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Economic Decisions, Engineering Costs and Cost Estimating

1

1-1

(a) Yes. The choice of an engine has important money consequences and so would be suitable for engineering economic analysis.

(b) Yes. This has important economic—and social—consequences. Some might argue the social consequences are more important than the economics.

(c) There are probably a variety of considerations much more important than the economics.

(d) No. Picking a career on an economic basis sounds terrible.

(e) No. Picking a spouse on an economic basis sounds even worse.

1-2

Of the three alternatives, the $150,000 investment problem is most suitable for economic analysis. There are not enough data to figure out how to proceed, but if the “desirable interest rate” were 9%, then foregoing it for one week would mean an immediate loss of:

1/52 (0.09) = 0.0017= 0.17%

It would take over a year at 0.15% more to equal the 0.17% foregone now.

The candy bar problem is suitable for economic analysis. Compared to the investment problem it is, of course, trivial.

Joe’s problem is a real problem with serious economic consequences. The difficulty may be in figuring out what one gains if he pays for the fender damage, instead of having the insurance company pay for it.

1-3

It is not solely an economic problem—it is a complex problem.

1-4

Since it takes time and effort to go to the bookstore, the minimum number of pads might be related to the smallest saving worth bothering about. The maximum number of pads might be the quantity needed over a reasonable period of time, like the rest of the academic year.

1-5

The overall problems are all complex. The student will have a hard time coming up with examples that are truly simple or intermediate without breaking them into smaller and smaller sub-problems.

1-6

This is a challenging question. One approach might be:

(a) Find out what percentage of the population is left-handed.

(b) What is the population of the selected home-town?

(c) Next, market research might be required. With some specific scissors (quality and price) in mind, ask a random sample of people if they would purchase the scissors. Study the responses of both left-handed and right-handed people.

(d) With only two hours available, this is probably all the information one could collect. From the data, make an estimate.

A different approach might be to assume that the people interested in left handed scissors in the future will be about the same as the number who bought them in the past.

(a) Telephone several sewing and department stores in the area. Ask two questions:

(i) How many pairs of scissors have you sold in one year (or six months or?).

(ii) What is the ratio of sales of left-handed scissors to regular scissor?

(b) From the data in (a), estimate the future demand for left-handed scissors.

Two items might be worth noting.

(1) Lots of scissors are universal, and equally useful for left- and right-handed people.

(2) Many left-handed people have probably never heard of left-handed scissors.

1-7

Some of the alternatives the student might consider are:

(1) Moving to a part of town where rents are lower and accepting a longer commute

(2) Arranging to share accommodation with other students

(3) Taking part-time work to increase the money available for renting

(4) Buying a tent and camping out (may not work well in winter months)

(5) Arranging a loan, to be paid back after graduation

Depending on where the student comes from and where his university is situated, not all of these may be feasible.

1-8

A common situation is looking for a car where the car is purchased from either the first dealer or the most promising alternative from the newspaper’s classified section. This may lead to an acceptable or even a good choice, but it is highly unlikely to lead to the best choice. A better search would begin with *Consumer Reports* or some other source that summarizes many models of vehicles. While reading about models, the car buyer can identify alternatives and clarify which features are important. With this in mind, several car lots can be visited to see many of the choices. Then either a dealer or the classifieds can be used to select the best alternative.

1-9

(a) Maximize the difference between output and input.

(b) Minimize input.

(c) Maximize the difference between output and input.

(d) Minimize input.

1-10

(a) Maximize the difference between output and input.

(b) Maximize the difference between output and input.

(c) Minimize input.

(d) Minimize input.

1-11

Some possible answers:

(1) There are benefits to those who gain from the decision, but no one is harmed (Pareto Optimum).

(2) Benefits flow to those who need them most (welfare criterion).

(3) Minimize air pollution or other specific item.

(4) Maximize total employment on the project.

(5) Maximize pay and benefits for some group (e.g., union members).

(6) Most aesthetically pleasing result.

(7) Fit into normal workweek to avoid overtime.

(8) Maximize the use of the people already within the company.

1-12

Surely planners would like to use criterion (a). Unfortunately, people who are relocated often feel harmed, no matter how much money, etc., they are given. Thus planners may consider criterion (a) unworkable and use criterion (b) instead.

1-13

Major benefits typically focus on better serving future demand for travel measured in vehicles per day (extra market), lower traffic accident rates (extra market), time lost due to congestion (extra market), happy drivers (intangible), and urban renewal of decayed residential or blighted industrial areas (intangible).

Major costs include the money spent on the project (market), the time lost to travelers due to congestion caused by construction (extra market), unhappy drivers (intangible) and the lost residences and businesses of those displaced (intangible).

1-14

(a) Alternatives:

(1) To stay in the dormitory the rest of the year. We will regard this as the baseline case and compare the costs of the other alternatives with it.

(2) Move into an apartment now.

(3) To stay in the dormitory the balance of the first semester and move into an apartment for the second semester.

(b) Costs of alternatives:

1. Baseline, treat this as zero cost.
2. Income: $300/month from student who buys contract, plus $150/month saved on food; Expenditure: $400/month on rent and utilities. So this yields a net saving of $50/month, which adds up to $350 over seven months.
3. Income: $400/month from student who buys contract, plus $150/month saved on food; Expenditure: $400/month on rent and utilities. So this yields a net saving of $150/month, which adds up to $600 over four months

c) Alternative 3 is the most profitable, though Alternative 2 gets Jovis into an apartment more quickly. Our recommendation depends on how urgently he wants to move out of residence.

1-15

The situation is an example of the failure of a low-cost item that may have major consequences in a production situation. While there are alternatives available, one appears so obvious that that foreman discarded the rest and asks to proceed with the replacement.

One could argue that the foreman, or the plant manager, or both are making decisions. There is no single “right” answer to this problem.

1-16

Each student’s answer will be unique, but there are likely to be common threads. Alternatives to their current major are likely to focus on other fields of engineering and science, but answers are likely to be distributed over most fields offered by the university. Outcomes include degree switches, courses taken, changing dates for expected graduation, and probable future job opportunities.

At best criteria will focus on joy in the subject matter and a good match for the working environment that pleases that particular student. Often economic criteria will be mentioned, but these are more telling when comparing engineering with the liberal arts than when comparing engineering fields. Other criteria may revolve around an inspirational teacher or an influential friend or family member. In some cases, simple availability is a driver. What degree programs are available at a campus or which programs will admit a student with a 2.xx GPA in first-year engineering.

At best, the process will follow the steps outlined in this chapter. At the other extreme, a student’s major may have been selected by the parent and may be completely mismatched to the student’s interests and abilities.

Students shouldn’t abandon a major lightly, as changing majors represents real costs in time, money, and effort and real risks that the new choice will be no better a fit. Nevertheless, it is a large mistake to not change majors when a student now realizes the major is not satisfying.

1-17

(1) Recognize problem: I’m going to graduate in one more semester and I need to decide what I’m going to do.

(2) Define the goal or objective: I do not want to move back in with my parents. I would much rather be independent, live on my own, and do something that I enjoy.

(3) Assemble relevant data: How much money do I need to live on my own? Where would it be best for me to live so I can continue with my favourite activities? How important is it that I be close to family? Are jobs available that allow me to do what I enjoy? What types of teaching assistantship are available?

(4) Identify feasible alternatives: Find a job near my hometown or at least in my home province. Apply for graduate assistantships at several universities.

(5) Select the criteria to determine the best alternative: Will I enjoy what I will be doing? Will it provide me with enough money to live comfortably? Will I be able to continue with my favourite activities?

(6) Construct a model: List possible job activities and study topics and assign each a number from 1 to 10 based on personal preference. Make a range of acceptable remuneration and assign a 1 for below range, 2 for within range, and 3 for above range. List favourite activities and assign each a number between 1 and 3 depending on how much you like to do it.

(7) Predict each alternative’s outcomes or consequences: For this scenario there will be two steps here. First, use the model and decision criteria to decide to which jobs and graduate schools to apply. Second, when you receive offers, use the model again.

(8) Choose the best alternative: Choose the job or graduate school offer having the largest number.

(9) Audit the result: In six months reflect on your decision. Are you happy? Have you earned enough money to live comfortably? Are you doing activities that you enjoy?

1-18

Test marketing and pilot plant operation are situations where it is hoped that solving the sub-problems gives a solution to the large overall problem. On the other hand, Example 1-1 (shipping department buying printing) is a situation where the sub-problem does not lead to a proper complex problem solution.

1-19

The criterion will be to maximize net after-tax income considering risk, social and environmental factors, and ethicality.

1-20

The criteria would be legality, balance (equity and fairness), harmfulness to others, ability to live with yourself.

1-21

Student answers will vary depending on their experience. In Table 1-1, the author offers some examples of ethical lapses than can occur at the various steps of the design process. We hope that students will find some examples of laudable ethical decisions as well as lapses.

1-22

(a) Ethical issues that might arise include: (1) excessive road improvements in areas where council or board members live or own property, (2) acquiring land for building a new school in areas where school board members live or own property, (3) approving building improvements that favour the hiring of relatives or using a company owned by one of the school board members, (4) firing a person for personal reasons not related to their job performance, (5) promoting a personal agenda not in step with sound teaching practices or at odds with the vast majority of the scientific community.

(b) Many large cities have City Ethics Commissions to administer and enforce the laws related to government ethics, campaign finance, and lobbyist activities. They may engage in mandated programs, introduce ethic reforms, conduct investigations, audit campaigns, summarize disclosure reports, provide advice about the law, prepare statements of incompatible activities for various departments, boards and commissions, and meet with community groups.

(c) Student answers will vary depending on what they find.

1-23

(a) Ethical issues that might arise include: (1) the road improvement may be intended to benefit a new large business or mall at the expense of existing small businesses who lose business during the construction and/or who suffer parking loss after the construction, (2) local businesses may lose business because commuters can travel through the area much faster, (3) road improvements usually mean widening so local residences and businesses may lose property to the improvement, (4) the road improvement may divert money away from other more cost effective projects, (5) the improvement that mostly aids commuters may, in fact, be paid for by a bond issue that is ultimately paid off by local property and sales taxes.

(b) Student answers will vary depending on what they find.

(c) Many cities have Ethics Boards that can address these issues. Many states allow such boards to be more restrictive than the minimum standards set by state laws.

1-24

Student answers to this question will be highly variable. What follows below is only a sample of what you may expect.

(a) The mostly likely ethical question to arise here is the use of eminent domain to shift the ownership of property from one private party to another. To shift ownership to another private party for indirect public benefits like increased tax revenue is not as clear-cut as shifting ownership from a private party to government, and requires a careful ethical analysis, perhaps using a utilitarian principle, i.e. do the net benefits outweigh the net harm, taking into account all parties concerned.

(b) Student answers will vary depending on what they find. If you need to point to an example, try the recent case of Ontario farmer Frank Meyers versus the federal government.

(c) A recent CBC discussion may be helpful: http://www.cbc.ca/news/canada/windsor/windsor-expropriation-airport-1.3541418

1-25

Student answers to this question will be highly variable depending on what they find.

(a) The most obvious ethical issue would be a conflict of interest where a certain project is promoted that, if funded, would help the company for which the engineer works or has ties to through family, friends or, in the worst case, ownership. Along these lines of favouring a particular company, other conflicts could be relaxation of environmental regulations, special tax considerations, changing fee structures by regulated utilities, etc.

(b) Answers will vary according to province.

(c) Student answers will vary depending on what they find. An example here may be difficult to locate, but looking at the magazine published by the provincial engineering association may be helpful. Such magazines typically report on ethics cases that have come before the Ethics Board of the provincial association.

1-26

Student answers to this question will be highly variable depending on what they find.

(a) Possible ethical conflicts that may arise are: (1) working in a governmental regulatory capacity and having a financial interest in a private concern that the regulations cover, (2) using previous governmental contacts to influence favourable legislation for a private industry, (3) using secret or classified information learned in governmental work to make financial investments after becoming a private citizen, (4) using your influence as a private person on a public works project to promote a favourite but, perhaps, unsafe design, (5) taking a job involving public contracts in which you participated as a public employee.

(b) Most provinces have an Ethics Commission that is at least minimally charged with educating public and former public employees about ethical rules, which, when violated, could lead to civil and criminal penalties.

(c) Student answers will vary depending on what they find. An example here may be difficult to locate.

1-27

Student answers to this question will be highly variable depending on what they find.

(a) Possible ethical and legal conflicts that may arise are: (1) exploitation of workers can be effected by placing them on salary with no extra pay for overtime, (2) workers may “fake” work in order to receive overtime pay, (3) the existence of overtime pay may be used by employers to “force” employees to work longer hours, i.e. “don’t complain, you’re getting paid for it,” (4) an employer may make you work 70 hours one week and only 10 the next but only pay you for a normal 80 hours every two weeks (probably illegal), (5) your employer may fire you for challenging questionable overtime practices (probably illegal).

(b) Answers will vary according to province.

(c) Student answers will vary depending on what they find.

1-28

Student answers to this question will be highly variable. What follows below is only a sample of what you may expect.

(a) Projects may be funded that benefit small numbers of people compared to the proportion of funding required, that benefit a company with ties to the Member of Parliament’s family or friends or in which the MP’s “blind trust” owns stock, that benefit industries that are major polluters, that benefit special interest groups that have helped elect the MP, or that lead to expressways or bridges named after the MP himself!

(b) Student answers will vary depending on what they find.

(c) Student answers will vary depending on the example used.

1-29

Student answers to this question will be highly variable depending on what they find.

(a) Possible ethical conflicts that may arise are: (1) moving an industry to a developing country to take advantage of lax environmental laws, (2) exporting garbage or toxic waste to developing countries, (3) selling products to developing countries that are banned in the west, (4) exploiting developing countries for their oil, timber, and minerals.

(b) Student answers will vary depending on what they find. An example here may be difficult to locate, but the publications and website of Engineers Without Borders may be helpful.

(c) Many binding international agreements concerning international environmental law exist. They cover such topics as atmospheric and water pollution through wildlife and biodiversity protection.

1-30

Student answers to this question will be highly variable depending on what they find.

(a) Possible ethical conflicts that may arise are: (1) moving an industry to a developing country to take advantage of lax health and safety laws, (2) moving an industry to a developing country to take advantage of non-existent child labor laws, (3) agreeing to build a dangerous chemical plant in a foreign country that insists on plant staffing with little educated but supposedly “trained” local workers.

(b) Student answers will vary depending on what they find. An example here may be difficult to locate. Union Carbide’s decision to locate a methyl isocyanate plant in the populous city of Bhopal and the 1984 disaster at that plant would be one extreme example.

(c) Many organizations exist throughout the world that are making an attempt through education and exposure to attack this intractable problem. Some examples are: (1) Office of Health, Safety, and Security in the USA through international studies, (2) National Institute for Occupational Safety and Health Hazards in the UK through publication of a magazine, (3) International Chemical Workers Union Council Center for Worker Health and Safety Education with many consortium members through training and publications, and (4) Clean Clothes Campaign through a code of conduct, publications and international campaigns.

1-31

Student answers to this question will be highly variable depending on what they find.

(a) Possible ethical conflicts that may arise are: (1) a project that disrupts the environment more than intended, say a dam or road, (2) a project that causes disruption of social mores, say mechanized farm machinery where beasts-of-burden have been used for millennia, (3) a project with operating costs that are too high and not sustainable by the indigenous population, such as a sewer system, (4) a project that over stresses the environment, such as too much logging or too many tourists.

(b) Student answers will vary depending on what they find. Again, Engineers Without Borders is a good place to look.

(c) Many national and international organizations offer education and advice related to sustainable development. Some are: US Government’s Sustainable Development Partnerships (SDP), UK’s Sustainable Development Commission, World Business Council for Sustainable Development, European Sustainable Development Network, International Institute for Sustainable Development, etc. Canada had its own government organization for this purpose (the Canada International Development Agency) until it was merged into the Department of Foreign Affairs by the Harper government in 2013.

1-32

Student answers to this question will be highly variable. What follows below is only a sample of what you may expect.

(a) Bribery can cause people to make purchases that do not reward the most efficient producer, can result in substandard or even dangerous products being sold to an unsuspecting public, can degrade the respect one has towards fellow human beings, and can produce cynicism and distrust of institutions.

(b) Student answers to this question will be highly variable depending on what they find. The literature is replete with examples so one should not be hard to locate. The 2017 case of a Bombardier employee in Sweden would be a good example. Most will involve the wanton disregard of any ethical principles in the pursuit of monetary gain.

(c) The Organization for Economic Cooperation and Development (OECD) Convention on Combating Bribery of Foreign Public Officials in International Business Transactions (Anti-bribery Convention) has been ratified by 35 signatories. The main attempt of the OECD is to promote the putting in place and then enforcement of anti-bribery laws under the convention in each of the signing countries.

1-33

The key institutional groups include:

* Contractor: Morton Thiokol designed and built the solid rocket boosters used for the shuttle. They had noted problems during testing concerning the field joint and O-ring long before the Challenger launch. They had seen that the O-ring was leaking and allowing hot gases to escape, thus further degrading the O-ring.
* Government (funding agent): The fate of NASA’s budget is a decision of Congress, and they were not pleased with NASA’s performance at this time. Therefore, NASA felt under pressure to perform.
* European Space Agency (ESA): They were in the process of building a cheaper alternative to the shuttle, exerting additional pressure on NASA and their performance.

The day of the launch was colder than any previous launch. The Thiokol engineers believed that the cold weather would exacerbate the O-ring problems, but there was little data to indicate its dependency on temperature—just the subjective opinion of the engineers. Given no conclusive data, the launch proceeded.

It was unethical to act with inconclusive data. The ethical approach would have been for the engineers to act on their beliefs concerning the safety, health, and welfare of the astronauts. The lack of data should have prompted them to delay until data concerning the question could be compiled. The decision-making processes of NASA were an issue as well, and were reviewed and modified. Decision making should never be left to one person. On critical factors such as this, engineers should have the ability to bring to the table their opinions without feeling that their careers may be jeopardized by raising concerns about a product’s or process’s performance and safety.

1-34

Based on studies, committees, commissions, etc., it was concluded that there were problems with the design of the levee system, but that the Corps of Engineers was not liable, claiming ignorance of the issues in the 1965 time frame. An independent study by the National Science Foundation referenced a 1986 study by the Corps that indicated an awareness of potential problems with the I-Wall design that could lead to separations. An investigative team from Louisiana State University noted that some pilings were driven only 10 or 11 feet into the ground instead of the 25 feet that are needed to maintain strength.

The Army Corps were found to be responsible for the flooding by a court on 19 November 2009. They determined that the Corps did not properly maintain the levees to the necessary standards.

Project engineers should always keep in mind the safety, health, and welfare of the public. The Corps test in 1986, which created a concern regarding potential problems, should have resulted in action to correct the design. The cost to fix would have been difficult to justify, but the consequences, as was observed, were significant.

1-35

Toyota was plagued with reports of sudden acceleration. This resulted in the halt of production of eight of its top-selling cars and the recall of over nine million vehicles. It was reported that the problems were produced by sticky gas pedals or gas pedals that would get stuck due to interaction with the floor mats. The sticky gas pedal problem was believed to be associated with the accelerator’s friction level that may have arisen from condensation and corrosion from the car’s heater. The fix involved lengthening the friction level and changing the linkage materials (lubricants). The gas pedal was shortened to eliminate potential interference with the floor mats.

Toyota has worked hard to restore their reputation by offering incentives to buyers that, in addition to cash rebates, included providing up to two years of free maintenance to new car buyers. This offer to stand by their product helps to restore customers’ faith in the quality of the product.

1-36

The best approach is to construct a matrix showing the payoff for each strategy for each possible distance driven. We note that even the longest distance driven, 800 km, will require only 68 liters of gas, which is within the capacity of the tank.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Distance Driven (KM)** | | |
| **250.00** | **400.00** | **800.00** |
| Gas consumed (L) | 21.25 | 34.00 | 68.00 |
| Return Full (pay $0.97/L) | 20.62 | 32.98 | 65.96 |
| No refuel (pay $1.15/L) | 24.44 | 39.10 | 78.20 |
| Pay $40 | 40.00 | 40.00 | 40.00 |

From this matrix, we see that returning the car with a full tank is always a more profitable strategy than returning it part-full. So we should always use this strategy unless we’re going 800 km, in which case the $40 deal is more attractive.

If we charge $30/4 = $7.50 for the time required to fill up the gas tank, we add a new line to the matrix. Now returning the car part-full is the most attractive option in all cases except the 800 km case, where the $40 deal remains the most attractive.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Distance Driven (KM)** | | |
| **250.00** | **400.00** | **800.00** |
| Gas consumed (L) | 21.25 | 34.00 | 68.00 |
| Return Full | 20.61 | 32.98 | 65.96 |
| Return Full, charge for time | 28.11 | 40.28 | 73.46 |
| No refuel, Pay $1.15/L | 24.44 | 39.10 | 78.20 |
| Pay $40 | 40.00 | 40.00 | 40.00 |

1-37

We begin by assuming that it’s legal to drive at 110 km/hr throughout the trip, so we don’t have to factor in the cost of speeding tickets.

Total Cost = Cost of Gas + Cost of Time Spent on the Road

= (km Driven/km per l)(Cost/l) + (km Driven/Speed)\*(Cost/hr)

= (kms Driven)[ (Cost/l)/(km per l) + (Cost/hr)/(Speed) ]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **$/l** | **$/hr** | **Speed** | **km/l** | **Cost of Gas** | **Cost of Time** | **Total Cost** |
| 0.9 | 18 | 90 | 10.53 | 68 | 160 | 228 |
| 0.9 | 12 | 90 | 10.53 | 68 | 107 | 175 |
| 0.9 | 9 | 90 | 10.53 | 68 | 80 | 148 |
| 1 | 18 | 90 | 10.53 | 76 | 160 | 236 |
| 1 | 12 | 90 | 10.53 | 76 | 107 | 183 |
| 1 | 9 | 90 | 10.53 | 76 | 80 | 156 |
| 1.25 | 18 | 90 | 10.53 | 95 | 160 | 255 |
| 1.25 | 12 | 90 | 10.53 | 95 | 107 | 202 |
| 1.25 | 9 | 90 | 10.53 | 95 | 80 | 175 |
| 0.9 | 18 | 110 | 8.70 | 83 | 131 | 214 |
| 0.9 | 12 | 110 | 8.70 | 83 | 87 | 170 |
| 0.9 | 9 | 110 | 8.70 | 83 | 65 | 148 |
| 1 | 18 | 110 | 8.70 | 92 | 131 | 223 |
| 1 | 12 | 110 | 8.70 | 92 | 87 | 179 |
| 1 | 9 | 110 | 8.70 | 92 | 65 | 157 |
| 1.25 | 18 | 110 | 8.70 | 115 | 131 | 246 |
| 1.25 | 12 | 110 | 8.70 | 115 | 87 | 202 |
| 1.25 | 9 | 110 | 8.70 | 115 | 65 | 180 |

We use this formula to generate the table above, covering all possible cases

1. Comparing Row 1 and Row 10 in the Table, we see that driving at 110 km/hr is cheaper
2. Comparing Row 5 and Row 14, we see that driving at 90 km/hr is cheaper
3. Comparing Row 9 and Row 18, driving at 90 km/hr is cheaper

1-38

The fundamental concept here is that we will trade an hour of study in one subject for an hour of study in another subject so long as we are improving the total results. The stated criterion is to “get as high an average grade as possible in the combined classes.” (This is the same as saying “get the highest combined total score.”)

Since the data in the problem indicate that additional study always increases the grade, the question is how to apportion the available 15 hours of study among the courses. One might begin, for example, assuming five hours of study on each course. The combined total score would be 190.

Decreasing the study of mathematics one hour reduces the math grade by 8 points (from 52 to 44). This hour could be used to increase the physics grade by 9 points (from 59 to 68). The result would be:

|  |  |  |
| --- | --- | --- |
| Math | 4 hours | 44 |
| Physics | 6 hours | 68 |
| Engr. Econ. | 5 hours | 79 |
| Total | 15 hours | 191 |

Further study would show that the best use of the time is:

|  |  |  |
| --- | --- | --- |
| Math | 4 hours | 44 |
| Physics | 7 hours | 77 |
| Engr. Econ. | 4 hours | 71 |
| Total | 15 hours | 192 |

1-39

Area A: We have to include both the cost of buying the inert fill and the cost of hauling it in. However, we are not given the distance over which the inert fill must be hauled, so we will assume that the given figure of $9.40 per cubic meter includes both the purchase of the fill and the cost of hauling it to Area A.

Total Cost = 2 × 106 × $9.40 = $18,800,000

Area B: Difference in Haul

0.60 × 8 km = 8.0 km

0.20 × –3 km = –0.6 km

So on average, choosing Area B will entail an average increase of 7.4 km additional haul per load

Extra time spent per load = additional haul/speed = 7.4 km/25 kph = 0.30 hours

Extra cost per load = 0.3 × $140 = $41.4

14 million cubic meters of rubbish will require 14,000,000/20 loads = 700,000 loads

Total extra cost of moving these loads = $41.4 \* 700,000 = $29,000,000

So Area A is cheaper than Area B by slightly more than $10,000,000

1-40

12,000 liters is 12 cubic meters

Let: L = tank length in meters; r = tank diameter in meters

The volume of a cylindrical tank equals the end area × length:

Volume = Π r2L = 12 m3

So L = 12 /(Π r2)

The total surface area is the two end areas + the cylinder surface area:

S = 2 Π r2 + 2Π rL

Substitute for L:

S = 2Π r2 + 2Πr (12/(Πr2)

= 2Πr2+24r−1

Take the first derivative with respect to r and set it equal to zero:

dS/dr = 4Πr – 24r−2 = 0

4Πr = 24/r2

r3 = 6/Π

r = 1.24 meters

Substitute back to find L:

L = 12/(Π r2) = 2.48 meters

Check: Volume = Π r2L = Π x 1.242 x 2.48 = 12 m3, as required

Tank diameter = 2.48 meters

Tank length = 2.48 meters

1-41

Profit = Income – Cost

= PQ – C where PQ = 35Q − 0.02Q2

C = 4Q + 8,000

d(Profit)/dQ = 31 − 0.04Q = 0

Solve for Q:

Q = 31/0.04 = 775 units/year

d2 (Profit)/dQ2 = –0.04

The negative sign indicates that profit is maximum at Q equals 775 units/year.

Answer: Q = 775 units/year

1-42

Skilled workers: $33.00 × 2.6 hours = $85.80/unit

Team Assembly: 4 × $19.00 × 1.0 hrs = $76.00/unit

Team Assembly is less expensive.

1-43

Let t = time from the present (in weeks)

Volume of apples at any time = (1,000 + 120t − 20t)

Price at any time = $3.00 − $0.15t

Total Cash Return (TCR) = (1,000 + 120t − 20t) ($3.00 – $0.15t)

= $3,000 + $150t − $15t2

This is a minima–maxima problem.

Set the first derivative equal to zero and solve for t.

dTCR/dt = $150 – $30t = 0

t = $150/$30 = 5 weeks

d2TCR/dt2 = –10

(The negative sign indicates the function is a maximum for the critical value.)

At t = 5 weeks:

Total Cash Return (TCR) = $3,000 + $150 (5) – $15 (25) = $3,375

1-44

(a) The suitable criterion is to maximize the difference between output and input. Or simply, maximize net profit. The data from the graphs may be tabulated as follows:

|  |  |  |  |
| --- | --- | --- | --- |
| **Output Units/Hour** | **Total Cost** | **Total Income** | **Net Profit** |
| 50 | $300 | $800 | $500 |
| 100 | $500 | $1,000 | $500 |
| 150 | $700 | $1,350 | $650 ← |
| 200 | $1,400 | $1,600 | $200 |
| 250 | $2,000 | $1,750 | $–250 |

$200

$400

$600

$800

$1,000

$1,200

$1,400

$1,600

$1,800

$2,000

50 100 150 200 250

Output (units/hour)

0

Cost

Cost

Profit

Loss

(b) Minimum input is, of course, zero, and maximum output is 250 units/hour (based on the graph). Since one cannot achieve maximum output with minimum input, the statement makes no sense.

1-45

(a) 500 parts

Average cost = $13

Marginal cost = $13

(b) 1500 parts

Average cost = ((1000)($13) + (500)($12)) / 1500 = $ 12.67

Marginal cost = $12

(c) 2500 parts

Average cost = ((1000)($13) + (1500)($12)) / 2500 = $12.40

Marginal cost = $12

(d) 3500 parts

Average cost = ((1000)($13) + (2000)($12) + 500($11)) / 3500 = $12.14

Marginal cost = $11