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freqencies. In this example, if you repeat the decision many times you will, on average, gain £5,000 - but if you make only one decision you are likely to lose £50,000. n ABC analyses categorise items according to their importance. How does this change if the interest is paid more frequently? How many people - from initial designers through to the person who delivered it - were involved in supplying this high-quality product? Many industries work with standard figures for this - a supermarket might make 3%, a newsagent 15%, a carpet wholesaler 20% and a guesthouse 60%. But it is not a perfect answer, and it does not represent the true rate of inflation felt by certain groups whose buying habits are not 'typical'. 11.6 The area representing feasible solutions that satisfy all constraints, including the non-negativity conditions. Blending Distilling Finishing Growbig Thrive 1 2 1 2 1 1 If the factory makes a net profit of a300 on each batch of Growbig and a200 on each batch of Thrive, how many batches of each should it make in a week? 2.16 What are the values of (a)  $x_1/2 \times x_1/4$ , (b)  $(x_1/3)3$ , (c) 90.5, (d) 42.5, (e) 73.2, (f)  $41.5 \times 63.7 / 61.7$ ? 2.17 If  $\log a = 0.3010$ ,  $\log b = 0.4771$  and  $\log c = 0.6021$ , what is the value of  $\log(ab/c)$ ? 19.10 It is the chain of activities that determines the project duration. You might start with your own experiences and Measuring quality 453 say that you are happy with the quality of, say, a pen when it writes easily and clearly; you think an airline gives a high-quality service when you get to your destination on time and without too much hassle; an electricity supplier gives high quality if you never have to worry about supplies or costs. 4.4 Auditors want to select a sample of 300 invoices from the 9,000 available. n Problem maps give a useful way of adding structure for decisions. Here the economic order quantity is calculated as 200, corresponding to one delivery a month. Design a questionnaire or other method of data collection. The reliability of this report (phrased in terms of the probability of a favourable report, given that the drilling cost will be low etc.) is given in this table: Drilling well cost Favourable report Unfavourable report £32,000 £44,000 £56,000 0.8 0.2 0.6 0.4 0.2 0.8 Questions n What would a decision tree of the farmers' problem look like? n n n Total Quality Management has the whole organisation working together to guarantee - and systematically improve - quality. The company wanted to maximise its returns on this new investment, but there were regulations and guidelines on the types of investment they could make. He has used this approach to amass considerable wealth. The table summarises their findings. There are also problems with emotional responses, so asking customers how they liked the food in a restaurant is likely to get replies based on the whole experience, including who they were with, how they felt, what the weather was like, how attractive the servers were and so on. But financial markets change very quickly, and the data used in the model had to be updated frequently. For instance, if  $y = 10$  for all values of  $x$ , then we can take two arbitrary values of  $x$ , say 2 and 14, and get the two points (2, 10) and (14, 10). So if you have, say, four variables, you need four simultaneous equations to find all the values. Figure 5.15 shows a frequency distribution for the percentage gain in value of certain unit trusts over the past five years, and the associated histogram. It sells a quarter of them at a 20% discount and a further 10% at a 40% discount. Sources: www.statistics.gov.uk 7.6 What are the mean price relative index and simple aggregate index? n With an inspection after wiring, the expected costs per unit are: n cost of inspection =  $r_2$ .00 n cost of faults detected and corrected after wiring = proportion of faults detected  $\times$  cost of repairing each =  $0.04 \times 0.95 \times 3 = r_0.114$  n cost of faults not found until later = proportion not detected  $\times$  cost of later repair =  $0.04 \times (1 - 0.95) \times 20 = r_0.04$  This gives a total of  $2.00 + 0.114 + 0.04 = r_2.154$  a unit. We might calculate an economic order quantity and then find the period that gives orders of about this size. To start the Delphi forecast, the company contacts a number of experts from various backgrounds including divers, technical staff from oil companies, ships' captains, maintenance engineers and robot designers. In practice, few relationships are perfect and there is inevitably some random noise. Seven years ago, she added a recycling unit to refill customers' old cartridges. This is not necessarily true and there may be a systematic reason for the non-responses. There is also the problem that manual inspections are only 80% accurate. The fourth part of the book showed how such uncertainty can be measured and analysed using probabilities. Within a short period, Mattel identified 20 million toys at risk worldwide, and had three separate recalls (including 600,000 Barbie dolls). What is the reorder level when the lead time is (a) 1 week, (b) 2 weeks? The average time a customer spends in the queue is:  $W_q = 4(6-4) = 20/30 \times 10 = 0.0667$  hours = 4 minutes If customers' costs are assigned to only the time they are waiting, the cost per hour is  $(20 \times 4 / 60 \times 10) = £13.33$ , giving a total cost of  $(13.33 + 30) = £43.33$  an hour. n When the number of units sold is higher than the break-even point, revenue is greater than total cost and there is a profit (shown in Figure 8.2): profit =  $N(P - C) - F$  n When the number of units sold equals the break-even point, revenue exactly equals total cost:  $N(P - C) = F$  n When the number of units sold is less than the break-even point, total cost is higher than revenue and there is a loss: loss =  $F - N(P - C)$  19.2 Finance and performance Figure 8.2 A company sells 200 units of a product every week. The obvious measure is range, but this can be affected by a few outlying results. The equations are fairly messy, but Figure 9.7 shows the values of  $n, |x|, |y|, |xy|$  and  $|x^2|$ . This is not an improvement because the tail of the histogram is now extended even more. The actual price of crude oil reached \$70 a barrel in 2006, peaked at \$107 in 2008, fell sharply and then returned to \$75 in 2010. Event Gain A B C D E F 100 950 -250 0 950 500 448 Making decisions ==\*= -- INFORMATION ENTERED =- NUMBER OF STATES: 5 NUMBER OF ALTERNATIVES: 5 HURWICZ COEFFICIENT: 0.3 ==\*= == PAYOFF TABLE VALUE OF EACH ALTERNATIVE 1 2 3 1.00 5.00 9.00 3.00 7.00 3.00 6.00 4.00 8.00 2.00 7.00 6.00 9.00 4.00 1.2 3 4 5.4 2.00 5.00 6.00 1.00 8.00 6.00 2.00 ==\*= -- RESULTS =- ==\*= == CRITERION 1. 15.12 The following figures show the number of defective components supplied each day by a factory. n How effective is quality control at Bremen Engineering? Histograms are often confused with bar charts, but they show frequency distributions for continuous data and represent the frequency by the area of a bar. n You solve an equation by using known values to find a previously unknown value for a constant or variable. When G finishes H can start, so its earliest start is 5, and adding the duration of 4 gives an earliest finish of  $5 + 4 = 9$ . An ABC analysis starts by calculating the total annual use of each item in terms of value, by multiplying the number of units used in a year by the unit cost. Last week a consumer group tested these figures by timing a sample of 30 journeys. Finished goods - goods that have finished their operations and are waiting to be delivered to customers. However, managers really do have to be aware of the analyses available, understand the underlying principles, recognise the limitations, have intelligent discussions with experts and interpret the results. Then the first point, (2, 7), is 2 units along the x-axis and 7 units up the y-axis, and is shown as point A in Figure 3.3. The Graphs on Cartesian coordinates 53 Worked example 3.1 continued Figure 3.3 Graph of points for Worked example 3.1 Figure 3.4 Connecting points to emphasise the relationship second point, (5, 20), is 5 units along the x-axis and 20 units up the y-axis, and is shown by point B. IDEAS IN PRACTICE Vancouver Electrical Factors In 2005 Edwin Choi worked for Vancouver Electrical Factors, who make and supply around 10,000 products for their range of electric motors. The following give more general material. Then, you might ask, why you should do any calculations - why not leave everything to the computer? Dividing both sides of this new equation by C gives:  $T K = C \times C$  or  $K = T C$  All three forms are simply rearrangements of the first equation, and if you know two values you can use the appropriate form to find the third. 12.12 Probabilities of the form  $P(a/b)$ , giving the probability of event a occurring, given that event b has already occurred. When SemiShan reject a batch of contracts, they want to be 97.5% sure that the mean is above 0.04. 18.14 How is the order size calculated for a periodic review system? ?') how strongly these views are held ('On a scale of 1 to 5, how strong are your feelings about this development . As we saw in Chapter 4, market surveys collect data from representative samples of customers and analyse this to show likely behaviour of the whole population. You can draw it on a threedimensional graph, but the results are generally complicated and difficult to interpret. Find some real examples of this effect. For airlines, there are two key issues in yield management. Specifically, the service level is defined as the probability that the lead time demand is less than the reorder level. Solution (a)  $\log 232$  is the power to which you raise the base 2 to give 32. The farmers now face the option of either connecting to the local mains water supply at a cost of £44,000 or drilling a new well. Solution It probably means that in a particular, relatively small test - and under certain conditions - eight out of ten dog owners who expressed an opinion said that their dog seemed to show some preference for this food over some alternative they were offered. If, say,  $n = 4$  and  $m = 2$ , we get  $b_m / b_n = b_2 / b_4 = b_2 - 4 = b_2$  and we have to interpret a negative power. n You can use the standard method for drawing graphs for any relationship where  $y$  is a function of  $x$  - described as  $y = f(x)$  - including higher polynomials and exponential curves. In the last example, the only uncertainty was whether a unit was accepted or rejected, and we used random numbers for this decision. Solution You can do a simple calculation to find the best value for money.  $A_0 = A_n \times (1 + i)^{-n} = A_5 \times (1 + i)^{-5} = 300,000 \times (1 + 0.2)^{-5} = r_120,563$  n Option 2 has  $i = 0.2$ ,  $n = 10$  and  $A_{10} = 500,000$ . (b) Find solutions that best meet the decision-makers' objectives. In other words, for small changes the total benefit is the sum of the separate benefits of increasing each resource separately. 8.15 What is the difference between the straight-line and reducing-balance methods of depreciation? n What are their best choices and expected costs? As the price differences are small, we have highlighted the pattern by plotting only the relevant part of the y-axis. (a) Weights of books posted to a bookshop (b) Numbers of pages in books (c) Position of football teams in a league (d) Opinions about a new novel. How do these figures compare with those from other countries? The other two constraints would become active long before this, and they would limit production and leave spare distilling. Adding equations (4) and (5) gives: (5) 3 3 (2) (3) 36 Calculations and equations Figure 2.1 Using the Excel 'Solver' tool to solve simultaneous equations Clearly, this kind of arithmetic manipulation gets messy and it is easier to use a computer. Then you have to balance the benefits of having primary data with the cost and effort of collecting it. If the evidence does not support the null hypothesis it is rejected, otherwise it cannot be rejected. Continuous data can take any value and is not restricted to integers. But the noise means that Measuring relationships 219 Figure 9.3 Noise introduces errors in observations there is a difference between the actual value of the dependent variable and the expected value. But it would be interesting to see what happens when several resources are increased at the same time. The result is called a p-chart. 4 Wainer H., How to display data badly, The American Statistician, Volume 38, pages 137-147, May 1984. Although accurate, this description is very messy and does not give direct comparisons of the number of crimes in, say, years 1 and 4. We can represent this using the two formats in Figure 19.1. The choice between these is largely a matter of personal preference. WORKED EXAMPLE 16.8 Humbolt Oil drills an exploratory well in deep water off the Irish coast. Edwin calculated the economic order quantity from these figures: Demand,  $D = 1,000$  units a year Unit cost,  $UC = \$400$  a unit Reorder cost,  $RC = \$1,000$  an order Holding cost,  $HC = (0.18 + 0.01 + 0.02) \times 400 + 20 + 15 + 40 = \$159$  a unit a year Then he suggested ordering 120 units, with an order about every six weeks and annual costs of \$18,000. Draw a graph of this amount over the next 20 years. Most of them are fairly minor and we can make them using a combination of experience, intuition, judgement and common sense. Formulate this as a linear programme. Demand is met from the second bin until this is empty. 418 Testing hypotheses Figure 15.11 Calculations for Problem 15.15 RESEARCH PROJECTS 15.1 This chapter mentioned several examples of automatic systems that implicitly include hypothesis tests - including airport security systems, e-mail spam filters, Internet search results, automatic recorders of earthquakes, burglar alarms and roadside speed cameras. With interest we know that an amount  $A_0$  increases at a fixed rate,  $i$ , each period and after  $n$  periods has a value of:  $A_n = A_0 \times (1 + i)^n$  With depreciation the amount is decreasing at a fixed rate, so we simply subtract the rate  $i$  instead of adding it. Other countries have similar publications, and the results are summarised by international bodies such as the United Nations, the European Union, the World Bank and the International Monetary Fund. 4.15 What is wrong with the following survey questions? This is why multiple regression is never tackled by hand. This is near to the point where  $x = 4$  and  $y = 6$  (confirming a result that we calculated in Worked example 2.19). WORKED EXAMPLE 9.9 Kipram Jansaporanam runs an apprentice scheme that judges the performance of trainees by a combination of interviews and job performance. To change a decimal with one digit to a fraction, you put the number after the decimal point over 10, so  $0.6 = 6/10 = 3/5$ . Then  $i = I / 100$ , and an interest rate of 10% means that  $i = 0.1$ , an interest rate of 15% has  $i = 0.15$ , and so on. This is called regression. n Superscripts show that a value is raised to a particular power - or multiplied by itself this number of times. Gross D., Shortle J.F., Thomson J.M. and Harris C.M., Fundamentals of Queuing Theory (4th edition), John Wiley and Sons, Hoboken, NJ, 2008. What features do you think there should be? Barlow J.F., Excel Models for Business and Operations Management (2nd edition), John Wiley, Chichester, 2005. Waters D., Operations Management, FT-Prentice Hall, Harlow, 2002. In 2007 the company had a major problem when some toys purchased from Chinese manufacturers were found to be decorated with paint that contained high levels of lead. This is an important point - that we can change things in the model to assess their affects. Chapter 16 describes an approach to decision-making, where managers can give structure to problems and make decisions in conditions of uncertainty. 3.7 They correspond to the points where  $y > 3x + 5$ . residual ( $R$ ) - the random noise that we cannot explain properly. The Retail Price Index (RPI) originated in 1947 and is the most widely used for giving 'headline inflation rates'. 9.10 Interpolation considers values for the independent variable within the range used to define the regression; extrapolation considers values outside this range. Then it follows the operations through a typical series of months. He makes decisions based on experience gained through 35 years of work with the company and discussions with staff. These help managers to tackle problems in a variety of circumstances, including certainty, uncertainty and risk. 24 26 23 24 23 24 27 26 28 25 21 22 25 23 26 29 27 24 25 24 25 6.3 What measures can you use for the following discrete frequency distribution? The notional profit for this machine is  $r^4$  a unit. 4.15 (a) leading question, (b) too vague, (c) several questions in one, (d) speculative. However, they are useful in a variety of other analyses, and this makes them the most widely used measures of dispersion. 16 Managers and numbers PROBLEMS The answers to these problems are given on the companion website: www.pearsoned.co.uk/waters 1.1 At last year's Southern Florida Amateur Tennis Championships there were 1,947 entries in the women's singles. Exponential curves have the general form  $y = nemx$ , where  $n$  and  $m$  are constants. Could you work these into something more forceful within the next couple of days? Question n If you were Hari Chandrasan how would you put the figures into a suitable format for the presentation? Rather than choosing a discount rate and using this to calculate the net present value, we can set a target present value and calculate the discount rate that gives this. Taking a value of  $a = 0.2$ , the forecast for the next period is:  $Ft+1 = ayt + (1 - a)Ft = 0.2 \times 180 + (1 - 0.2) \times 200 = 196$  The method notices the optimistic forecast and adjusts the forecast for the next period downwards. These demands are independent of each other, so that the demand from one customer is not related to the demand from another. By working together we can share ideas and get mutual benefits.' The General Manager waited for a few minutes and said, 'I find it incredible that we are sending poor quality goods to one of our biggest customers. If you choose the best option, there is clearly no regret.  $F \times (1 + i)^n - F_i$  An annuity is the reverse of a mortgage, and allows someone with a lump sum to invest it and receive regular income over some period in the future. One of the most widely used performance ratios is utilisation, which shows how much of the available capacity is actually used. Berkun S., The Art of Project Management, O'Reilly, Sebastopol, CA, 2008. Solving equations 31 WORKED EXAMPLE 2.16 Sempervig Securitas employs 10 people with costs of £500,000 a year. 4.9 Because it is too expensive, time-consuming and impractical to collect data from whole populations, 6.12 Why is the standard deviation so widely used when its practical meaning is unclear? For example, we can describe queues as long, medium or small. These are inevitable in our society, which are often surprising and bizarre. Network analysis A 'project network' is a diagram that shows the

consuming or impractical to collect data from whole populations. 6.12 Why is the standard deviation so widely used, when its practical meaning is unclear? For example, we can describe sweaters as large, medium or small. These inevitably incur costs, which are often surprisingly high. Network analysis A project network is a diagram that shows the relationships between all the activities that make up the project. With constant demand of D, this means that we place an order when the stock level falls to lead time  $\times$  demand, and this point is the reorder level. Moving averages are more flexible, setting forecasts as the average of the latest n observations, and ignoring all older values. We haven't improved quality because we didn't agree to improve it, and any improvement would increase our costs. 3.9 The points where the curve crosses the x-axis. Chapter 7 - Describing changes with index numbers 7.1 To measure the changes in a variable over time. For example, the UK government's Statistical Service publishes broad reviews in a Monthly Digest of Statistics2 and an Annual Abstract of Statistics.3 Their Guide to Official Statistics4 lists the more specialised figures they publish. Solution Activity Description Duration Depends on Activity A B C D E F G Design internal equipment Design building Order parts for equipment Order material for building Wait for equipment parts Wait for building material Employ equipment assemblers Employ building workers Install equipment Complete building 10 5 3 2 15 10 5 - A A B C D A 4 20 30 B E, G, J F, H A B C D E F G H I J H I J Figure 19.9 shows the network for this problem.  $n = n_1 n_2 = 24$ , so the logarithm to the base 2 of 16 is 4, which means that you raise the base 2 to the power 4 to give 16. 7.2 index was reset to 100 in January 1974, and again in January 1987. Because air might affect the taste, the company allowed a maximum of 1 cm<sup>3</sup> of air in a can. Do you think this is a reasonable approach? This is commonly called an annual percentage rate (APR), which gives the true cost of borrowing (including any fees etc). One measure that overcomes this problem is the coefficient of variation, which is defined as the ratio of standard deviation over the mean: coefficient of variation = standard deviation / mean. The coefficient of variation relates the spread of data to its absolute value, with higher values suggesting more dispersed data. In 1995 there was concern that, despite rising public expenditure of education, SAT scores were falling. As you can see, there are 53 values with a mean of 41.2. The deviation of each class is the distance its midpoint is away from the mean. Expected values The usual way of solving problems involving risk is to calculate the expected value of each alternative, which is defined as the sum of the probabilities multiplied by the value of the outcomes. Then, if the organisers choose plan 1, the expected value is  $0.84 \times 20 + 0.16 \times 18 = 19.68$ ; if the organisers choose plan 2, the expected value is  $0.84 \times 28 + 0.16 \times 10 = 25.12$ . But it is more worrying when people deliberately present information in a confusing way, perhaps to support their own opinions or to give a false view of a product. The population for a survey of student opinion is clearly the students - but does this mean only full-time students, or does it include part-time, day-release, short-course and distance-learning students? On the other hand its weaknesses include: n n n there can be several modes, or none it ignores all data that is not at the mode it cannot be used in further analyses. Table 5.1 Weekly sales of a product Week 1 2 3 4 5 6 7 8 9 10 11 12 13 Totals Quarter 1 Quarter 2 Quarter 3 Quarter 4 Total 51 60 58 56 62 69 58 76 80 82 68 90 72 84 91 82 78 76 75 66 57 78 65 50 61 54 49 44 41 45 38 28 37 40 42 22 25 26 21 30 32 30 32 31 29 30 41 45 44 47 53 54 214 227 211 211 207 201 191 214 245 213 190 230 201 882 917 458 498 2,755 This is clearer than the original list, and you can now see that sales are higher in the first two quarters and lower in the second two. Sources: O'Neil J., An automated valuation model for hotels, Cornell Hotel & Restaurant Administration Quarterly, August, 2004; www.entrepreneur.com. Phelps B., Smart Business Metrics, FT-Prentice Hall, Harlow, 2003. The rest of this figure shows some results when the 'Regression' function in Excel's Data Analysis ToolPak automatically does multiple regression. For example, in a new restaurant, a value-based sales forecast would look at the profit margins needed to cover all costs, and see if this is in line with the current performance of local businesses. (Actually, computers generate 'pseudo-random' numbers but they are good enough for most purposes.) Suppose that you want to collect data from a random sample of people visiting an office. For obvious reasons, this is called the '5 whys' method. When the noise is overwhelming, it hides any underlying relationship and data appears to be random. (a) We can find the probability that the project is not finished before day 26 from the Normal distribution shown in Figure 19.15. To get a stratified sample of views, you divide the population of employees into two strata - women and men - and randomly select 60% of your sample from women and 40% from men. Suppose you want to fit a quadratic equation through a set of points and are looking for a relationship of the form  $y = a + b_1x + b_2x^2$ . In practice, it is debatable whether this adds much to our understanding of the data, so it is rarely used. He repays this by regular instalments at the end of every year. However, not all queues involve people - for example, there are queues of programs waiting to be processed on a computer, telephone calls waiting to use a satellite, items moving along an assembly line, faulty equipment waiting to be repaired, ships queuing to land and so on. Eventually, all forecasts would home in on the new level of demand. But they do not happen by chance - they have to be carefully designed. Periodic review Earlier we said that there are two different ordering policies: n n fixed order quantity - which we have been discussing, where an order of fixed size is placed whenever stock falls to a certain level periodic review - where orders of varying size are placed at regular intervals. 5.6 What is a frequency distribution? 6.12 Because it gives standard results that we can interpret and use in other analyses. To overcome any bias, the spreadsheet calculates an adjusted figure of  $n = n_1 n_2 n_3 n_4 n_5 n_6 = 0.607$ . We are usually more interested in the underlying patterns than the random variations, and can emphasise this by drawing a smooth trend line through the individual points, as shown in Figure 5.4(c). To help with this, she has kept records of the number of clients she dealt with during her first eight weeks at work, and during the same eight weeks this year. Many other packages also have graphics functions, such as presentation packages, desktop publishing packages, design packages and picture editors. The hotel's total cost is P for power plus 2P + 300 for heat, and we know that this came to £1,800, so:  $3P = 1,500$  P = £500 Power cost £500 and heat cost  $2P + 300 = 2 \times 500 + 300 = £1,300$ . 3.16 What does it mean when two graphs cross each other? It is easy to spot ridiculous examples of assumed cause and effect - the number of lamp posts is related to prosecutions for drunken driving, the number of storks nesting in Sweden is related to the birth rate in Northern Europe, the number of people in higher education is related to life expectancy and in the nineteenth century the number of asses in America was related to the number of PhD graduates! Unfortunately, not all mistakes of this kind are as easy to spot. How can the manpower be smoothed? When the electric wiring is fitted, faults are introduced to 4% of units. Putting these abbreviations into the general equation gives: C = T = T/K K Now you have an equation relating the variables in a general, concise and accurate form. Even simple changes to phrasing can give very different results. Now we have to return these deseasonalised values that occur halfway through periods to values for whole periods. What this really means is that most - or at least enough - customers are satisfied with the product because it meets their specific requirements. Now Tina wants to make some improvements to the dining room and hopes that the bank will lend her the money. A decision-maker in this region already has a lot of money and would not put a high value on even more. She will outline her approach to these problems and the benefits the company could expect. So we can calculate the overall expected value of following the recommended decisions as:  $0.5 \times 25.12 + 0.26 \times 22.42 + 0.24 \times 18.00 = 22.71$  So the expected profit of using the advance sales information is £22,710. Linear relationships 9.5 221 Two people suggest different equations for describing the relationship between two variables. Here the Lorenz curve for after-tax wealth is considerably closer to the diagonal, and this shows that taxes have had an effect in redistributing wealth. It would be useful to have a way of monitoring these changes and accurately describing the effects over time. How much would costs rise with a 97% service level? In the following period, the new price index is 132. Sampling is inherently less accurate - but it is also easier, cheaper and faster. To put it another way, distilling has a marginal value of a100. A machine costing £20,000 with an estimated resale value of £5,000 after a useful life of 5 years has an annual depreciation of:  $20,000 - 5,000 / 5 = £3,000$  annual depreciation = Straight-line depreciation is easy to calculate, but it does not reflect actual values. On the other hand, some activities have no flexibility at all - activities A, D, F and I have no flexibility because their latest start time is the same as their earliest start time. Project evaluation and review technique (PERT) is a useful extension to CPM that allows for uncertainty in duration. (c) Identify and agree the best overall solution. Then: n n n 00 to 49 (that is 50% of pairs) represent acceptance 50 to 64 (that is 15% of pairs) represent reworking 65 to 84 (that is 20% of pairs) represent reinspection, and 85 to 99 (that is 15% of pairs) represent rejection. So a census is difficult, time-consuming, expensive - and still not entirely reliable. You find b, the power of 10, by counting the number of places to the left that the decimal point has to move. This is called solving an equation. What should Lars do to maximise the expected profit? Diagrams of data 123 Ideas in practice continued Figure 5.14(a) Published graph of public education expenditure against SAT combined scores Figure 5.14(b) More accurate view of expenditure per pupil against SAT combined score And as the number of pupils has risen, a fairer view would show the expenditure per pupil, shown in Figure 5.14(b). Another consideration is that the revenues from A are declining, suggesting that the project has a limited life span of around 5 years; revenues from project B are rising, implying a longer potential life. Then the data has two modes - it is bimodal - at 3 and 7, as shown in Figure 6.5(b). An item of stock has a unit cost of £40, a reorder cost of £50 and a holding cost of £1 a unit a week. The result is a completely random sample, which should give a fair representation of the population. We used this method to draw graphs of quadratic equations, which have the general form  $y = ax^2 + bx + c$ . 7 Main study with the questionnaire sent to 1,215 companies, with follow-up of those that did not initially reply, giving a response rate of 17%. n The noise means that there is a difference between expected values and observed values. Current-weighted index Suppose that in a period, n, a family's shopping basket contains quantities, Qn, of different items at prices Pn and the total cost is £QnPn. We can compare this with the cost of the same products in the base period, which would have been £QnP0. PROBLEMS 6.1 When Winnie Mbembe was in hospital for two weeks, the numbers of visitors she received on consecutive days were 4, 2, 1, 5, 1, 3, 3, 5, 2, 1, 6, 4, 1 and 4. Granada TV has been monitoring the progress of a group of 14 children - then adults - since 1964. n Design a plan for NWB's data collection including timing, costs and assumptions. Panel surveys are expensive and difficult to administer, so they use very small samples. For example, the point G = 20, T = 10 is on the line and substitution gives:  $1 \times 20 + 2 \times 10 = 40$  This is true and shows the extreme values allowed by the constraint. You might be tempted to ignore non-responses. 4.3 No - there is an almost limitless amount of data that can be collected, but only some of it is useful and cost effective. Some are distinct pieces of work that are largely self-contained and make a unique product. For instance, it is easy to describe the population of houses with broadband connections, but it is much more difficult to identify them all. 8 Add provincial surtax - when the provincial tax is above a certain limit, a percentage of the amount over this limit is added as a provincial surtax. When an engine is replaced any time during the year, it is assumed to be one year old at the end of the year. Figure 8.9 shows two ways of doing the calculations. The company cannot make a negative number of batches, so both G and T are positive. Elsom can use this model to forecast future production. Year 1 2 3 4 5 6 7 8 Index 1 Index 2 100 138 162 196 220 100 125 140 165 (a) What are the base years for the indices? This formulation makes a number of assumptions that are implicit in all LPs. Most importantly, the objective function and constraints are all linear functions of the decision variables. The Giving structure to decisions 425 Figure 16.1 Start of a problem map for increasing profit decision-maker is the person who owns the house and they have the alternatives of: 1 insure the house 2 do not insure the house. The survey might also rank the prices charged for these services. Their clients have a range of problems of different severity and symptoms, but in practice their main concern is people who suffer from long-term back problems. But the view that high quality reduces costs seems to go against the commonsense view that you can only buy higher-quality products at a higher price. Periodic review 495 Figure 18.10 Two ways of dealing with varying demand: (a) fixed order quantity; (b) periodic review When demand is constant these two systems are identical, so differences appear only when the demand varies (shown in Figure 18.10). The alternative dependent demand approach looks at the meals the chef plans to cook each day, analyses these to see what ingredients are needed and then orders the specific ingredients to arrive when they are needed. Figure 17.15 shows a printout from a simple package that takes data, suggests a sampling plan and shows the operating curve for this plan and the average outgoing quality. But specialised software can be more complicated and more expensive, so you have to balance the benefits with the extra effort and cost. Activity Depends on Activity Depends on A B C D E F - - A A C B, D G H I J K L B G E, F H, I E, F K 19.2 (a) BiilsMoore Amateur Dramatic Society is planning its annual production and wants to use a network to coordinate the various activities. This move has brought changes to the timing and role of inspections. This suggests a way of finding the optimal solution. The two main rules are: n n Before an activity can begin, all preceding activities must be finished. Power stations need 'warming-up' before they start supplying electricity, so a stable demand would make operations much easier. Wild T., Best Practices in Inventory Management (2nd edition), Butterworth-Heinemann, Oxford, 2002. Solution x = -6 y = 51 We have to take a convenient series of values for x between -6 and +5 and substitute them into the equation to find corresponding values for y, so we might start with: x = -6, and substitution gives  $y = 2x^2 + 3x - 3 = 2 \times (-6)^2 + 3 \times (-6) - 3 = 51$  n x = -5, and substitution gives  $y = 2x^2 + 3x - 3 = 2 \times (-5)^2 + 3 \times (-5) - 3 = 32$  n = -5 - 4 32 17 - 3 - 2 - 1 0 1 2 6 - 1 - 4 - 3 2 11 3 4 24 41 5 62 Plotting these points on Cartesian axes and drawing a curved line through them gives the graph in Figure 3.10. 4 Murray-West R., Home-owners are £550 a year poorer under Labour, The Daily Telegraph, 25th January 2006. There is always pressure on managers' time, so they prefer fast methods - arguing that when data collection takes too long, the results become obsolete and irrelevant before they prepared. WORKED EXAMPLE 2.26 Use scientific notation for (a) 123,000, (b) two million, (c) 0.05, (d) 0.000123. This distribution market is dominated by two major companies, and it might be a useful area for expansion. The doctors made no comment on the figures. There are many different criteria and we can

illustrate with three common ones. 'Uncertainty' means that we can list the events that might occur, but do not know in advance which one actually will happen. A special economy rate has a standing charge of £22.70 a quarter, with each unit of electricity used during the day costing £0.162, but each unit used during the night costing only £0.082. n Graphs are one of the most useful types of diagram, and usually use Cartesian coordinates to show a relationship between two variables. The reliability of their report (phrased in terms of the probability of a favourable report, given the likely advertising profit etc.) is given in the following table. IDEAS IN PRACTICE Stroh Brewery Company Until 1999, when they sold their brands, the Stroh Brewery Company was the third-largest producer of beer in the USA. The second step is to decide which data is needed to achieve this purpose. You might think it is difficult to organise this weighting, but in practice we can do it by using the latest observation to update a previous forecast. The first is an average rate of return, which is the average annual revenue as a percentage of the initial investment. When there are more than, say, six or seven slices they become too complicated and confusing. n Chapter 5 described some diagrams for summarising data, and this chapter showed how numerical measures give more objective and accurate descriptions. PROBLEMS 5.1 5.2 5.3 summarise this data. You meet decimals more often, as they are the standard format for calculators and computers. In its broadest sense, quality is the ability of a product to meet – and preferably exceed – customer expectations. At first, it seems easy to collect data. How reliable are the results? An emergency breakdown service suggests that 50% of all drivers are registered with their service. How can they summarise this data? Solution One approach is to randomly select two regions, then randomly select three parliamentary constituencies in each of these, then randomly select three wards in each of these and so on. Solution Using the standard rules: (a)  $1/b_4 = b - 4$  (b)  $b_5 \times b_{1/2} = b_5 + 1/2 = b_{11/2} = (b_{1/2})_{11} = (b_{1/2})_{25} = 5$  (d)  $91.5 = 93/2 = (91/2)3 = (9)_3 = 27$  (e)  $80.67 = 82/3 = (81/3)2 = 22 = 4$  Calculations and equations WORKED EXAMPLE 2.25 If you leave £100 in the bank earning 6% interest, at the end of  $n$  years you will have  $\£100 \times 1.06^n$  (we discuss this in Chapter 8). It is impossible to have a negative number of mistakes, so they should simply forecast zero. Then there are two alternatives: n n a census collecting data from every entry in the sampling frame – which is the whole population a sample collecting data from only a representative sample of entries in the sampling frame. and Romano J.P., Testing Statistical Hypotheses (3rd edition), Springer, New York, 2010. IDEAS IN PRACTICE SenGen Instrumental SenGen Instrumental has a warehouse outside Geneva, from which it supplies materials to Central and Southern Europe. And when someone is negotiating to buy a house they may increase their offer by £5,000 and consider it a relatively small amount. These safety stocks are available if the normal working stock runs out (as shown in Figure 18.7). Historically, they saw it as a benefit, with high stocks allowing operations to continue normally when there were problems with deliveries from suppliers. Pictograms are very eye-catching and are good at conveying general impressions, but they are not always accurate. We can describe fractions as either: n n common fractions (invariably just described as 'fractions') – such as  $-1/2$  or  $-1/4$  decimal fractions (usually described as 'decimals') – such as 0.5 or 0.25. These play an essential role in the decision-making of every organisation, and they form a set of tools that every manager should understand and use effectively. To change fractions into decimals, you divide the numerator by the denominator, so that  $-1/4$  is 1 divided by 4, which is 0.25. Burr J.T. (ed.), Elementary Statistical Quality Control (2nd edition), Marcel Dekker, New York, 2005. For a cost of £30,000 they will give either a favourable or an unfavourable report on the chances of the series being a success. Substituting the optimal values into the constraints gives: (1)  $X + Y \leq 10$  (2)  $X - Y \leq 2$  (3)  $X \geq 4$  (4)  $Y \leq 5$   $X + Y = 4 + 2 = 6$ , giving spare capacity of  $10 - 6 = 4$   $X - Y = 4 - 2 = 2$ , giving no spare capacity and an active constraint  $Y = 2$ , giving spare capacity of  $5 - 2 = 3$  You can see from these examples that the feasible region is always a polygon without any indentations, and the optimal solution is always at a corner or extreme point. n People can invest (or borrow) money to earn (or pay) interest. The Observer, 31 July 1994. It follows that shadow prices of non-limiting resources are zero. But you already get the idea that interactions in business are complex and it is easy to get bogged down in the detail and lose track of the broader arguments. But when one or more samples are some distance away from the expected value, it is a sign that something is wrong. Rockwall has to compare amounts of money generated at different times, and can do this by comparing the present value of each. Network analysis is the most widely used tool for planning projects. The intercept = 15.376. 18.3 Demand for an item is steady at 20 units a week and the economic order quantity has been calculated at 50 units. n Linear regression finds the line of best fit through a set of data. If Hamil discounts future amounts by 10% a year, what are the current values of all these amounts? Historical analogy When a company introduces a new product, it may have a similar product that it launched recently and can assume that demand will follow a similar 254 Forecasting pattern. Alan Stevens of the Institute for Mathematics and its Applications says, 'I hear the general public saying it, and particularly journalists on television – newsreaders say they've always been rubbish at it – as if they're proud of it'. 10.11 By using a lower value of  $n$ . n For demand, using a two-digit random number: n Demand 10 20 40 50 Probability 0.1 0.15 0.25 0.25 0.15 0.05 0.05 Random number 00- 09 10- 24 50- 74 75- 89 95- 99 25- 49 60 90- 94 70 These schemes need two streams of random digits, which Conal can generate using a spreadsheet's RANDBETWEEN function. In particular, it uses the observation that activity durations often follow a beta distribution. Most linear graphs are not parallel to the x-axis, but they either slope upwards or downwards. The second quartile, or median, is value number  $(11 + 1)/2 = 6$ , which is 30. (b) To finish in 11 weeks needs a further reduction of two weeks in the critical path. A queue is formed whenever a customer arrives at a service, finds the server is already busy, and waits to be served. 11.7 To give the measure by which solutions are judged, and hence allow an optimal solution to be identified. The normal rate has a standing charge of £18.20 a quarter, and each unit of electricity used costs £0.142. Zelazny G., Say it with Charts (4th edition), McGraw-Hill, New York, 2006. Question n Mary needs a way of presenting these figures to her employers in a form that they will understand. The second supplier offers a Superstamp machine, which makes higher quality parts. 17.15 Why does an ideal operating characteristic curve have a vertical central section? What other analyses can you do? A resource-based forecast would look at the capacity limitations on the service and ensure that these are high enough to cover costs. When you build a regression model you estimate values,  $E_i$ , which show what the observations would be if there were no noise. It is a bit more difficult to find the mode of data that is grouped in a frequency distribution. For example, if the old base value was 200 and the new base value is 500, you always find the new index for any period by multiplying the old index by 200 / 500. Even these were not as safe as they had been in the past. No shortages are allowed so they incur no costs, so we can ignore these. This gave an optimal batch size of 245 units, which was rounded to 300 units. Quota sampling often uses interviewers who are given a number of people with different characteristics to interview. The fourth part of the book introduces uncertainty through probability and statistical analyses. This is the basis of algebra – which uses symbols to represent variables and to describe the relationships between them. Similarly, it would be difficult to identify populations of people who bought an imported television set within the last five years, or people who use a particular supermarket or people who caught a cold last winter. The expected duration of the project is 24. Rounding to two decimal places gives 1.33. A cause-and-effect diagram draws these relationships as coming from spines, like a fish bone, as shown in Figure 17.7. 464 Quality management Figure 17.7 Cause-and-effect (or fishbone) diagram for complaints in a restaurant Figure 17.8 Aspects of statistical quality control Probably the best known tool for quality control is routine sampling. 540 Queues and simulation Simulation models Simulation gives a way of tackling big queuing problems – or any other complex problem. But sometimes it is better to use other kinds of weighting. This is scientific notation which is used in many calculators, and describes numbers in the format:  $a \times 10^b$  where  $n$   $n$   $a$  is a number between 1 and 10 (or  $-1$  and  $-10$  for negative numbers)  $b$  is a power of 10. 3 Use the calculated trend and seasonal indices to forecast future values, using  $F = T \times S$ . You can see how to interpret this from the work that we have already done. WORKED EXAMPLE 1.3 In Worked example 1.1 we described an automatic ticket machine that accepts only pound coins and gives out: 1 ticket for £1, 3 tickets for £2, 5 tickets for £3, 7 tickets for £4, and 9 tickets for £5. Ross S.M., Simulation (4th edition), Elsevier, Amsterdam, 2006. Cleland D.I. and Ireland L.R., Project Management (5th edition), McGraw-Hill, New York, 2006. This course might come in various guises, such as quantitative analysis, decision-making, business modelling, numerical analysis, business statistics and so on. 1.3 Managers must be good mathematicians. January February March April May June July August September October November December Year 1 Year 2 Year 3 Year 4 Year 5 136 109 92 107 128 145 138 127 135 141 147 135 135 112 100 116 127 132 146 130 127 156 136 141 141 121 135 138 159 131 129 137 149 144 138 117 105 121 133 154 136 134 148 140 143 118 121 135 136 147 140 142 147 147 Solution There are many different ways of summarising these, with some options shown in the spreadsheet in Figure 5.1. Figure 5.1 Table of results for Carlson Industries Frequency distributions The results shown in a frequency table form a frequency distribution. 468 Quality management Figure 17.10 Operating characteristic curve for sampling plan n consumer's risk (b) – the highest acceptable probability of accepting a bad batch, with more defects than LTPD. This seems an attractive move, but the customers have to be convinced that it is worth paying Fred more to get the better service. This raises two questions: n n How can you identify the underlying pattern, finding the equation that best describes a relationship? If there is r12,000 available to reduce the duration, what is the shortest time the project can be completed within? You can confirm this using the LOG function in Excel; this has the format LOG(number,base), so LOG(32,2) returns the value 5. There is a clear relationship between the price of overcoats and the sales of ice cream, but one does not cause the other – and both are really a result of the prevailing Figure 3.1 Cartesian axes 52 Drawing graphs Figure 3.2 Locating points with Cartesian coordinates weather. On the other hand, if one of the critical activities is made shorter then the overall project duration may be reduced. The network shows that the project starts with activities A and B, but this does not mean that these must start at the same time – only that they can both start as soon as convenient and must be finished before any following activity can start. Each observation has an error, so in principle we can find the mean of these from:  $\sum E_i / n$   $n$   $\sum (y_i - E_i)^2 / n$  mean error = But the mean error has the major drawback (which we met with variance in Chapter 6) of allowing positive and negative errors to cancel. When Heather started her pension scheme, the insurance company quoted illustrations of what returns she might expect when she retired – but these were not guarantees. WORKED EXAMPLE 7.2 Amil Gupta's car showroom is giving a special offer on one model. This is the purpose of quality control. This put more emphasis on prevention and appraisal, where costs have risen. and Piff S., Quantitative Methods for Business, Management and Finance (3rd edition), Palgrave, Basingstoke, 2010. Work-in-progress – materials that have started but not yet finished their journey through operations. The most common is based on the assumption that shortage costs are much higher than holding costs, so organisations are willing to hold additional stocks – above their perceived needs – to add a margin of safety and avoid the risk of shortages. Figure 18.6 shows the resulting stock level. Do some searches on the Web to find sites that are useful for this book. and Patton P., Essential Mathematics for Economics and Business, John Wiley, Chichester, 2002. 3.14 Where does the line  $y = 20x + 15$  cross the line  $y = 2x^2 - 4x + 1$ ? It may be fairly easy to find this by looking at quotations or recent invoices from suppliers. In particular: n n long-term forecasts look ahead several years – the time typically needed to build a new factory medium-term forecasts look ahead between three months and two years – the time typically needed to replace an old product with a new one short-term forecasts cover the next few weeks – describing the continuing demand for a product. % 66 Drawing graphs Ideas in practice continued Konrad Schimmer is a financial analyst of the Frankfurt Stock Exchange, and he plots graphs for every aspect of companies' performances. Find some figures for transport over the past 20 years and present these in useful formats. In both of these examples the quoted average is accurate, but it does not represent a typical value or give any real feeling for the data. Figure 8.7 shows this cumulative effect on the value of  $a_1$  invested over time with interest rates between 3% and 25%. For instance, a Rolls-Royce car has the highest possible quality of engineering, but most people include price in their judgement and buy a cheaper make; champagne may be the highest quality wine, but most of us normally buy other types. n There is a huge number of measures for different aspects of performance. This shows a reasonably strong linear relationship. Sometimes histograms help with further statistical analyses. An optimistic decision-maker chooses a value of 2 close to one – a pessimistic decision-maker chooses a value close to zero. CHAPTER 2 Calculations and equations Contents Chapter outline Working with numbers Changing numbers to letters Solving equations Simultaneous equations Powers and roots Chapter review Case study – The Crown and Anchor Problems Research projects Sources of information 19 20 27 29 32 36 45 46 46 47 49 Chapter outline The following chapters describe quantitative methods that are widely used by managers. Often she can deal with a client's problem quite quickly – when she thinks the trader has done nothing wrong, or when she advises customers to go back to the place they bought a product and complain to the manager. Solutions Manual comes in a PDF or Word format and available for download only. The first part gave the background and context for the rest of the book. CASE STUDY Workload planning Maria Castiglioni is head of the purchasing department of Ambrosiana Merceti, a medium-sized construction company. Usually a few expensive items account for a lot of use, while many cheap ones account for little use. Using similar reasoning you can depreciate the

value of assets to give a reducing value over time. Formulation 289 WORKED EXAMPLE 11.3 StatFunt Oil makes two blends of fuel by mixing three oils. So you would expect the number visiting on the fifth day to be around 20, but would not be surprised by a small difference between the actual number and the expected one. However, despite many campaigns and noticeably higher earnings for people with mathematical qualifications, people still go around saying, 'I am no good at maths.' There are several reasons for holding stock, but the main one is to give a buffer between supply and demand. The graphs in Figures 10.9 Forecasts with seasonality and trend 275 Worked example 10.10 continued and 10.10 clearly show that there are four periods in a season - so you need to calculate four seasonal indices. What do the results show? 14.3 When a series of samples are taken from a population and a mean value of some variable is found for each sample, these means form the sampling distribution of the mean. Figure 6.14 Data description with Excel 162 Using numbers to describe data Sources of information References 1 HM Revenue and Customs, Income Tax Statistics and Distributions, HMSO, London, 2006. You can never add standard deviations in this way. This is a payoff matrix or payoff table and it shows the cost to the house owner of every combination of alternative and event. 15.5 5% significance. Mattel's problems started when it outsourced manufacturing to low-cost areas. This means that with a weekly production of  $x$  units, the unit cost is  $200 - 5x$ . Most people in the world are proud of their education and attainments, and British people would not be happy to admit failings in other areas, such as reading. The number of companies operating in each region in each category is shown in the following table. In this sense 'independent' means that the two equations are not simply different ways of saying the same thing. Figure 18.14 shows the printout from a computer program that has done some basic calculations. Graphs show relationships between two variables and highlight the underlying patterns. 15.11 There are many circumstances - but generally whenever you want to check a hypothesis about a population. 3.3 With Cartesian coordinates, what are the coordinates of the origin? A 250 g bar of chocolate might weigh between 249.9 g and 250.1 g and still be considered the right weight. The interest is the lender's reward for lending money - and is usually quoted as a percentage of the principal, so you might pay interest of 7% a year. Chapter review 45 CHAPTER REVIEW This chapter reviewed some of the basic tools that are needed to understand later chapters. Essentially they identify the feasible region and then search the extreme points around the edge until they find an optimum. Barlow J., Excel Models for Business and Operations Management (2nd edition), John Wiley, Chichester, 2005. Map 3 Map of chapters - Part Three CHAPTER 8 Finance and performance Contents Chapter outline Measures of performance Break-even point Value of money over time Discounting to present value Mortgages, annuities and sinking funds Chapter review Case study - OnlineInkCartridges.com Problems Research projects Sources of information 185 185 190 197 201 208 211 212 213 214 215 Chapter outline Managers use a range of different measures to monitor the performance of their organisations. Mareco's main problem comes from the quality of interviewers, who are often students who want short-term employment. This was a significant part of her take-home pay, but she felt that it would allow her to retire on her sixtieth birthday in 2010. This is not a coincidence but is a fundamental property of all linear programmes. 17.7 Gunta Hans took 30 samples of 15 units from a process. Can you find any obvious trends? 5.2 To simplify raw data, remove the detail and show underlying patterns. Draw Lorenz curves and other diagrams to represent this data. There are several other rules to make sure the completed network is sensible: n n n To make things clear, you add one 'start' and one 'finish' activity to a network to define the whole project. We develop this theme in Chapter 5, but here we introduce the idea of a graph - sometimes called a line graph - to show the relationship between two variables. What is the price index in each month using January as the base month? 5.17 Why would you draw histograms when bar charts are easier and can have more impact? Stock control for production 489 Stock control for production The economic order quantity makes a series of assumptions, but we can remove these to give models that are more realistic and useful in many different circumstances. Alternatively, we can square the deviations and calculate the mean squared deviation - or the variance. Many books describe how to use spreadsheets at different levels: Further reading Albright S., Management Science Modelling, South Western College Publishing, Cincinnati, OH, 2008. In practice, activity-on-node networks have probably become more common, so we will stick to this format. Then you simply take random points either side of the line and see which ones break the constraint. 1000 ||| Working with numbers 23 WORKED EXAMPLE 2.2 Describe as decimal fractions: (a) 5/4, (b) 38/8, (c) -12/16. so  $0 = 7x - 28$   $x=4$  You can always solve sets of proper simultaneous equations, but there are two things that you have to be careful with. IDEAS IN PRACTICE The Channel Tunnel In December 1990 Transmanche Link, a consortium of 10 British and French companies, finished the first continuous tunnel under the English Channel. Other extensions consider sinking funds, annuities and mortgages. 8.6 The number of units that must be sold before covering all costs and making a profit. How reliable are these figures? They had a long-term supplier based in Hong Kong, but this company then subcontracted work to another company that did not use Mattel-approved paint. If it is near to 1 then most of the variation is explained by the regression, there is little unexplained variation and the line is a good fit for the data. CASE STUDY Hamerson and Partners Albert Hamerson is Managing Director of his family firm of builders' merchants. In particular, they looked for ways of balancing the costs of holding stocks against the costs of shortages to find optimal policies that minimised the overall costs. Time series Projective forecasts often work with time series, which are series of observations taken at regular intervals - such as monthly unemployment figures, daily rainfall, weekly sales, quarterly profit and annual fuel consumption. Arithmetic mean If you ask a group of people to find the average of 2, 4 and 6, they will usually say 4. These are examples of causal relationships where changes in the first (dependent) variable are actually caused by changes in the second (independent) variable. CHAPTER REVIEW This chapter showed how managers can approach decisions, describing the foundations of decision analysis. Do the main data collection. Then we reject the first unit (based on 5), accept the second (based on 2), accept the third (based on 8) and so on. With monthly payments the interest rate,  $i$ , is 0.01 and after 36 months you have With weekly payments the interest rate,  $i$ , is  $0.12 / 52 = 0.0023$  and after 156 weeks you have  $2,000 \times (1 + 0.0023)^{156} = r2,862.04$ . The easiest way of doing this is to divide the underlying pattern into separate components, and forecast each component separately. This chapter describes a number of calculations for measuring performance - particularly financial returns and the flows of money. WORKED EXAMPLE 19.6 The project network in Figure 19.10 has a duration of 14 with A, B and C as the critical path. 8.15 Straight-line depreciation reduces the value by a fixed amount each year; the reducing-balance method reduces the value by a fixed percentage each year. These problems limit its use, and a more widely used alternative is the variance. ?') general feelings for an issue ('Do you think this development is beneficial?'. We also know that period 13 is the first period in a season, and the seasonal index is 1.240. Review questions Solution Total expenditure is  $C + R + O$  and this must be less than or equal to the budget, so:  $C + R + O \leq 200,000$  2.5 Why do managers use algebra? 13.16 Binomial and Poisson distributions describe discrete data; the Normal distribution describes continuous data. The top of the hill, or bottom of the valley, is called a turning point where the graph changes direction and the gradient changes sign. 2.19  $1.23 \times 10^9$  and  $2.53 \times 10^{-7}$ . Solving equations An equation shows the relationship between a set of constants and variables - saying that the value of one expression equals the value of a second expression. These tutorials are produced by universities, institutions, publishers, training companies, software providers, tutoring services, consultants and so on. He paid with a r20 note and noticed that his change contained at least one euro coin. WORKED EXAMPLE 5.5 South Middleton Health District has five hospitals, with the following numbers of beds in each. In particular, he noted that SAT scores ranged from 400 to 1,600, and the full scale should be used. Another approach uses market comparisons to see how much similar hotels have sold for and then to make subjective adjustments. The supplier uses an acceptance quality level of 2% defective, while Juliet accepts batches with a maximum of 6% defective. For activity A: Activity Depends on Duration Optimistic Most likely Pessimistic A B C D E F G H I - - A, G B B C, F D, E 2 4 8 4 3 2 6 5 6 3 5 10 4 6 5 6 7 8 10 12 12 4 15 8 6 15 10 expected duration =  $(O + 4M + P) / 6 = (2 + 4 \times 3 + 10) / 6 = 4$  variance =  $(P - O)^2 / 36 = (10 - 2)^2 / 36 = 1.78$  Repeating these calculations for other activities gives the results shown in Figure 19.13. WORKED EXAMPLE 8.7 Rockwall Trust is thinking of investing in a new technology company. This is NOT the TEXT BOOK. 18.4 How would the results for Problem 18.1 change if the part could be supplied only at a fixed rate of 10 units a week? 446 Making decisions IDEAS IN PRACTICE Yield management in airlines Yield management includes different types of analysis for allocating scarce resources to different types of customers. The aim of forecasting is to make the best possible predictions for future events, minimise errors and provide the most reliable information possible. I assumed that most managers would be familiar with a range of quantitative methods. Oakland J.S., Statistical Process Control (6th edition), Butterworth-Heinemann, Oxford, 2007. The procedure for this is: 1 For each alternative, find the mean value of the outcomes - that is, the average of each row in the payoff matrix. So there are realistically two options: n n use a computer package that automatically finds more complicated lines of best fit transform the data into a linear form. 6.2 Find the mean, median and mode of the following numbers. Golub A.L., Decision Analysis, John Wiley, New York, 1997. Year 1 Year 2 Wage Number Wage 1 2 3 4 125 205 245 408 55 125 66 9 133 211 268 473 60 132 71 13 143 224 293 521 Use different indices to describe the changes in wages paid and the numbers employed. How can you check their claims? 3 Collection of secondary data to find comparisons for the research. However, the full study included a hypothesis test, using the standard deviations of weight loss (4.0 kg for diets and 3.9 kg for exercise). 3 Ackoff R.L., Scientific Method, John Wiley, New York, 1962. You really have two jobs - data reduction (processing to reduce the amount of detail), and data presentation to show the results in a useful format. We divided our initial task of building a greenhouse (Worked example 19.1) into four activities. Draw a pie chart to represent these. Historically, these included construction of the Hoover Dam, with a selection of other signature projects including: 1985 - James Bay Hydro Complex harnessing the power of three rivers in Quebec to generate 10,300 megawatts of electricity at a cost of \$13.8 billion 1994 - the 32-mile undersea leg of the Channel Tunnel between England and France 1998 - one of the world's largest aluminium smelters in Alma, Quebec for Alcan with a capacity of more than 400,000 tons a year 2004 - Athens metro for the summer Olympic games 2004 - 600-kilometre Salah natural gas pipelines in the desert of Algeria 2005 - Jubail Industrial City, Saudi Arabia, recognised as the largest single industrial development project in history with a cost of \$20 billion 2005 - CSPC Petrochemicals project in Nanhai, China covering 1,055 acres and costing \$4.3 billion 2006 - Boston Central Artery, the most complex urban transport project ever undertaken in the USA, taking 30 years of planning and 12 years in construction. Linear regression (with results in rows 24 to 26) shows that the deseasonalised trend line is:  $Y = 1,156.75 - 64.92T$  Forecasts with seasonality and trend 277 Worked example 10.12 continued This equation gives the deseasonalised values in column C. of flow time Maximum flow time standard deviation = 1.0 standard deviation =  $2.0 \ 128 \ 0 \ 1.97 \ 5 \ 3 \ 125 \ 13.74 \ 2.10 \ 1.69 \ 2.85 \ 0 \ 0.15 \ 61 \ 4.06 \ 31.13$  Date Collection: 0 to 1000 minutes CPU Seconds = 0.1420 Figure 20.11 Sample printout for simulating queues in the office 548 Queues and simulation Review questions 20.10 Why are random numbers used in simulation? 2 This rule is actually quite conservative, and empirical evidence suggests that for a frequency distribution with a single mode, 68% of values usually fall within one standard deviation of the mean, 95% of values within two standard deviations and almost all values within three standard deviations. The result is more efficient operations, easier planning, regular schedules, routine workflow, fewer changes and so on. The easiest way of doing this is to put one equation in the form 'x = something', and then substitute this value for x into the second equation. There are useful guidelines for designing questionnaires. Personal insight This has a single expert who is familiar with the situation producing a forecast based on their own judgement. When:  $n = bp$  then:  $p = \log_b n$  In practice, only two types of logarithm are used much: n Common logarithms use the base 10, so that:  $y = \log x$  n means that  $x = 10^y$  If you do not explicitly put in the base of the logarithm, it is assumed to be 10. For convenience, we round such numbers to one of the following: n n A certain number of decimal places, showing only a reasonable number of digits after the decimal point. WORKED EXAMPLE 9.1 Sonja Prznišcz collects eight pairs of observations that she thinks are related by the equation  $y = 3x + 3$ . n n Calculations are always done in the same order, with multiplication and division done before addition and subtraction. Age Female Male How could you organise a quota sample of 1,200 people? The results for this are shown in the spreadsheet in Figure 17.3. The quality management

programme was introduced in year zero. They look at the characteristics of the population, and then specify the characteristics needed in the sample to match this exactly. Logarithms and the exponential function One other format for numbers uses logarithms. If you buy a pair of shoes that get a hole the first time you wear them, you will not buy another pair from that source, no matter how cheap they are. There are six weeks in this range. After answering some standard questions, which takes an average of two minutes, customers are passed on to one of two offices. If the proportion of defects moves outside this range, the process is out of control. There are two formats for this: n n Activity on arrow – each arrow represents an activity, and nodes represent the points when activities start and finish. 3.9 What are the roots of a quadratic equation? This effect is summarised in Figure 18.8. To give a cycle service level above 50% we have to add a safety stock that is used when demand is greater than the mean – and then the reorder level







depreciation: annual depreciation cost of equipment – scrap value life of equipment 10,000 – 1000 , = 5 = r1,800 = Discounting to present value 20' Worked example 8.11 continued (b) For reducing-balance depreciation: An = A0 × (1 – i) n With reducing-balance we want A3 to be r2,000, so: A3 = A0 × (1 – i) 3 Then after 5 years: A5 = 10,000 × (1 – 0.3) 5 = r1,681 (c) With straight-line depreciation and a final value of r2,000 after 3 years, the annual depreciation is: annual depreciation = 10,000 – 2,000 = 3 = r2,667 or 2,000 = 10,000 × (1 – i) 3 Then: 0.2 = (1 – i) 3 – 1 = 0.585 i = 0.415 giving a depreciation rate of 41.5%. 2.20 Logarithms are defined by the relationship that  $n = \log_b(p)$  meaning that  $p = b^n$ . 10.8 Because observations contain random noise which cannot be forecast, Solution gives: A10 = 0 Rohan wants to find the initial payment, A0, that gives F = -10,000 (the negative sign showing a receipt rather than a payment) with i = 0.12. What are the 95% and 99% confidence intervals for the true length of calls? No method is always best, and managers have to choose the most appropriate for particular circumstances. Then select some of these regions at random, and divide them into smaller subdivisions – perhaps parliamentary constituencies or local government areas. Spam is a huge problem on the Internet and most people use filters that would not allow random questionnaires through. This gives the timings in the following table, and you can also see these at the ends of the bottom rows of figures for each activity in Figure 19.8. Activity Duration Earliest start Earliest finish Latest start Latest finish A B C D E F G H I J K L M N O P Q R S T U V W X Y Z 10 11 10 11 15 Critical activities have flexibility in their timing – activities can start as early as the week 3, or as late as week 8. To be generous, this may be a simple mistake in presenting the data poorly, but the truth is that many people make a deliberate decision to present data in a form that is misleading and dishonest. They achieve this by moving – activities within their time slots, and by discounting the present value of all costs from the present value of all revenues gives a net present value, but they only give a description and do not suggest a solution. Some other measures are: Units Units Units Units Units Units Units Units // kg or raw material £/ hour £/ of labour RWh £/ of energy 2009 2010 Percentage increase 0.96 0.499 0.233 0.91 0.100 1.000 1.207 0.047 0.26 / 0.021 0.068 0.800 5.6 – 4.1 14.6 10.5 – 14.0 – 20 % 188 Finance and performance Worked example 8.1 continued In general, labour productivity has stayed at the same and energy productivity has fallen. The choice of best format is often a matter of personal judgement and preference. Although the number of activities on the critical path is small, we can reasonably assume that the overall duration of the project is Normally distributed (at least to illustrate the calculation), and Wykes C., Plain Figures (2nd edition), HMSO, London, 1996. (b) How would you describe the sum of values numbered 18 to 35 in a set of data? There is a notional time scale going from left to right with earlier decisions, or events on the left, followed by later ones towards the right. There is no point in adding up the relevant information about costs and times. What is 'more'? There are several approaches to this. 4. What is the appropriate population to give data about the following? What benefit do you think that would bring to your organisation? The main measure of a decision is its impact on the outcome. A similar approach would give a better answer. A simulation model takes a move of the system. We can show how this happens with the obvious statement that  $3 > 2 > 3.14$  What is the difference between NPV and IRR? A standard answer is that you have to understand the methods so that you can interpret and implement the results correctly. Draw the network for the project and do the relevant analysis. The final decision is largely a matter for management judgement. Researchers use marked surveys to collect data and process it to give information about consumer opinions. Bar charts can be drawn as pictograms, but you have to be careful not to divert attention away from, or obscure, the important figures. In practice, there is no clear distinction between data reduction and data presentation, and we usually combine them into a single activity. But for it to start at 10 both B and F must finish by 10, so this gives both of their latest finish times. ABC analysis of stock 499 Figure 18.12 ABC analysis of stocks for Worked example 18.6 WORKED EXAMPLE 18.6 A small store has 10 categories of product with these costs and annual demands: Product B1 P2 P3 P4 P5 P6 P7 Unit cost £/ 20 10 20 10 10 50 5 P8 P9 P10 P11 Annual 250,000 200,000 6,000 1,500 600 1,000 500 100,000 5,000 Demand do a ABC analysis of item 18.6 WORKED EXAMPLE 18.6 A small store has 10 categories of product with these costs and annual demands: Product B1 P2 P3 P4 P5 P6 P7 Unit cost £/ 20 10 20 10 10 50 5 P8 P9 P10 P11 Annual 250,000 200,000 6,000 1,500 600 1,000 500 100,000 5,000 Demand do a ABC analysis of item 18.6 WORKED EXAMPLE 18.6 A small store has 10 categories of product with these costs and annual demands: Product B1 P2 P3 P4 P5 P6 P7 Unit cost £/ 20 10 20 10 10 50 5 P8 P9 P10 P11 Annual 250,000 200,000 6,000 1,500 600 1,000 500 100,000 5,000 Demand do a ABC analysis of item 18.6 WORKED EXAMPLE 18.6 A small store has 10 categories of product with these costs and 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5 P

ive good results, include subjective data etc. Solution Listing the values we know:  $D = 200$  units per week  $O = 40$  units reorder level,  $ROL = LD + \text{safety stock} = 3 \times 200 + \text{safety stock} = 600 + \text{safety stock}$  For a 95% service level,  $Z = 1.645$  standard deviations from the mean. We have already used several in this book, and you can see more in papers, magazines, books, reports and websites. WORKED EXAMPLE 10.7 Remko van Rijn collected the demand figures shown in Figure 10.8. Use an initial forecast of 500 to compare exponential smoothing forecasts with different values of  $\alpha$ . When there is little noise, forecasting is relatively easy and we can get good results, but when there is noise it hides the underlying pattern and forecasting becomes more difficult. Then the airline sells a seat at a discount only when the discounted price is greater than the expected value from selling the seat later. We can emphasise the underlying patterns by reducing the data. 2.16 In ascending order,  $(-12)^4 = 0.0625$ ;  $4-1 = 0.25$ ;  $14 = 1$ ;  $2 = 2$ ;  $41 = 4$ ;  $(-12)^{-4} = 16$ . But when the lead time demand is Normally distributed about a mean of  $LD$ , the demand is actually greater than this mean in half of stock cycles - and by symmetry it is less than the mean in the other half of cycles. 12.13 Bayes' theorem states that  $P(a/b) = P(b/a) \times P(a)/P(b)$ ; it is used for calculating conditional probabilities. Of this, the regression explains 1191.630, giving the explained SSE. The area of each slice - and hence the angle at the centre of the circle - is proportional to the number of observations in the category. Solutions to review questions 571 6.16 The general shape of a distribution. This kind of data can follow a growth curve of the form  $y = ax^b$  where  $x$  is the independent variable,  $y$  is the dependent variable, and both  $a$  and  $b$  are constants. A survey of the amount people spend on transport is biased if one randomly chosen person is a film star who just bought a Boeing 747. This has the benefits of reducing costs and being convenient to organise - and it is especially useful for surveying practices, when individual companies form the clusters. Index 1 106 129 154 173 195 231 Index 2 100 113 126 153 172 If the company had 645 agents in year 4, how many did it have in the other years? 9.11 The proportion of the total sum of squared error that is explained by the regression. Random samples are taken from each batch and if quality is too low the whole batch is rejected, checked and reworked as necessary. Choose the best sampling method and sample size. and Granville D., Excellence in Inventory Management, Cambridge Academic, Cambridge, 2007. By all accounts, the tunnel was a triumph of construction. Finally, we can start fixing the glass, which takes 1 day so finish by the end of day 8. For example, displays of clothes in a shop might be refilled every evening to replace whatever was sold during the day. 2 Find the regret for every entry in the column - the difference between the entry itself and the best entry in the column. Then we might find that advertising explains 60% of the variation in sales, but a second term for price explains 75% of the variation, and adding a third term for unemployment explains 85% of the variation and so on. Before adjusting the system, the company wanted to check the effects of their proposed changes and ran a series of simulations. 9.12 Values from -1 to +1. Figure 19.14 Network for PERT Worked example The duration of the critical path is the sum of the durations of activities making up that path - and when the duration of each activity is variable, the overall duration of the project is also variable. During one surgery the doctor was called away for an emergency that lasted an hour and patients who had appointments during this time were told to come back later. 1.2 European coins have denominations of 1, 2, 5, 10, 20 and 50 cents, and 1 and 2 euros. With a single decision most people would choose not to invest. We have a major complaint about our quality. Here, it suggests that 80% of stock items need 20% of the attention, while the remaining 20% of items need 80% of the attention. And high-quality products may not guarantee a firm's success, low-quality ones will certainly guarantee its failure. Numbers and management Numbers are such an integral part of our lives that it comes as no surprise that managers use quantitative reasoning to aid their decisions. 14.13 The number of independent pieces of data. Quantitative

ods for Business 12th Edition Anderson Anderson Solutions Manual only NO Test Bank for the Text book included on this purchase. The profit depends on market reaction and there is a 30% chance that this will be good, a 40% chance it will be medium and a 30% chance it will be poor. Adding these together gives the total amount of distilling and this must be less than, or at worst equal to, the amount of distilling available (40 hours). Project A has the highest NPV and is the one that FHP should choose (all things being equal). The tests give three results - A, B and C - with the following conditional probabilities of results given the size of find. Do a survey to compare available observations. Most real simulation is done by comprehensive languages such as Renque, SimEvents, SimPy, SIMSCRIPT and Simul8, Monte Carlo simulation 547 WORKED EXAMPLE 20.4 An office organises appointments for its customers so that one should arrive at a reception desk every eight minutes. If they have a resale value of ¥40,000, what is the value at the end of each year with straight-line depreciation? Many people find probabilistic ideas more difficult than deterministic ones, so we have drawn a clear separation between the two. They measure performance in terms of profit, return on investment, turnover and share price; to increase returns they look at growth, costs, profitability and sales; when considering output they measure capacity, productivity and employee numbers; to assess marketing they look at the number of customers, market share and sales; annual accounts give a numerical review of overall performance. Spearman's coefficient gives a correlation for ranked data. But this definition is still vague because it is no direct measures of quality and cannot give a clear view when different customers have different expectations. 578 Appendix A 17.5 No. 17.6 By minimising the total quality cost - and this usually means perfect quality. Here we are using 'population' in the statistical sense of all people or entities that share some common characteristic. The value depends on the information you want to present - with the base year chosen as a fixed reference point. It can be very important to interpret the indices properly. Each index is affected by noise in the data, so it is only an approximation. 17.15 Because it gives perfect differentiation between good batches (where the probability of acceptance is 1) and bad batches (where the probability of acceptance is 0). However, we should give a word of warning about outliers - single observations that are some distance away from the regression line. Decision making- Mathematical models. They have collected the following data from a sample of hotels. CASE STUDY Natural Wholemeal Biscuits Naturalsomemeal Biscuits (NWB) make a range of foods that they sell to health food shops around eastern Canada. Imagine that you use a questionnaire to collect a group of people's answers to five questions. We also want the correlation between advertising and price to be low, ideally less than its value of 0.535. Chapter 8 describes some calculations for company and performance. You can find some general data about, say, the Burlington Northern Railroad very easily (it runs trains, employs staff etc.); for more detailed data you need a trip to a specialised transport library (perhaps finding what kinds of engines it has, or staff at different grades); for yet more detailed data you need to search the company's own records; for yet more detailed data you need a special survey of employees. Use a selection of graphical methods to Year 1 Male 21 Female 4 5.4 2 3 22 20 6 3 4 5.6 18 5 28 26 12 16 7 8 29 30 14 19 9 10 32 17 29 25 The following table shows the quarterly profit in millions of dollars reported by the Lebal Corporation, and the corresponding closing share price quoted in cents on the Toronto Stock Exchange. Number of deliveries Number of weeks 20-39 14 40-59 19 60-79 13 80-99 5 100-119 0 120-139 0 140-169 1 Sometimes it is important to highlight outlying values - but usually it is just confusing. We start by identifying the modal class, which is the class with most managers. Then managers can draw a bar chart of problems, identify the few areas that give most problems and give these special attention. As part of these changes, the company negotiates an annual basic pay rise, which is proposed by a committee of representatives from all parts of the company along with a number of independent members. 15.3 Coaches Ltd say that their long-distance coaches take 5 hours for a particular journey. You might like drawing graphs in the traditional way, by hand on graph paper - but it is easier and more reliable to use a specialised graphics packages. This has stock kept in two bins - one bin holds the reorder level, and the second holds all remaining stock. When  $x = 2.21$ ,  $y = 2x + 10 = 2 \times 2.21 + 10 = 14.42$ , giving the point (2.21, 14.42), which we estimated to be (2, 14). A low negative value of r shows a weak linear relationship, and as one increases the other decreases. Figure 16.5 Decision tree with added probabilities and terminal values (Worked example 16.11) Sequential decisions 441 Having drawn a decision tree, the next step is to analyse it, moving from right to left and putting a value on each node in turn. and Hussey R., Business Research, Palgrave Macmillan, Basingstoke, 2003. If they had wanted to return the table to its original price, they would have reduced it by the proportion 1,600/9,600, which equals 16.67 / 100 or 1.67%. So with an extra assistant they pay more for the service but less for waiting - meaning that they have shorter queues with the same overall cost. If the prevailing interest rate is 12%, how much will this cost? Janet's aim is to maximise the value of her assets over the next 10 or 15 years, by which time she will be ready to take early retirement. Product quality has clearly risen, giving lower failure costs. WORKED EXAMPLE 2.19 Two variables, x and y, are related by the equations:  $3y = 4x + 2$  (1)  $y = -x + 10$  (2) What are the values of x and y? 24 Calculations and equations WORKED EXAMPLE 2.5 Find the values of: (a)  $1/2 + 1/4$ , (b)  $1/2 + 4/5$ , (c)  $3/4 - 1/6$ . Panel consensus A single expert can easily make mistakes, but collecting together a panel of experts and allowing them to talk freely and exchange ideas should lead to a more reliable consensus. As soon as activity A is finished, both C and D can start; E can start as soon as D is finished, and F can start as soon as B is finished. Each expert is then asked if they would like to reassess their answer in the light of other replies. 13.18 When the number of events, n, is large and the probability of success is relatively large (with np greater than 5). WORKED EXAMPLE 2.28 If  $2x = 32$ , use logarithms to find the value of x. The usual format for a p-chart draws a mean, expected proportion of defects in a sample. G L O S S A R Y [Figures in sets show the chapter where the topic is discussed] 5-whys method [17] - repeatedly asking questions to find the cause of faults ABC analysis [18] - Pareto analysis for inventory items acceptable quality level (AQL) [17] - the poorest level of quality, or the most defects, that is acceptable in a batch acceptance sampling [17] - tests a sample from time to see whether or not the whole batch reaches an acceptable level of quality achieved quality [17] - shows how closely a product conforms to its designed specifications aggregate index [7] - monitors the way that several variables change over time algebra [2] - use of symbols to represent variables and to describe relationships between them native hypothesis [15] - hypothesis that is true when the null hypothesis is rejected annual equivalent rate or annual percentage rate [8] - true interest rate for borrowing or lending money annuity [8] - amount invested to give a fixed income over some period a-priori [12] - probability calculated by analysing circumstances arithmetic [2] - any of calculation with numbers arithmetic mean [6] - the 'average' of a set of numbers autocorrelation [9] - relationship between the errors in multiple regression average [6] - typical value for a set of data, often the arithmetic mean axes [3] - rectangular scales for drawing graphs bar chart [5] - diagram that represents the frequency of observations in a class by the length of a bar base [2] - value of b when a number is represented in the logarithmic format of  $n = bp$  base period [7] - fixed point of reference for an index base-weighted index [7] - aggregate index which assumes that quantities purchased do not change from the base period base value [7] - value of a variable in the period Bayes' theorem [12] - equation for calculating conditional probabilities 556 Glossary bias [4] - systematic error in a sample binomial distribution [13] - distribution that shows the probabilities of different numbers of successes in a number of trials break-even point [8] - sales volume at which an organisation covers its costs and begins to profit calculations [1] - arithmetic manipulation of numbers capacity [8] - maximum output that is possible in a specified time cardinal data [4] - data that can be measured causal forecasting [9] - using a relationship to forecast the value of a dependent variable that corresponds to a known value of an independent variable causal methods [10] - quantitative methods of forecasting that analyse the effects of outside influences and use these to produce forecasts cause-and-effect diagram, Ishikawa diagram or fishbone diagram [17] - diagram that shows the causes of problems with quality census [4] - sample of the entire population central limit theorem [14] - theorem that describes the distribution of observations about the mean chi-squared (or c2) test [15] - non-parametric hypothesis test class [5] - range or entry in a frequency distribution cluster sample [4] - result of choosing a sample in clusters rather than individually coefficient of correlation or Pearson's coefficient [9] - measure of the strength of a linear relationship coefficient of determination [9] - proportion of the total sum of squared errors from the mean that is explained by a regression coefficient of skewness [6] - measure of the symmetry or skewness of a set of data coefficient of variation [6] - ratio of standard deviation over mean combination [13] - number of ways of selecting r things from n when the order of selection does not matter common fraction or fraction [2] - part of a whole expressed as the ratio of a numerator over a denominator, such as 1/5 common logarithm [2] - logarithm to the base 10 compound interest [8] - interest paid on both the principal and the interest previously earned conditional probabilities [12] - probabilities for

of selection does not matter common fraction or fraction [2] - part of a whole expressed as the ratio of a numerator over a denominator, such as 1/3 common logarithm [2] - logarithm to the base 10 compound interest [8] - interest paid on both the principal and the interest previously earned conditional probabilities [12] - probabilities for dependent events with the form  $P(a/b)$  confidence interval [14] - interval that we are, for instance, 95% confident that a value lies within constant [2] - number or quantity that always has the same fixed value, such as p, e or 2 Glossary 557 constrained optimisation [11] - problems with an aim of optimising some objective subject to constraints consumer's risk [17] - highest acceptable probability of accepting a bad batch with more defects than LTPD contingency table [15] - table showing the relationship between two parameters continuous data [4] - data that can take any value (rather than just discrete values) coordinates [3] - values of x and y that define a point on Cartesian axes critical activities [19] - activities at fixed times in a project critical path [19] - series of critical activities in a project critical path method (CPM) [19] - method of project planning that assumes each activity has a fixed duration critical value [15] - test value for a chi-squared test cumulative frequency distribution [5] - diagram showing the sum of frequencies over classes cumulative percentage frequency distribution [5] - diagram showing the sum of percentage frequencies in lower classes current-weighted index [7] - aggregate index which assumes that the current amounts bought were also bought in the base period curve fitting [9] - finding the function that best fits a set of data cycle-service level probability that all demand can be met in a stock cycle data [4] - raw facts that are processed to give information data collection [4] - gathering of facts that are needed for making decisions data presentation [5] - format for showing the characteristics of data and emphasising the underlying patterns data reduction [5] - reducing the amount of data in data to emphasise the underlying patterns decimal fraction [2] - part of a whole described by a number following a decimal point, such as 0.5 decimal places [2] - number of digits following a decimal point decision criteria [16] - simple rules that recommend an alternative for decisions involving uncertainty decision nodes [16] - points in a decision tree where decisions are made decision tree [16] - diagram that represents a series of alternatives and events by the branches of a tree decision variables [11] - variables whose values we can choose degrees of freedom [14] - measure of the number of independent pieces of information used in probability distributions denominator [2] - mean line of a common fraction dependence table [19] - table showing the relationships between activities in a project 558 Glossary dependent demand [18] - situation in which demands for materials are somehow related to each other dependent events [12] - events in which the occurrence of one event directly affects the probability of another dependent variable [3] - variable whose value is set by the value of the independent variable (usually the y value on a graph) depreciation [8] - amount by which an organisation reduces the value of its assets designed quality [17] - quality that a product is designed to have deterministic [12] - describing a situation of certainty deviation [6] - distance observation is away from the mean discount factor [8] - value of  $(1 + i)^{-n}$  when discounting to present value discount rate [8] - value of i when discounting to present value discounting to present value [8] - calculating the present value of an amount available at some point in the future discrete data [4] - data that is limited to integer values economies of scale [8] - effect where the average cost per unit rises as the number of units produced increases distribution-free tests (or non-parametric test) [15] - hypothesis tests that make no assumptions about the distribution of the population e or exponential constant [2] - constant calculated from  $(1 + 1/n)n$ , where n is an indefinitely large empirical probability [12] - probability found by observation or experiment equation [2] - algebraic formula that shows the relationship between variables, saying that the value of one expression equals the value of a second expression error [9] - difference between an expected value and the actual observation, often described as noise expected value [16] - sum of the probability multiplied by the value of the outcome exponential constant or e [2] - mean calculated from  $(1 + 1/n)n$ , where n is an indefinitely large number; it equals 2.7162816. For more complicated curves, you have to plot a number of points and draw a line through them. 1.8 No - we can use any approach that is efficient and gets a good answer. This is a good company to work for and I hope you settle in and will be very good here. Indices that measure changes in a number of variables are called aggregate indices. An alternative is to square the deviations and calculate a mean squared deviation - which is always described as the variance. WORKED EXAMPLE 16.2 A restaurateur is going to set up a cream tea stall at a local gala. Forecasts with seasonality and trends methods we have described so far give good results for constant time series, but they need adjusting for other patterns. We can extend this reasoning to more complex fractional powers. 13.6 Permutations. However, we can choose samples carefully to make them more reliable. Table 5.1 shows the weekly sales of the product mentioned above, this gives the general format for tables. This gives rise to the other two measures: n producer's risk (a) - the highest acceptable probability of rejecting a good batch, with fewer defects than the AQL. You can write  $35 \geq 4$  this as  $\Sigma a$ . There must be no loops in the network. For instance, a train operator runs a particular service at the same time day, a manufacturer makes a stream of similar cars, surgeons do a series of identical operations and a shop serves a series of customers. (b) You find Index 1 by multiplying Index 2 by a constant amount. Philip Crosby4 - analysed the total costs of quality and described straightforward methods for implementing quality management. You can fine this with a call centre where most customers are happy to wait 3 seconds before their call is answered, but operators describe a response as defective if it is not answered before the second ring. You could plot a graph of the crimes each year and this would certainly show the pattern - but it would not give a measure of the changes. When multiply b by itself three times you get  $b^3$ , which is described as 'b to the power 3' or 'b cubed'. n Algebra is based on the use of abbreviated names for constants and variables. If he has to cover fixed costs of £100, how many units must he sell to cover all his costs? 11.7 What is the role of the objective function in an LP model? n An employee scheduling module, which takes the pattern of employees needed and the staff available in the store and uses linear programming to produce schedules for staff members. BA B.T.E.V.E Management problems involving uncertainty. This book is divided into five parts, each of which covers a different aspect of quantitative methods. With an initial

later inspection. Rounding to four significant figures gives 1.333. In this chapter we look at project network analysis, which is the most widely used method of organising complex projects. Once we have built the simulation model and defined all the logic, it is easy to extend it to give more repetitions. There are many types of diagram and the choice is often a matter of personal preference. WORKED EXAMPLE 4.2 J.T. Eriksson received 10,000 invoices in the last financial year. Fowler F.J., Survey Research Methods (4th edition), Sage Publications, London, 2008. 32 Calculations and equations As with equations, inequalities remain valid if you do exactly the same thing to both sides. 2 Statistical Service, Monthly Digest of Statistics, Office for National Statistics, London. It takes a random sample from a batch and checks that the number of defects is below a maximum permitted number. Repeat this calculation for every column. 1 Initial review of published material, interviews and discussions to identify a suitable research project. We have made a deliberate decision to avoid proofs, derivations and rigorous (often tedious) mathematics. If there are two digits after the decimal point you put ( 59 ) them over 100 | so  $4.59 = 4$ , if there are three digits you put them over 100 || ( 273 ) 1000 | so  $12.273 = 12$  and so on. The results in this printout confirm our optimal solution and provide more information about sensitivity. Use a decision tree to find the most that Wilshaw should pay for this survey. Until calculators appeared, these were the easiest way of doing some calculations, and they are still the best way of solving certain types of problem. Source: Schimmer K., Using Charts to Identify Stock Market Trends, Financiers' Guide to Data Mining, Frankfurt, 2010. So the sequence of activities for analysing data starts with data collection, moves to data reduction and then data presentation. What other measures can you use? 252 Forecasting IDEAS IN PRACTICE Forecasting demand for new businesses New businesses have a particularly difficult job in forecasting demand for their products. You can draw a graph of any relationship where  $y$  is a function of  $x$ ; meaning that  $y = f(x)$ . Substituting this value into the finishing constraint gives  $T = 10$ . What else could they do with the data? In Worked example 19.1, levelling the ground must be done first and as soon as this is finished the base can be built. The implication is that data collection is essential in every organisation, because it starts the process of decision-making - and without proper data collection, managers cannot make informed decisions. Some of the results were quite disappointing. Sometimes it is convenient to give items different service levels depending on their importance. A fairer conclusion is that there is statistically significant difference between the average weight loss for the two methods. Her skills undoubtedly form part of the company's assets, and if she leaves then the remaining shareholders are likely to discount the company's value by about 50%. Notice that Hans has to pay a total of  $25 \times 11,241 = £281,025$ , which is 2.34 times the original amount. In our example, you could not define adjacent classes of 20-30 and 30-40 because a value of 30 could be in either. We can add variances in demand, but not standard deviations. To get around this problem, we define three different types of average: n arithmetic mean, or simple average median, which is the middle value mode, which is the frequent value. We can repeat this analysis to find a shadow price for finishing, by using a new finishing constraint:  $2G + T = 40$  (new finishing constraint) Solving these equations gives  $G = 14$  and  $T = 12$ , and substituting these values in the objective function gives a new maximum profit of  $12 \times 200 + 14 \times 300 = £600$ . 3 Statistical Service, Annual Abstract of Statistics, Office for National Statistics, London. Wilshaw can run a survey to test market reaction with results A, B or C. 3.2 Find some examples of graphs presented in newspapers and magazines. The only realistic way of getting close to this is to take large samples. (c) Study the problem more

I think this gives a good summary of our operations, and should give a useful focus for your presentation. The finance director looked at the figures for a few minutes and then asked for some details on how trade had changed over the past 10 years. Janet thought about these alternatives, but found them all bring. n Making products with perfect quality requires the focused effort of everyone in the organisation. If resources for stock control are limited, which items should be given least attention? The total cost of placing an 502 Inventory management order is £800 and holding costs are £400 a unit a year. IDEAS IN PRACTICE Survey into use of quantitative methods In 2002 Peder Kristensen sent a questionnaire to 187 managers asking them how much they used standard quantitative analyses. If you want the Test Bank please search on the search box. Then each major part can be taken in turn and broken down into further activities, represented by a series of more detailed networks. To fit a more complicated function through a set of data we use non-linear regression - or more generally curve fitting. Such a contradiction means that there is no feasible solution and you have to assume that there is a mistake in one of the equations. In reality, there are many different ways of forecasting - sometimes one method works best, sometimes another method is better. What is her best alternative? n Without using further geological testing, the probabilities of minor, significant and major finds are 0.3, 0.5 and 0.2 respectively, so the expected profits for each speed of development are: QUICK:  $0.3 \times 100 + 0.5 \times 130 + 0.2 \times 180 = 131$  n SLOW:  $0.3 \times 80 + 0.5 \times 150 + 0.2 \times 210 = 141$  n The company should develop the find slowly with an expected value of \$141 million. But if the actual demand in week 105 suddenly rises to 200 units, simple averages give a forecast for week 106 of:  $F_{106} = (104 \times 100 + 200) / 105 = 100.95$  A rise in demand of 100 gives an increase of only 0.95 in the forecast. Even when we can identify a fluctuation in principle, there can be difficulties translating this into actual sources of data. 8.17 How would you calculate the payment worth making for an annuity? This is a fairly arbitrary classification because one company's finished goods are another company's raw materials. However, foreign companies investing in Poland do not know the market well and they want to learn about the new market. Part Four describes some statistical methods focusing on probabilities, probability distributions, sampling and statistical inference. Measuring the strength of a relationship 231 Coefficient of correlation A second measure for regression is the coefficient of correlation, which answers the basic question 'are x and y linearly related?' The coefficients of correlation and determination obviously answer very similar questions and a standard result shows that: coefficient of correlation = coefficient of determination Now you can see why we refer to the coefficient of determination as  $r^2$  - so that we can refer to the coefficient of correlation as  $r$ . Figure 18.2 Stock cycle has length T and we know that: amount entering stock in the cycle = amount leaving stock in the cycle  $Q = D \times T$  Figure 18.2 Stock level over time with fixed order quantities The economic order quantity 485 Figure 18.3 A single stock cycle We also know that the stock level varies between Q and 0, so the average level is  $(Q + 0) / 2 = Q/2$  4.4 What is (a) 23/40 as a percentage, (b) 65% as a fraction, (c) 17% as a decimal, (d) 12% of 74, (e) 27 as a percentage of 85? 554 Queues and simulation Sources of information Further reading Books on queuing - like the subject - soon become very mathematical. For simplicity, suppose that each activity in the Gantt chart in Figure 19.11 uses a unit of a particular resource - perhaps one team of workers. There are several types of sample including random, systematic, stratified, quota, multi-stage and cluster samples. 424 Making decisions Giving structure to decisions Everybody has to make decisions - choosing the best car to buy, whether to invest in a personal pension, where to eat, software to use, where to go on holiday, which phone to buy and whether to have tea or coffee. WORKED EXAMPLE 16.1 The manager of La Pigalle Restaurant has a booking for a large wedding banquet. Unfortunately shortage costs are notoriously difficult to find and are generally little more than informed guesses. Further reading Most of books on mathematics mentioned at the end of Chapter 2 also refer to diagrams. n Option 2 gives a profit of r500,000 in 10 years' time. If your forecast sales are less than this, you have to make some adjustments, either by reducing costs and overheads or increasing sales and prices. This is why people often keep the same base even when it rises very high (like the Nikkei index of the Tokyo stock exchange which was once approaching 20,000). Secondly, the company does not have to install enough capacity to match peak sales, when this would be underutilised during quieter periods. Rather than draw a row of small mushrooms, the farmer uses sketches of single mushrooms. Figure 9.1 Stages in decision-making Solving problems 9 Stage 1: Identify a problem. The gradient of a straight line is clearly the same at any point, so we can find the increase in y when x increases from, say, n to n + 1:  $n$  when  $x = n$ ,  $y = ax + b = an + b$  when  $x = n + 1$ ,  $y = ax + b = a(n + 1) + b = an + a + b$ . These people did 1,100 separate tests on a batch of beer. What is the percentage increase in output each year? Most equipment loses a lot of value in the first years of operation, and it is actually worth less than its depreciated value. and Cole R., Brilliant Project Management, Prentice Hall, Englewood Cliffs, NJ, 2009. WORKED EXAMPLE 3.1 Solution Plot these points on a graph. It also shows at the end of projects, analysing results of surveys and writing reports for clients. People often assume that because there is a relationship there must be some cause and effect - but this is not true. Removing these takes away the purely random element and ultimately makes the analyses less reliable. The network expands systematically, starting from left to right, until you have added all the activities and the network is complete. BG, along with every other energy company, has to decide whether to bid for exploration rights in available blocks, and how much to bid. Notice that the data for drawing the control charts was collected when the process was known to be working normally. M.H., Nachsheim C.J. and Li W., Applied Linear Regression Models, McGraw-Hill, New York, 2010. Single-server queues 539 IDEAS IN PRACTICE Meecham Financial Services Fred McMurray runs an independent financial service from a shop in the centre of Meecham. They look very similar to bar charts, but there are important differences. Example, with 5 shifts, bonus of 10, overtime of 20 and morale of 6, their expected production is: production =  $346.33 + 181.80 \times 5 + 50.13 \times 10 + 96.17 \times 20 - 28.70 \times 6 = 3,508$  However, they should investigate the data to see if there really is a significant relationship between, say, production and bonus. The usual tests are based on process that monitor performance over time. 2.2 What is the value of: (a)  $(-12) / (-3)$ , (b)  $(24/5) \div (3/7)$ , (c)  $((2 - 4) \times (3 - 6)) / (7 - 5)$ ? 18.3 List four types of cost associated with stock. 288 Linear programming WORKED EXAMPLE 11.1 A political campaign wants to hire photocopies to make leaflets for a local election. Demand follows the pattern: 10, 20, 30, 40, 50, 60, 70. Probability 0.1, 0.15, 0.25, 0.15, 0.05, 0.05. There are currently 40 units in stock, and Conal wants to simulate the system for the next 10 months. Wilcox R.R., Introduction to Robust Estimation and Hypothesis Testing (2nd edition), Elsevier, Amsterdam, 2005. 8.7 No - there may also be diseconomies of scale.

There are currently 40 units in stock, and Conal wants to simulate the system for the next 10 months. Wilcox R.R., Introduction to Robust Estimation and Hypothesis Testing (2nd edition), Elsevier, Amsterdam, 2005. 8.7 No - there may also be diseconomies of scale. boundaries between categories of items are sometimes unclear, but in this case P4 is clearly an A item, P2, P3 and P6 are B items, and the rest are C items. But you should not do this! You should ignore a point only when there is a genuine reason, like a mistake or because the point is not strictly comparable with the rest of the data. The length of critical path sets the overall project duration. Review questions 6.1 What is the main weakness of using diagrams to describe data? Then we can use multiple regression to find the values of a, b<sub>1</sub> and b<sub>2</sub>. Figure 9.19 shows these results, and in rows 15 to 18 you can see that the line of best fit is:  $y = 2.65 - 0.97x_1 + 9.59x_2$  or  $y = 2.65 - 0.97x + 2$   $y = a + b_1x_1 + b_2x_2$  Figure 9.19 Using multiple regression for fitting a quadratic equation Review questions 9.19 What is the difference between non-linear regression and curve fitting? Then the book works from basic principles and develops ideas in a logical sequence, moving from underlying concepts through to real applications. When we split integers into smaller parts, we get fractions. Cost (u) Rating Rooms Location Facilities Meals Staff 90 170 80 130 70 240 30 32 56 120 240 190 110 120 36 56 4 6 5 2 9 12 2 2 6 8 12 8 2 2 12 4 1 3 2 4 3 5 1 1 2 4 5 3 2 2 1 3 45 90 120 30 40 240 8 12 40 100 60 80 50 45 40 30 2 4 1 1 5 3 5 4 2 1 3 3 4 1 1 4 10 8 6 4 5 12 2 2 6 10 12 8 10 8 2 6 70 Regression and curve fitting Sources of information Further reading There are some books specifically about regression, but they tend to get very complicated. You need not worry about its exact form (illustrated in Figure 20.2), except that it has the useful feature that the probability of service being completed within some specified time, T, is:  $P(t \leq T) = 1 - e^{-mT}$  where: m = mean service rate = the average number of customers served in a unit of time. Check the calculations in this chapter and describe the effects of changing parameter values. 11.4 What happens when you formulate a linear programme? If you multiply a demand of 32.63 by a unit cost of a17.19, you should quote the total cost to at most two decimal places. A high value of n takes the average of a large number of observations and the forecast is unresponsive - it smoothes out random variations, but may not follow genuine changes. If you spend a500 a month on housing, a200 a month on food and entertainment, a300 a month on other things, your total expenditure is a1,000 a month, which is the same as a12,000 a year or a230.77 a week. Home / Solutions Manual / Quantitative Methods for Business 12th Edition Anderson Solutions Manual \$28.50 Download SampleQuantitative Methods for Business 12th Edition Anderson Solutions Manual. This fifth shows how to tackle a range of problems that include uncertainty, using these ideas of probabilities and statistical analyses. (a)  $4r / (33 - 3x) = q / 2p$  (b)  $(q - 4x) / 2q - 7p / r = 0$  2.12 What is an inequality? If demand in the past five weeks has been 10, 20, 30, 40 and 50, it seems reasonable to project this pattern into the future and suggest that demand in the next week will be 60. Inequalities give less precise descriptions of relationships, typically of the form  $a < b$ . What other factors might be relevant? However, one thing that you have to be careful about is the assumption in algebra that adjacent variables are multiplied together - so  $a \times b$  is written as ab,  $4 \times a \times b \times c$  is written as 4abc.  $a \times (b + c)$  is written as a(b + c), and  $(a + b) \times (x - y)$  is written as (a + b)(x - y). To test this, a consumer group found the cost of maintaining 10 cars for a 5 3 15.15 Figure 15.11 shows a spreadsheet doing the calculations for a t-test on the mean of two samples. At each stage, the more data you want, the more it costs to collect. The company got a 5% risk of rejecting good batches, and a 10% risk of accepting bad batches. Year 1 2 3 4 5 6 7 8 9 10 11 Cost 0.8 1.0 1.3 1.7 2.0 2.4 2.9 3.8 4.7 6.2 7.5 Solution You can see, without drawing a graph or calculating the correlation, that the data does not form a straight line, but is rising quickly. Sources of information 215 Sources of information 1 Tran M., Enron chief 'ignored financial irregularities', Guardian, 26th February 2002. news.bbc.co.uk: www.manchestereveningnews.co.uk. 6.8 In Excel useful functions are AVERAGE, MEDIAN and MODE. where the dots represent an unending row of 3s. 10.7 What are the main problems and benefits of judgemental forecasting? The authors use real, memorable examples to demonstrate how and when to use the methods found in the text. 9.14 They are essentially the same, but Pearson's coefficient is used for cardinal data and Spearman's is used for ordinal data. A large variance shows more spread than a smaller one, so data with a variance of 42.5 is more spread out than 22.5, but we cannot say much more than this. Positive and negative errors cancel each other, so the mean error should be around zero unless there is bias. 5.19 'A fair Lorenz curve should be a straight line connecting points (0, 0) and (100, 100).' Is this true? Now he wants a convenient format to present this to the Bany Board of Directors. 9.6 10 Person A B C D E F G H I J K L Rank 1 Rank 2 5 8 10 7 12 10 4 1 9 12 1 2 3 4 7 6 2 5 11 9 8 11 6 3 9.7 10 19 69 114 29 163 42 231 51 60 272 299 73 361 79 90 101 411 483 522 Blaymount Amateur Dramatic Society is staging a play and wants to know how much to spend on advertising. Failure costs can be particularly high, but fall with increasing quality. 7.11 Not really - the RPI monitors the changing prices paid for some items by a 'typical' family - but people question its reliability. Solution We have already done the timing analysis for this project, and the columns labelled A, B, C etc. So after some time, TP, production stops - demand from customers continues at a rate D and this is met from the accumulated stock. What other features do you think they should add to the spreadsheet? For example, with 15,762 the decimal point moves four places to the left, so 10 is raised to the power 4, giving  $1.5762 \times 10^4$ . To get a more accurate value we would have to find the average discounted return. With 20 inspections they have to be a bit more careful because substitution gives  $95.86 - 7.88 \times 20 = -61.74$ . n An alternative approach uses periodic reviews to place orders of variable size at regular intervals. n Sometimes a dependent variable is related to several independent variables. Sometimes it is not obvious whether a constraint restricts solutions to points above the line or below it (constraint 2, for example). Part Five shows how to use these statistical ideas for problems involving uncertainty, including decision analysis, quality, inventory and project management, queues and simulation. As a result, managers have to look at the forecasting methods available for specific decision and choose the most appropriate. Other activities have flexibility in timing and are non-critical. 20.2 No - a balance is needed between the costs of providing a large number of servers and losing potential customers. 1.3 The following table shows the number of units of a product sold each month by a shop, the amount of space available for displaying items and the selling price. Pearson W. S., Sigma Mathematical Statistics, McGraw-Hill, New York, 2004. The problem with this is that first it is not clear what it is asking. The second problem is that it is not clear what it is asking. The third problem is that it is not clear what it is asking.

for each unit, and the selling price. Brussee W., Six Sigma Made Easy, McGraw-Hill, New York, 2004. The way to avoid this is to define the highest class so that it includes all the outliers, which we can do here by defining the top class as '80 or more', with 6 entries. These numbers give essential information. It enables a view of the data that is se, but still accurate. Use an initial value of  $F_1 = 208$  and say which value of 2 is best. Measuring change Year Value Calculation Index 1 2 3 4 127 142 116 124 127 142 116 124 1.02 1.15 0.94 1.00 // 124 124 124 165 You can use indices to monitor the value of any variable that changes over time, but one of the most common uses describes the changing price of an item. and Loats J., Algebra Unplugged, Clearwater Publishing, Broomfield, CO, 1996. Some guidelines for good practice include: n n n n n always label both axes clearly and accurately show the scales on both axes the maximum of the scale should be slightly above the maximum observation wherever possible, the s on axes should be continuous from zero; if this is too difficult, or hides patterns, show any break clearly in the scale where appropriate, give the graph a title. Unfortunately, you soon find that most of this is irrelevant, faulty, and you are swamped by details that are of no interest. But the values of mos tables in business change over time - income, sales, profit, share price, productivity, number of customers and so on. 78, 64, 36, 70 and 52 are data that we process to give the information that the average exam mark of five students is 60%. Month 1 Productivity 22 24 28 27 23 24 20 18 20 23 Production manager 23 26 32 28 20 26 24 16 21 23 man 22 28 29 29 24 26 21 21 24 25 Management 21 25 26 27 Services 24 23 20 20 19 24 9.2 x y 9.3 2 3 4 5 6 7 8 9 6 21 41 75 98 132 153 189 211 243 267 301 Use linear regression to forecast sales for the next year. What assumptions do the functions make? n The reorder level indicates when it is time to place an order. Find the equation for one of best fit through the data. Unnecessary decoration is sometimes called 'chartjunk' and people refer to the 'ink ratio' - which compares the amount of ink used to describe the data with the amount used in decoration. There were almost no complaints about the food, so customers were clearly pleased with what they were eating. Thankfully, standard software includes multiple regression as a standard function. Data of different types - and with different uses - is collected in different ways. Gitlow H.S., Oppenheim A.J. and Oppenheim R., Quality Management (3rd edition), McGraw-Hill, New York, 2004. But there can also be diseconomies of scale. Again, it makes no sense to say that rice index for raw materials is 200 and for wages is 100, so the mean price relative index is  $(200 + 100) / 2 = 150$ . This combined activity of summarising data has the advantages of: n n n n n showing results in a compact form using formats that are easy to understand allowing diagrams, graphs or pictures to be produced highlighting underlying patterns allowing comparisons of different sets of data using quantitative measures. If we have 10 values in a class 20 to 29, we assume that all 10 have the value  $(20 + 29) / 2 = 24.5$ . Then we calculate the mean in the usual way. IDEAS IN PRACTICE 'I'm no good at maths . A decision-maker here is likely to look for a balance of risk and fit. and White D., Research Methods, Response Books, New Delhi, 2007. Generally, the more effort that is put into quality control, the higher is the final quality of the product - and the higher the costs of achieving this. Joseph Juran3 - emphasised the role of senior management and the definition of good quality as satisfying customer demand. Uses the DRAW options for Sources of information drawing the skeleton of the tree, with calculations described in appropriate cells using normal spreadsheet functions. Review questions 18.1 What is the main reason for holding stock? Chapter 2 - Calculations and equations 2.1 You might want to check the figures, do some easy calculations by do initial calculations to get rough estimates, get a feel for the numbers involved or a host of other reasons. n Exponential smoothing is an efficient forecasting method which adds portions of the latest observation to the previous forecast. 0 3 1 4 2 8 3 10 4 15 5 18 6 20 7 22 8 27 Monthly sales for Sengler Marketing for the past year are: 9 28 multiple regression to find the line of best fit through the following data. In particular, he wants the company to expand rapidly, with turnover increasing by 100% a year for the next five years. This is a high value and shows a strong linear relationship, with 95% of all the variation explained by the regression and only 5% due to . Let: X1 be the amount of money put into investment 1 n X 2 be the amount of money put into investment 2 n money - the total invested must equal £1 million:  $X_1 + X_2 + X_3 + X_4 + X_5 + X_6 = 1,000,000$  n The trust wants to invest the £1 million with minimum risk, but with a dividend of at least £70,000 a year, average growth of at least 12% in average rating of at least 7. What follow-up action could they recommend? n If more than 6 units are defective, reject the batch. n There is an upper limit on sales, given by the intercept - and when the price is reduced to zero the expected sales are limited to 100. We could collect enough data to show how the system actually works - and then build make up other sets of figures that have exactly the same patterns. 47 2.13 What can you say if (a)  $3x + 4 \geq 6x - 3$ , (b)  $2x + 7 > 13 > 3x - 4$ ? But we have problems when there is a lot of data. - is a fastfood restaurant chain that specialises in Mexican cuisine. Walkenbach J., Excel 2007 Charts, John Wiley & Sons, New York, 2007. 19.8 The difference between the maximum amount of time available for an activity and the time it actually needs. .'. Decision making with strict uncertainty 427 In reality, even decisions under certainty can be difficult. You can see the general pattern here, but this becomes even clearer when we join the points, as shown in Figure 5.4(b). Dependent demand usually uses the methods of materials requirement planning to expand a production schedule and design timetables for the delivery of materials. On average, orders should arrive when there are 114 units left. n A population consists of all the people or items that could supply data. And for this we must consider the characteristics of a decision, can be summarised as: n n n n a decision-maker - the manager - who is responsible for making the decision a number of alternatives available to the decision-maker an aim of choosing the best alternative after the decision has been made, events occurring over which the decision-maker has no control each combination of an alternative then followed by an event happening leading to an outcome that has some measurable value. n n Fixed order quantity - where an order of fixed size is placed whenever stock falls to a certain level. Firstly, the company can smooth its operations so that production does not have to follow the seasonal pattern of demand. The views of the third tor should really be given more weight, and we can do this with a weighted mean. The average adjustment for each period is shown in rows 18 to 24. To help with this, he converted the effort involved with different tasks into 'standard work units'. What happens when the objective function changes? Suppose you have some money to spare and

into a bank account - effectively lending your money to the bank. Sometimes, though, the histogram is very asymmetrical and the measures are some distance apart. Continue in this way until you have small enough areas, and then identify a sample of individuals from within these areas. Remember that percentage point changes are not the same as percentage changes - and a rise of 15 percentage points is not the same as a rise of 15%. He had to decide how to market his idea, and in the short term his options could be summarised as selling the valve locally, selling nationally through a website, entering a partnership with an existing company or selling the patent. Table of contents :  
.....Page 1 Quantitative methods for business.....Page 2 Brief contents.....Page 8 Contents.....Page 10 Preface.....Page 18 Part One - Background.....Page 22 Why use numbers?.....Page 24 Solving problems.....Page 28 Useful software.....Page 33 Case Study - Hamerson and Partners.....Page 36 Research projects.....Page 37 Sources of information.....Page 38 Chapter outline.....Page 40 Working with numbers.....Page 41 Changing numbers to letters.....Page 48 Solving equations.....Page 50 Simultaneous equations.....Page 53 Powers and roots.....Page 57 Chapter review.....Page 66 Problems.....Page 67 Research projects.....Page 68 Sources of information.....Page 70 Graphs on Cartesian coordinates.....Page 71 Quadratic equations.....Page 79 Drawing other graphs.....Page 83 Graphs of simultaneous equations.....Page 87 Chapter review.....Page 91 Case study - McFarlane & Sons.....Page 92 Problems.....Page 93 Sources of information.....Page 94 Part Two - Collecting and summarising data.....Page 96 Data and information.....Page 98 Types of data.....Page 103 Using samples to collect data.....Page 106 Organising data collection.....Page 113 Chapter review.....Page 120 Case study - Natural Wholemeal Biscuits.....Page 121 Problems.....Page 122 Sources of information.....Page 123 Data reduction and presentation.....Page 124 Tables of numerical data.....Page 127 Diagrams of data.....Page 132 Continuous data.....Page 145 Chater review.....Page 150 Case study - High Acclaim Trading.....Page 151 Problems.....Page 152 Sources of information.....Page 154 Measuring data.....Page 155 Measures of location.....Page 157 Measures of spread.....Page 167 Other measures of data.....Page 176 study - Consumer Advice Office.....Page 180 Problems.....Page 181 Research projects.....Page 182 Sources of information.....Page 183 Measuring change.....Page 184 Changing the base period.....Page 190 Indices for more than one variable.....Page 192 Chapter review.....Page 198 Problems.....Page 199 Research projects.....Page 201 sources of information.....Page 202 Part Three - Solving management problems.....Page 204 Measures of performance.....Page 206 Break-even point.....Page 211 Value of money over time.....Page 218 Discounting to present value.....Page 222 Mortgages, annuities and sinking funds.....Page 229 Chapter review.....Page 232 Case study - eInkCartridges.com.....Page 233 Problems.....Page 234 Research projects.....Page 235 Sources of information.....Page 236 Measuring relationships.....Page 237 Linear relationships.....Page 242 Measuring the strength of a relationship.....Page 249 Multiple regression.....Page 256 Curve fitting.....Page 261 Chapter review.....Page 265 Case study - Western General Hospital.....Page 266 Problems.....Page 267 Research projects.....Page 268 Sources of information.....Page 269 Forecasting in organisations.....Page 270 Judgemental forecasts.....Page 273 Projective forecasts.....Page 276 Forecasts with seasonality and trend.....Page 290 Case study - Workload planning.....Page 300 items.....Page 301 Sources of information.....Page 302 Constrained optimisation.....Page 304 Formulation.....Page 305 Using graphs to solve linear programmes.....Page 311 Sensitivity of solutions to changes.....Page 317 Solving real problems.....Page 320 Case study - Elemental Electronics.....Page 326 Problems.....Page 327 Sources of information.....Page 330 Part Four - Introducing statistics.....Page 332 Measuring uncertainty.....Page 334 Calculations with probabilities.....Page 338 Conditional probabilities.....Page 344 Chapter review.....Page 352 Case study - The Gamblers' Press.....Page 353 Problems.....Page 354 Research projects.....Page 355 Sources of information.....Page 356 Frequency distributions.....Page 357 Combinations and permutations.....Page 359 Binomial distribution.....Page 362 Poisson distribution.....Page 368 Normal distribution.....Page 374 Case study - Machined components.....Page 387 Problems.....Page 388 Research projects.....Page 389 Sources of information.....Page 390 Purpose of sampling.....Page 391 Sampling distribution of the mean.....Page 393 Confidence intervals.....Page 398 One-sided confidence intervals.....Page 403 Using small samples.....Page 406 Case study - Kings Fruit Farm.....Page 409 Problems.....Page 411 Sources of information.....Page 412 Aim of hypothesis testing.....Page 413 Significance levels.....Page 417 Tests with small samples.....Page 422 Testing other hypotheses.....Page 423 Chi-squared test for goodness of fit.....Page 428 Tests of association.....Page 433 Chapter review.....Page 436 Problems.....Page 437 Sources of information.....Page 439 Part Five - Management problems involving uncertainty.....Page 440 Chapter outline.....Page 444 Giving structure to decisions.....Page 445 Decision making with certainty.....Page 447 Decision making with strict uncertainty.....Page 448 Decision making with risk.....Page 453 Sequential decisions.....Page 460 Chapter review.....Page 467 Problems.....Page 468 Research projects.....Page 471 Sources of information

information.....Page 551 Features of queues.....Page 552 Single-server queues.....Page 554 Simulation models.....Page 561 Monte carlo simulation.....Page 565 Case study - The Palmer Centre for Alternative Therapy.....Page 572 Problems.....Page 573 Sources of information.....Page 575 Glossary.....Page 576 Appendix A Solutions to review questions.....Page 558 Appendix B Probabilities for the binomial distribution.....Page 602 Appendix C Probabilities for the Poisson distribution.....Page 607 Appendix D Probabilities for the Normal distribution.....Page 611 Appendix E Probabilities for the t-distribution.....Page 612 Appendix F Critical values for the x<sup>2</sup> distribution.....Page 613 Index.....Page 615 Citation preview Quantitative Methods for Business Fifth Edition Managers in every organisation use quantitative methods. Non-responses Even the best questionnaire will not get a response from everyone in the sample. The second unit arrived at time 2 from the arbitrary start time, was accepted and joined the queue (column E shows the number in the queue after this unit joins it). Chapter 15 - Testing hypotheses 15.1 To test whether or not a statement about a population is supported by the evidence in a sample. IDEAS IN PRACTICE Reasoning test in the USA, education is largely organised by state governments. What is the limit of best fit through the following results? Some formal procedures are included, but these are kept to a minimum. In particular, linear regression draws a line of best fit through a set of data, and the amount of variation around this line shows how good the fit is. How can the forecasts be improved? So managers should not base their decisions on present circumstances, but on conditions as they would be if the decisions become effective. It is worth realising that ordinal data is far less precise than cardinal. Solution (a) The break-even point is:  $N = F / (P - C) = 200 \times (20 - 10) = 750$  meals. Actual sales are above this, so there is a profit of:  $\text{profit} = N(P - C) - F = 200 \times (20 - 10) - 750 = 250$  a day Break-even point 195 Words example 8.4 continued (b) The average cost of a meal is: average cost =  $(\text{fixed cost} + \text{variable cost}) / \text{number of meals} = (1,750 + 250 \times 10) / 200 = 17.5$  a meal (c) Serving 250 meals a day would give: average cost =  $(1,750 + 250 \times 10) / 250 = 17.5$  a meal Spreading the overheads over more meals is only one reason for economies of scale. This was checked by testing 3 cans from the production line, 5 times a shift. Sources: www.lorealparis.com; www.olay.co.uk; Watson R.E.B., et al. A cosmetic anti-ageing product improves photo-aged skin, British Journal of Dermatology, 161(2), 419-426, 2004. 1.36  $\text{standard deviation} = \text{np}/\text{variance}$ , p.13.10 0.2753. They can do simple data collection, but lack the skills for in-depth interviews or other more demanding data sources. Websites at www.cra.gc.ca and www.statcan.ca. Event Alternative House burn down House does not burn down Insure house Do not insure house u600 200,000 0.00 to 0.00. Obvious, we have simplified problems here, in reality there is a choice of many insurance companies, some may be damaged but not destroyed by fire, others may be more expensive. We want to adopt any batch with fewer defects than AOL, perhaps buying a flight of AOL and add 1%. You can see the effect in WORKED EXAMPLE 10.5 Use a generic spreadsheet to calculate the forecasted error in this case. This year the same items cost £62 million, 32 percent of total sales. The forecast is £75 million. You will start drawing an ogive by plotting the point (100, 12) to show that 12 observations are in the class '100 or less'. For example, a UK logistics company might get a broad view of industrial prospects from secondary data collected by the government and the European Union, more details come from secondary data collected by the Road Haulage Association and the Chartered Institute for Transport and Logistics. How would the costs change with a 0.0% service level? In practice, the target net present value is invariably set to zero, and the discount rate that achieves this is the internal rate of return. They had transferred an additional \$20 million into their life policy reserves in 2004, but now felt that they should add another \$30 million. 19.2 What is project management? Measuring change The previous two chapters showed how to summarise data with diagrams and numerical measures. If you have several unknowns, you need several equations to find all of them (which we discuss in the next section). This raises the questions of how many offices the centre will need for varying levels of demand and how big the waiting areas should be. The principle is always that data consists of raw numbers and facts, while information gives some useful knowledge. They use an inventory management system that was installed by a local IT specialist and it has worked well for several years. A particular strength of bar charts is that we can show several sets of data in the same diagram to make direct comparisons. 8.14 NPV uses a fixed discount rate to get a present value. IDEAS IN PRACTICE Software for drawing diagrams There is a lot of software available for drawing diagrams, ranging from simple programs that you can download free from websites to specialised graphics packages used by commercial artists. We could stand and watch the operation for as long as we needed to get a reliable view of its working. 9.15 No - it shows that 90% of the variation in the dependent variable is explained by, but not necessarily caused by, the relationship with the independent variable. 19.17 The project duration is Normally distributed with mean equal to the sum of the expected durations of activities on the critical path, and variance equal to the sum of the variances of activities on the critical path. Multiplying the deseasonalised trend by the seasonal index gives the forecast for period 13: forecast =  $458.05 \times 1.240 = 568$  Repeating this calculation for the other periods gives these forecasts. Webber L. Measures Sales Cost of sales Gross profit Distribution, research, development, selling, general and administrative costs Other operating income Operating profit Financial expenses and tax 32,804 5,775 =  $27,049$  16,039 553 27,029 + 553 = 16,039 + 11,543 532 73,363 + 2,363 \$ million Profit Dividends paid Total assets at end of financial year 11,543 - 3,999 Financial ratios Earnings per share \$ 32,804 - 5,775 Measures Earnings = 3,999 = 754 436 54,920 1,451 million \$42.19 \$15.19 (\$7,544 million / 1,451 million) Dividend per share \$ 32,804 (\$3,336 million / \$1,451 million) Gross return on assets 21.0% (\$11,543 million / \$42,900 million) Share price to earnings 8.1 (\$42.19 / \$15.19) Yield 5.5% (\$2.30 / \$42.19) Sources: AstraZeneca Annual Report 2009; www.astrazeneca.com; www.uk.finance.yahoo.com; www.lse.co.uk; you handle these in the same way as equations, but you must be careful with the direction of the sign when multiplying or dividing by a negative number. The three criteria described are due to Laplace, Wald and Savage. Then observations often follow an underlying pattern with superimposed noise. Whether you are studying for a HND, a first degree, an MBA or postgraduate degree, or a professional qualification, the book covers key topics in an easy to follow and practical way. The alternative collects data from a representative sample of the population and uses this to estimate values for the whole population. Trainee A B C D E F G Interview Job performance 3 1 2 3 6 2 5 4 2 1 4 7 6 5 7 8 Is there a link between the results of interviews and job performance? Do they suggest any patterns of workload? Changes in the objective function The other aspect of sensitivity analysis considers changes to the objective function, expected value =  $\sum (\text{probability of event } x \times \text{value of outcome } x)$  Decision making with risk 4.33 If you spin a coin and win a20 if it comes down heads and lose a40 if it comes down tails: expected value =  $0.5 \times 20 - 0.5 \times 40 = -10$  The expected value of an alternative is the average gain (or cost) when a decision is repeated a large number of times. In this book we illustrate calculations with a generic spreadsheet, which is based on Microsoft Excel. CHAPTER 19 Project management Contents Chapter outline Project planning Network analysis Timing of projects Project evaluation and review technique Chapter review Case study - Westin Contractors Problems Research projects Sources of information 504 505 506 511 521 526 527 528 529 530 Chapter outline A 'project' consists of a set of related activities with a clear start and finish and the aim of making a distinct product. 7.4 When circumstances change significantly or when the old index gets too high. How much should each payment be? Reading the list of data, p4 is the fourth number, 6, p5 is the fifth number, 8 and so on. This gives the general rule that  $(b/mn) = b/mn$ . WORKED EXAMPLE 10.9 Find the deseasonalised trend in the following set of observations using: (a) linear regression (b) moving averages, consumables such as oil, fuel, paper etc. n Solution n With annual payments the interest rate, i, is 0.12 and after 3 years you have 2,000  $\times (1 + 0.12)^3 = 2,809.86$ . The mean squared error is the most widely used. 18.5 C - depending on the economic order quantity. 5 Choose the alternative with the best - the lowest of these highest regrets. IDEAS IN PRACTICE Pengelly's Restaurant Pengelly's is a well-established business near the centre of Cape Town. This has a rather long tail with only 8 observations in the last four classes, and you might be tempted to combine these into one class with 8 observations. Here we consider the situation where they decide to join the queue. The number visiting is around 20, but there is some unexplained variation. After some discussion, Georgina agreed to write a report describing the type of problem that she could tackle. For the expansion they will have to go to the centre, and build another office %55 Queues and simulation Case study continued and waiting area for the new therapist. These are fractions when the bottom line is 100, and the '100' has been replaced by the abbreviation '%'. Then the string: 528477016914356756457930717494317709465825 represents accept, accept, reject, accept, reject and so on. What are the errors in these observations? Maximise: 300G + 200T objective function subject to:  $G + 2T \leq 40$   $2G + T \leq 25$   $T \leq 25$  constraints with  $G \geq 0$  and  $T \geq 0$  non-negativity constraints This illustrates the features of all linear programming formulations, which consist of: n n in decision variables an objective function a set of constraints a non-negativity constraint. Drawing larger networks In principle, you can draw networks of any size, simply by starting at the left-hand side with activities that do not depend on any others. But this negotiation adds subtlety to the calculations, and we no longer have a purely objective measure. 14.7 Wider, External failure costs are the costs of having a unit go through the entire production process and being delivered to a customer, who then finds a fault. Solution This is a straight-line graph with intercept of 20 and gradient of 4, as shown in Figure 3.8. You can also see that: for any point actually on the line,  $y = 4x + 20$  for any point below the line,  $y < 4x + 20$ . So for each branch we find the probability of leaving down the branch, and multiply this by the value of the following node. If your computer says that a company made £140 million profit last year or that a share price rose by 1200% overnight, it might be good news - or you might have some feel for the calculations and realise that there is a mistake. For example, when people have different opinions about some issue, you cannot measure those opinions but you can ask if they agree with a particular statement. In looking logically and objectively at a problem n measure key variables and the results in 'Most of my work is communicating with managers in companies and government offices. Chapter 3 - Drawing graphs 3.1 A variable whose value is set by the value taken by the independent variable. So the first benefit of numbers is that they give a clear measure - and a second benefit is that you can use them in calculations. n A project is defined as a self-contained piece of work that has a clear start and finish. On the morning of the gala she visits the wholesale market and has to decide whether to buy large, medium or small quantities of strawberries, scones, cream and other materials. The idea of a tunnel under the Channel is not new. Sources: BG Annual Reports and websites www.bgroup.com and www.thetimes100.co.uk Solving problems Figure 1.3 The role of modelling in solving a problem 11.12 Managers and numbers Review questions 1.5 Why do managers use models? A common problem with such surveys is choosing an appropriate sample. For example, imagine someone owning a house valued at £200,000 and deciding whether to take out fire insurance at an annual cost of £600. 18.18 B items and probably C items, depending on circumstances, dev. How does this affect the overall project duration? WORKED EXAMPLE 9.4 Offlenta Travel arrange a large number of holidays, and in some of these they make administrative mistakes. Muller M., Essentials of Inventory Management, Jaico Publishing House, Mumbai, 2008. What depreciation rate should the company use with the reducing-balance method, and what is a van's book value each year? To find the mean of a set of values you: n n add all the values together to get the sum divide this sum by the number of values to get the mean. How good is this fit? Lehmann E. All businesses have limited resources and if the constraints are too tight they may prevent a business meeting its target output, taking advantage of opportunities or even covering costs. Source: www.fastlinkolutions.co.uk Value of money over time If you want to buy a house, you can try saving enough money to pay cash - but this will take a very long time, and experience suggests that house prices rise a lot faster than savings. If we reduce the critical path by more than 4, the path G-H-I also becomes critical. If an optimal solution exists for a linear programme, it is at an extreme point of the feasible region. A formal measure for the quality management developed as a separate function to check the output of production departments. By 2008 there were nine major research companies, with Maroco the largest, having won up to 90% of some markets. This gives the most widely used measure of spread, which is the standard deviation. They insist that the agents make errors in Worked example 5.4. Here the bars represent the actual data and the dashed lines represent the expected values? This shows the most widely used measure of spread, which is the standard deviation. 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can say that the process is working as planned and that everything is under control. An entire project may be divided into a number of major parts, represented by an overall network. Experimenting with real operations is at best expensive and at worst impossible, so the only feasible alternative is to build a model and experiment with this. If you buy three bars of chocolate that cost 30 pence each, you know the total cost is 90 pence; if you pay for these with a £5 note you expect £4.10 in change. Figure 9.17 Curve fitting for John Mbulu's accountant's costs An alternative to using appropriate software is to see if the data can be transformed into a linear form. Although it is difficult to go beyond such general guidelines, you should notice one other factor. 4.12 What types of sampling can you use? Tom Geoghegan says, 'The British are uniquely happy to admit being bad at maths'. (a) The consumption of cakes and biscuits in a particular country last year (b) The amount of time people spend on the telephone (c) Potential sales of a new format for PC data storage (d) Likely membership of a new running club (e) Opinions about traffic congestion charges (f) Satisfaction with government policies (g) Views on local government expenditure and financing. Show these figures in a number of different bar charts. 20.9 No - with proper care, artificial data can still have the same features as real data. PA R T O N E Background Managers are the people who run their organisations. We can use the example of the cost of driving a car to illustrate another important point. Young T. Successful Project Management (3rd edition), Kogan Page, London, 2010. These checks focus on materials entering a process and on products leaving the process (as shown in Figure 17.8). 88 Collecting data In business, a more common approach uses random numbers, which are a stream of random digits - such as 5 8 6 4 5 3 0 1 1 7 2. In practice, not all queues involve people and there are many queues of inanimate - and even intangible - objects. Source: Company Reports, La Milla Ferensa, Milan, 2010. Forecast values for the next 5 weeks. So for project A: 500 in year 1 has a present value of  $500 / 1.1 = 454.54$  in year 2 has a present value of  $400 / 1.12 = 330.579$  in year 3 has a present value of  $300 / 1.13 = 225.394$  and so on. Thus, the machine has a residual value of £2,000 at the end of a year, 20% of this is written off for the next year to give a new residual value of  $2,000 \times 0.8 = £1,600$ . Dividing observations in column B by the corresponding values in column C gives the seasonal indices in column D. In recent years, these have had mean annual returns of 9.2%, 17.0% and 14.8% respectively. 13.17 The mean and standard deviation. This is typically set around 5%. So 78, 64, 36, 70 and 52 are data that we 104 Diagrams for presenting data process to give the information that the average mark of five students in an exam is 60%. Each problem needs its own specific model and these can be both large and complex - which means that they can be expensive and time-consuming. Define the population and sampling frame to give primary data. The use of resources is an important part of project planning, with managers generally aiming for a steady work level. Some are outside her control, such as the trends in eating out, national income, and local unemployment. In other words, the observations do not all fall exactly on a line but are somewhere close. Managers have to balance many factors and for this they have to keep a clear picture of a problem. The following table shows the gross domestic product of Germany at current prices for a period of 10 years.





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