KAMPALA INTERNATIONAL UNIVERSITY

COURSE MODULE – QUANTITATIVE METHODS

Faculty	**:**	**BUSINESS MANAGEMENT**
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College	**:**	**College of Economics and Management**
Department	**:**	**Accounting and Finance**
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Description

Quantitative techniques for management are basically operations research techniques commonly used in order to arrive at more objective decisions. These techniques often require the qualification of elements, that is, the use of numbers, symbols and mathematical expressions. Operations research tools of linear programming, programme evaluation and review techniques, critical path method, simulation and others are surveyed from an applied rather than theoretical viewpoint, for use in the resolution of management problems associated with resource allocation, project monitoring, maximization of objective function or minimization of costs; sequencing, waiting line and inventory control.

Course content

Unit 1

1.0 Introduction to unit One

QT introduces a body of knowledge, with problem solving and decision making. It introduces students to quantitative analysis and decision making, models of cost, revenue and profit, quantitative methods in practice.

QT is a body of knowledge which involves rational approaches to decision making based on the scientific method of problem solving. This body of knowledge is often referred to as ***management science***, ***operations research*** or ***decision science***.

QT as problem solving and decision making, it has adopted seven steps of problem solving. i.e.,

(First 5 steps are the process of decision making)

- Identify and define the problem.
- Determine the set of alternative solutions.
- Determine the criteria for evaluating the alternatives.
- Evaluate the alternatives.
- Choose an alternative.

- Implement the chosen alternative.
- Evaluate the results.

Why a quantitative analysis approach to decision making?

1. The problem may be complex
2. The problem is critical/important
3. The problem is new
4. The problem is repetitive

1.1 Quantitative Analysis Process

What are the quantitative analysis process?

a) **Develop the Model**
b) Data Preparation
c) Model Solution
d) Report Generation

a) Model Development

Models: are representations of real objects or situations. Three ***forms of models*** are iconic, analog, and mathematical.

- Iconic models are physical replicas (scalar representations) of real objects.
- Analog models are physical in form, but do not physically resemble the object being modeled.

- Mathematical models represent real world problems through a system of mathematical formulas and expressions based on key assumptions, estimates, or statistical analyses.

Advantages of Models

- Generally, experimenting with models (compared to experimenting with the real situation):
  - Requires less time
  - Is less expensive
  - Involves less risk

Mathematical models

- Cost/benefit considerations must be made in selecting an appropriate mathematical model.
- Frequently a less complicated (and perhaps less precise) model is more appropriate than a more complex and accurate one due to cost and ease of solution considerations.
- Relate decision variables (controllable inputs) with fixed or variable parameters (uncontrollable inputs).
- Frequently seek to maximize or minimize some objective function subject to constraints.
- Are said to be stochastic if any of the uncontrollable inputs is subject to variation, otherwise are said to be deterministic.
- Generally, stochastic models are more difficult to analyze.
- The values of the decision variables that provide the mathematically-best output are referred to as the optimal solution for the model.

Example: Project Scheduling

Consider a construction company building a 250-unit apartment complex. The project consists of hundreds of activities involving excavating, framing, wiring, plastering, painting, landscaping, and more. Some of the activities must be done sequentially and others can be done simultaneously. Also, some of the activities can be completed faster than normal by purchasing additional resources (workers, equipment, etc.).

What is the best schedule for the activities and for which activities should additional resources be purchased?

Question:

How could management science be used to solve this problem?

Answer:

Management science can provide a structured, quantitative approach for determining the minimum project completion time based on the activities' normal times and then based on the activities' expedited (reduced) times.

Question:

What would be the uncontrollable inputs?

Answer:

- Normal and expedited activity completion times
- Activity expediting costs
- Funds available for expediting
- Precedence relationships of the activities

Question:

What would be the decision variables of the mathematical model? The objective function? The constraints?

Answer:

- Decision variables: which activities to expedite and by how much, and when to start each activity
- Objective function: minimize project completion time
- Constraints: do not violate any activity precedence relationships and do not expedite in excess of the funds available.

Question:

Is the model deterministic or stochastic?

Answer:

Stochastic. Activity completion times, both normal and expedited, are uncertain and subject to variation. Activity expediting costs are uncertain. The number of activities

and their precedence relationships might change before the project is completed due to a project design change.

Question:

Suggest assumptions that could be made to simplify the model.

Answer:

Make the model deterministic by assuming normal and expedited activity times are known with certainty and are constant. The same assumption might be made about the other stochastic, uncontrollable inputs.

Example: Austin Auto Auction

An auctioneer has developed a simple mathematical model for deciding the starting bid he will require when auctioning a used automobile. Essentially, he sets the starting bid at seventy percent of what he predicts the final winning bid will (or should) be. He predicts the winning bid by starting with the car's original selling price and making two deductions, one based on the car's age and the other based on the car's mileage. The age deduction is $800 per year and the mileage deduction is $.025 per mile.

Question:

Develop the mathematical model that will give the starting bid (B) for a car in terms of the car's original price (P), current age (A) and mileage (M).

Answer:

The expected winning bid can be expressed as:

P - 800(A) - .025(M)

The entire model is:

B = .7(expected winning bid) or

B = .7(P - 800(A) - .025(M)) or

B = .7(P) - 560(A) - .0175(M)

Question:

Suppose a four-year old car with 60,000 miles on the odometer is up for auction. If its original price was $12,500, what starting bid should the auctioneer require?

Answer: B = .7(12,500) - 560(4) - .0175(60,000) = $5460.

Question:

The model is based on what assumptions?

Answer:

The model assumes that the only factors influencing the value of a used car are the original price, age, and mileage (not condition, rarity, or other factors).

Also, it is assumed that age and mileage devalue a car in a linear manner and without limit. (Note, the starting bid for a very old car might be negative!)

Example: Iron Works, Inc.

Iron Works, Inc. (IWI) manufactures two products made from steel and just received this month's allocation of b pounds of steel. It takes a_1 pounds of steel to make a unit of product 1 and it takes a_2 pounds of steel to make a unit of product 2.

Let x_1 and x_2 denote this month's production level of product 1 and product 2, respectively. Denote by p_1 and p_2 the unit profits for products 1 and 2, respectively.

The manufacturer has a contract calling for at least m units of product 1 this month. The firm's facilities are such that at most u units of product 2 may be produced monthly.

Mathematical Model

- The total monthly profit =

(profit per unit of product 1)
x (monthly production of product 1)
+ (profit per unit of product 2)
x (monthly production of product 2)

$$= p_1x_1 + p_2x_2$$

We want to maximize total monthly profit:

$$\text{Max} \quad p_1x_1 + p_2x_2$$

The total amount of steel used during monthly production =

(steel required per unit of product 1)
x (monthly production of product 1)
+ (steel required per unit of product 2)
x (monthly production of product 2)

$$= a_1x_1 + a_2x_2$$

This quantity must be less than or equal to the allocated b pounds of steel:

$$a_1x_1 + a_2x_2 \leq b$$

The monthly production level of product 1 must be greater than or equal to m:

$$x_1 \geq m$$

The monthly production level of product 2 must be less than or equal to u:

$$x_2 \leq u$$

However, the production level for product 2 cannot be negative:

$$x_2 \geq 0$$

$$\begin{aligned} \text{Max} \quad & p_1x_1 + p_2x_2 \\ \text{s.t.} \quad & a_1x_1 + a_2x_2 \leq b \\ & x_1 \geq m \\ & x_2 \leq u \\ & x_2 \geq 0 \end{aligned}$$

Question:

Suppose $b = 2000$, $a_1 = 2$, $a_2 = 3$, $m = 60$, $u = 720$, $p_1 = 100$, $p_2 = 200$. Rewrite the model with these specific values for the uncontrollable inputs.

Answer:

Substituting, the model is:

$$\begin{aligned} \text{Max} \quad & 100x_1 + 200x_2 \\ \text{s.t.} \quad & 2x_1 + 3x_2 \leq 2000 \\ & x_1 \geq 60 \\ & x_2 \leq 720 \\ & x_2 \geq 0 \end{aligned}$$

Question:

The optimal solution to the current model is $x_1 = 60$ and $x_2 = 626\ 2/3$. If the product were engines, explain why this is not a true optimal solution for the "real-life" problem.

Answer:

One cannot produce and sell 2/3 of an engine. Thus the problem is further restricted by the fact that both x_1 and x_2 must be integers. They could remain fractions if it is assumed these fractions are work in progress to be completed the next month.

Example: Ponderosa Development Corporation

Ponderosa Development Corporation (PDC) is a small real estate developer operating in the Rivertree Valley. It has seven permanent employees whose monthly salaries are given in the table on the next slide.

PDC leases a building for $2,000 per month. The cost of supplies, utilities, and leased equipment runs another $3,000 per month.

PDC builds only one style house in the valley. Land for each house costs $55,000 and lumber, supplies, etc. run another $28,000 per house. Total labor costs are figured at $20,000 per house. The one sales representative of PDC is paid a commission of $2,000 on the sale of each house. The selling price of the house is $115,000.

Employee	Monthly Salary
President	$10,000
VP, Development	6,000
VP, Marketing	4,500
Project Manager	5,500
Controller	4,000
Office Manager	3,000
Receptionist	2,000

Question:

Identify all costs and denote the marginal cost and marginal revenue for each house.

Answer:

The monthly salaries total $35,000 and monthly office lease and supply costs total another $5,000. This $40,000 is a monthly fixed cost. The total cost of land, material, labor, and sales commission per house, $105,000, is the marginal cost for a house.

The selling price of $115,000 is the marginal revenue per house.

- Question:

What is the breakeven point for monthly sales of the houses?

Answer: $r(x) = c(x)$ or $115{,}000x = 105{,}000x + 40{,}000$

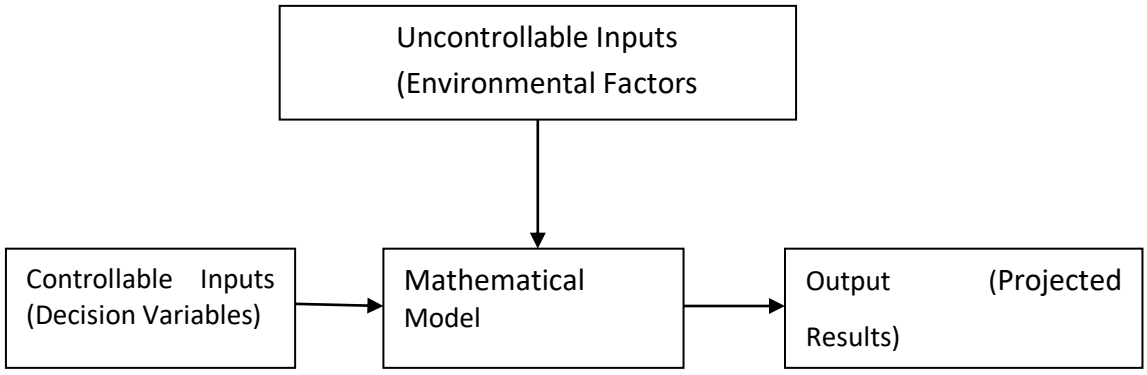
Solving, $x = 4$.

Question:

What is the monthly profit if 12 houses per month are built and sold?

Answer: $p(12) = 10{,}000(12) - 40{,}000 = \$80{,}000$ monthly profit

Transforming Model Inputs into Output



1.2 Role of quantitative methods in management

Let us analyse the importance of quantitative methods in seven functional areas of management.

1. **Marketing**

   Quantitative marketing is about data, facts, information and knowledge. We define quantitative marketing as the utilization of facts and knowledge to understand better the behavior of consumers across the marketing enterprise to maximize marketing investment.

2. **Business Analytics**

Business Analytics is a specialized domain that has been growing at an annual rate of about 30 percent. Companies incur significant expenditure on business intelligence. Besides the job being challenging, diversified and refreshing, the pay packet is quite attractive. Analytics include complex statistical analysis, computational modeling and data mining. The domain encompasses enterprise decision management, predictive science, strategy science, fraud analytics, credit risk analysis, marketing analytics, and soon. With the growing popularity of Business Intelligence) tools, the business significance of analytics is gaining greater acceptance in industry.

3. Marketing Engineering

Marketing engineering is computer assisted marketing analysis and planning. Marketing managers must make ongoing decisions about product features, prices, distribution options and sales compensation plans. When making these decisions, managers choose from among alternative courses of action in a complex and uncertain world. Marketing engineering provides managers with new concepts, methods and technologies to make decisions in increasingly data-intensive marketing environments.

4. Data Mining

Knowledge of advanced data mining techniques enables marketers to gather and organize data and address key business questions, to learn how to leverage the growing volume of customer data captured in the marketing process. Multiple regression analysis, logistic regression analysis, decision trees, factor analysis, cluster analysis, risk modeling, neural networks, Web log analysis, and market basket analysis are used to organize, analyse and summarise the data and make relevant inferences about the behaviour of different segments of customers.

5. Production

5.1 Facility location

Plant expansion and new facility construction are among the most far reaching decisions an organization faces. Break even analysis can be done for the selection of best location by comparing alternative locations on an economic basis. Factor rating is a means of assigning quantitative values to all the factors related to each decision and deriving a composite score

that can be used for comparison. Further linear programming can be applied to find out the transportation costs for raw materials and finished goods so that they can decide the location of a plant.

5.2 Product Design

It is the structuring of components/parts or activities so that as a unit they can provide a specified value. Computer Aided Design (CAD),Computer Aided Manufacturing (CAM), Group technology(GT),and Computer Integrated Manufacturing system (CIM) are designed to integrate product design and manufacturing activities with both the suppliers of materials and components as well as the customers of the firm's products.

5.3 Process planning

It consists of designing and implementing a work system to produce the desired goods or services in the required quantities at the appropriate time and within acceptable costs. Monte Carlo Simulation can be done using software such SIMSCRIPT, GPSS, DYNAMO, SLAM, SIMAN etc. Assembly and flow-process chart can also be used

5.4 Project management

A project is a unique set of activities that must be completed to achieve a specific objective within a limited time period by utilizing appropriate resources. The network models Critical–path method and program evaluation and review technique used for project scheduling

6. Human Resource

6.1 Performance Appraisal

Qualitative approaches like interviews and questionnaires are not always suitable. For example, if your aim is to compare jobs for pay purposes, you may need to say that, in effect, Job A is twice as challenging as Job B and so is worth twice the pay. To do this, we must be able to assign quantitative values to each job. The position analysis questionnaire and the US Department of Labor approach are popular quantitative methods.

6.2 Position Analysis questionnaire (PAQ):

A questionnaire used to collect quantifiable data concerning the duties and responsibilities of various jobs. It is a very structured job analysis questionnaire. The PAQ contains 194 items, each of which (such as written materials) represents a basic element that may or may not play an important role in the job. The job analyst decides if each item plays a role and if so to what extent. For example, written materials received a rating of 4, indicating that written materials (like books, reports, and office notes) play a considerable role in this job. The analyst can do this on line. The advantage of the PAQ is that it provides a quantitative score or profile of any job in terms of how that job rates on five basic activities: (1) having decision making /communication /social responsibilities,(2) performing skilled activities, (3) being physically active, (4) operating vehicles/equipment, and (5)processing information. The PAQ's real strength is thus in classifying jobs. In other words, it lets you assign a quantitative score to each job based on its decision making, skilled activity, physical activity, vehicle/equipment operation, and information processing characteristics. You can therefore use the PAQ results to quantitatively compare jobs and then assign appropriate pay levels for each job. US Department of Labor (DOL) Job analysis procedure: A standardized method by which different jobs can be quantitatively rated, classified, and compared based on data people and things scored. The US Department (DOL) job analysis procedure also provides a standardized method by which to quantitatively rate, classify and compare different jobs.

7. Finance

Financial markets and others generate vast amounts of data on asset returns, their volatility, and other financial variables in long and high-frequency time series. The ability to analyse market behaviour requires knowledge of the properties of time series and appropriate estimation methods. Since the early 1980s techniques for analysing time series which exhibit auto-regression have yielded important studies of financial markets, increasing our knowledge of financial variables' volatility. It examines techniques for the valuation of different classes of securities, analyses criteria for guiding investment decisions, considers the measurement of asset risk and return and discusses statistical techniques of forecasting. E-Views software is provided for

regression analysis and diagnostic procedures. It improves the confidence and skill in the use of the mathematical and statistical methods used in the analysis of financial instruments and financial markets, including the calculation of financial market yields and prices, frequency distributions, risk and probability, correlation and regression analysis.

Answers to the puzzle:

A) A simple problem of Logistics: Total requirement-6 buses. 3 buses to be positioned on each side, in the beginning. B) A simple problem of Probability: 2 or 3 cards

1.3 Limitations of quantitative methods

Questions to answer

1. What is quantitative methods?
2. Name the advantages and disadvantages of QT
3. What are quantitative analysis process