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MATHEMATICAL PROBABILITY AND STATISTICAL TOOLS

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Introduction

The purpose of this article is to recommend the basic mathematical, probability and statistical tools needed for management science work. Three general question areas were surveyed as a guide for these recommendations. These questions were : (1) What quantitative mathematical techniques are required for systems and management sciene work; (2) Is too much mathematics being required from students preparing for work in management science and systems engineering; (3) What is a general statement of the quantity of mathematics that is used in industry in management science and systems work ?

Many of the articles and books examined for this survey were published in recent months. They reflect a survey of some of the current thinking on the amount and level of mathematics required for systems and management science. This chapter reviews the literature published by several authors. Credit is given to these authors listed in the references at end of chapter.

The first section discusses how mathematics requirements are being reviewed at the universities. Some schools are beginning to review their math needs and specific course work recommendations are considered. The second section of the article looks at the mathematics used by industry in management science and systems work. General mathematical analysis methods are discussed. The third section briefly looks at the gap between industry and the university. Finally, some conclusions are discussed based on the literature reviewed as well as some specific recommendations by the author related to the quantitative mathematical techniques required for management science work.

I. Mathematics Requirements Are Being Reviewed at the Universities

The mathematics requirements for students in management science and systems is being examined and reviewed by universities. Such things as the distinction between pure mathematics and applied mathematics are being discussed. Since applied mathematics relates to the real world, it is receiving increased attention to help solve the problems that are arising in the real world. Certainly, the educators in the business schools are beginning to take a closer look at their mathematics needs. Bowen tells how some of the mathematics in the undergraduate business curriculum is being examined. The premise of Bowen's paper is that a concentration on quantitative methods is needed in order to be competent in management science. Some of the main ideas are worth looking at closely.

Bowen states that the need for more mathematics for students of business is an applications need. This applied mathematics will be used on problems in the area of decision theory, risk analysis, operations research. He points out that the quantitative approaches being developed in the management area by management scientists are much more than a passing fad. At a minimum, students of business must know enough of the language of mathematics to be able to translate those parts that become relevant to them. This leads to the question of what courses should be required to translate the language of modern management science.

There is a definite trend in business schools to require more mathematics. Bowen sugggests a core curriculum in mathematics that would allow the student to read management science material and lay a foundation for further elective study in the quantative methods area. He suggests the mathematical core should extend over three semesters. It should include calculus, probability and statistics, matrix algebra, and some work with an electronic computer in a mathematical context. The core should be taught with management science types of applications in mind, but such applications should be introduced sparingly and only for purposes of motivation. The core should be concerned mainly with mathematics. Applications should be treated elsewhere, either in whole courses or as parts of other courses. Students going on for graduate study should have a core in more depth that might add differential equations, calculus of several variables, and mathematical computation on an electronic computer.

As the schools of business are upgrading and increasing the math requirements for their students, it is interesting to see what is being recommended. Bowen has indicated quite clearly what he recommends. He suggests the needs for management science students are in applied mathematics with an emphasis on calculus, statistics, and matrix algebra. Bowen makes a final comment that he feels mathematics will remain on the business college scene and grow in importance.

The main thrust of several recent articles implies a new approach is needed in the study of systems and management science in university business education. Murdick and Ross explain what has happened in the past and in recent years in their article on education for systems. The past, and to a great extent, the current approach to teaching business subject matter in universities has been the management by practice approach. This has consisted of placing the practice of business in the various functional areas of marketing, production, finance and personnel. The basic course of principles of management and business policy have rested on the study and application of the statements of practitioners and armchair theorists.

Murdick and Ross continue by saying that in recent years the contributions of research methodology and management science have made a large impact ont today's managers. These methods of solution to business problems have grown rapidly. Management science has applied analysis and synthesis to the development of systems models for the solution of business problems. It has been primary because of the optimization techniques of management science that business firm has come to be regarded as a system rather than a collection of isolated problems.

The authors propose a curriculum that would lead to graduates who will be prepared for the future instead of the past. Murdick and Ross propose learning goals selected from a hierarchy according to whether the student desires to become a systems manager or a system designer. They suggest a sequence of courses that would constitute a curriculum to meet the learning goals. Essentially, modern business needs two kinds of systems people. One is the manager who functions as a gross systems designer and decision maker. He is responsible for solving major problems, making major decisions and providing direction to the systems specialists and the people who perform the operational tasks. The second kind of individual is the systems designer, who applies a high degree of expertise to translating performance specifications and gross system design into an operational reality. The system approach is a complete break from the old functional and experience approach to the study of business.

The authors easily demonstrate they have put a great deal of thought into their proposed curriculum. They divide needs of modern business between the two systems men, managers and systems designers, as described above. Murdick and Ross also recommend the appropriate educational level for undergraduate students in management or systems design. The table used to show the educational levels they suggest has been made a part of this report in Table I. As shown in the table, sequence B of the proposed curriculum covers the nature and tools of scientific inquiry.

M — MANAGEMENT STUDENTS S — SYSTEMS AND MANAGEMENT SCIENCE STUDENTS	KNOWLEDGE	UNDERSTANDING	SKILL IN APPLICATION	ANALYSIS & EVALUATION	SYNTHESIS
SEQUENCE A					
1. Macroeconomics		M,S			
2. Comparative economic systems	M,S				
3. Business in the social-legal-political environment		M,S			
4. Consumer behavior, and industrial and institutional buying		M,S			
5. Business policy, strategy, and long-range planning			S	M	S
6. Operational Systems		M,S		M,S	
7. Organizational behavior		M			
9. Venture management and entrepreneurship.		M,S			
SEQUENCE B					
1. Science, research and communication			M,S		
2. Computer science			M,S		
3. Probability and statistics			M,S		
4. Finite math with business applications		M	S		
5. Calculus with business applications		M	S		
6. Modeling and simulation		M			S

TABLE I

UNDERGRADUATE CORE CURRICULUM AND LEARNING LEVELS AS RECOMMENDED BY MURDICK AND ROSS

Sequence B should be looked at closely. By the first item in Table I, Science, Research, and Communication, the authors propose to study the purposes and methods of science, the nature of evidence and the meaning of research. Under Computer Science the topics covered would include the basic components of computers, computer logic, capabilities and Statistics as it is included in many present modern courses. In Finite Mathematics With Business Applications they suggest a wide variety of topics for a plausibility and application perspective. Calculus with Business Applications would include selected topics in calculus developed from a plausibility and application perspective. Under Modeling and Simulation they suggest a combined application of quantitative techniques and computer science to business system problems.

An author who has written extensively in areas of management science is William T. Morris. Professor Morris has written a recent article on the art of modeling. His discussion focuses on specific hypotheses concerning the differences between the teaching of models and the teaching of modeling. He states that the process by which the experienced management scientist arrives at a model of the phenomenon he is studying is probably best described as intuitive. The article looks at what can be done for the inexpereinced person who wishes to progress as quickly as he can toward a high level of intuitive effectiveness in management science. Also, Morris comments that skill in modeling certainly involves a sensitive and selective perception of management situations. This leads the management scientist to search for analogies or associations with previously well developed logical structures.

It is where Morris discusses the other sources of modeling skill that he makes some interesting comments on studying mathematics for management science work. He says sensitivity to certain other ideas appears also to be associated with the achievement of facility in modeling. For example, it is obvious that a feeling of being at ease with mathematics is important. One of the reasons that one studies advanced mathematics that will probably not be "useful", is to achieve a more comfortable and relaxed grasp of less advanced mathematics which is likely to be used. This one idea expressed by Morris has probably been partially responsible for the extensive study of advanced mathematics by many students in management science. Is this extensive study worthwhile just to be more comfortable and relaxed with less advanced math ? Perhaps, a look at some of the mathematics used by industry in management science and systems work will give more insight into the problem.

II. Mathematics Used by Industry in Management Science and System Work

Quantitative analysis has been used increasingly since World War II in industrial and commercial operations. This increase in the use of the quantitative tools of management science has involved a complete rethinking of many industrial concepts of management. Rudolf Skandera discusses some of this rethinking in an article where he talks about industrial management going back to school to learn the "New Math." He states that two apparent trends emerge from this swing to quantified methodology : one is development of a new hierarchy of analytical tools distinct from all concepts of quantitative analysis used heretofore in business and industry; the other is utilization of electronic computers to identify the complex dynamic processes of business and industry so as to describe their behavior and control them.

Two forces compelling the adoption of the scientific method in business administration are the continued fast expansion of the economy and the advent of computers. Skandera says that no sooner did electronic computers appear on the scene than they were adopted to commercial data processing. Their use created demands for new skills : computer programming. a facility in the language and grammar of computing; and systems analysis, elaboration of programming to large purpose of management decisions and ideas. These new skills call for a higher level of abstract reasoning and interest in mathematics than is normally required in conventional administrative functions.

About the time computers first appeared in commercial and industrial operation, quantitative techniques were beginning to be employed in dealing with problems of business management. Many of these problems have come to be grouped under the concept of decision-theory. Usually presented in mathematical or logical terms, these techniques are frequently referred to as models. Skandera admits that being mainly quantitative, the operations increase the importance of mathematics in business administration. While computers have become the "instruments of the hand' 'in the quantitative techniques of decision-theory, mathematics has provided business administration with the instruments of the mind.

It is worthwhile to look briefly at the effectiveness of thought that quantitative analysis has brought historically to management. First, the arithmetic tools were used to search for answers to problems of commerce, finance, and industry. The second phase of the development of quantative techniques was in the concept of differential analysis that emerged from Newton's principles of infinitesimal calculus. For example, differential analysis is applied in economic doctrine and mathematical theories like marginal utility. Next came the awareness of stochastic events. This awareness of a range of values with different probabilities can be gathered under a single quantitative index of mathematical expectation. Skandera suggests that the fourth phase of quantification in business administration was introduced in the form of a theory of games approach to business. He says according to some views, applied manifestations of decision theory are apparent in operations research.

Mathematics has attained significance in industrial management science because of a growing need for abstract thinking and formal reasoning. This need has been attributed by Skandera to such things as the growing use of computers, increasing applications of operations research, and great numbers of scientific people coming into management science.

As a side comment, Montello describes the high value industry has recently placed on advanced education. He says the technological revolution placed professional people in particular demand. Today, one of the strongest determinants of site location is accessibility to at least one high quality university, technical institute, or college faculty. Professional and technical personnel demand top quality community educational facilities. Since quality educational opportunities at all levels must be available in communities competing for new industries, there is little doubt that industries will be demanding excellence in the management science curriculum. This curriculum will have to include the mathematics required by industry for its management science and systems work.

Industrial management science uses both analysis and simulation methods. A recent article that discusses and compares the two is written by A.S. Philippakis. This article looks at the main differences between analytical and simulation methods in systems management. Since this section of the report is looking at the mathematics used by industry in management science and systems work, it is necessray to look at how mathematical analysis is applied. Philippakis says the application of mathematical analysis of two stages. First, an observed real system must be cast into the form of a mathematical model. The correspondence between reality and the meaning attached to the components of the model is crucial. Once the model has been formulated, the use of mathematical deductive methods yields a solution to the problem. This solution is guaranteed to be a correct implication of the structure of the model. Of course, while it may be correct for the model, it may be false in terms of reality if the original model-reality correspondence was inappropriate.

Simulation methods, like analytical ones, have to be concerned with the correspondence between reality and the model. But even if this correspondence is appropriate, simulation methods do not provide guarantees that a correct solution will be derived. Whether we make observations in the form of inferences formed will not provide certainty of their correctness. At most we may have a probabilistic estimate of their correctness. Otherwise we only have some intuitive feel that the inferences we draw are actually implied by the model. Philippakis states that, simulation methods is that do not have adequate analytic techniques for certain models.

One of the things that Philippakis points out is the "beauty" of mathematical analysis in systems management. This beauty comes from the fact the solution procedures are derived within the formal mathematical system and they apply regardless of the meaning attached to the variables of a particular model. With this in mind, it might be good to consider briefly the three basic elements of any mathematical structure :

1. A set of **postulates, axioms or assumptions.** These are propositions that are not derivatives of other propositions. Euclid conisdered them self-evident truths. It was not until nineteenth century that the broader characteristic of man-made assumptions replaced the notion of self-evident truths.

2. **Logic.** The cognitive process of man, which can manipulate the assumptions or postulates according to the rules of rational operations. This is a deductive process.

3. **Derived propositions.** Applications of logic to the basic assumptions or postulates that yield a number of new, derived, propositions, usually referred to as theorems.

Of course, the interesting part of their discussion from the point of view of this report is the level and amount of mathematics the authors recommend for systems designers.

For the systems designer, the authors suggest his basic contribution is the application of special knowledge to the solution of systems problems. His training should primaily give him greater technical skills. He must gain depth of knowledge of business problems, MIS systems management science and computer applications. Murdick and Ross say he must also gain skill in application of analysis and design techniques. They remain rather general in describing quantitative techniques for the systems designer. The authors use a five-point scale to describe the level of understanding they feel is required for different jobs in systems design. They give the highest rating to problem solving by the system designer. Here, he should be able to handle the theory and practice of logic, decision making and creative thinking. He should be able to apply the techniques of operations research and management science. Also, the systems designer must be able to formulate decision rules, use simulation, apply the principles of modeling, and other techniques in systems design. The authors say the ideal system designer will have a college degree based on either operations research, mathematics, or management science. Those without such a background should have the ability to be trained in quantitative methods.

Another recent article by C. Orville Elliott discusses the fundamentals of business systems tchniques. Although much of what Elliott talks about is not quantitative, he does tell where the systems men are using quantitative methods. He says these tools are used to provide answers and alternatives to some business problems. There are two main categories of problems where these techniques may be applicable. One is where several courses of action are possible and these are evaluated to determine the best one. The other broad category involves problems more of a developmental nature in which currently available alternative techniques are no longer suitable and a new approach must be developed.

Elliott says other techniques, of which the systems man should have some basic knowledge, include those related to the statistical and probability theory areas. In the application of these areas, statistical sampling techniques are applied to a population area to select samples by some form of random sampling. From these samples, certain inferences, based on probability theory, may be made and expressed. At given levels of confidence, the predictions are representative of the population being analyzed. It is interesting to notice that Elliott only recommends a level of «some basic knowledge" in statistics and probability.

Del Burchfield looks at systvms analysis as a quantified decision making procedure. Systems analysis is basically just one name for an approach to problems of decision-making that good management has always practiced. The author describes the kind of thinking required in systems analysis. He says every decisions should be viewed from some meaningful context, then reduced to its component parts, and, finally, system analysis becomes an aid to good judgement. Burchfield says systems analysis managers are being called on to quantify. The quantification must start in the development phase of the life cycle of the system or equipment, during the period when technical performance characteristics are being developed. In order to control development, we must quantify objectives, identify necessary inputs, measure progress, and verify outputs. Burchfield is saying that in order to manage we must quantify.

These three elements, in brief, constitute the basic structure of a mathematical system, as indicated by Philippakis. The process of applying deductive logic may then be extended from the original postulates to derive propositions to derive new propositions, and so on. The process can be carried out to a great extent, as the vastness of mathematical knowledge indicates.

With the above general background, a look can now be taken at what some recent articles are calling for in mathematics for management science and system work in industry. Another article by Murdick and Ross discusses education for systems, with an emphasis on management information systems. The authors describe training programs that businessmen need obviously do not meet the educational goals of university students. A business must look for shorter range-now-returns for its large investment in training ; it cannot afford to provide long periods of education whose payoff may be both intangible and remote in time. Therefore, companies are concerned mainly with bringing their men abreast of new technologies so that the individuals may attempt to continue to remain abreast on their own initiative. This applies to training programs for management information systems as well as any other programs.

Murdick and Ross studied both the government and industry to determine the need for systems designers and the content of training programs. Results of both investigations indicated that the leaders in industry and government are groping for ways to organize for and utilize the tremendous payoffs possible with computer-based information systems. The leap form straight data processing to computer-based systems problem solving has been sudden. Understanding and assimilation of the potentialities for decision making have energized leaders in all forms of endeavor. This is another article that points to the growing use of quantitative techniques in management.

A series of articles by Marvin J. Bevans describe how mathematics for managers is a subject of growing interest. He says there is a relatively new school of thinking which believes that some aspects of mathematics can help the manager examine, clarify, and improve his decision-making. General Electric's management has done a great deal of work in the area of applying mathematics to business, and has developed an excellent training program, according to Bevans. There are four text books used in their training program that were written by G.E. consultants. They cover the following subjects : (1) Basic Mathematics; (2) Advanced Methods and Models; (3) Statistical Inference; (4) Probalistic Models. The texts are not designed to produce professional mathematicians; but are designed to help managers function in a mathematical situation with some degree of understanding. The text books consider a broad range of mathematical concepts, including algebra, calculus, and matrices. In the three articles Bevans discusses some statistical parameters like averages, median, and mode. He then mentions some very basic algebra in the area of square roots, exponents, and logarithms. Later, set theory and other concepts of basic mathematics are presented. Bevans is writing to the administrative manager. He emphasizes basic mathematics and indicates there is a growing use of mathematics in management.

Certainly, these articles give some indication of what industry is saying it wants for a mathematics background for its management scientists. Before drawing some conclusions, the industrial-academic interface will be discussed briefly.

III. The Gap Between Industry and the University

One final topic that deserves mentioning is the gap between what industry wants and what the universities are providing. No article was found that dealt specifically with industry's mathematics needs and what the university is providing. Nevertheless, it is worth looking briefly at what George S. Hammond has to say about his analysis of industrial/academic interaction.

Hammond says that the traditoinal concept of interaction between the universities and industries has been almost classically simple. Three components are involved : (1) contribution of money by the industries, in the form of gifts or taxes, to help support the educational institution, (2) transfer of students from academia to the industrial world, and (3) some exchange of substantive information acquired in research laboratories. Direct industrial support of academic institutions is not very impressive because during the past two decades there has been a steady growth of public financing. Students, the principal product of universities, are being produced in large numbers. Many of them are bright and well informed. Still, industry is not entirely enchanted, since many of the sharpest students are not interested in industrial careers or using their knowledge and creativity in service of their employers.

The exchange of information is also thoroughly unsatisfactory, according to Hammond. Information is accumulating at an enormous rate that far exceeds the capacity of the human mind to assemble it. The potential of the computer to bridge the information transfer gap may go a long way towards solving the problem. There is another component of the information exchange problem. There is a necessary and desirable difference between the character and objectives of academic and industrial research. Most academic research is basically dedicated to finding general solutions to problems. In industrial research the primary objective is normally to obtain an answer to the problem at hand. Consequently, the methodologies of the two kinds of research must differ.

The really meaningful value of industrial-academic interaction comes from the fact that academic research does develop theories and models that have some generality. These have two kinds of value in applied research. First, some of the models directly suggest solutions to applied problems. A second, more important effect is establishment of the fact that the behavior of things in the universe is systematic.

Academia and industry have much in common. Certainly, the amount and level of mathematics required to work in management science should be an important area of interaction between industry and the universities. Perhaps the universities sould do some hard listening to find the need for mathematics in management science in industry.

IV. Conclusions and Recommendations

The list of references used for this chapter contains some outstanding articles. The article by Bowen described quite well the new thinking that is going on in university business schools concerning mathematics. Both of the articles by Murdick and Ross, which appeared in the **Journal of System Management,** show that some thorough research is being done on a quantitative curriculum for systems work. Many of the other books and articles were excellent. They show that mathematics for management science and systems work is a subject of growing interest.

Much of the recent literature indicates there is an examination taking place concerning the amount of mathematics that should be taught in management science. Quantitative methods are being studied in decision theory, risk analysis, and other areas of applied mathematics. The recommended mathematics curriculum for management science includes probability statistics, finite mathematics, calculus, and modeling and simulation. Only in one case was higher level, more abstract mathematics recommended. In this case, Morris suggests the student would then be more comfortable with the less advanced mathematics he may need in applied management science.

There is little doubt that there has been a great increase in the use of quantitative methods since World War II. New quantitative analysis tools and electronic computers are being used extensively in management science. The mathematical and logical skills of decision-theory are being applied in industrial management science. There seems to be a growing need for abstract thinking and formal reasoning. Mathematics provides the language for this thinking and reasoning. Industrial mathematics requirements in management science seem to include the applied mathematics of modeling, probability, statistics, quantified decision making, algebra, calculus, and matrices. All of the articles imply a growing use of applied mathematics in management science and systems work.

If universities want to find out what level and amount of mathematics should be included in management science courses, they should investigate thoroughly the requirements of industry. Hammond suggests the industrial-academic gap can be bridged by the universities listening hard to find industry's needs. This also applies to the mathematics of industrial management science and systems work.

The author has accumulated a list of quantitative methods (Appendix 1) that he considers essential for the management scientist to be able to identify the mathemaical, probability and statistical tools available to provide solutions when the problems arise. The level of competence in handling these quantitative tools depends on the specific areas of application within the optimization, simulation and control techniques.

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QUANTITATIVE METHODS
REQUIRED FOR MANAGEMENT SCIENCE

MATHEMATICS

A. Sequences

1. Arithmetic Progressions
2. Geometric Progressions
3. Weighted Moving Averages
4. Exponential Smoothing

B. Relations, Functions, and Graphs

1. Linear Functions
   - a) Slope
   - b) Sectional Continuity
2. Quadratic Functions
3. Exponential Functions
4. Logarithmic Functions
5. Line of Regression

C. Matrices

1. Column and Row Vectors
2. Operations on Matrices
   - a) Addition and Subtraction
   - b) Multiplication of Matrices
3. Definitions of Terms
   - a) Identity or Unit Matrix
   - b) Matrix Inverse
   - c) Matrix Transpose

D. Linear Programming

1. Recognition of the Formulation of Linear Programming Problems
2. Simplex Method
   - a) Non-Negative Assumption
   - b) Non-Degeneracy Assumption
   - c) Slack Variables
   - d) Artificial Variables
   - e) Basic Feasible Solution
3. Concept of the Dual Linear Programming Problem
4. Special Cases
   - a) Transportation Problems
   - b) Zero Sum Games

E. Statements and Set Theory

1. Statements
   - a) Atomic
   - b) Compound
   - c) Truth Tables
   - d) Tree Diagrams
2. Operating With Sets
   - a) Complementation
   - b) Union
   - c) Intersection
   - d) Venn Diagrams
3. Critical Path Analysis
   - a) Slack Time
   - b) Free Slack
   - c) Independent Slack

F. Mathematics of Finance and Accounting

1. Compound Interest Problems
   - a) Solve for Future Amount
   - b) Solve for Present Value
   - c) Solve for Interest Rate
   - d) Solve for Number of Payments
2. Depreciation Calculations
   - a) Straight Line
   - b) Sum-of-the-Year's Digits
   - c) Double Declining Balance
3. Breakeven Analysis
4. Double Classification Bookkeeping (as Distinguished from Double Entry)

G. Computation Topics

1. Representation of Numbers
   - a) Binary, Octal, Decimal, and Hexadecimal
   - b) Floating Point
2. Significant Digits
3. Rounding
   - a) Decimal Rounding with Binary Numbers
   - b) Balancing Sums of Rounded Numbers

4. **Iteration**

5. Calculation as an Alternative to Table **Look Up.**

H. Counting or Enumeration

1. Permutations
2. Combinations
3. Compositions
4. Partitions

STATISTICS & PROBABILITY

A. Introduction to Statistics

1. Effective Uses of Statistics

2. Misuses of Statistics

3. Decision - Parameters
   - a) Frequency Distribution
   - b) Averages
   - c) Measures of Variation
   - d) Measures of Relationship

B. Elementary Probability Theory for Finite Sample Spaces

1. Probability
   - a) Experiments
   - b) Sample Spaces
   - c) Events and Sets
   - d) Mutually Exclusive and Independent Events
   - e) Randomness

2. Conditional Probability

C. Introduction to Random Variables, Distributions, and Distribution Properties

1. Random Variables
   - a) Random Variables and Their Probability Functions
   - b) Mathematic Expectation of a Random Variable
   - c) Mean, Average, and Variance of a Random Variable Function
   - d) Probability Distribution
   - e) Frequency Distribution

2. The Normal Distribution
   - a) Joint Probability Function of Two Random Variables
   - b) Probability Graphs for Continuous Random Variables
   - c) Probabilities Represented by Areas
   - d) Cumulative Probability Graphs
   - e) The Normal Curve and the Normal Probability Distribution

D. Theory of Sampling; Statistical Inference

1. Calculations of the Distribution of a Sum

2. The Variance of the Distribution of the Sum of Two Independent Random Variables

3. Variance of the Sum and of the Average of Several Variables

E. Binomial Probability Distribution and Central Limit Theorem

1. Binomial Experiments
2. Expected Value of a Binomial Random Variable.
3. Binomial Probability Tables
4. Binomial Distribution Properties
5. The Central Limit Theorem for the Binomial

F. Time Series Analysis

1. Determination of Trends
2. Variations - Periodic, Cycle, Irregular
3. Smoothing Techniques

G. Control Charts

1. Chance vs Caused Effects
2. Process **Control**
3. Acceptance Sampling