Spreadsheet Modeling and Analysis

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Model

- A model is an abstraction or representation of a real system, idea, or object.
- Models capture the most important features of a problem and present them in a form that is easy to interpret.
- Models can be descriptive, predictive or prescriptive.
- They are used in wide variety of business applications.

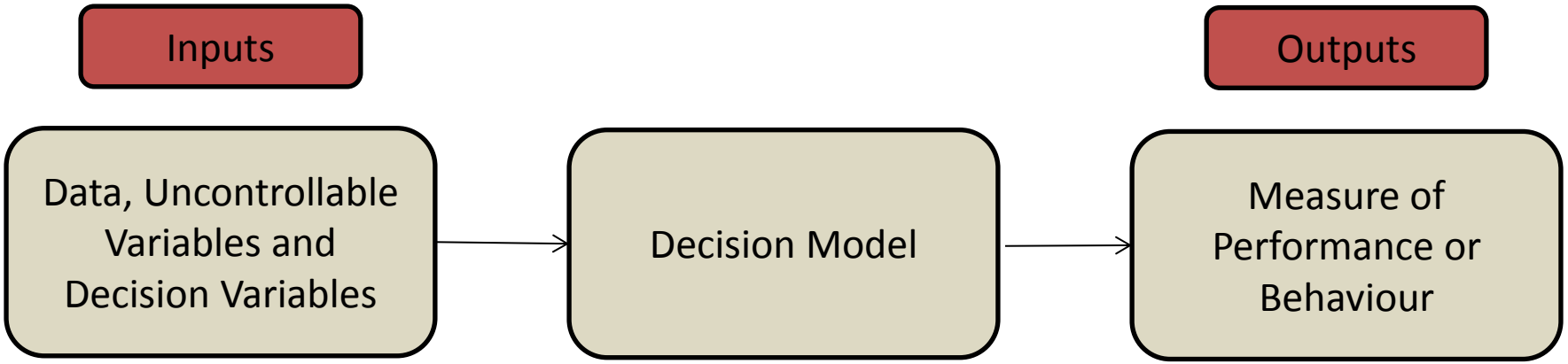
Examples

- A verbal description of some phenomenon
  - As the price of a product increases, the demand decreases.
- A visual representation such as a graph or a flow chart
  - This could be represented with the help of scatter chart.
- A mathematical or spreadsheet representation
  - The line function can help in demand prediction.

Decision Model

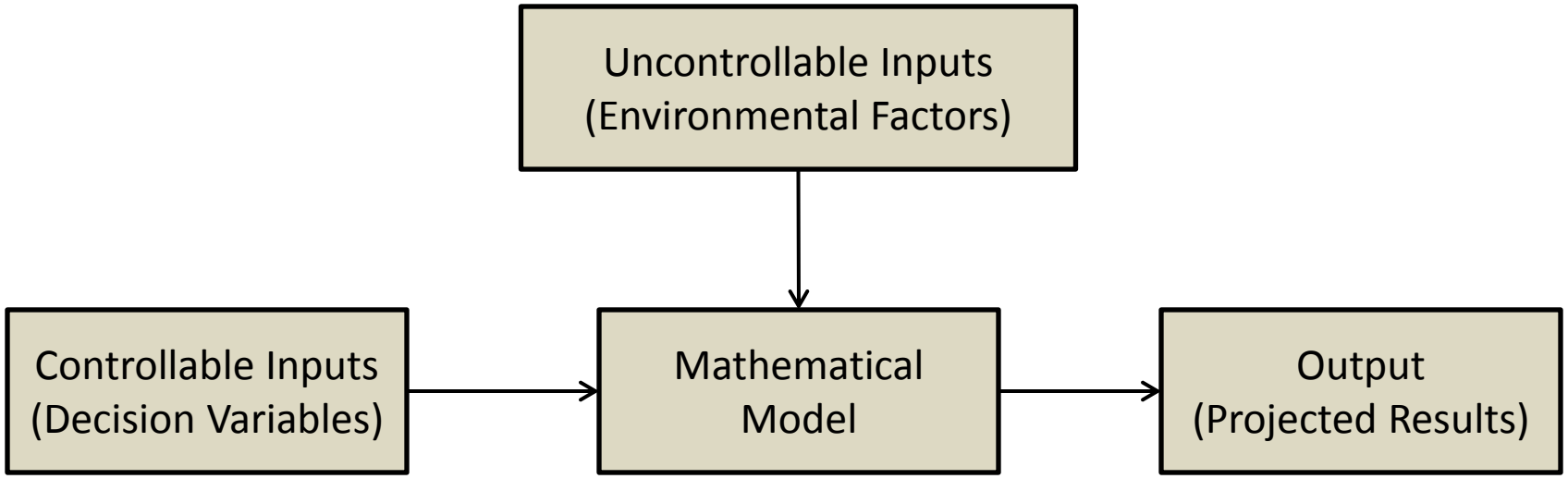
- It is a logical or mathematical representation of a problem or business situation that can be used to understand, analyze or facilitate making a decision.
- Three types of inputs
  - Data: assumed to be constant for purpose of model. E.g. cost, machine capacity
  - Uncontrollable variables: quantities that can change but cannot be directly controlled by the decision maker. E.g. customer demand, inflation rates
  - Decision Variables: which are controllable and can be selected at the discretion of the decision maker. E.g. production quantity, staffing levels.

Nature of Decision Models



- They characterize the relationships among the data, uncontrollable variables and decision variables.
- Spreadsheets provide versatility in managing data, evaluating different scenarios and presenting results of decision models.

Flowchart of the Process of Transforming Model Inputs into Output



- Deterministic Model: if all uncontrollable inputs to a model are known and cannot vary.
- Stochastic or probabilistic model: if any of the uncontrollable inputs are uncertain and subject to variation.

Quantitative Models

- They involve relationship between volume variable such as production volume or sales volume and cost revenue and profit.
- To determine the projected cost, revenue and/or profit associated with an established production quantity or a forecasted sales volume.
- Applications: financial planning, production planning, sales quotas etc:

Cost and Volume Model

- The cost of manufacturing or producing a product is a function of the volume produced.
- It is sum of two costs:
  - Fixed cost: it does not depend on the production volume. Is a constant.
  - Variable cost: dependent on and varies with the production volume.

$$C(x)=3000 + 2x$$

Where, x- production volume in units

C(x)- total cost of producing x units

The setup cost incurred regardless of the number of units eventually produced is Rs 3000. The variable labor and material costs are Rs 2 for each unit produced.

- Marginal Cost is defined as the rate of change of the total cost with respect to production volume.

Revenue and Volume Model

- A model for relationship between revenue and volume.
- To determine information on the projected revenue associated with selling a specified number of units.

$$R(x) = 5x$$

where x – sales volume in units

R(x) – total revenue associated with selling x units

Rs 5 is the selling price of the product

- Marginal revenue is defined as the rate of change of total revenue with respect to sales volume.

Profit and Volume Model

- To determine total profit associated with a specified production sales volume .
- Total profit denoted by P(x) is total revenue minus total cost

$$P(x) = R(x) – C(x)$$

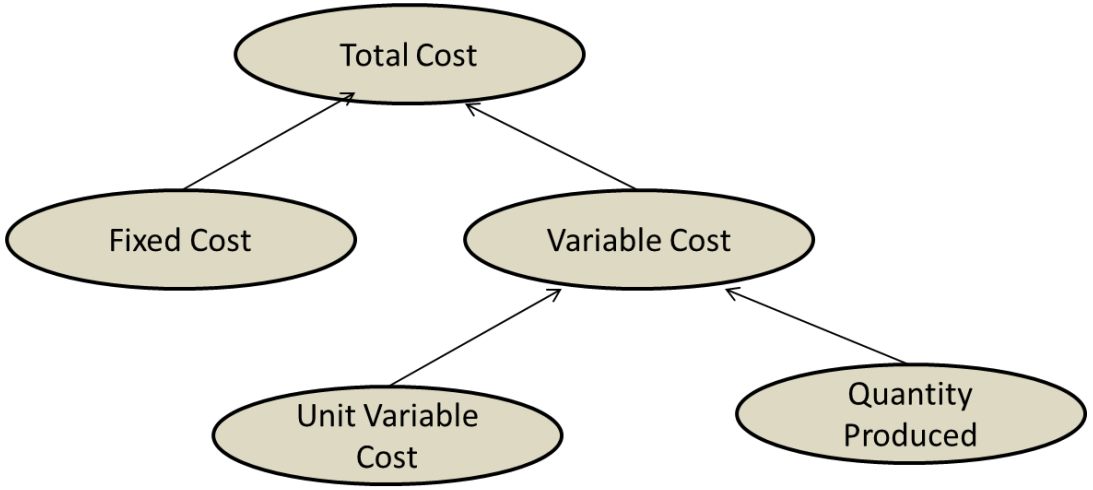
It provides the total profit associated with producing and selling x units.

- To know the profit implication of their decision.

Influence Diagram

- It is a visual representation to describe how various elements of the model influence or relate to others.
- It is a useful approach for conceptualizing the structure of a model and can assist in building a mathematical or spreadsheet model.
- The elements of the model are represented by circular symbols called nodes.
- Arrows called branches connect the nodes and show which elements influence others.

Influence Diagram for Total Cost



Total Cost= Fixed Cost + Variable Cost

Variable Cost = Unit Variable Cost x Quantity Produced

Total Cost = Fixed Cost + Variable Cost
= Fixed Cost + Unit Variable Cost x Quantity Produced

$$TC = F + V*Q$$

Reasons to use Quantitative Approach in the Decision Making Process

- The problem is complex and the manager cannot develop a good solution without the aid of quantitative analysis.
- The problem is especially important (e.g. a great deal of money is involved) and the manager desires a thorough analysis before attempting to make a decision.
- The problem is new, and the manager has no previous experience from which to draw.
- The problem is repetitive, and the manager saves time and effort by relying on quantitative procedures to make routine decision recommendations.

Breakeven Analysis

- The volume that results in total revenue equaling total cost is called the breakeven point.
- If the breakeven point is known then the manager can quickly infer that
  - A volume above breakeven point will result in a profit
  - A volume below breakeven point will result in a loss
- The breakeven point for a product provides valuable information for a manager who must make a yes/no decision concerning production of the product.

Spreadsheet Modeling

Break-even Analysis: Consider a scenario that involves a manufacturer who can produce a part for $125/unit with a fixed cost of $50,000. The alternative is to outsource production to a supplier at a unit cost of $175.

Mathematical models for the total manufacturing cost and the total cost of outsourcing as a function of the production volume Q is:

TC(manufacturing) = $50,000 + $125xQ

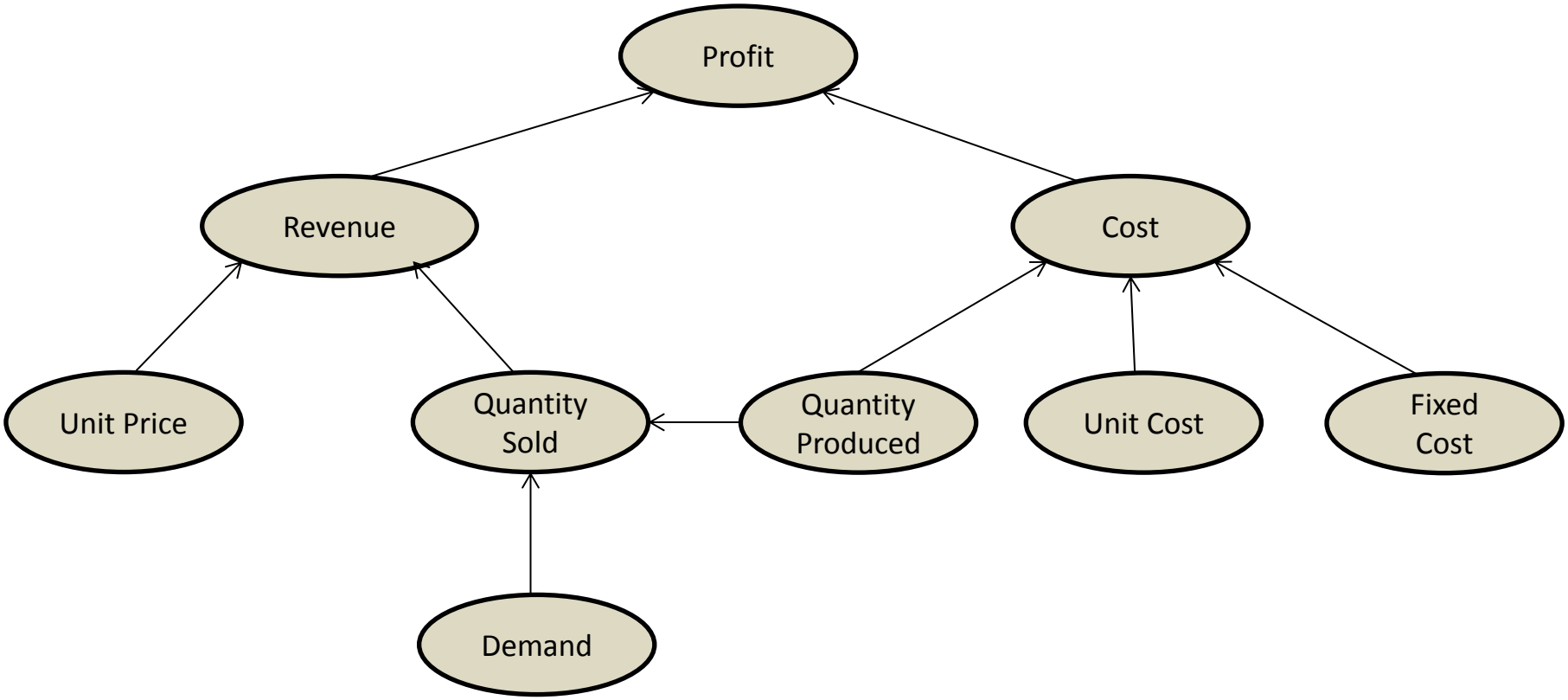
TC (outsourcing)= $175 x Q

Excel file Outsourcing Decision Model

Spreadsheet Quality

- Verification is the process of ensuring that a model is accurate and free from logical errors.
- Three basic approaches to improve spreadsheet quality
  - Improve the design and format of the spreadsheet itself.
  - Improve the process used to develop a spreadsheet.
  - Inspect your results carefully and use appropriate tools available in Excel.

Influence Diagram for Profit



Profit Model

To develop a decision model for predicting profit in the face of uncertain future demand.

Profit = revenue – cost

The cost (C) depends on the unit cost(c), quantity produced (Q), and fixed costs (F) of productions

$$C = F + cQ$$

Revenue depends upon unit price(p) and quantity sold (S)

$$\text{Revenue } R = pS$$

However if demand is uncertain, then the amount produced may be less than or greater than the actual demand. Thus the quantity sold depends upon both the demand and the quantity produced. It must be smaller of the demand (D) and the quantity produced (Q)

$$S = \min \{D,Q\}$$

$$\text{Therefore } R=p*\min \{D,Q\}$$

Substituting these results into the basic formula for profit P=R – C, we have

$$P=p*\min \{D,Q\} – (F + cQ)$$

Spreadsheet Implementation of Profit Model

	A	B	C
1	**Profit Model**		
2			
3	**Data**		
4			
5	**Unit Price**	$40.00	
6	**Unit Cost**	$24.00	
7	**Fixed Cost**	$400,000.00	
8	**Demand**	50000	
9			
10			
11	**Model**		
12			
13	**Unit Price**	$40.00	
14	**Quantity Sold**	40000	
15	**Revenue**		$1,600,000.00
16			
17	**Unit Cost**	$24.00	
18	**Quantity Produced**	40000	
19	**Variable Cost**		$960,000.00
20	**Fixed Cost**		$400,000.00
21			
22	**Profit**		$240,000.00
23			

Models Involving Multiple Time Periods

- Most practical models are complex and involve basic financial analysis.
  - Decision to launch new product. For example, R&D in pharmaceutical is a long, expensive and arduous process.
- Models for these types of applications typically incorporate multiple time periods that are logically linked together.
- Predictive analytics capabilities are vital to making good business decisions.

New Product Development

Moore Pharmaceuticals has discovered a potential drug breakthrough in the laboratory and needs to decide whether to go forward to conduct clinical trials and seek FDA approval to make the drug.

Total R&D costs are expected to reach $700 million

Cost of clinical trials will be about $150 million

The current market size is estimated to be 2 million people and is expected to grow at a rate of 3% each year.

In the first year, Moore estimates gaining an 8% market share which is anticipated to grow by 20% each year.

A monthly prescription is anticipated to generate revenue of $130 while incurring variable costs of $40. A discount rate of 9% is assumed for computing the net present value of the project.

The company needs to know how long it will take to recover its fixed expenses and the net present value over the first 5 years.

Net Present Value (NPV)

- Net Present Value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows. NPV is used in capital budgeting to analyze the profitability of a projected investment or project.
- The following is the formula for calculating NPV:

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_o$$

where

Ct = net cash inflow during the period t

Co = total initial investment costs

r = discount rate, and

t = number of time periods

Spreadsheet Implementation of Moore Pharmaceuticals Model

	A	B	C	D	E	F
1	Moore Pharmaceuticals					
2						
3	Data					
4						
5	Market size	2,000,000				
6	Unit (monthly Rx) revenue	$ 130.00				
7	Unit (monthly Rx) cost	$ 40.00				
8	Discount rate	9%				
9						
10	Project Costs					
11	R&D	$ 700,000,000				
12	Clinical Trials	$ 150,000,000				
13	Total Project Costs	$ 850,000,000				
14						
15	Model					
16						
17	Year	1	2	3	4	5
18	Market growth factor		3.00%	3.00%	3.00%	3.00%
19	Market size	2,000,000	2,060,000	2,121,800	2,185,454	2,251,018
20	Market share growth rate		20.00%	20.00%	20.00%	20.00%
21	Market share	8.00%	9.60%	11.52%	13.82%	16.59%
22	Sales	160,000	197,760	244,431	302,117	373,417
23						
24	Annual Revenue	$ 249,600,000	$ 308,505,600	$ 381,312,922	$ 471,302,771	$ 582,530,225
25	Annual Costs	$ 76,800,000	$ 94,924,800	$ 117,327,053	$ 145,016,237	$ 179,240,069
26	Profit	$ 172,800,000	$ 213,580,800	$ 263,985,869	$ 326,286,534	$ 403,290,156
27						
28	Cumulative Net Profit	$ (677,200,000)	$ (463,619,200)	$ (199,633,331)	$ 126,653,203	$ 529,943,358
29						
30	Net Present Value	$ 185,404,860				

Single Period Purchase Decisions

- New Vendor problem can represents many practical situations in which a one-time purchase decision must be made in the face of uncertain demand.
- Examples:
  - Department store buyers must purchase seasonal clothing well in advance of the buying season
  - Candy shop must decide on how many special holiday gift boxes to assemble.
- The general scenario is commonly known as Newsvendor problem.

Newsvendor Problem

A street newsvendor sells daily newspapers and must make a decision about how many to purchase.

Assume R > C > S

Where, R – selling price of item

C – purchasing price of item

S – salvage value of unsold items

Let D – number of units demanded during the period (uncontrollable input)

Q – quantity purchased (decision variable)

If demand is known (D=Q) optimal solution is possible

If D is not known in advance then

Q < D we lose the opportunity of realizing additional profit since R > C

Q > D loss is incurred since C > S

Net profit = R x quantity sold + S x surplus quantity – C xQ

Spreadsheet Implementation of Newsvendor problem

A small candy store makes Valentine's Day gift boxes that cost $12.00 and sell for $18.00. In the past, at least 40 boxes have been sold by Valentine's Day, but the actual amount is uncertain, and in the past, the owner has often run short or made too many. After the holiday, any unsold boxes are discounted 50% and are eventually sold.

$$\text{Net profit} = 18.00 \times \min\{D,Q\} + 9.00 \times \max\{0,Q-D\} - 12.00 \times Q$$

Using Newsvendor Model Excel file

Overbooking Decisions

- Operation decision for service business such as hotels, airlines and car rental companies.
- The number of reservations to accept to effectively fill capacity knowing that some customers may not use their reservation.
- A common practice in these industries is to overbook reservations.
- The decision becomes how much to overbook to balance the costs of overbooking against the lost revenue for underuse.

Hotel Overbooking Model

A popular resort hotel has 300 rooms an is usually fully booked.

The hotel charges $120 per room. Reservations may be canceled by the 6 pm deadline with no penalty.

The hotel has estimated that the average overbooking cost is $100.

	A	B
1	Hotel Overbooking Model	
2		
3	Data	
4		
5	Rooms available	300
6	Price	$120
7	Overbooking cost	$100
8		
9	Model	
10		
11	Reservation limit	310
12	Customer demand	312
13	Reservations made	310
14	Cancellations	6
15	Customer arrivals	304
16		
17	Overbooked customers	4
18	Net revenue	$35,600

Model Assumptions, Complexity and Realism

- Models cannot capture every detail of the real problem, and managers must understand the limitations of models and their underlying assumptions.
- Validity refers to how well a model represents reality.
  - Identify and examine the assumptions
- There is no “perfect” model
  - To add more realism to a model generally requires more complexity and analysts have to know how to balance these.

Data and Models

- The data comes from subjective judgement based on
  - Past experience
  - Existing database and other data sources
  - Analysis of historical data, or surveys, experiments
  - Other methods of data collection
- Profit Model: query accounting records for values of unit cost and unit price.
- Statistical methods are used to estimate data required in predictive models.
  - Mean demand from historical data
  - Use quartiles or percentiles in the model to evaluate different scenario

Retail Pricing Markdowns

A chain of department stores is introducing a new brand of bathing suit for $70. The prime selling season is 50 days during the late spring and early summer,

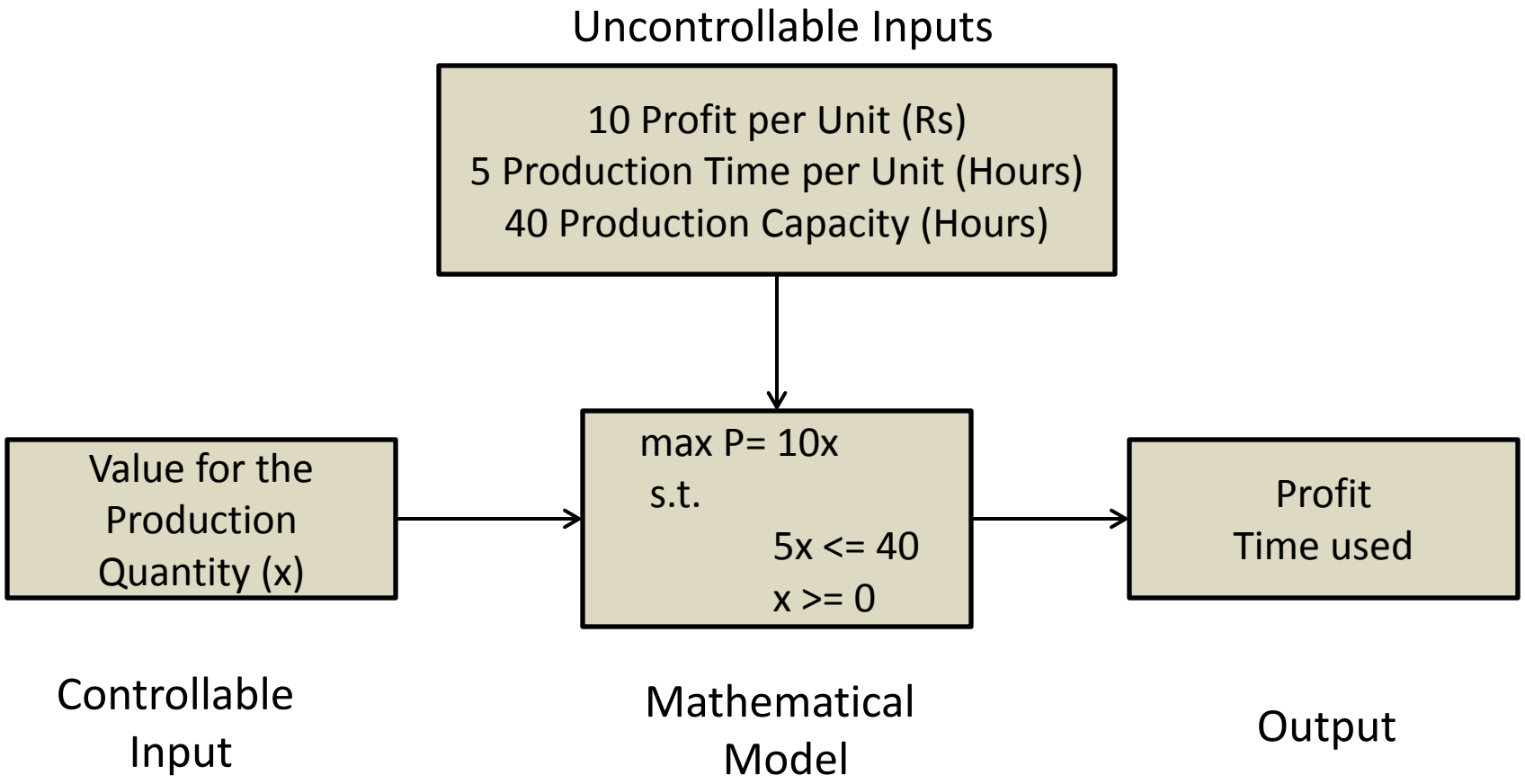
After that the store has clearance sale around July 4 and marks down the price by 70% (to $21.00), typically selling any remaining inventory at the clearance price.

Merchandise buyers have purchased 1,000 units and allocated them to the stores prior to the selling season. After a few weeks, the stores sold an average of 7 units/day, and past experience suggests that this constant level of sales will continue over the remainder of the selling season.

Simple Production Problem

- The per unit production cost of an item is Rs 10/-. It requires 5 hours to produce each unit of item. The total production time available is 40 hours per week. How many units of the product should be scheduled each week to maximize profit?
- Let x represent the number of items. Profit could be represented as P=10x.

Flowchart for the Production Model



Model Solution

- To identify the values of the decision variables that provide the “best” output for the model.
- The specific decision-variable value or values providing the “best” output will be referred to as the optimal solution for the model.
- If a particular decision alternative does not satisfy one or more of the model constraints, the decision alternative is rejected as being infeasible.
- If all constraints are satisfied, the decision alternative is feasible and a candidate for the “best” solution or recommended decision.

Trial and Error Solution for the Production Model

Decision Alternative (Production Quantity) x	Projected Profit	Total Hours of Production	Feasible Solution? (Hours Used <= 40)
0	0	0	Yes
2	20	10	Yes
4	40	20	Yes
6	60	30	Yes
8	80	40	Yes
10	100	50	No
12	120	60	No

Analyzing Uncertainty and Model Assumptions

- The predictive Analytical Models are based on assumptions about the future and incorporate variables that most likely will not be known with certainty.
- It is important to investigate how these assumptions and uncertainty affect the model outputs.
- What-if analysis is about changing values in a spreadsheet and recalculating the outputs.
  - Data tables, Scenario Manager and Goal Seek

Data Tables

- It specifies the impact of one or two inputs on a specified output.
- Two types of data tables
  - A one-way data table evaluates an output variable over a range of values for a single input variable.
  - Two way data tables evaluate an output variable over a range of values of two different input variables.
- Data tables can be selected from What-If Analysis menu

One-Way Data Table

- For Uncertain Demand
  - Create a one-way data table for profit for varying levels of demand.

- With Multiple Outputs
  - To examine the impact of the uncertain demand on revenue in addition to profit

Two Way Data Table

- Type a list values for one input variable in a column and a list of input value for second input variable in a row.
  - The unit cost might be affected by supplier price changes and inflationary factors.
  - Marketing might be considering price adjustments to meet profit goals.
- Two way data tables can evaluate only one output variable.

Scenario Manager

- It allows to create scenarios-sets of values that are saved and can be substituted automatically on worksheet.
- To evaluate multiple output variables.
- To evaluate four different strategies in the Markdown Pricing Model Excel file.

Goal Seek

- If we know the result that we want from a formula but are not sure what input value the formula needs to get that result.
- It works with only one variable input value.
- On the Data tab, in the Data Tools group, click What If analysis and then Goal Seek.
- To find break even point in Outsourcing Decision Model Excel file

Summary

- Building good decision model in a functional area requires a solid understanding of basic business principles.
- Models often evolve from simple to complex and from deterministic to stochastic.
- The models are analyzed to evaluate future scenarios and ask what-if types of questions to facilitate better business outcomes.