Operational Research Technique List

Produced by GORS in conjunction with John Ranyard and Graham Rand (Lancaster University)

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LANCASTER UNIVERSITY

GORS

Government Operational Research Service

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Introduction

The GORS competency framework gives the core skills and specialist skills required at each grade from Level 1 to SCS. The core skills reflect the core skills for civil servants in the Professional Skills for Government (PSG) framework. The specialised skills reflect the use of analysis and evidence in Government Operational Research.

To supplement the core and specialist skills, GORS collated a list of techniques that were being used across Government.

John Ranyard and Graham Rand from Lancaster University supplemented this list with definitions and reference material.

Different departments and individuals will develop their skill in techniques in different ways. However, all GORS members should have an appreciation of the range and diversity of Operational Research techniques.

Appraisal and Evaluation

1. Decision Analysis

Decision Analysis (DA) is the discipline comprising the philosophy, theory, methodology, and professional practice necessary to address important decisions in a formal manner.

Decision Analysis includes many procedures, methods, and tools for identifying, clearly representing, and formally assessing the important aspects of a decision situation, for computing recommended course of action by applying the maximum expected utility action axiom to a well-formed representation of the decision, and for translating the formal representation of a decision and its recommendation into insight for the decision-maker and other decision participants.

The term Decision Analysis was coined in 1964 by Ronald A. Howard, who since then, as a professor at Stanford University, has been instrumental in developing much of the practice and professional application of DA.

Decision Analytic methods are used in a wide variety of fields, including business (planning, marketing, and negotiation), environmental remediation, health care research and management, energy exploration, litigation and dispute resolution, etc.

2. Decision Trees

In Operational Research, and Decision Analysis specifically, a Decision Tree is an idea generation tool that generally refers to a graph or model of decisions and their possible consequences, including chance event outcomes, resource costs, and utility. A Decision Tree is a decision support tool, used to identify the strategy most likely to reach a goal. Another use of trees is as a descriptive means for calculating conditional probabilities.

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3. Discount Rates and Net Present Values

The discount rate is the interest rate used to discount future cash flows to their present values. Most firms have a well-defined policy regarding their capital structure. So the weighted average cost of capital (after tax) is appropriate for use with all projects. Alternately, higher discount rates can be used for more risky projects. Another method is to apply higher discount rates to cash flows occurring further along the time span, to reflect the yield curve premium for long-term debt.

Net Present Value (NPV) is a standard method for financial evaluation of long-term projects. Used for capital budgeting, and widely throughout economics, it measures the excess or shortfall of cash flows, in present value (PV) terms, once financing charges are met. All projects with a positive NPV are profitable; however this does not necessarily mean that they should be undertaken since NPV does not account for opportunity cost. Assuming a firm aims to maximise profit, projects should be undertaken only if their NPV is greater than the opportunity cost. In financial theory, if there is a choice between two mutually exclusive alternatives, the one yielding the higher NPV should be selected. NPV = Present value of cash flow minus initial investment.

4. Experimental Design (**Also known as Evaluation Methods)**

The most important principles of experimental design are:

Randomization

The process of making something random

Replication

Repeating the creation of a phenomenon, so that the variability associated with the phenomenon can be estimated

Blocking

The arranging of experimental units in groups (blocks) which are similar to one another

Orthogonality

i.e. perpendicular, at right angles or statistically normal.

Analysis of the design of experiments was built on the foundation of the analysis of variance, a collection of models in which the observed variance is partitioned into components due to different factors which are estimated and/or tested.

In 1950, Cox and Cochran published the book Experimental Design which became the major reference work on the design of experiments.

Developments of the theory of linear models have encompassed and surpassed the cases that concerned early writers. Today, the theory rests on advanced topics in abstract algebra and combinatorics. Both classical and Bayesian experimental designs exist.

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5. Stated Preference Techniques

Stated Preference (SP) techniques are a family of market research tools that allow researchers to uncover how consumer's value different product/service attributes. SP asks respondents to rank, rate or choose between different hypothetical product/service scenarios, that are made up of different attribute mixes. The choices made by the respondents can be used to infer how they value different attributes.

6. Techniques of Investment Appraisal

Techniques of Investment Appraisal include:

payback period: which measures the time required for the cash inflows to equal the original outlay. It measures risk, not return.

cost-benefit analysis: which tries to include issues other than cash.

real option method: which attempts to value managerial flexibility that is assumed away in NPV.

Internal Rate of Return (IRR): which calculates the rate of return of a project without making assumptions about the re-investment of the cash flows (hence internal)

Modified Internal Rate of Return - similar to Internal Rate of Return, but it makes explicit assumptions about the re-investment of the cash flows. Sometimes called Growth Rate of Return.

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Collection and Production of Statistics

7. Data Matching

Data matching is the computerised comparison of two or more sets of records which relate to the same individual. It is primarily used as a method for combating fraud. It involves the full or partial integration of two or more datasets on the basis of information held in common. It enables data obtained from separate sources to be used more effectively, thereby enhancing the value of the original sources. Data matching can also reduce the potential burden on data providers by reducing the need for further data collection. However where data matching involves the integration of records for the same units (persons, households, companies, etc) it also raises important issues of privacy and subject consent. The holding of identifying information also raises issues about confidentiality and security.

Data matching includes the following methods:

Exact Matching

This is achieved when there is complete agreement between key variables such as the National Insurance number. The proportion of data that will be exactly matched will depend directly upon the quality of the base statistical sources, and in many cases it may be desirable to combine exact and probability matching.

Probability Matching

This enables matches to be made where there are small discrepancies in the data as the result of, say, a misspelt name, or an error in the date of birth. During probability matching both statistical sources are grouped using one or more blocking variables such as the postcode. Specific key variables from each record in the statistical sources are then compared, weights are allocated depending on the level of agreement and these are summed to produce an indication of the overall level of concordance. Matches are then made by comparing the highest total weight to a specified threshold.

Statistical Matching

This involves the matching of similar rather than identical units is not only acceptable but is expected. Statistical matching is therefore frequently used where the base statistical sources have few or no common records, making the matching of identical records impossible for the majority of the data. Statistical matches are made on the basis of similarity of characteristics rather than uniquely identifying information as is the case with exact and probability matching.

Data Linking

This involves the creation of associations between data held in two or more different statistical sources. The associations may allow access to another statistical source or may be used for simultaneous updating. The association is removed once the statistical reason for its creation ceases to exist. Data linking does not result in a matched statistical source and there are no additional issues raised for this protocol provided that the two base statistical sources continue to be secured separately.

There are a number of examples of data matching being undertaken by government agencies. The DWP has established a Housing Benefit Matching Service aimed at detecting benefit fraud. The Audit Commission uses data matching across local authorities regarding benefit claims, education awards and activities of local authority employees. The Social Security Administration (Fraud) Bill provides for wider sharing by central and local government and the Post Office for fraud prevention or detection purposes.

8. Data Quality Control and Monitoring

The first principle is to prevent data contamination. Underlying the Total Quality Management philosophy is the understanding that all company employees should feel be responsible for product (i.e., database) quality.

Basic concepts and strategies for improving data quality include outlier detection for the purpose of elimination of data contamination; reduction of keypunch errors; filter programs for illegal data; detection of outliers in samples; and detection of outliers and leverage points in simple linear regression.

An outlier is simply an extreme value for a variable, given the statistical model in use. Outlier detection is part of the process of checking the statistical model assumptions, a process that should be integral to any formal data analysis. The detection of outliers is an intermediate step in the elimination of contamination. Once the outlier is detected, attempts should be made to determine if some contamination is responsible.

Sources of contamination due to data entry errors can be eliminated or greatly reduced in several ways. One excellent strategy is to have the data independently keyed by two data entry technicians, and then computer-verified for agreement. This practice is commonplace in professional data entry services, and in service industries such as the insurance industry.

Illegal data are variable values or combinations of values that are literally impossible for the actual phenomenon of interest. For example, non-integer values for a count variable or values outside of the interval [0,1] for a proportion variable would be illegal values. Illegal combinations occur when natural relationships among variable values are violated, e.g., if Y1 is the age last year, and Y2 is the same person's age this year, then Y1 must be Y2 - 1. These kinds of illegal data often occur as data entry errors, but also for other reasons. A simple and widely-used technique for detecting these kinds of contamination is an illegal data filter: a program which simply checks a list of variable value constraints on the master data set and creates an output data set including an entry for each violation with identifying information and a message explaining the violation.

One of the oldest and most widely used procedures for detecting contamination in samples is Grubbs' test (Grubbs and Beck, 1972). Outliers in regression can be detected by means of studentized residuals.

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9. Design of Data Collection Mechanisms (**Also known as Data Specification / Survey Design)**

A data collection (or survey) method refers to both the selection of sampled units and the way data is collected from them. The data collection method influences a number of factors. The most important ones include survey design: the selection of sampled units, probable response and non-response rates, and the cost of data collection. The data collection method also has a bearing on the timetable of the survey and on the quality of the final results. The choice of data collection method is not an isolated decision in survey design, as it influences the whole statistical survey process. For instance, it has an impact on the design and preparation of the questionnaire, on the quantity and quality of the data that are to be collected, and on the cost and the timetable of the survey.

Three factors are usually considered when surveys are classified into different types: the general survey design, the data collection method, and the technology for data acquisition, though the most important division is that between longitudinal surveys and cross-sectional surveys. In longitudinal surveys, data are collected more than once from the same sampling units, at more or less regular intervals, whereas in cross-sectional surveys, data are collected only once. In longitudinal surveys data may be collected the same way each time, or the data collection method may vary. A panel survey is a special type of longitudinal survey.

It is important to make a distinction between the mode of administration of data collections and the technology applied in data acquisition. In the administration modes one distinguishes whether interviewers are used (interviewer-administration) or whether respondents are to answer by themselves (self-administration).

Collected data should be recorded on a standardised form or questionnaire. Questionnaires may be classified according to two factors: the administration mode (who enters the data), and whether the instrument is an electronic one or a paper version (the technology applied). The central principle in the designing of any question is that the respondent should clearly understand what is being asked, can be expected to know the answer to the question, and understands how the answer should be given.

In order to minimise variation caused by interviewers, a standardised interview method is strongly recommended to ensure that all interviewers present the questions in the same manner. Therefore, presentation standards guiding the interviewers' behaviour and question presentation and probing are employed in interviews. With long and complicated interviews, interviewers usually have to be trained before the survey, and this may prolong considerably the total duration of the survey.

Survey design requires an estimate of the sample size or the number of respondents in the final sample. In most cases, the reliability of a survey increases as the sample size increases. Another important factor is the quantity and quality of information obtained from each respondent. For example, a long interview should not be conducted by telephone. Also, a face-to-face interview is the only option if objects such as visual scales or pictures need to be shown to respondents.

The duration of a survey and the response rate are often inversely related. The more time and resources spent during the fieldwork, the higher the response rate will be. The accepted non-response rate is always a compromise. The often quoted basic thesis is that only two out of the three requirements of low costs, high response rate and fast timetable can be achieved in one survey. Different administration modes typically have different non-response rates, the highest being in postal surveys. Many other factors also influence the non-response rate. For example, the duration of the interview and the complexity of questionnaire may increase non-response.

Longitudinal surveys are more reliable for describing change - or the dynamics of society - than repeated cross-sectional surveys. Additionally, longitudinal surveys may save resources because the same sample, and at least partly the same data collection instruments, can be used. The practical routines become more efficient. A disadvantage in some cases is the panel effect, meaning that respondents become aware of belonging to a panel and change their behaviour or responses.

In face-to-face interview surveys, fieldwork and its organisation requires more resources and generates more costs than would be the case with telephone or postal surveys. On the other hand, the presence of an interviewer makes the interview situation controllable and a face-to-face interview makes it possible to clarify both questions and answers. Face-to-face interviewing is the most expensive data collection mode.

One of the advantages of a postal survey is low cost. It is also easier to answer sensitive questions on a paper questionnaire than in a telephone or a face-to-face interview. Choosing from several alternative replies (more than 6) requires visualisation, which is possible only in postal surveys and face-to-face interviews.

Computer assisted data collection offers many new possibilities compared to paper questionnaires. For example, it facilitates the use of diverse question and response combinations. Different question routings for different respondents are easy to implement, and it is possible to attach background information, e.g. from registers, for each sampling unit. The coding of answers, e.g. by occupation, is also possible during the interview. Computer assisted data collection lessens the amount of data entry errors and makes the completion of the collected material faster, because the interviewer (or respondent) enters the data directly into a computer during the interview, and checks for correctness and logical consistency can be programmed into the questionnaire.

10. Editing and Imputation

Data editing is about detecting and correcting errors in the information returned by the contributors of the data. Editing should start at the lowest level of the data, that is, at the micro level (micro editing), followed the more aggregated levels (macro editing). Mutual compatibility between levels should be aimed at in the end. The whole data must be examined with care in order to avoid significant distortions to the survey results. Statistical editing is needed at each phase, starting from the planning of the data collection all the way to data file formation and data processing and analysis. Further editing of the data may become necessary even years after the completion of data collection, e.g. when cross-sectional data are combined with other data, that is, when longitudinal data files are formed.

Imputation is a procedure used for entering a value for a specific data item where the response is missing or unusable. Imputation implies that a missing value for a variable is replaced with an imputed value, which has to be as correct as possible with regard to the true but unknown value. Imputation is usually used for correcting item non-response, but it can also be applied at the unit response level. This is referred to as mass imputation in large-scale and automated imputation situations.

11. Estimation Methods

The parameters that are the focus of interest in descriptive statistical surveys are usually totals, averages or proportions at the total population level or relative to parts of it. In surveys where the emphasis is on analysis, the interest falls on connections and interdependences between phenomena. Parameters are connected with statistical models, such as linear models, and are represented by coefficients of correlation or regression, for example. An important stage in both types of survey is the estimation of unknown parameters as reliably as possible. Analytical surveys often include more extensive interpretations of the results than do descriptive surveys.

Estimation uses the available survey data or other observation data to produce numeric estimates for unknown parameters. The calculation method or algorithm needed in the estimation is called the estimator, and its numeric value is called the estimate. The reliability of an estimate is assessed by calculating the standard error or coefficient of variation of the estimator used. The confidence interval (e.g. 95 per cent confidence interval) for a parameter can be calculated using the estimated standard error. Information on confidence intervals and coefficients of variation is essential for evaluating the reliability of statistics, and must also be reported to the users.

The most important theoretical attributes of the estimators connected with reliability are unbiasedness, precision and accuracy. An estimator is unbiased when the mean of all possible estimates, corresponding to all possible samples of a given size, is the same as the value of the unknown parameter, in other words, the expected value of the estimator equals the value of the parameter. A weaker, but also more prevalent, attribute is consistency of the estimator. The estimator is consistent if its expected value approaches the value of the parameter as the sample size increases, and matches the value of the parameter when the sample size equals the population size. Precision refers to the fluctuation of estimates around their expected values. The smaller the fluctuation is, the greater is the estimator's precision. An accurate estimator is both unbiased (or at least consistent) and precise.

12. Analysis of Variance (ANOVA)

One way Analysis of Variance allows comparison of several groups of observations, all of which are independent but possibly with a different mean for each group. A test of great importance is whether or not all the means are equal. Two Way Analysis of Variance is a way of studying the effects of two factors separately (their main effects) and (sometimes) together (their interaction effect). The Analysis of Variance F tests assume that treatments have been applied randomly.

The structure of the experiment in a completely randomised design is assumed to be such that the treatments are allocated to the experimental units completely at random.

The randomised complete block design is a design in which the subjects are matched according to a variable which the experimenter wishes to control. The subjects are put into groups (blocks) of the same size as the number of treatments. The members of each block are then randomly assigned to different treatment groups. A factorial design is used to evaluate two or more factors simultaneously. The treatments are combinations of levels of the factors. The advantage of factorial designs over one-factor-at-a-time experiments is that they are more efficient and they allow interactions to be detected.

The Main Effect is the simple effect of a factor on a dependent variable. It is the effect of the factor alone averaged across the levels of other factors. An interaction is the variation among the differences between means for different levels of one factor over different levels of the other factor.

In certain experiments, particularly clinical trials, the comparison of treatments may be distorted if the patient, the person administering the treatment and those evaluating it know which treatment is being allocated. It is therefore necessary to ensure that the patient and/or the person administering the treatment and/or the trial evaluators are 'blind to' (don't know) which treatment is allocated to whom. Sometimes the experimental set-up of a clinical trial is referred to as double-blind, that is, neither the patient nor those treating and evaluating their condition are aware (they are 'blind' as to) which treatment a particular patient is allocated. A double-blind study is the most scientifically acceptable option.

13. Sampling Theory

The basic sampling method is Simple Random Sampling (SRS), which is a self-weighting sampling design, meaning that all the elements in a population have an equal probability of being included in the sample. A convenient way to draw a Simple Random Sample is to assign each population element a (pseudo) random number, sort the data set according to the random numbers, and finally select the required sample size from any sequential part of the population, normally beginning from the first element and continuing until the desired sample size is reached.

Sample size is affected by various determinants: the precision at which parameter estimates are required, the way in which small domains and sub-domains are to be covered (i.e. classification), and population heterogeneity. Naturally, the available resources will also influence the sample size. It can be said that precision, as well as accuracy, will improve when sample size is increased, because the standard errors of the estimates will decrease. However, the improvement is not proportional to the increase in the sample size but occurs more slowly.

In cluster sampling, either all elements from each selected cluster can be included in the sample (one-stage cluster sampling) or a sub-selection can be made from within the selected clusters (two-stage cluster sampling).

In stratified sampling, the population is first divided into mutually exclusive sub-populations known as strata. The aim is to achieve as homogenous sub-populations as possible given the available information.

Systematic sampling means that every rth element is selected over the whole sampling frame. Sampling is started by selecting the first element from the range [1, r] and elements are then selected at the sampling interval r to the end of the frame.

If the elements are in a random order, systematic sampling is essentially equivalent to simple random sampling. However, if the population contains some (hidden) order or sequence, systematic sampling may yield a sample that consists of very similar elements that do not reflect the true population variation and thus the sample can lead to erroneous or biased results.

If a sample is to be selected from a much skewed population, e.g. the elements are of different size, the overall sample accuracy can be improved markedly by attaching to each element an inclusion probability that is related to the element size. PPS samples can be either with or without replacement.

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14. Cost-Benefit Analysis

Cost-Benefit Analysis is an important technique for project appraisal: the process of weighing the total expected costs against the total expected benefits of one or more actions in order to choose the best or most profitable option.

The process involves monetary calculations of initial and ongoing expenses vs. expected return. Constructing plausible measures of the costs and benefits of specific actions is often very difficult. In practice, analysts try to estimate costs and benefits either by using survey methods or by drawing inferences from market behaviour. For example, a product manager may compare manufacturing and marketing expenses to projected sales for a proposed product, and only decide to produce it if he expects the revenues to eventually recoup the costs. Cost-Benefit Analysis attempts to put all relevant costs and benefits on a common temporal footing. A discount rate is chosen, which is then used to compute all relevant future costs and benefits in present-value terms. Most commonly, the discount rate used for present-value calculations is an interest rate taken from financial markets (Frank, 2000).

During Cost-Benefit Analysis, monetary values may also be assigned to less tangible effects such as risk, loss of reputation, market penetration, long-term strategy alignment, etc. This is especially true when governments use the technique, for instance to decide whether to introduce business regulation, build a new road or offer a new drug on the state healthcare. In this case, a value must be put on human life or the environment, often causing great controversy. The cost-benefit principle says, for example, that we should install a guardrail on a dangerous stretch of mountain road if the dollar cost of doing so is less than the implicit dollar value of the injuries, deaths, and property damage thus prevented (Frank, 2000).

Cost-benefit calculations typically involve using time value of money formula. This is usually done by converting the future expected streams of costs and benefits to a present value amount.

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15. Data Envelopment Analysis (Frontier Analysis)

Data Envelopment Analysis (DEA), sometimes known as Frontier Analysis, is a linear programming methodology to measure the efficiency of multiple Decision Maker Units (DMUs) when the production process presents a structure of multiple inputs and outputs.

Some of the benefits of DEA are:

- no need to explicitly specify a mathematical form for the production function

- proven to be useful in uncovering relationships that remain hidden for other methodologies

- capable of handling multiple inputs and outputs
- capable of being used with any input-output measurement
- the sources of inefficiency can be analysed and quantified for every evaluated unit.

In the DEA methodology, formerly developed by Charnes, Cooper and Rhodes (1978), efficiency is defined as a weighted sum of outputs to a weighted sum of inputs, where the weights structure is calculated by means of mathematical programming and constant returns to scale are assumed. In 1984, Banker, Charnes and Cooper developed a model with variable returns to scale.

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16. Stochastic Frontier Analysis

Modern textbook presentations of production economics typically treat producers as successful optimisers. Conventional econometric practice has generally followed this paradigm, and least squares based regression techniques have been used to estimate production, cost, profit and other functions. In such a framework deviations from maximum output, from minimum cost and cost minimizing input demands, and from maximum profit and profit maximizing output supplies and input demands, are attributed exclusively to random statistical noise. However casual empiricism and the business press both make persuasive cases for the argument that, although producers may indeed attempt to optimise, they do not always succeed. Stochastic Frontier Analysis develops econometric techniques for the estimation of production, cost and profit frontiers, and for the estimation of the technical and economic efficiency with which producers approach these frontiers. Note that these frontiers envelop rather than intersect the data, and also that the traditional econometric belief in the presence of external forces contributing to random statistical noise is maintained.

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17. Factor Analysis (Multi-Variate Methods)

The expression is used rather loosely to denote the analysis of data which are multivariate in the sense that each member bears the values of p variates. The principal techniques of multivariate analysis, beyond those admitting of a straightforward generalisation, e.g. regression, correlation and variance analysis, are factor and component analysis, classification, discriminatory analysis, canonical correlation and various generalisations of homogeneity tests.

18. Quantitative Risk Assessment/Monitoring

Risk is a concept that denotes a potential negative impact to an asset or some characteristic of value that may arise from some present process or future event. In everyday usage, "risk" is often used synonymously with the probability of a loss. In professional risk assessments, risk combines the probability of an event occurring with the impact that event would have and with its different circumstances.

Risk does not always only refer to the avoidance of negative outcomes. In game theory and finance, risk is only a measure of the variance of possible outcomes. Insurance is a classic example of an investment that reduces risk. The buyer pays a guaranteed amount, and is protected from a potential large loss. Gambling is a risk increasing investment, wherein money on hand is risked for a possible large return, but also the possibility of losing it all. By this definition, purchasing a lottery ticket is an extremely risky investment (a high chance of no return, but a small chance of a huge return), while putting money in a bank at a defined rate of interest is a risk- averse course of action (a guaranteed return of a small gain).

In statistics, risk is often mapped to the probability of some event which is seen as undesirable. Usually the probability of that event and some assessment of its expected harm must be combined into a believable scenario (an outcome) which combines the set of risk, regret and reward probabilities into an expected value for that outcome.

Risk management is the process of measuring, or assessing, risk and developing strategies to manage it. Strategies include transferring the risk to another party, avoiding the risk, reducing the negative effect of the risk, and accepting some or all of the consequences of a particular risk. Traditional risk management focuses on risks stemming from physical or legal causes (e.g. natural disasters or fires, accidents, death, and lawsuits). Financial risk management, on the other hand, focuses on risks that can be managed using traded financial instruments. Risk assessment may be the most important step in the risk management process, and may also be the most difficult and prone to error. Once risks have been identified and assessed, the steps to properly deal with them are much more straightforward.

In project management, risk management includes the following activities:

Planning how risk management will be held in the particular project. Plan should include risk management tasks, responsibilities, activities and budget.

Assigning a risk officer – a team member other than a project manager who is responsible for foreseeing potential project problems. Typical characteristic of risk officer is a healthy scepticism.

Maintaining live project risk database. Each risk should have the following attributes: opening date, title, short description, probability and importance. Optionally a risk may have an assigned person responsible for its resolution and a date by which the risk must be resolved.

Creating anonymous risk reporting channel. Each team member should have possibility to report risk that he foresees in the project.

Preparing mitigation plans for risks that are chosen to be mitigated. The purpose of the mitigation plan is to describe how this particular risk will be handled. What, when, by who and how will be done to avoid it or minimize consequences if it becomes a liability.

Summarizing planned and faced risks, effectiveness of mitigation activities and effort spend for the risk management.

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Forecasting

19. Forecasting

Forecasting is the process of estimation in unknown situations. Prediction is a similar, but more general term, and usually refers to estimation of time series, cross-sectional or longitudinal data. Forecasting is commonly used in discussion of time series data.

20. Econometrics

Econometrics is the application of statistical and mathematical methods in the field of economics to describe the numerical relationships between key economic forces such as capital, interest rates and labour.

21. Regression-Based Forecasting

There are several widely-used approaches for modelling and analyzing time series data, of which regression methods play a fundamental role. Building regression models based on time series data poses a number of technical problems, which arise from common trends to be found in many time series. If standard regression models are developed this may lead them to fail the basic regression assumptions, in particular, the assumption that the model errors are independent of each other (i.e. the model errors are in fact correlated, a phenomenon labelled autocorrelation). If a model shows evidence of auto-correlated errors, the model builder should consider developing an enlarged model that includes lagged values of both the dependent and the explanatory variables.

22. Seasonal Adjustment

The first step in seasonal adjustment is to compute a centred moving average and then calculate the ratio to the moving average, i.e. the original data divided by the moving average, for each season. The estimated seasonal index for each season is determined by first averaging all the ratios for that particular season, and then renormalizing the ratios if necessary so that they sum to exactly 100% multiplied by the number of periods in a season. The seasonally adjusted data is obtained by dividing the original data by the seasonal indices.

23. Time Series Analysis and Forecasting

Time series methods use historical data as the basis for estimating future outcomes. Smoothing of forecasts always involves some form of local averaging of data such that the non-systematic components of individual observations cancel each other out. The most common technique is moving average smoothing which replaces each element of the series by either the simple or weighted average of n surrounding elements, where n is the width of the smoothing "window". Medians can be used instead of means. Exponential smoothing is an alternative. Regression analysis using linear regression or non-linear regression, autoregressive moving average (ARMA), and autoregressive integrated moving average (ARIMA) e.g. Box-Jenkins are other possibilities.

In the relatively less common cases (in time series data), when the measurement error is very large, the distance weighted least squares smoothing or negative exponentially weighted smoothing techniques can be used. All those methods will filter out the noise and convert the data into a smooth curve that is relatively unbiased by outliers.

Many monotonic time series data can be adequately approximated by a linear function; if there is a clear monotonic nonlinear component, the data first need to be transformed to remove the nonlinearity. Usually a logarithmic, exponential, or (less often) polynomial function can be used.

Some forecasting methods use the assumption that it is possible to identify the explanatory factors that might influence the variable that is being forecasted. If the causes are understood, projections of the influencing variables can be made and used in the forecast.

Judgemental forecasting methods incorporate intuitive judgements, opinions and probability estimates. Techniques include composite forecasts, surveys, the Delphi method, scenario building, technology forecasting and forecast by analogy.

24. Trend Analysis/Projection

Trend analysis utilises linear and nonlinear regression with time as the explanatory variable, and is used where patterns over time have a long-term trend. Unlike most time series forecasting techniques, Trend Analysis does not assume the condition of equally spaced time series. Nonlinear regression does not assume a linear relationship between variables. It is frequently used when time is the independent variable.

There are no proven "automatic" techniques to identify trend components in the time series data; however, as long as the trend is monotonic (consistently increasing or decreasing) that part of data analysis is typically not very difficult. If the time series data contain considerable error, then the first step in the process of trend identification is smoothing.

References

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Modelling and IT skills

25. Basic Spreadsheet Modelling

Originally a spreadsheet was a sheet of paper, marked with a grid, in which financial data was recorded and totals calculated manually. Nowadays it is usually a computer simulation of such a system of recording tabular data, with totals and other formulae calculated automatically. Microsoft's Excel, which is part of their Office suite, still dominates the industry. A number of companies have attempted to break into the spreadsheet market with programs based on very different paradigms. Lotus introduced what is likely the most successful example, Lotus Improv, which saw some commercial success, notably in the financial world where it's powerful data mining capabilities remain well respected to this day.

Spreadsheets have evolved into powerful programming languages; specifically, they are functional, visual, and multi-paradigm languages. Many people find it easier to perform calculations in spreadsheets than by writing the equivalent sequential program. This is due to two traits of spreadsheets. They use spatial relationships to define program relationships. Like all animals, humans have highly developed intuitions about spaces, and of dependencies between items. Sequential programming usually requires typing line after line of text, which must be read slowly, and carefully to be understood and changed. They are forgiving, allowing partial results and functions to work. One or more parts of a program can work correctly, even if other parts are unfinished or broken. This makes writing and debugging programs much easier, and faster. Sequential programming usually needs every program line and character to be correct for a program to run. One error usually stops the whole program and prevents any result.

The Visual Basic for Applications (VBA) programming language is used in Excel to create advanced calculations and OR-type models e.g. simulations

References

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26. Database Design

Traditional data processing was based on a collection of separate programs, each with its own data organisation. Most current information systems have comprehensive architecture, where the vast majority of data is stored and maintained centrally. A particular feature is the client-server mode of operation, which is a network with a huge number of clients being provided with data and programs from a server computer or network of servers.

A common standard of database design is that of relational databases, with the following principles:

- All the information is organised in terms of attributes to entity sets, which are collections of entities with the same attribute but individual attribute values.
- There is no hierarchy between entity sets, enabling immediate access.
- Any information is stored only once and no redundancy is allowed. This is the essence of the normalisation concept of relational database structures.

The Structured Query Language (SQL) is often used to strip required information from relational databases. The use of data mining techniques can enable commercially-important relationships to be discovered.

References

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- Laudon, K. C. and Laudon, J. P. (2006) Management Information Systems: managing the digital firm (9th ed.), Pearson Education, New Jersey.

27. GIS Capabilities

A Geographic Information System (GIS) is a system for capturing, storing, analyzing and managing digitized data and associated attributes which are spatially referenced to the earth. It is a computer system capable of integrating, storing, editing, analyzing, sharing, and displaying geographically-referenced information. In a more generic sense, GIS is a tool that allows users to create interactive queries (user created searches), analyze the spatial information, edit data, and present the results of all these operations.

GIS software is the main method through which geographic data is accessed, transferred, transformed, overlaid, processed and displayed. Various software form integral components of this interface to GIS data. There are numerous commercial, open source and even shareware products that fill these roles. Commercial software is mostly used in industry with ESRI being the leader, while government and military departments often use custom software, open source products, such as GRASS, or more specialized products. The public and small organizations generally use free GIS readers, rapidly expanding online resources or shareware.

GIS statistical software uses standard database queries to retrieve data and analyse data for decision making. The data is sometimes referenced with postal/zip codes and street locations rather than with geodetic data. This is used to characterize an area for marketing or governing decisions. Standard DBMS can be used or specialized GIS statistical software. These are many times setup on servers so that they can be queried with web browsers. Examples are MySQL or ArcSDE.

Most requirements that can be set for a GIS can be satisfied with free or open-source software. Well-known open source GIS software includes GRASS GIS, Quantum GIS, MapServer, GDAL/OGR, PostGIS, uDig, OpenJUMP, gvSIG, and others.

Many disciplines can benefit from GIS technology. An active GIS market has resulted in lower costs and continual improvements in the hardware and software components of GIS. These developments will, in turn, result in a much wider use of the technology throughout science, government, business, and industry, with applications including real estate, public health, crime mapping, national defence, sustainable development, natural resources, transportation and logistics. GIS is also diverging into location-based services (LBS). LBS allows GPS enabled mobile devices to display their location in relation to fixed assets (nearest restaurant, gas station, fire hydrant), mobile assets (friends, children, police car) or to relay their position back to a central server for display or other processing. These services continue to develop with the increased integration of GPS functionality with increasingly powerful mobile electronics (cell phones, PDA's, laptops).

Using models to project the data held by a GIS forward in time have enabled planners to test policy decisions. These systems are known as Spatial Decision Support Systems.

References

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- Chang, K.S. (2005) Introduction to Geographic Information System, 3rd Edition. McGraw Hill, New York.
- Heywood, I., Cornelius, S. and Carver, S. (2006) An Introduction to Geographical Information Systems, 3rd edition. Prentice Hall, New Jersey.

28. Monte Carlo Approaches

Monte Carlo methods are a widely used class of computational algorithms for simulating the behaviour of various physical and mathematical systems, and for other computations. They are distinguished from other simulation methods (such as molecular dynamics) by being stochastic, that is nondeterministic in some manner - usually by using random numbers (or, more often, pseudo-random numbers) - as opposed to deterministic algorithms. Because of the repetition of algorithms and the large number of calculations involved, Monte Carlo is a method suited to calculation using a computer, utilizing many techniques of computer simulation.

A Monte Carlo algorithm is often a numerical Monte Carlo method used to find solutions to mathematical problems (which may have many variables) that cannot easily be solved, for example, by integral calculus, or other numerical methods. For many types of problems, its efficiency relative to other numerical methods increases as the dimension of the problem increases. Or it may be a method for solving other mathematical problems that relies on (pseudo-)random numbers

These are mainly used in simulation for sampling and variance reduction. In simulation, Monte Carlo refers to the generation of appropriate random numbers to represent the behaviour of activities in the system. For example, if the service time for customers at a post office counter is known to follow the normal distribution, then the service times in the simulation can be randomly generated from a normal distribution. The approach can also be used for variance reduction (e.g. importance sampling) so as to improve the efficiency of simulations.

References

- Wilson J. R. (1984) Variance reduction techniques for digital simulation, American Jnl. Mathematical Management Science, 4, 277-312

29. Numerical Approximation Approaches

Numerical analysis is the study of algorithms for the problems of continuous mathematics (as distinguished from discrete mathematics), mainly concerned with obtaining approximate solutions while maintaining reasonable bounds on errors.

Direct numerical approximation methods compute the solution to a problem in a finite number of steps. These methods would give the precise answer if they were performed in infinite precision arithmetic. Examples include Gaussian elimination, the QR factorization method for solving systems of linear equations, and the simplex method of linear programming. In practice, finite precision is used and the result is an approximation of the true solution (assuming stability).

In contrast to direct methods, iterative numerical approximation methods are not expected to terminate in a number of steps. Starting from an initial guess, iterative methods form successive approximations that converge to the exact solution only in the limit. A convergence criterion is specified in order to decide when a sufficiently accurate solution has (hopefully) been found. Even in infinite precision arithmetic these methods would not reach the solution in finitely many steps (in general). Examples include Newton's method, the bisection method, and Jacobi iteration. In computational matrix algebra, iterative methods are generally needed for large problems.

Most algorithms are implemented and run on a computer. The Netlib repository contains various collections of software routines for numerical problems, mostly in Fortran and C. Commercial products implementing many different numerical algorithms include the IMSL and NAG libraries; a free alternative is the GNU Scientific Library.

MATLAB is a popular commercial programming language for numerical scientific calculations, but there are commercial alternatives such as S-PLUS and IDL, as well as free and open source alternatives such as FreeMat, GNU Octave (similar to Matlab), IT++ (a C++ library), R (similar to S-PLUS) and certain variants of Python. Performance varies widely: while vector and matrix operations are usually fast, scalar loops vary in speed by more than an order of magnitude. Many computer algebra systems such as Mathematica or Maple (free software systems include SAGE, Maxima, Axiom, calc and Yacas), can also be used for numerical computations. However, their strength typically lies in symbolic computations. Also, any spreadsheet software can be used to solve simple problems relating to numerical analysis.

References

- Gilat, Amos (2004). MATLAB: An Introduction with Applications, 2nd edition, John Wiley & Sons, New York.
- Leader, Jeffery J. (2004). Numerical Analysis and Scientific Computation. Addison Wesley, Boston, MA.

30. Object-Oriented Programming

Object-Oriented Programming (OOP) may be seen as a collection of cooperating objects, as opposed to a traditional view in which a program may be seen as a list of instructions to the computer. In OOP, each object is capable of receiving messages, processing data, and sending messages to other objects. Each object can be viewed as an independent little machine with a distinct role or responsibility.

Object-Oriented Programming is intended to promote greater flexibility and maintainability in programming, and is widely popular in large-scale software engineering. By virtue of its strong emphasis on modularity, object oriented code is intended to be simpler to develop and easier to understand later on, lending itself to more direct analysis, coding, and understanding of complex situations and procedures than less modular programming methods.

References

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31. Visual Basic for Applications (VBA)

The original Basic programming language was developed to enable non-experts to develop effective computer programs. A successor to Basic, VBA, is used in Excel to create advanced calculations and OR-type models e.g. simulations. In particular it enables:

- Increased productivity by automating routine tasks in Excel.
- Writing Excel applications that can be used by those who are not familiar with Excel.
- Writing Excel applications which otherwise might require a stand-alone programming language.

Good programming practice enables the more effective use of VBA in Excel.

References

Kimmel, P., Bullen, S., Green, J. and Bovey, R. (2004) Excel 2003 VBA Programmers Reference (Programmer to Programmer), Wiley, Chichester

32. C# and C++

C# is an object-oriented programming language which is simple and easy to learn. In many ways it has the power of C++, the elegance of Java, and the ease of development of Visual Basic. C# allows developers to build a wide range of applications that run on the .NET Framework (which Microsoft has been promoting). ADO.NET data components in Visual Studio enable quicker development of database applications with fewer mistakes.

References

- Price J, (2003) Mastering C# Database Programming, Sybex, [B Red AZKF.C1]

33. Structured Query Language (SQL)

SQL is designed for a specific purpose: to query data contained in a relational database. SQL is a set-based, declarative computer language, not an imperative language such as C or BASIC. (Imperative languages are general-purpose and designed to solve a much broader set of problems.) It is commonly used in conjunction with Microsoft Access and in data mining applications.

References

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34. Stock Flow Modelling/Inventory Control & Supply/Demand

Inventory problems arise in a wide variety of contexts, but the most common contexts are the purchasing and production of goods. Inventories enable a product to be made at a distance (both in space and time) from customers or from raw material supplies. There are two aspects to decoupling. First, inventories are necessary because it takes time to complete an operation and to move products from one stage to another. These are called process and movement inventories. Organisational inventories, on the other hand, let one production unit schedule its operations more or less independently of another. To allow the production rate of products that exhibit seasonal sales patterns to be kept relatively smooth it is necessary to build up stocks when sales are low. These stocks are frequently referred to as anticipation stocks. The existence of set-up costs makes it economic to produce goods in lots. This inevitably leads to inventories. Stocks of raw materials may be carried in anticipation of rising prices. This does not necessarily apply to commodity markets, because it is possible to buy for future delivery, but may frequently apply to the purchase of raw materials for manufacturing.

There are two basic decisions that can be made. The first, is the quantity to be obtained (whether by purchase or production) and, secondly, the frequency of the acquisition. Costs included in the inventory models should represent out-of-pocket expenditure i.e. cash actually paid out, or foregone opportunities for profit. Stockholding costs increase in direct proportion to increases in stock and the time for which stock is held. A major component is the cost of invested capital, which, although it is an interest charge, often requires careful investigation. Other stockholding costs that need to be considered include handling, storage, insurance and taxes, and depreciation, deterioration and obsolescence. Shortage (or stockout) costs are difficult to estimate with a high degree of accuracy because they include the ill-defined item loss of customer goodwill. Costs arising from changes in the production rate include set-up costs that result from changing the production rate from zero to some positive amount or the fixed administrative costs of placing an order. The unit cost of purchased items may depend on the quantity purchased because of price breaks or quantity discounts. The unit cost of produced items may also be lower because of greater efficiency of men and machines in long continuous production runs.

The demand for an item (number required per period) is not necessarily the amount sold, because some demand may go unfilled because of stockouts. It is, though, the amount that would be sold if all that is required were available. The demand for future time periods needs to be estimated in some way.

If the demand for an item is independent (i.e. unrelated to demand for other items) then it must be forecast using one of the many standard techniques available. This will most frequently apply to end products, i.e. those actually sold to consumers and which are not component parts of another product.

Component parts of a product will have a demand that is dependent in that it is directly related to the demand for another product. Dependent demand should not be forecast, as it can be precisely determined from the demand for those items that are its sole cause.

The delay between placing an order and delivery (or between requesting a production run and it taking place) is called the lead time. If this is known than the order needs to be placed in advance by the amount of time equal to the lead time. If it is only known probabilistically, the question of when to order is more difficult.

There are two basic types of inventory policy.

a) Re-order level policies, in which decisions concerning replenishment are based on a level of inventory held.

b) Re-order cycle policies, in which decisions concerning replenishment are made on a time basis.

In both cases a service level is specified. Service Level defines the probability of running out of stock during an order lead time. It does not state directly how frequently stockouts will occur each year. The service to be given by the stocks might be expressed on the basis of a desired maximum frequency of stockouts over some period. e.g. a company may say it wants stockouts to occur no more than once every four years. An alternative approach is to specify the expected average stock level prior to an order arriving, which is the same as specifying the amount of demand over time that will be satisfied or the expected number of units short.

References

- Silver, E. A., Pyke, D. F. and Peterson, R. (1998) Inventory Management and Production Planning and Scheduling, Third Edition, John Wiley & Sons, New York.

35. Web design

A website is a collection of information about a particular topic or subject. Designing a website is defined as the arrangement and creation of web pages that in turn make up a website. A web page consists of information for which the website is developed. For example, a website might be compared to a book, where each page of the book is a web page. A website typically consists of text and images. The first page of a website is known as the Home page or Index. Some websites use what is commonly called a Splash Page. Splash pages might include a welcome message, language/region selection, or disclaimer. Each web page within a website is an HTML file which has its own URL. After each web page is created, they are typically linked together using a navigation menu composed of hyperlinks.

Once a website is completed, it must be published or uploaded in order to be viewable to the public over the internet. This is done using an FTP client. Once published, the webmaster may use a variety of techniques to increase the traffic, or hits, that the website receives. This may include submitting the website to a search engine such as Google or Yahoo, exchanging links with other websites, creating affiliations with similar websites, etc.

A relatively new technique for creating websites called Remote Scripting has allowed more dynamic use of the web without the use of Flash or other specialized plug-ins. Leading the various techniques is Ajax, although other methods are still common, as Ajax is not a fully developed standard.

Links

UK Web Design Association – http://www.ukwda.org/

Optimisation methods

36. Mathematical Programming

In general this is the study of how one optimises the use and allocation of scarce resources. It is considered a branch of applied mathematics as it deals with the theoretical and computational aspects of finding the maximum (minimum) of a function f(x), subject to a set of constraints in the form of inequalities. The Linear Programming (LP) model is the prime example of the problem; others, which have specific constraints, include integer programming, non-linear programming, quadratic programming and goal programming.

37. Linear Programming

LP is one of the most widely used techniques in OR/MS. Its name means that planning (programming) is being done with a mathematical model (a linear programming model) where all the functions in the model are linear functions.

Applications include oil refinery blending of products (to maximise revenues) and portfolio planning in investment (to maximise growth/return) food production. The Transportation problem is a special case of a key type of LP problem, the minimum-cost network-flow model. This involves determining how to distribute goods through a distribution network at minimum cost.

Two things have facilitated the solution of large linear programming models: Dantzig's simplex method and the dramatic increase in power of modern computers. George Dantzig developed the simplex method in 1947 by exploiting some basic properties of optimal solutions for linear programming models. Because all the functions in the model are linear functions, the set of feasible solutions is a complex polyhedral set. If there is just one optimal solution it must be at a vertex (extreme point) of the feasible region. The simplex is an iterative process that only examines extreme points of the feasible region. Nowadays LP packages have further refinements to enable the solution of large real world problems.

Associated with any LP problem is another LP problem called the dual. Also, the relationship between the original problem (called the primal) and it's dual is a symmetric one, so that the dual of the dual is the primal. There are many useful relationships between the primal and dual problems that help in post-optimality analysis, i.e. analysis done after finding the optimal solution to the model. A key part of post-optimality analysis is sensitivity analysis, which involves finding out which are sensitive parameters i.e. those that change the optimal solution if a small change in the value of the parameter is made and exploring the implications.

38. Lagrangean Method (Lagrangean multipliers)

Lagrangean multipliers are the multiplicative, linear-combination constants that appear in the Lagrangean of a mathematical programming problem. They are generally dual variables (shadow prices) in LP, giving the rate of change of the optimal value with constraint changes, under appropriate conditions. Lagrangean relaxation is an integer programming decomposition method.

39. Integer Programming

This is a mathematical programming problem where some or all of the variables are restricted to integer values.

40. Non-linear Programming

This term has come to mean that collection of optimisation problems where non-linear relationships may be found in the objective function or in the constraints.

41. Quadratic Programming

Quadratic programming concerns a special class of mathematical programmes in which a quadratic function of the decision variables is required to be optimised.

References

- Kallrath, J. & Wilson, J.M. (1997) Business Optimisation Using Mathematical Programming. Macmillan.
- Williams, H.P. (1999) Model Building in Mathematical Programming (4th edition). Wiley, Chichester
- Winston, W.L. (2004) Operations Research - Applications and Algorithms (4th edition) Duxbury.
- Wisniewski, M. (2001) Linear Programming, Palgrave, Basingstoke.

42. Heuristics

Heuristic methods are techniques, which aim to achieve good, though not necessarily optimal, solutions to real problems within a reasonable computing time and for which exact optimal procedures are unavailable or inappropriate, as is very frequently the case. They are in practical use for all sorts of problems in more or less all decision-making environments. They are also an extremely fertile area of current research all over the world. Widely used heuristic methods include Simulated Annealing, Genetic Algorithms and Taboo Search.

43. Network Analysis (Network Optimisation)

Optimising the flows in networks (such as roads, telecommunications etc) involves two issues: operational planning and system design. Operational planning addresses how to use a given network as efficiently as possible and the field is known as network flow problems. Optimisation models for supporting decision making for many such problems have been developed. System design addresses finding the best design of a network, which will offer cost efficient and effective service to all users. This involves simultaneously creating the network structure and routing the flows on it. Again optimisation models have been developed for these network design models.

See also graph theory.

References

- Smith, David K. (1982) Network optimisation practice: a computational guide. E. Horwood Chichester.

Performance Management and Assessment

44. Balanced Scorecard

In 1992, Robert S. Kaplan and David Norton introduced the balanced scorecard, a concept for measuring a company's activities in terms of its vision and strategies, to give managers a comprehensive view of the performance of a business. The key new element is focusing not only on financial outcomes but also on the human issues that drive those outcomes, so that organizations focus on the future and act in their long-term best interest. This strategic management system forces managers to focus on the important performance metrics that drive success. It balances a financial perspective with customer, process, and employee perspectives. Measures are often indicators of future performance. Numerous software tools are available for scorecard management and relating scorecard measures to individual goals, including modules in PeopleSoft and similar software, and standalone programs.

References

- Cobbold, I. and Lawrie, G. (2002). The Development of the Balanced Scorecard as a Strategic Management Tool. Performance Measurement Association, Cranfield
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- Kaplan R. S. and Norton D. P. (1992) The balanced scorecard: measures that drive performance, Harvard Business Review, Jan-Feb pp71-80.

45. Efficiency and Effectiveness

In statistics, an unbiased estimator's efficiency is the relative size of its variance compared to other unbiased estimators. For a maximising multi-objective problem, an efficient solution is a feasible solution for which an increase in value of one objective can only be achieved at the expense of a decrease in value of at least one other objective.

46. Measures of System Performance

Performance tuning is the improvement of system performance. This is typically a computer application, but the same methods can be applied to economic markets, bureaucracies or other complex systems. The motivation for such activity is called a performance problem, which can be real or anticipated. Most systems will respond to increased load with some degree of decreasing performance. A system's ability to accept higher load is called scalability, and modifying a system to handle a higher load is synonymous to performance tuning. Systematic tuning follows these steps:

Assess the problem and establish numeric values that categorize acceptable behaviour.

Measure the performance of the system before modification.

Identify the part of the system that is critical for improving the performance. (This is called the bottleneck.)

Modify that part of the system to remove the bottleneck.

Measure the performance of the system after modification.

This is an instance of the measure-evaluate-improve-learn cycle from quality assurance. A performance problem may be identified by slow or unresponsive systems. This usually occurs because high system loading, causing some part of the system to reach a limit in its ability to respond. This limit within the system is referred to as a bottleneck. A handful of techniques are used to improve performance. Among them are code optimization, load balancing, caching strategy, and distributed computing.

References

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- Simons R. (1999) Performance Measurement and Control Systems for Implementing Strategy â€“ Texts and Cases, Prentice Hall, NJ

47. Performance Indicators/Measurement

Key Performance Indicators (KPI) are financial and non-financial metrics used to quantify objectives to reflect strategic performance of an organization. KPIs are used in Business Intelligence to assess the present state of the business and to prescribe a course of action. The act of monitoring KPIs in real-time is known as business activity monitoring. KPIs are frequently used to "value" difficult to measure activities such as the benefits of leadership development, engagement, service, and satisfaction. KPIs are typically tied to an organization's strategy (as exemplified through techniques such as the Balanced Scorecard). The KPIs differ depending on the nature of the organization and the organization's strategy. They help an organization to measure progress towards their organizational goals, especially toward difficult to quantify knowledge-based activities. KPIs should not be confused with a Critical Success Factor. For the example above, a critical success factor would be something that needs to be in place to achieve that objective; for example, a product launch.

References

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- Parmentor D. (2007) Key Performance Indicators (KPI): Developing, Implementing and Using Winning KPIs, Wiley, Chichester

48. Multi-Criteria Decision Methods (MCDM)

MCDM are ways of approaching problems in which decision alternatives impact multiple attributes. The attractiveness of an alternative therefore depends on how well it scores on each attribute of interest and the relative importance of these attributes. Common examples include selecting a house or job and resource allocation in a public health programme. The methods include Preference Theory, which studies the fundamental aspects of individual choice behaviour, such as how to identify and quantify an individual’s preference over a set of alternatives; and Utility Theory, which is the systematic study of preference structures and ways to represent preferences quantitatively. The Analytic Hierarchy Process (AHP) is a general theory of measurement. It is used to derive ratio scales from both discrete and continuous paired comparisons in multi-level hierarchic structures. It has made its greatest impact in MCDM, planning and resource application and in conflict resolution. (Goal Programming/Linear Goal Programming is a special case of Linear Programming, which is now mainly considered to be a multi-criteria decision making method.)

References

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- Keeney RL and Raiffa H (1976) Decisions with multiple objectives: Preferences and Value Tradeoffs, John Wiley, New York
- Saaty TL (1980) Analytic Hierarchy Process, McGraw Hill, New York.

49. Productivity

In economics, productivity is the amount of output created (in terms of goods produced or services rendered) per unit input used. For instance, labour productivity is typically measured as output per worker or output per labour-hour. With respect to land, the "yield" is equivalent to "land productivity". Within Capitalism, productivity increases lead to higher standards of living for the general population. As Henry Hazlitt explains in Economics in One Lesson, increasing production reduces prices, and therefore goods become more widely available. Automobiles, for example, were initially hand made and only available to the wealthy. As productivity increased, and the price of automobiles fell, they became widely available to the general population.

Qualitative Techniques/Soft Systems Modelling

50. Problem Structuring Techniques

These are a broad group of model-based problem handling approaches, known as Problem Structuring Methods (PSM), whose purpose is to assist in the structuring of problems rather than directly with their solution. They are particularly appropriate for problems which are ill-defined, where the objectives are unclear or multiple and where there are many stakeholders, often with different perceptions of the problem. They are usually participative and interactive in character, with the OR consultant acting as expert facilitator. They place emphasis on dialogue to help people think through strategic problems, identify the salient issues, formulate goals and negotiate action plans for achieving these.

51. Soft Systems Modelling (SSM)

SSM was developed by Peter Checkland in a programme of action research into the kinds of real world situations that are often referred to as wicked or messy. The use of SSM can be thought of as an intervention in a human situation, in order to find accommodations, which will enable actions to improve the situation to be taken. It therefore consists of analysis to understand the story of the situation and how it has arisen, and analysis to find out the accommodations between different interests, which enable action to be undertaken. The mnemonic CATWOE indicates the elements of a SSM study, i.e. Customers (those directly affected by the activity), Actors (who carry out the activities), Transformation (any purposeful action can be expressed as a transformation of an input into an output), World view (which makes sense of this purpose), Owner (who could stop the activity) and Environment (which has constraints on the activity). Checkland advocates the development of a rich picture as an aid to understanding the problem situation. This consists of a sketch of all of the individuals involved in or influenced by the activity, together with their perspectives and goals. The rich picture can be helpful at the beginning of many OR projects, hard and soft, as it often provides hidden insights into the resolution of the problem.

52. Strategic Choice

Strategic Choice is a problem structuring method, which assists in the strategic management of uncertainty and commitment. It is an interactive method for facilitating group decision-making. It provides techniques and processes for the agreement of a problem focus, the identification of feasible decision schemes, the establishment of working shortlist and paired comparisons designed to highlight relevant uncertainty. Outputs are structured into a commitment package of decisions, exploratory actions and deferred choices.

53. Cognitive Mapping

Cognitive maps, mental maps, mind maps, cognitive models, or mental models are a type of mental processing, or cognition, composed of a series of psychological transformations by which an individual can acquire, code, store, recall, and decode information about the relative locations and attributes of phenomena in their everyday or metaphorical spatial environment. Tolman is generally credited with the introduction of the term 'cognitive map'. Here, 'cognition' can be used to refer to the mental models, or belief systems, that people use to perceive, contextualize, simplify, and make sense of otherwise complex problems. Cognitive maps have been studied in various fields of science, such as psychology, planning, geography and management. As a consequence, these mental models are often referred to, variously, as cognitive maps, scripts, schemata, and frames of reference.

Put more simply, cognitive maps are a way we use to structure and store spatial knowledge, allowing the "mind's eye" to visualize images in order to reduce cognitive load, and enhance recall and learning of information. This type of spatial thinking can also be used as a metaphor for non-spatial tasks, where people performing non-spatial tasks involving memory and imaging use spatial knowledge to aid in processing the task.

54. Strategic Options Development and Analysis (SODA)

SODA is a problem structuring method for supporting group decision-making. Individual cognitive maps are elicited for participants and then merged into a strategic map, which is used in workshop mode to facilitate discussion and commitment.

55. Other Problem Structuring Methodologies

Other PSMs that have been developed and/or used within the OR community include Strategic Assumption Surfacing and Testing, and Drama Theory.

References

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- Rosenhead J.V. and Mingers J. (2001) Rational analysis in a problematic world revisited, second edition. Wiley, Chichester UK.

56. Brainstorming

Brainstorming is a group creativity technique that was intended to be a method for generating ideas for the solution of a problem. Brainstorming originated in 1957 in a book called Applied Imagination by Alex Faickney Osborn, an advertising executive. Although traditional brainstorming does not contribute to the productivity of groups, it may still provide some of the additional benefits suggested by its advocates, such as enjoyment and the improvement of morale. It may be an effective exercise for team building. Brainstorming is typically done in a group. The participants are encouraged, and often expected, to share their ideas with one another as soon as they are generated. Complex problems or brainstorm sessions with a diversity of people may be prepared by a chairman. The chairman is the leader and facilitator of the brainstorm session.

The key to brainstorming is to not interrupt the thought process. As ideas come to mind, they are captured and stimulate the development of better ideas. Thus a group brainstorm session is best conducted in a moderate-sized room, and participants sit so that they can all look at each-other. A flip chart, blackboard, or overhead projector is placed in a prominent location. The room is free of telephones, clocks, or any other distractions.

References

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57. Decision Support Approaches **(Also known as Decision Support Systems)**

Decision support systems are a class of computer-based information systems including knowledge based systems that support decision making activities

The term Decision Support System (DSS) was originally proposed by Keen & Morton (1973) with the following characteristics:

- A DSS is designed for specific decision makers and their decision tasks
- A DSS is developed by cycling between design and implementation (prototyping)
- .A DSS is developed with a high degree of user involvement
- A DSS contains both data and models

The design of the user-machine interface is a critical task i8n the development of a DSS. Thus a DSS comprises 3 main components: a database that holds the relevant information or date; a model base, which carries out analysis; and a user interface, which enables the decision maker to explore options.

References

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practice. Prentice Hall, Englewood Cliffs, N.J.

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58. Facilitation

The term facilitation is broadly used to describe any activity, which makes easy the tasks of others. For example:

- Facilitation is used in business and organisational settings to ensure the designing and running of successful meetings.

A person who takes on such a role is called a facilitator. Specifically:

- A facilitator is used in a variety of group settings, including business and other organisations to describe someone whose role it is to work with group processes to ensure meetings run well and achieve a high degree of consensus.

59. Content Analysis

The method of content analysis enables the researcher to include large amounts of textual information and systematically identify its properties, e.g. the frequencies of most used keywords by detecting the more important structures of its communication content. Yet such amounts of textual information must be categorised according to a certain theoretical framework, which will inform the analysis, providing at the end a meaningful reading of content under scrutiny.

References

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- Weber R.P. (1990) Basic Content Analysis. 2nd ed., Newbury Park, CA: Sage

60. Social Network Analysis

A social network is a social structure made of nodes which are generally individuals or organizations. It indicates the ways in which they are connected through various social familiarities ranging from casual acquaintance to close familial bonds. The maximum size of social networks tends to be around 150 and the average size around 124. Social network analysis (related to network theory) has emerged as a key technique in modern sociology, anthropology, sociolinguistics, geography, social psychology, information science and organizational studies, as well as a popular topic of speculation and study. Research in a number of academic fields has shown that social networks operate on many levels, from families up to the level of nations, and play a critical role in determining the way problems are solved, organizations are run, and the degree to which individuals succeed in achieving their goals.

Social networking also refers to a category of internet applications to help connect friends, business partners, or other individuals together using a variety of tools. These applications, known as online social networks are becoming increasingly popular.

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- Scott, J. (2000). Social Network Analysis: A Handbook, 2nd Edition. Sage, Newberry Park, CA.

61. Strategic Planning

Strategic planning is an organization's process of defining its strategy and making decisions on allocating its resources to pursue this strategy, including its capital and people. The outcome is normally a strategic plan which is used as guidance to define functional and divisional plans, including Technology, Marketing, etc.

There are many approaches to strategic planning but typically a three-step process may be used:

- Situation - evaluate the current situation and how it came about.
- Target - define goals and/or objectives (sometimes called ideal state)
- Path - map a possible route to the goals/objectives.

One alternative approach is called Draw-See-Think:

- Draw - what is the ideal image or the desired end state?
- See - what is today's situation? What is the gap from ideal and why?
- Think - what specific actions must be taken to close the gap between today's situation and the ideal state?
- Plan - what resources are required to execute the activities?

In other terms strategic planning can be as follows:

- Vision - Define the vision and set a mission statement with hierarchy of goals
- SWOT - According to the desired goals conduct analysis
- Formulate - Formulate actions and processes to attain these goals
- Implement - Implementation of the agreed upon processes
- Control - Monitor and get feedback from implemented processes to fully control the operation

References

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62. Scenario Analysis/Planning

Scenario analysis is a process of analyzing possible future events by considering alternative possible outcomes (scenarios). The analysis is designed to allow improved decision-making by allowing more complete consideration of outcomes and their implications. For example, in economics and finance, a financial institution might attempt to forecast several possible scenarios for the economy (e.g. rapid growth, moderate growth, slow growth) and it might also attempt to forecast financial market returns (for bonds, stocks and cash) in each of those scenarios. It might consider sub-sets of each of the possibilities. It might further seek to determine correlations and assign probabilities to the scenarios (and sub-sets if any).

Depending on the complexity of the financial environment, in economics and finance scenario analysis can be a demanding exercise. It can be difficult to foresee what the future holds (e.g. the actual future outcome may be entirely unexpected), i.e. to foresee what the scenarios are, and to assign probabilities to them; and this is true of the general forecasts never mind the implied financial market returns. The outcomes can be modelled mathematically/statistically e.g. taking account of possible variability within single scenarios as well as possible relationships between scenarios.

References

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- Van Der Heijden, K., (1996) Scenarios: Art of Strategic Conversation, Wiley, Chichester.

63. Horizon Scanning and Futures Work

Horizon scanning looks far ahead. As usually practised, it searches far into the future for challenging visions that may influence policy decisions taken today. The UK's Horizon Scanning Centre carries out a range of such work. One of its recent projects is Intelligent Infrastructure Futures - Towards 2055. It set out to examine the challenges and opportunities for the UK in bringing intelligence to its infrastructure the physical networks that deliver such services as transport, telecommunications, water and energy. In particular, the project explored how, over the next 50 years, we can apply science and technology to the design and implementation of intelligent infrastructure for robust, sustainable and safe transport, and its alternatives. And so it did. Fifteen state of the science reviews looked into such topics as pervasive tagging, sensors and data collection; delivering information for the management of infrastructure; intelligent distribution and logistics. Other sub-groups studied social, environmental and sustainability factors in future transport.

Statistical Techniques

64. Bias and Variance

Bias deprives a statistical result of representativeness by systematically distorting it, as distinct from a random error which may distort on any one occasion but balances out on the average.

It may arise for several reasons, for example in surveys of human populations by interview, bias may be present in responses or recorded information as a direct result of the action of the interviewer.

The variance is the mean square deviation of the variable around the average value. It reflects the dispersion of the empirical values around its mean.

65. Bootstrapping

Bootstrapping is the use of repeated sampling in order to estimate an unknown distribution. The sampling is taken from (probably sparse) observed data which you have relating to the problem. The sampling is sampling with replacement.

One major advantage of bootstrapping is that with this technique it is not necessary to assume that the data follows a given distribution, for example the normal distribution. A more exact distribution can therefore be established. A particular use of this method is to establish confidence intervals.

There are many ways of actually carrying out bootstrapping. The process could involve writing a simple computer program or using specialist statistics software. Once a distribution has been estimated it could be used as an input to a simulation model or an inventory control system.

Links

A good example of bootstrapping - http://www.stat.berkeley.edu/~nolan/Papers/JSM2001.pdf

References

- Lunneborg, Clifford, E. (2003) Data Analysis by Re-sampling: Concepts and Applications. Duxbury, Pacific Grove, CA.

66. Data Mining

Data mining consists of variety of techniques to identify nuggets of information or decision-making knowledge in bodies of data, and extracting these in such a way that they can be put to use in the areas such as decision support, prediction, forecasting and estimation. The data is often voluminous, but in its original form is of low value as no direct use can be made of it; it is the hidden information and relationships in the data that is useful.

The techniques used include decision trees, multivariate analysis (clustering), logistic regression, neural networks, data summarization, learning classification rules, finding dependency networks, analysing changes, and detecting anomalies.

References

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67. Descriptive Statistics and Hypothesis Testing

Descriptive statistics is a term used to denote statistical data of a descriptive kind or the methods of handling such data, as contrasted with theoretical statistics which, though dealing with practical data, usually involve some process of inference in probability for their interpretation. Descriptive statistics includes measures of location (e.g. mean, median, mode) and spread (e.g. variance, standard deviation)

Hypothesis testing is a term used generally to refer to testing significance when specific alternatives to the null hypothesis are considered.

68. Neural Networks

A neural network is a computing paradigm that is loosely modelled after cortical structures of the brain. The output of a neural network relies on the cooperation of the individual neurons within the network to operate. Processing of information by neural networks is often done in parallel rather than in series (or sequentially). Since it relies on its member neurons collectively to perform its function, a unique property of a neural network is that it can still perform its overall function even if some of the neurons are not functioning. That is, they are very robust to error or failure (i.e., fault tolerant). Neural networks are trainable systems that can often "learn" to solve complex problems from a set of exemplars and generalize the "acquired knowledge" to solve unforeseen problems, i.e., they are self-adaptive systems.

Links

Wikipedia entry for neural networks - http://en.wikipedia.org/wiki/Neural_networks

References

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69. Multivariate Analysis

The expression is used rather loosely to denote the analysis of data which are multivariate in the sense that each member bears the values of p variables. The principal techniques of multivariate analysis, beyond those admitting of a straightforward generalisation, e.g. regression, correlation and variance analysis, are factor and component analysis, classification, discriminatory analysis, canonical correlation and various generalisations of homogeneity tests. Classification might be done using cluster analysis, in which the aim is to see whether the individuals fall into groups or clusters. There are several methods of procedure; most depend on setting up a metric to define the closeness of individuals.

References

- Barbara G. Tabachnick and Linda S. Fidell, (2007) Using Multivariate Statistics, 5/E. Allyn & Bacon, Boston.

70. Probability and Bayesian Statistics

Probability is a basic concept which may be taken either as indefinable, expressing in some way a degree of belief, or as the limiting frequency in an infinite random series. Both approaches have their difficulties and the most convenient axiomatisation of probability theory is a matter of personal taste. Fortunately, both lead to much the same calculus of probabilities.

Bayesian probability is an interpretation of probability suggested by Bayesian theory, which holds that the concept of probability can be defined as the degree to which a person believes a proposition. Bayesian theory also suggests that Bayes' theorem can be used as a rule to infer or update the degree of belief in light of new information.

References

- Lipschutz, Seymour (2000) Schaum's Outline of Probability, 2nd Edition, McGraw-Hill, New York.

71. Queuing Theory

Queuing Theory is the mathematical study of waiting lines. The theory enables mathematical analysis of several related processes, including arriving at the (back of the) queue, waiting in the queue (essentially a storage process), and being served by the server(s) at the front of the queue. The theory permits the derivation and calculation of several performance measures including the average waiting time in the queue or the system, the expected number waiting or receiving service and the probability of encountering the system in certain states, such as empty, full, having an available server or having to wait a certain time to be served.

Queuing Theory is considered a branch of Operational Research because the results are often used when making business decisions about the resources needed to provide service. It is applicable in a wide variety of situations that may be encountered in business, commerce, industry, public service and engineering. Applications are frequently encountered in customer service situations as well as transport and telecommunication. Queuing Theory is directly applicable to intelligent transportation systems, call centres, PABXs, networks, telecommunications, server queuing, mainframe computer queuing of telecommunications terminals, advanced telecommunications systems, and traffic flow.

References

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72. Linear Regression

Linear Regression determines the relationship between a dependent, or response, variable y, and an independent, or explanatory, variable x. All linear models can be written so that y is equal to a matrix of coefficients acting on x.

This method is called "linear" because the relation of the response to the explanatory variables is assumed to be a linear function of some parameters.

Links

Wikipedia page for linear regression – http://en.wikipedia.org/wiki/Linear_regression

73. Binary and Multinomial Regression

Binary regression is concerned with situations where the outcome variable takes on one of two possible values (disease/no disease, success/failure, presence/absence of some characteristics, etc.). The two most popular models are the LOGISTIC and the PROBIT models:

Multinomial regression is an extension of binary regression to more than two variables.

References

- Barbara G. Tabachnick and Linda S. Fidell, (2007) Using Multivariate Statistics, 5/E. Allyn & Bacon, Boston.

74. Weighted Least Squares Regression

Weighted least squares is a method of regression, similar to least squares in that it uses the same minimization of the sum of the residuals, but instead of weighting all points equally, they are weighted such that points with a greater weight contribute more to the fit.

75. Correlation

Correlation, also called correlation coefficient, indicates the strength and direction of a linear relationship between two random variables. In general statistical usage, correlation or co-relation refers to the departure of two variables from independence, although correlation does not imply causation. In this broad sense there are several coefficients, measuring the degree of correlation, adapted to the nature of data.

A number of different coefficients are used for different situations. The best known is the Pearson product-moment correlation coefficient, which is obtained by dividing the covariance of the two variables by the product of their standard deviations.

76. Multiple Regression

Multiple regression aims to explain or predict changes in the Dependent variable by a (linear) set of explanatory variables.

The aim is often to build a causal explanation of why the variable of interest changes.

The data used can be cross-sectional, where the observations represent subjects (such as individuals, firms or countries/regions) at the same point of time, or without regard to differences in time, which differs from time series data, which follows one subject's changes over the course of time. Another variant, panel data (or time-series cross-sectional (TSCS) data), combines both and looks at multiple subjects and how they change over the course of time.

In general, fluctuations in any system (that need to be explained or predicted through the development of a model) have many causes or influences that need to be taken into account in the model.

77. Statistical Distributions

In mathematics and statistics, a probability distribution, more properly called a probability distribution function, assigns to every interval of the real numbers a probability, so that the probability axioms are satisfied.

Every random variable gives rise to a probability distribution, and this distribution contains most of the important information about the variable. If X is a random variable, the corresponding probability distribution assigns to the interval [a, b] a probability Pr that denotes the probability that the variable X will take a value in the interval [a, b].

A distribution is called discrete if its cumulative distribution function consists of a sequence of finite jumps, which means that it belongs to a discrete random variable X: a variable which can only attain values from a certain finite or countable set. A distribution is called continuous if its cumulative distribution function is continuous.

Several probability distributions are so important in theory or applications that they have been given specific names. Amongst the most frequently used distributions are:

Discrete Distributions:

- The Bernoulli distribution, which takes value 1 with probability p and value 0 with probability $q = 1 - p$.
- The binomial distribution describes the number of successes in a series of independent Yes/No experiments.
- The discrete uniform distribution, where all elements of a finite set are equally likely.
- The hyper-geometric distribution, which describes the number of successes in the first m of a series of n Yes/No experiments, if the total number of successes is known.
- The geometric distribution, a discrete distribution which describes the number of attempts needed to get the first success in a series of independent Yes/No experiments.
- The negative binomial distribution, a generalization of the geometric distribution to the nth success.
- The Poisson distribution, which describes a very large number of individually unlikely events that happen in a certain time interval.

Continuous Distributions:

- The Beta distribution on [0,1], of which the uniform distribution is a special case, and which is useful in estimating success probabilities.

- The continuous uniform distribution on [a,b], where all points in a finite interval are equally likely.
- The rectangular distribution is a uniform distribution on [-1/2,1/2].
- The chi-square distribution, which is the sum of the squares of n independent Gaussian random variables. It is a special case of the Gamma distribution, and it is used in goodness-of-fit tests in statistics.
- The exponential distribution, which describes the time between consecutive rare random events in a process with no memory.
- The F-distribution, which is the distribution of the ratio of two (normalized) chi-square distributed random variables, used in the analysis of variance.
- The Gamma distribution, which describes the time until n consecutive rare random events occur in a process with no memory.
- The Erlang distribution, which is a special case of the gamma distribution with integral shape parameter, developed to predict waiting times in queuing systems.
- The log-normal distribution, describing variables which can be modelled as the product of many small independent positive variables.
- The Pareto distribution, or "power law" distribution, used in the analysis of financial data and critical behaviour.
- The Weibull distribution, of which the exponential distribution is a special case, is used to model the lifetime of technical devices.
- The normal distribution, also called the Gaussian or the bell curve. It is ubiquitous in nature and statistics due to the central limit theorem: every variable that can be modelled as a sum of many small independent variables is approximately normal.
- Student's t-distribution, useful for estimating unknown means of Gaussian populations.

78. Stochastic processes

In the mathematics of probability, a stochastic process is a random function. In the most common applications, the domain over which the function is defined is a time interval (a stochastic process of this kind is called a time series in applications) or a region of space (a stochastic process being called a random field).

Familiar examples of processes modelled as stochastic time series include stock market and exchange rate fluctuations, signals such as speech, audio and video; medical data such as a patient's EKG, EEG, blood pressure or temperature; and random movement such as Brownian motion or random walks. Examples of random fields include static images, random terrain (landscapes), or composition variations of an inhomogeneous material.

A stochastic process is a sequence of measurable functions, that is, a random variable X defined on a probability space with values in a space of functions F. Thus a stochastic process can also be regarded as an indexed collection of random variables, where the index i ranges through an index set I, defined on a probability space and taking values on the same codomain

D (often the real numbers R). This view of a stochastic process as an indexed collection of random variables is the most common one.

A notable special case is where the index set is a discrete set I, often the nonnegative integers {0, 1, 2, 3, ...}.

In a continuous stochastic process the index set is continuous (usually space or time), resulting in an uncountably infinite number of random variables.

Each point in the sample space corresponds to a particular value for each of the random variables and the resulting function (mapping a point in the index set to the value of the random variable attached to it) is known as a realisation of the stochastic process. In the case the index family is a real (finite or infinite) interval, the resulting function is called a sample path.

A particular stochastic process is determined by specifying the joint probability distributions of the various random variables.

Stochastic processes may be defined in higher dimensions by attaching a multivariate random variable to each point in the index set, which is equivalent to using a multidimensional index set. Indeed a multivariate random variable can itself be viewed as a stochastic process with index set {1, ..., n}.

Links

Wikipedia page for stochastic processes - http://en.wikipedia.org/wiki/Stochastic_processes

References

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- Stirzaker, David, (2005) Stochastic processes and models, Oxford University Press, Oxford.

Communication and Consultancy

79. Project Management and Evaluation

Project management means different things to different people. In OR/MS, it has traditionally been almost exclusively concerned with technical aspects using PERT/CPM where the objective is to complete the project on time with an efficient use of resources. Outside of OR/MS, there has been much more of a concern with human aspects: the management of a group of people who are engaged in a project. In recent years, it seems that this has become a concern of managers of OR/MS groups. Organisational structure plays an important role in project management. The increasing need for fast response has motivated both the trend to flatter organisational structures and much of the recent thinking about project management (Handy, 1993).

The management of a project team involves skills such as leadership, coaching, supporting, decision-making (Boddy and Buchanan, 1992). The individual members of the project team require skills such as team-working (Belbin, 1981); time management (Adair, 1988); report-writing and presenting (Woolcott and Unwin, 1983); networking and negotiating (Kennedy, 1982); and interviewing.

Commercial software is widely available: a commonly used package is PRINCE2.

References

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80. Planning Projects

Several methods are available for planning projects, often given the generic name of network planning. They include the Critical Path Method (CPM), Program Evaluation and review Technique (PERT) and Critical Chain.

81. Business Planning **(Also known as Business Process Re-engineering)**

Business Process Re-engineering is a management approach aiming at improvements by means of elevating efficiency and effectiveness of the processes that exist within and across organizations. It is a fundamental and radical approach by either modifying or eliminating non-value adding activities.

The key steps involved in a BPR are:

- Defining the purpose and goal of the BPR project;
- Defining the scope of the project so as to include (or exclude) activities; A flowchart of the activities can assist to define the scope of the project;
- Identifying the requirements that will meet the needs of the clients;
- Assessing the environment - the position of competitors, prospective changes in technology, legislation or socio-economic factors;
- Redesigning the business processes and activities in light of the above;
- Implementing the redesigned processes;
- Monitoring the success/failure of the redesign.
- Business process reengineering is also known as BPR, Business Process Redesign, Business Transformation, or Process Change Management. Also see financial planning.

References

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- Sethi V. and King W. (1997) Organisational Transformation through Business Process Reengineering: Applying Lessons Learned, Prentice Hall, NJ.

82. Critical Path Analysis

The Critical Path Method, CPM, is a mathematical based algorithm for scheduling a set of project activities. It is a very important tool for effective project management. It was developed in the 1950's in a joint venture between DuPont Corporation and Remington Rand Corporation for managing plant maintenance projects. Today, it is commonly used in all forms of projects. Any project with interdependent activities can apply this method of scheduling.

The essential approach when using CPM is to construct a network model of the project. This involves:

1. The production of an activity list
2. The determination of the sequence in which the activities are to be performed and the

inter-relationship between them. For each activity determine which other activities must precede it and which activities cannot start until it has been completed.

3. The construction of a network to reflect the relationships, and only those relationships, implied in 2.

4. The determination of the duration of each activity.

This model can be analysed by determining the earliest and latest start times of each activity. This will reveal which activities have spare time, which is often called float and which have none. The later set of activities forms the critical path, the shortest time possible to complete the project. Any delay of an activity on the critical path directly impacts the planned project completion date. A project can have several, parallel critical paths. An additional parallel path through the network with the total durations shorter than the critical path is called a sub-critical or non-critical path.

The Program Evaluation and Review Technique commonly abbreviated PERT is a model for project management developed by Booz Allen Hamilton, Inc. under contract to the United States Department of Defence's US Navy Special Projects Office in 1958 as part of the Polaris mobile submarine-launched ballistic missile project. It aimed to incorporate uncertainty by making it possible to schedule a project not knowing precisely the details and durations of all the activities. PERT requires the use of three time estimates: an optimistic estimate (O), most likely estimate (M) and a pessimistic estimate (P). The expected time is calculated as the weighted average, $TE = (O + 4M + P)/6$ and the standard deviation is $(P-O)/6$. These results are used to estimate the probability that projects will be completed by specified time, but the results obtained are false, as there is no statistical foundation for the calculations.

In 1997, Eli Goldratt published a novel, Critical Chain, in which the application of his Theory of Constraints to project management is expounded. This approach allows for the inclusion of resources related to each activity.

Key questions in project management are cost optimization (what is the optimal length of the project given the cost of various levels of resources) and resource allocation (when resources are limited, to which activity should they be allocated). There is still no satisfactory method commercially available for these questions.

References

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Other Techniques

83. Equity

In business accounting, ownership equity is the owners' interest in all assets after all liabilities are paid. There is a greater discussion at shareholders' equity (when the owners are shareholders). Ownership equity is also known as equity, risk capital, and liable capital. In a bankruptcy court, creditors have the first claim on assets, and ownership equity is the last or residual claim against assets, paid only after all other creditors are paid. In real estate the owner's equity in a property is the difference between the market price of a property and the owner's mortgage debt, or the owner's 'home equity loan'. Equity capital is the amount of capital made available by the company's owner(s) to finance its assets at the end of the accounting year.

84. Expert Systems

An expert system, also known as a knowledge based system, is a computer program that contains some of the subject-specific knowledge of one or more human experts. This class of program was first developed by researchers in artificial intelligence during the 1960s and 1970s and applied commercially throughout the 1980s. The most common form of expert systems is a program made up of a set of rules that analyze information (usually supplied by the user of the system) about a specific class of problems, as well as providing mathematical analysis of the problem(s), and, depending upon their design, recommend a course of user action in order to implement corrections. It is a system that utilizes what appear to be reasoning capabilities to reach conclusions.

A related term is wizard. A wizard is an interactive computer program that helps a user solve a problem. Originally the term wizard was used for programs that construct a database search query based on criteria supplied by the user. However some rule-based expert systems are also called wizards. Other "Wizards" are a sequence of online forms that guide users through a series of choices, such as the ones which manage the installation of new software on computers, and these are not Expert Systems. Expert systems are most valuable to organizations that have a high-level of know-how experience and expertise that cannot be easily transferred to other members. They are designed to carry the intelligence and information found in the intellect of experts and provide this knowledge to other members of the organization for problem-solving purposes.

Simple systems use simple true/false logic to evaluate data, but more sophisticated systems are capable of performing at least some evaluation taking into account real-world uncertainties, using such methods as fuzzy logic. Such sophistication is difficult to develop and still highly imperfect.

Expert systems are designed and created to facilitate tasks in the fields of accounting, medicine, process control, financial service, production, human resources etc. Indeed, the foundation of a successful expert system depends on a series of technical procedures and development that may be designed by certain technicians and related experts. When a corporation begins to develop and implement an expert system project, it will use self sourcing, in sourcing and/or outsourcing techniques.

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85. Financial Planning

Financial planning usually covers some or all of the following processes: budgeting and business planning, financial and management accounting, setting up a basic record-keeping system, setting up a profit and loss account and managing cash flow. A balance sheet shows the assets and liabilities of a business and can help to assess its financial health. Financial modelling enables the forward projection financial statements or financial performance of an entity.

86. Game Theory

Game theory is often described as a branch of applied mathematics and economics that studies situations where players choose different actions in an attempt to maximize their returns. The essential feature, however, is that it provides a formal modelling approach to social situations in which decision makers interact with other minds. Game theory extends the simpler optimization approach developed in neoclassical economics.

Economists have long used game theory to analyze a wide array of economic phenomena, auctions, bargaining, duopolies, fair division, oligopolies, social network formation, and voting systems. This research usually focuses on particular sets of strategies known as equilibria in games. These "solution concepts" are usually based on what is required by norms of rationality. The most famous of these is the Nash equilibrium. A set of strategies is a Nash equilibrium if each represents a best response to the other strategies. So, if all the players are playing the strategies in a Nash equilibrium, they have no incentive to deviate, since their strategy is the best they can do given what others are doing.

The payoffs of the game are generally taken to represent the utility of individual players. Often in modelling situations the payoffs represent money, which presumably corresponds to an individual's utility. This assumption, however, can be faulty.

References

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87. Graph Theory

In mathematics and computer science, graph theory is the study of graphs, mathematical structures used to model pairwise relations between objects from a certain collection. A "graph" in this context refers to a collection of vertices and a collection of edges that connect pairs of vertices. A graph may be undirected, meaning that there is no distinction between the two vertices associated with each edge, or its edges may be directed from one vertex to another. The graphs studied in graph theory should not be confused with "graphs of functions" and other kinds of graphs.

Structures that can be represented as graphs are ubiquitous, and many problems of practical interest can be represented by graphs. The link structure of a website could be represented by a directed graph: the vertices are the web pages available at the website and a directed edge from page A to page B exists if and only if A contains a link to B. A similar approach can be taken to problems in travel, biology, computer chip design, and many other fields. The development of algorithms to handle graphs is therefore of major interest in computer science.

A graph structure can be extended by assigning a weight to each edge of the graph. Graphs with weights, or weighted graphs, are used to represent structures in which pairwise connections have some numerical values. For example if a graph represents a road network, the weights could represent the length of each road. A digraph with weighted edges in the context of graph theory is called a network.

Networks have many uses in the practical side of graph theory, network analysis (for example, to model and analyze traffic networks). Within network analysis, the definition of the term "network" varies, and may often refer to a simple graph.

Many applications of graph theory exist in the form of network analysis. These split broadly into two categories. Firstly, analysis to determine structural properties of a network, such as the distribution of vertex degrees and the diameter of the graph. A vast number of graph measures exist, and the production of useful ones for various domains remains an active area of research. Secondly, analysis to find a measurable quantity within the network, for example, for a transportation network, the level of vehicular flow within any portion of it.

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88. Logistics

In business, logistics may have either internal focus (inbound logistics), or external focus (outbound logistics) covering the flow and storage of materials from point of origin to point of consumption (often called supply chain management). The main functions of a logistics manager include inventory management, purchasing, transport, warehousing, and the organizing and planning of these activities. Logistics managers combine a general knowledge of each of these functions so that there is a coordination of resources in an organization.

References

- Christopher, Martin (2005) Logistics and Supply Chain Management: Creating Value-Adding Networks, Prentice Hall FT, Harlow, UK.

89. Management Accounting

Management accounting is concerned with the provisions and use of accounting information to managers within organizations, to provide them with the basis in making informed business decisions. Unlike financial accountancy information (which, for public companies, is public information), management accounting information is used within an organization (typically for decision-making) and is usually confidential and its access available only to a select few.

90. Management Gaming

Gaming is an activity in which people agree to abide by a set of conditions in order to create a desired state or end. Gaming can be regarded as a model with rules and tools in which people play certain roles and gradually create a future. A simulation game consists of two elements: human players and a computer. In this combination, a computer acts as a high-speed calculator, and it contains one ore more models, triggered by actions of players. War gaming is a specific type of gaming.

References

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91. Quality

The definition of quality, when applied to quality management, has been variously expressed. Definitions include:

"Conformance to requirements" (Philip B. Crosby in the 1980s). The difficulty with this is that the requirements may not fully represent what the customer wants; Crosby treats this as a separate problem.

"Fitness for use" (Joseph M. Juran). Fitness is defined by the customer.

"The loss a product imposes on society after it is shipped" (Genichi Taguchi). Taguchi's definition of quality is based on a more comprehensive view of the production system.

"Degree to which a set of inherent characteristic fulfils requirements" as ISO 9000

A key distinction is that there are two common applications of the term Quality as form of activity or function within a business. One is Quality Assurance which concerns the "prevention of defects", such as the deployment of a Quality Management System and preventative activities like FMEA. The other is Quality Control which concerns the "detection of defects", most commonly associated with testing which takes place within a Quality Management System typically referred to as Verification and Validation.

Many different techniques and concepts have evolved to improve product or service quality, including Statistical Process Control, Zero Defects and Six Sigma. Several prizes are available including the Malcolm Baldrige National Quality Award in the States and those awarded by the European Foundation for Quality Management. ISO 9000 is the International Standard. Total Quality Management (TQM) is the over-arching philosophy.

Links

Baldridge National Quality Programme – http://www.nist.gov/baldrige/

European Foundation for Quality Management – http://www.efqm.org/en/

92. Renewal Investment **(Also known as Replacement)**

Replacement investment is essentially a regenerative optimal stopping problem, that is, the key decision concerns when to terminate the life of existing plant and hence when to start over again. A large part of all investment activity is in fact replacement investment; indeed in a non-growing, stationary state, economy, effectively all investment is replacement investment. The key decision concerning such replacement investment is that of timing of deciding how long to keep existing plant and machinery. As an optimisation problem, the decision of when to renew capacity naturally depends on expectations regarding how existing and new plant operating costs change over time, and of course, on expectations regarding future capital costs and resale/salvage values. A standard approach is to envisage a replacement chain for investment in which the economic life of the first plant is determined by a trade off between expected benefits and costs associated with extending the economic life of existing plant. Keeping plant for an additional period involves incurring additional operating costs and suffering possible loss of second hand or salvage value, but reduces the present value costs associated with the chain of investments that subsequently follow.

References

- Dixit A. and Pindyck R., 1994, Investment under uncertainty, Princeton University Press, Princeton, New Jersey.

93. Robustness Analysis

Robustness Analysis is a problem structuring method, which aims to seek solutions to a problem with multiple stakeholders which satisfice on separate dimensions, rather than trading off onto a single dimension for optimization. (see also Qualitative Techniques work area)

References

- Rosenhead J. ed. (1989) Rational Analysis for a Problematic World: Problem Structuring Methods for Complexity, Uncertainty and Conflict, Wiley, Chichester, UK.

94. Total Quality Management (TQM)

TQM includes a number of basic ideas:

- Focus on the customer

- Everyone responsible for quality
- Team problem-solving
- Employee training
- Fact-based management
- Continuous improvement

As defined by the International Organization for Standardization (ISO):

"TQM is a management approach for an organization, centred on quality, based on the participation of all its members and aiming at long-term success through customer satisfaction, and benefits to all members of the organization and to society."

In Japan, TQM comprises four process steps, namely:

Kaizen Focuses on Continuous Process Improvement, to make processes visible, repeatable and measurable.

Atarimae Hinshitsu The idea that things will work as they are supposed to (e.g. a pen will write.).

Kansei Examining the way the user applies the product leads to improvement in the product itself.

Miryokuteki Hinshitsu The idea that things should have an aesthetic quality which is different from "atarimae hinshitsu" (e.g. a pen will write in a way that is pleasing to the writer.)

TQM requires that the company maintain this quality standard in all aspects of its business. This requires ensuring that things are done right the first time and that defects and waste are eliminated from operations.

An approach to TQM adopted by many organisations is Six Sigma, a disciplined, data-driven approach and methodology for eliminating defects (driving towards six standard deviations between the mean and the nearest specification limit). The statistical representation of Six Sigma describes quantitatively how a process is performing. To achieve Six Sigma, a process must not produce more than 3.4 defects per million opportunities. A Six Sigma defect is defined as anything outside of specification. A Six Sigma opportunity is then the total quantity of chances for a defect.

The fundamental objective of the Six Sigma methodology is the implementation of a measurement-based strategy that focuses on process improvement and variation reduction through the application of Six Sigma improvement projects. This is accomplished through the use of two methodologies: DMAIC and DMADV. The DMAIC process (define, measure, analyze, improve, control) is an improvement system for existing processes falling below specification and looking for incremental improvement. The DMADV process (define, measure, analyze, design, verify) is an improvement system used to develop new processes or products at Six Sigma quality levels. It can also be employed if a current process requires more than just incremental improvement.

References

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- Oakland, John S. (2004) Oakland on Quality Management (3rd edition), Butterworth-Heinemann Ltd, Oxford, UK.

- Oakland, John S. (2004) Statistical Process Control (5th edition), Butterworth-Heinemann Ltd, Oxford, UK.

95. Workforce Planning

Also known as Manpower planning

Workforce Planning is concerned with the quantitative aspects of the supply of and demand for people in employment. The aim is to have the right numbers of people of the right kinds in the right places at the right times. The presence of uncertainty in both the availability of and requirements for people means that the planning problem is stochastic. Two probability processes, the absorbing Markov chain and the renewal process have proved helpful in modelling the problem.

Strategic Workforce Planning involves analyzing and forecasting the talent that companies need to execute their business strategy, proactively rather than reactively, it is a critical strategic activity, enabling the organization to identify, develop and sustain the workforce skills it needs to successfully accomplish its strategic intent whilst balancing career and lifestyle goals of its employees.

References

- Bartholomew DJ, Forbes AF and McClean SI (1991) Statistical Techniques for Manpower Planning, 2nd edition, John Wiley, Chichester, UK

- Bennison M and Casson J (1984) The Manpower Planning Handbook, McGraw Hill, London

Simulation Modelling

96. Simulation Modelling

Simulation is the process by which a simplified model of a real world process is constructed with the aim of better understanding and controlling that process. It is an essential tool for designing processes that have yet to be built (e.g. a new car factory) and where experimentation with the real world process would be impracticable. Modern simulation packages are a valuable aid in building a simulation model e.g. Witness, Simul8.

Computer simulation was developed hand-in-hand with the rapid growth of the computer. Computer simulation is often used as an adjunct to, or substitution for, modelling systems for which simple closed form analytic solutions are not possible. There are many different types of computer simulation; the common feature they all share is the attempt to generate a sample of representative scenarios for a model in which a complete enumeration of all possible states of the model would be prohibitive or impossible.

Computer simulation models can be classified according to several criteria including:

Steady-state models use equations defining the relationships between elements of the modelled system and attempt to find a state in which the system is in equilibrium. Such models are often used in simulating physical systems, as a simpler modelling case before dynamic simulation is attempted.

Dynamic simulations model changes in a system in response to (usually changing) input signals.

Stochastic (as opposed to deterministic) models use random number generators to model chance or random events; they are also called Monte Carlo simulations.

Discrete event simulations see below

Agent-based simulations see below

Distributed models run on a network of interconnected computers, possibly through the Internet. Simulations dispersed across multiple host computers like this are often referred to as "distributed simulations". There are several military standards for distributed simulation.

97. Discrete Event Simulation

In Discrete Event Simulation, the operation of a system is represented as a chronological sequence of events. Each event occurs at an instant in time and marks a change of state in the system. For example, an event could be "lift at level 2" or "level 6 button pressed". A number of mechanisms have been proposed for carrying out discrete event simulation. Among them are the event-based, activity-based, process-based and three-phase approaches. The three-phase approach is used by a number of commercial simulation software packages, but from the user's point of view, the specifics of the underlying simulation method are generally hidden.

Simulation has found major uses in modelling manufacturing and communication systems, including call centres. Such systems are usually stochastic in nature, with a variety of random processes interacting in complex ways (thus precluding analytical solutions). A simulation model comprises three elements: input generation, bookkeeping and output analysis. The stochastic phenomena of the system under study needs to be generated e.g. the inter-arrival and service time distributions in queues. The bookkeeping phase keeps track of transactions moving around the system and the output phase uses statistical techniques to make valid statements concerning system performance. Appropriate validation of the models performance compared to the real system is essential before meaningful results can be obtained.

98. Monte Carlo Simulation

In simulation, Monte Carlo refers to the generation of appropriate random numbers to represent the behaviour of activities in the system. For example, if the service time for customers at a post office counter is known to follow the normal distribution, then the service times in the simulation can be randomly generated from a normal distribution.

Interestingly, Monte Carlo simulation methods do not generally require truly random numbers to be useful - for other applications, such as primality testing, unpredictability is vital. Many of the most useful techniques use deterministic, pseudo-random sequences, making it easy to test and re-run simulations. The only quality usually necessary to make good simulations is for the pseudo-random sequence to appear "random enough" in a certain sense. What this means depends on the application, but typically they should pass a series of statistical tests. Testing that the numbers are uniformly distributed or follow another desired distribution when a large enough number of elements of the sequence are considered is one of the simplest, and most common ones.

The approach can also facilitate variance reduction (e.g. importance sampling) so as to improve the efficiency of simulations.

99. Agent-Based Models

An agent is an entity, real or virtual, that perceives and acts in its environment. Agent-based simulation (A-BS) involves the use of autonomous agents within a simulation environment. A-BS extends from object-based simulation, which in turn provides a better mapping between the domain abstraction (e.g. subassemblies and work stations in a car factory) and the model abstraction (e.g. model objects and components) as compared to traditional modelling methods. (See object-oriented programming). In particular, both A-BS and object-oriented simulations provide stronger facilities for capturing decision-making aspects of a domain within the simulation model, which is important for some types of problem e.g. combat modelling.

References

RR Hill, Carl RG and Champagne LE (2007), Using agent-based simulation to empirically examine search theory using a historical case study, Journal of Simulation, 30 38.

100. Process Mapping

Process Mapping is a method for depicting a process, material or information flow in a diagrammatic form. It defines key process inputs and outputs and coupled with data analysis, is one of the steps in process redesign: weaknesses can be identified and corrected. Software tools are an aid to Process Mapping and simulation models can be used to validate the redesigned process. The Winter Simulation Conference Proceedings (see below) contains case studies and the Software section has suitable computer tools.

Links

[Proceedings of the Winter Simulation Conference]

References

- Booch, Grady (2003) Object-Oriented Analysis and Design with Applications. Addison-Wesley, New York.
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101. System Dynamics

System Dynamics is a computer-aided approach to policy analysis and design. It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems literally any system characterised by interdependence, mutual interaction, information feedback and circular causality.

The field developed initially from the work of Jay W Forrester, whose seminal book Industrial Dynamics is still a significant statement of philosophy and methodology in the field. Modern SD packages e.g. Ithink, are a valuable aid in building models and several are mentioned in the Software section.

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