable Cells

Cell	Name	Final Value	Reduced Gradient
$C$6	Decision Variables: X1	333.33	0.00
$D$6	Decision Variables: X2	200.00	0.00

Constraints

Cell	Name	Final Value	Lagrange Multiplier
$E$8	Labor:	200.00	26.67
$E$9	Budget:	6,333.33	0.00
$E$10	X1 lower:	333.33	0.00
$E$11	X2 lower:	200.00	-1.33

The Excel *Solver* Limits Report is:

Microsoft Excel 11.0 Limits Report

Worksheet: [PL.xls]Limits Report 2

Report Created: 12/13/2009 7:57:12 PM

	Target	
Cell	**Name**	**Value**
$E$7	Total Profit	5,066.67

	Adjustable		Lower	Target	Upper	Target
Cell	**Name**	**Value**	**Limit**	**Result**	**Limit**	**Result**
$C$6	Decision Variables: X1	333.33	100.00	3,200.00	333.33	5,066.67
$D$6	Decision Variables: X2	200.00	200.00	5,066.67	200.00	5,066.67

The most common optimization models can be solved by a variety of **mathematical programming methods**, including the following:

- Assignment (best matching of objects)
- Dynamic programming
- Goal programming
- Investment (maximizing rate of return)
- Linear and integer programming
- Network models for planning and scheduling
- Nonlinear programming
- Replacement (capital budgeting)
- Simple inventory models (e.g., economic order quantity)
- Transportation (minimize cost of shipments)

9. Multiple Goals, Sensitivity Analysis, What-If Analysis, and Goal Seeking

Multiple Goals

Today's management systems are more complex, and one with a single goals is rare - managers want to attain ***simultaneous goals***, some of which may conflict.

It is usually necessary to transform a multiple-goal problem into a single-measure-of-effectiveness problem before comparing the effects of the solutions (handling multiple goals in a LP model – *goal programming model*).

Methods of handling multiple goals used when working with MSS:

- Utility theory
- Goal programming
- Expression of goals as constraints, using LP
- A point system

With some methods, the decision maker needs to search the solution space for an alternative that provides for required attainment of all goals while searching for an efficient solution.

Sensitivity Analysis

Sensitivity analysis attempts to assess the impact of a change on the input data or parameters on the proposed solution (result variables).

Sensitivity analysis is important in MSS because it allows flexibility and adaptation to changing conditions and to the requirements of different decision-making situation, provides a better understanding of the model and the decision-making situation it attempts to describe, and permits the manager to input data in order to increase the confidence in the model.

Sensitivity analysis tests relationships such as the following:

- The impact of changes in uncontrollable variables and parameters on the outcome variables
- The impact of changes in decision variables and parameters on the outcome variables
- The effect of uncertainty in estimating external variables
- The effect of different dependent interactions among variables
- The robustness of decisions under changing conditions.

Sensitivity analysis are used for:

- Revising models to eliminate too-large sensitivities
- Adding details about sensitive variables or scenarios
- Obtaining better estimates of sensitive external variables
- Accepting and using the sensitive (and hence vulnerable) real world, leading to continuous and close monitoring of actual results
- The robustness of decisions under changing conditions.

Automatic Sensitivity Analysis

ASA is performed in standard quantitative model implementation such as LP.

Automatic sensitivity analysis is usually limited to one change at a time, and only for certain variables. It is very powerful because of its ability to establish ranges and limits very fast.

What-If Analysis

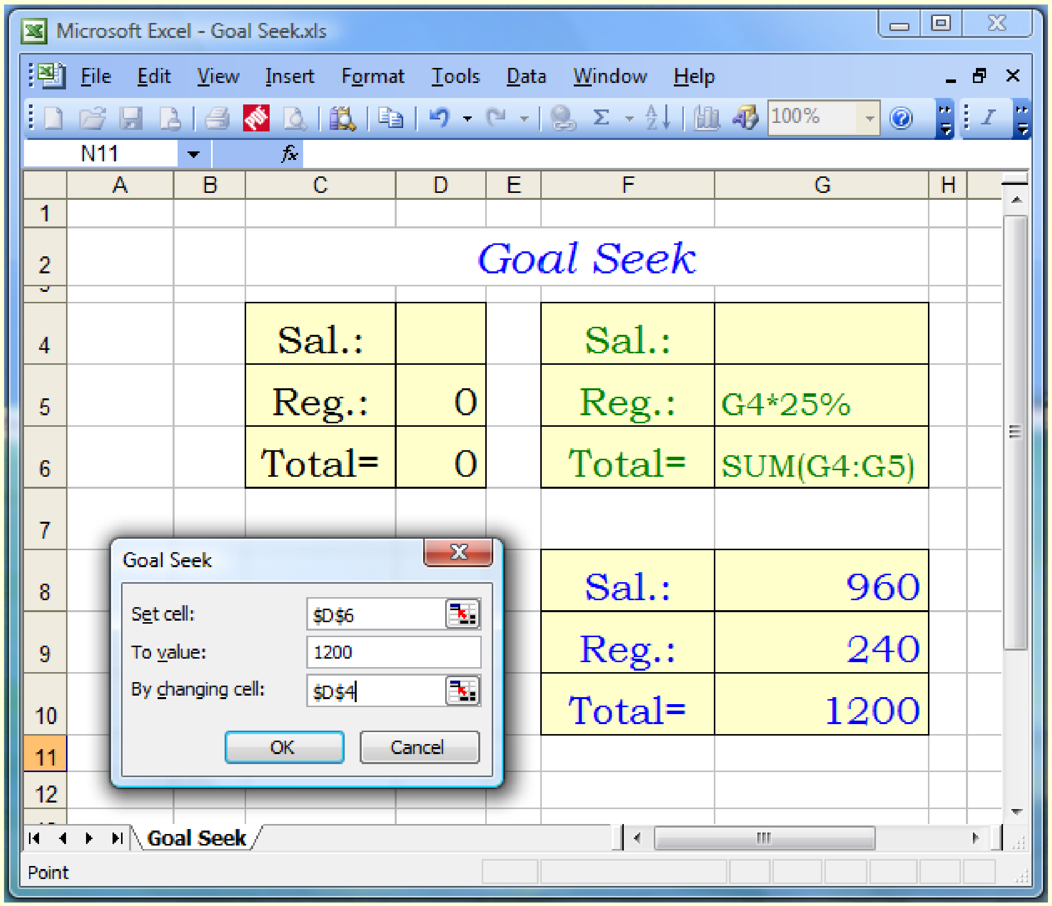
What-if analysis is structured as *What will happen to the solution if an input variable, an assumption, or a parameter value is changed?*

	a =	2.50	b =	1.75
x	\$100.00	\$110.00	\$121.00	\$133.10
y	\$200.00	\$220.00	\$242.00	\$266.20
$f(x,y)$	\$600.00	\$660.00	\$726.00	\$798.60
$g(x,y)$	\$325.00	\$357.50	\$393.25	\$432.58
$h(x,y)$	\$215.00	\$236.50	\$260.15	\$286.17

What-if analysis is common in ***expert systems***. Users are given the opportunity to change their answers to some of the system's questions, and a revised recommendation is found.

Goal Seeking

Goal seeking calculates the values of the inputs necessary to achieve a desired level of an output (goal). It represents a backward solution approach.



The following are some examples of **goal seeking**:

- *What annual budget is needed for an annual growth rate of 15% by 2009?*
- *How many nurses are needed to reduce the average waiting time of a patient in the emergency room to less than 10 minutes?*

10. Problem-Solving Search Methods

Search Methods are used in the choice phase of problem solving, and include ***analytical techniques***, ***algorithms***, ***blind searching***, and ***heuristic searching***.

Formal Search Approaches:

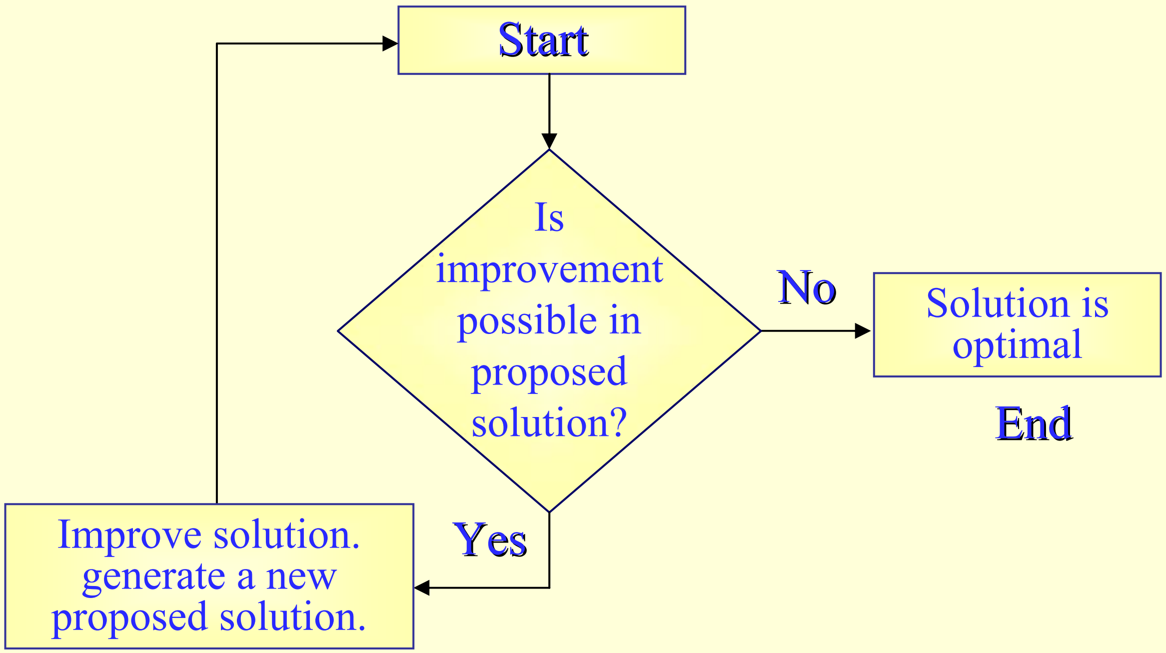
Search Approaches		Search Process	Stop Testing	Solution
Optimization (Analytical)		Generate improved solutions or get the best solution directly	Stop when no improvement is possible	Optimal (best)
Blind Search	Complete enumeration (exhaustive)	All possible solutions are checked	Comparisons: Stop when all alternatives are checked	Optimal (best)
Blind Search	Partial search	Check only some alternatives	Comparisons, simulation: Stop when solution is good enough	Best among alternatives checked
Heuristics		Only promising solutions are considered	Stop when solution is good enough	Good enough

Analytical Techniques

Analytical Techniques use mathematical formulas to derive an optimal solution directly to predict a certain result. Analytical techniques are used mainly for solving structured problems, usually of a tactical or operational nature, in areas such as resources allocation or inventory management. Blind or heuristic search approaches are generally employed to solve more complex problems.

Algorithms

Analytical Techniques may use algorithms to increase the efficiency of the search. An algorithm is step-by-step search process for obtaining an optimal solution.



Blind Searching

In conducting a search, a description of a desired solution may be given. This is called a ***goal***. A set of possible steps leading from initial conditions to the goal is called the ***search steps***. Problem solving is done bye searching through the possible solutions. The first of these search methods is **blind searching**. The second is **heuristic searching**.

Blind search techniques are arbitrary search approaches that are not guided. There are two types of blind searches:

- a complete enumeration – an optimal solution is discovered,
- an incomplete, or partial, search – until a good-enough solution is found.

Heuristic Searching

Heuristics are the informal, judgment knowledge of an application area that constitute the rules of good judgment in the field. Through domain knowledge, they guide the problem-solving process. Heuristic programming is the process of using heuristics in problem solving.

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