Chapter 1: Making Economic Decisions

1-1

There are a variety of possible answers to this question. Some examples are listed below.

Simple Problems: Should I…
- have cereal or toast for breakfast?
- park in this tight spot or a larger one three spots further?
- take my book to class or leave it in my room?

Intermediate Problems: Should I…
- repair the transmission in my 10 year old car for $3,800 or buy a used car to replace it?
- buy new tires with a 75,000 mile warranty at $140 each or the tires with a 45,000 mile warranty at $85 each?
- purchase a meal plan for the semester, buy groceries and cook myself, or a combination of the two using a lower volume meal plan?

Complex Problems: Should I…
- take a job in a big city in Texas at $65,000 (no state tax, long commutes, more social opportunities, etc.) or a job in a smaller city such as Mississippi at $62,000 (state tax, short commutes, closer to hometown, etc.)?

They may find that their approach to decision making for more intermediate and complex problems does not adequately consider all the factors. This course should give them the tools to make better decisions.

1-2

a) Yes. Selecting a hybrid versus a traditional combustion engine has important money and tax consequences, so it would be suitable for engineering economic analysis.

b) Yes. This situation involves important economic and social consequences. Some may argue that the social consequences are more important than the economics.

c) No. There is probably a variety of considerations much more important than the economics.

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

e) Yes. Some financial factors that could be considered include the loan amount and interest rate, your starting salary level, the amount of time your graduation is delayed and the impact of the delay on lifetime earnings. However, a non-financial factor that should not be overlooked is the impact of working on academic performances that could ultimately impact your chance of getting a job and increase your starting salary.

f) Yes. There are definite aspects to both options that can be evaluated economically.

1-3

Of the three alternatives, the $150,000 investment problem is the most suitable for economic analysis. There is not enough data to figure out how to proceed, but if the "desirable interest rate" was 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 sandwich shop 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.

1-4

Gambling, the stock market, drilling for oil, hunting for buried treasure—there are sure to be a lot of interesting answers. Note that if you could double your money every month, then:

2^x ($1,000) = $1,000,000

and x is less than 10 months.

1-5

There is nothing inherently wrong with writing a book to try to make money. However, if the author has no expertise on the book's topic (make millions) then it is an ethical issue if they are sharing ideas and concepts that are not true or have not been proven, or they are making false statements. If the person has in fact become a millionaire as a result of the methods and strategies expressed in the book then it would be acceptable.

1-6

It may look simple to the owner because he is not the one losing a job. For the three machinists it represents a major event with major consequences.

1-7

The design of a chair can become complex due to the fact that there may be competing tradeoffs that must be considered. For example, when designing a chair the material(s) from which it is made of directly impact cost, durability, and aesthetics. The selected materials, chair geometry, part tolerances, and overall finish (paint, upholstered, lacquer, etc.) define what, and the number of manufacturing processes that will be required to make the chair. We could cut corners to reduce costs, but at some point the life of the chair and some aspects of safety are impacted. Where do we draw the line? Given that there are often multiple manufacturing processes we could use to make some part of the chair (seat pan) and sometimes these alternatives may have different environmental concerns (e.g., emissions, non-recyclable waste, etc.). Ethically, we must make a decision as to the costs we are willing to pay to help the environment.

1-8

This problem is not solely an economic problem — it is a complex problem. The economic viability of the communities can be greatly impacted due to the loss of jobs.

1-9

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.

1-10

While there may be plenty of disagreements on the “correct” answer, only (c) the problem addressing car insurance represents a substantial amount of money as well as a situation in which money might be the primary basis for choosing between alternatives.

1-11

a) The overall problems are all complex. The student will have a hard time coming up with examples that are truly simple or intermediate until he/she breaks them into smaller and smaller subproblems.
b) Yes, this does come into play. The idea of building an automotive plant in an area impacts the residents in the area. Some residents will make money on land sale while the others will see a decrease in property value based on their proximity to the property. As well, there are great economic benefits for the overall area in terms of commerce, and increase in real-estate not in close proximity for worker housing. Such a plant will also attract other industries (tier suppliers).

1-12

These questions will create disagreements. None of the situations represents rational decision making.

Choosing the same career as a friend may be okay, but it doesn't seem too rational.

Jill did not consider all the alternatives.

Don thought he was minimizing cost, but it did not work. Maybe rational decision making says one should buy better tools that will last.

1-13

Possible objectives for NASA can be stated in general terms of space exploration or the generation of knowledge or they can be stated in very concrete terms. President Kennedy used the latter approach with a year for landing a man on the moon to inspire employees. Thus the following objectives as examples are concrete in nature. No year is specified here, because unlike President Kennedy we do not know what dates may be achievable.

Safely land a man safely on Mars and return him to earth by———.
Establish a colony on the moon by———.
Establish a permanent space station by———.
Support private sector tourism in space by———.
Maximize fundamental knowledge about science through *x* probes per year or for *$y* per year.
Maximize applied knowledge about supporting man's activities in space through *x* probes per year or for *$y* per year.

Choosing among these objectives involves technical decisions (some objectives may be prerequisites for others), political decisions (balance between science and applied knowledge for man's activities), and economic decisions (how many dollars per year can be allocated to NASA).

However, our favorite is a colony on the moon, because a colony is intended to be permanent and it would represent a new frontier for human ingenuity and opportunities. Evaluation of alternatives would focus on costs, uncertainties, and schedules. Estimates of these would rely on NASA's historical experience, expert judgment, and some of the estimating tools discussed in Chapter 2.

1-14

This is a challenging question. One approach may be:

a) Determine if such an event has occurred in the past and see if you can get information on the number of people that participated, as well as the type of event it was and the season (date) in which it was held.
b) Estimate the participation in this event based on a comparison with previous events while taking into consideration their participation numbers, type of event, and date, as well as weather conditions.
c) You could also perform a quick market research study by asking a random sample of people on-campus if they would participate in the event and then extrapolate out this value based on the student body population.
d) With only two hours available, this is probably all the information one could collect. From the data, make an estimate.

1-15

Possible alternatives may include:

1. Live at home.
2. Live in a room in a private home in return for work in the garden, etc.
3. Become a Resident Assistant in a university dormitory.
4. Live in a camper — or tent — in a nearby rural area.
5. Live in a trailer on a construction site in return for "keeping an eye on the place."

1-16

There are a variety of possible answers you may receive. You will want to see what alternatives were ignored and see if the student identifies why it would have been a viable alternative.

1-17

Choose the better of the undesirable alternatives.

1-18

a) Maximize the difference between output and input.
b) Minimize input.
c) Maximize the difference between output and input.
d) Minimize input.

1-19

a) Maximize the difference between output and input.
b) Maximize the difference between output and input.
c) Minimize input.
d) Minimize input.

1-20

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.

1-21

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 consider criterion (a) unworkable and use criterion (b) instead.

1-22

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 construction caused congestion (extra market), unhappy drivers (intangible), and the lost residences and businesses of those displaced (intangible).

1-23

The extra direct costs would be two nights to stay at the hotel as well as two days' of meals or (2) ($200 + $40) = $480. The savings on the airplane ticket would be $550 ($800 - $250). Thus, staying the extra two days saves $70 ($550 – $480). The non-economic factors will probably be associated with your personal life (e.g., a dinner and bridge party with friends missed on Friday evening, your daughter's soccer game missed on Saturday morning, the lawn not mowed on Saturday afternoon, a Church service missed on Sunday morning, etc.). These may be missed without drastic consequences. However, you may have a golf/business game with a client scheduled on Saturday afternoon that could have consequences related to your job and perhaps worth the $70 extra expense.

1-24

(a) and (b) – The three alternatives and their costs are:

1. To stay in the dormitory the rest of the year
   Food: 7 months at $350/month = $2,450

2. To stay in the dormitory the balance of the first semester; apartment for second semester (consider person paying $2,500 for second semester)
   Housing: 4½ months × $450 apartment − $2,800 dorm = -$775
   Food: 2½ months × $350 + 4½ × $300 = $2,225
   Total = $1,450
3. Move into an apartment now
   Housing: 7 months × $450 apartment – 7 × $500 dorm = -$350
   Food: 7 months × $400 = $2,100
   Total = $1,750

(c) He should stay in the dormitory for the rest of this semester and then move into an apartment. This alternative (#2) is the lowest cost.

1-25

This 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.

1-26

a) Considering only direct costs:
Plan A: Profit = Income − Cost = $1,200 – $750 = $450/acre
Plan B: Profit = Income − Cost = $1,400 – $800 = $600/acre
Plan C: Profit = Income − Cost = $1,500 – $1,000 = $500/acre
Plan D: Profit = Income − Cost = $1,650 – $1,300 = $350/acre

To maximize profit, choose Plan B.

b) Considering both direct and extra-market costs:
Plan A: Profit = Income − Cost = $1,200 – $750 - $150 = $300/acre
Plan B: Profit = Income − Cost = $1,400 – $800 - $450 = $150/acre
Plan C: Profit = Income − Cost = $1,500 – $1,000 - $250= $250/acre
Plan D: Profit = Income − Cost = $1,650 – $1,300 - $200 = $150/acre

To maximize profit, choose Plan A.

1-27

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 its best, the 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 informative 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 should not lightly abandon a major, as changing majors represents real costs in time, money, and effort, as well as real risks that the new choice will be not better a fit. Nevertheless, it is a large mistake to not change majors when a student realizes the major is not for them.

1-28

The most common large problem faced by undergraduate engineering students is where to look for a job and which offer to accept. This problem seems ideal for listing student ideas on the board or overhead transparencies. It is also a good opportunity for the instructor to add more experienced comments.

1-29

An example goal might be to pay off my house in 10 years after purchase:

1. Recognize the problem – Paying mortgage interest is like throwing away money. I need to pay off my house to eliminated debt and provide security.
2. Define the goal or objective – Pay off my mortgage in 10 years.
3. Assemble relevant data – Such data would include: What interest rates are available for the different types of available mortgages? What tax break do I get on mortgage interest? What interest rate can I make on the extra money I would put toward my house instead of investing? What value do I place on being out of debt?
4. Identify feasible alternatives – Get a 10-year mortgage when I purchase the home. Get a 15, 20, or 30-year mortgage and make extra payments? Should it be a fixed-rate versus an adjustable-rate mortgages?
5. Select the criteria to determine the best alternative – Will I be able to afford the mortgage payments? What emergency cash reserves will I have? Will it leave me with enough money to live on? Will I be able to continue with my favorite activities?
6. Construct a model – Create an amortization table for each possible loan. Build a worksheet that lists annual income, tax benefits, potential expenses, etc. to evaluate each alternative.
7. Predict each alternative's outcomes or consequences – Look at the tabulated results and consider other potential factors that have not been accounted for, as well as the uncertainty in any estimated values.
8. Choose the best alternative – Choose the mortgage option that best meets your criteria.
9. Audit the result – Reflect on your decision in six months. Are you happy? Have you earned enough money to live on? Are you doing extracurricular activities that you enjoy?

1-30

Test marketing and pilot plant operations 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.

1-31

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

1-32

Ethics consists of standards of behavior, conduct, and moral judgment.

1-33

Some ethical aspects to consider if a person were to take the second offer:

- Acceptance of the offer means you have stated that you are committed to come work for the employer following your graduation. If you take the second offer then you are "breaking" your commitment. A person's integrity has been compromised at this point.
- The person should ask themselves: "If I were in the position of the first company and a candidate did this to me, how would I feel?
- There would be a good chance that the candidate would be giving up the opportunity to work with that company in the future, or any other company that may get hear of the decision that you made.

1-34

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

1-35

a) The IEEE Code of Ethics emphasizes: (1) responsibility in decision making consistent with safety, health and welfare of the public, and avoiding endangerment of the public and environment, (2) avoiding conflicts of interest, (3) being honest when using data, (4) rejecting bribery, (5) improving understanding of technology, (6) maintaining and improving technical competence, (7) honest criticizing of technical work and proper crediting the contributions of others, (8) treating all people fairly, (9) avoiding injury to others by false or malicious action, and (10) assisting others in their professional development.

b) The NSPE Code of Ethics is much more detailed than IEEE's code. All of the items listed above are covered in one way or another in the NSPE code. The NSPE code includes much more detail about the conduct of an engineer in his employment, the disclosure of his work, his interactions with other firms, and his interactions with the public.

1-36

Student answers will vary depending on their experience or what they find. In Table 1-1, the author offers some excellent examples of ethical lapses that can occur during the various steps of the design process. It would be hoped that some positive ethical occurrences (i.e., opposites of lapses) will be included in their analyses.

1-37

a) Ethical issues that might arise include: (1) excessive road improvements in areas where assembly 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 favors 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) Student answers will vary depending on what they find.
c) Student answers will vary depending on what they find.

1-38

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) Student answers will vary depending on what they find.

1-39

a) Ethical issues that might arise include: (1) determining the location such that persons involved in the decision (or relatives thereof) benefit from increased land prices or the resulting increase in business located nearby, (2) construction of a large facility usually means local residences and businesses may lose property to the project, (3) approving construction firms that are owned by persons involved (or relatives thereof).
b) Student answers will vary depending on what they find.
c) Student answers will vary depending on what they find.

1-40

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

a) It would seem that the most likely ethical question to arise is the use of eminent domain to shift the ownership of property from one private party to another. It is well established in the U.S. Constitution that the Federal Government (5th amendment) and State Governments (14th amendment) can take private property for "public use" provided there is "just compensation." However, to shift ownership to another private party for indirect benefits such as increased taxes is not as clear cut and would seem to require an ethical analysis perhaps using a utilitarian principle (i.e., do the benefits outweigh the disbenefits for all parties concerned?).
b) Student answers will vary depending on what they find. If you need to point to an example, try the recent New Trumbell, Connecticut case.
c) Student answers will vary depending on what they find.

1-41

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 favoring a particular company, other conflicts could be relaxation of environmental regulations, special tax considerations, changing fee structures by regulated utilities, etc.
b) Student answers will vary depending on what they find.
c) Student answers will vary depending on what they find. An example here may be difficult to locate.

1-42

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 favorable 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 favorite but, perhaps, unsafe design, (5) taking a job involving public contracts in which you participated as a public employee.
b) Student answers will vary depending on what they find.
c) Student answers will vary depending on what they find. An example here may be difficult to locate.

1-43

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

1-44

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) legislators may pass laws favorable to large campaign donors, (2) lobbyists may present unfounded "facts" when arguing for favorable action, (3) lobbyists may provide favors (airplane travel, vacations, campaign money, etc.) to obtain desired legislation, (4) advocacy organizations may prepare documents that are one-sided and ignore or distort relevant scientific data, (5) legislators may expend taxpayer funds for unapproved purposes.
b) Student answers will vary depending on what they find.
c) Student answers will vary depending on what they find.

1-45

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 congressman's family or friends or in which the congressman's "blind trust" owns stock, that benefit industries that are major polluters, that benefit special interest groups that have helped elect the congressman, or that lead to expressways or bridges named after the congressman himself!
b) Student answers will vary depending on what they find.
c) Student answers will vary depending on what they find.

1-46

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 third-world country to take advantage of lax environmental laws, (2) exporting garbage or toxic waste to underdeveloped countries, (3) selling insecticides to third-world countries that are banned in the west, (4) exploiting third-world 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.
c) Student answers will vary depending on what they find.

1-47

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 third-world country to take advantage of lax health and safety laws, (2) moving an industry to a third-world 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.
c) Student answers will vary depending on what they find.

1-48

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 (e.g., a dam or road), (2) a project that causes disruption of social mores (e.g., mechanized farm machinery where beasts of burden have been used for millennia), (3) a project with too high of operating costs that are not sustainable by the indigenous population (e.g., a sewer system), (4) a project that over-stresses the environment (e.g., too much logging or too many tourists).
b) Student answers will vary depending on what they find. An example here may be difficult to locate.
c) Student answers will vary depending on what they find.

1-49

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, it can result in substandard or even dangerous products being sold to an unsuspecting public, it can degrade the respect one has towards fellow human beings, and it may produce cynicism and distrust of institutions.
b) Student answers will vary depending on what they find.
c) Student answers will vary depending on what they find.

1-50

a) Ford certainly did NOT hold paramount the safety, health, and welfare of the public. Their public statements at the time certainly were NOT objective and truthful as they continued to claim that the Pinto was a safe automobile to drive. They did NOT avoid deceptive acts. Finally, they did NOT conduct themselves honorably, responsibly, and ethically (although perhaps they were lawful). One would like to believe that the Pinto disaster was only due to management decisions and that engineers were not involved in the deception.
b) It would seem that the “greatest good” was limited to the company itself. The “greatest number” were the owners of the Pinto.
c) This is the “ultimate question” that you as an engineer dread! The best first thing to do is to reveal the problem through all available channels within the company - leave no legitimate way untried. The second, assuming you are being thwarted by a mid-level manager, is to go as close to the top as you can without being anonymous. A last resort, assuming the defect can result in injury to humans, is to whistle blow outside the company but beware of the potential negative consequences to your future.

1-51

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 allowing hot gases to escape 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 point in 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 magnify the O-ring problems; however, there was no data to indicate its dependency on temperature, just the subjective opinion of the engineers. Given no conclusive data, the launch can proceed.

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 are 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 the performance of a product or processes and safety.

1-52

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 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 Nov. 19, 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 creating a concern due to 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 were observed) were significant.

1-53

Ignoring the possibility of such events is not prudent, while over-engineering to prepare for them can be quite costly. Exploring cost effective measures to combat the impact of extreme weather should be considered for bridges, subways, tunnels, etc. Let us look specifically at electric systems and water treatment plants.

When areas impacted by storms are shut down there is an economic impact to our nation overall. Given our reliance on electricity for just about every aspect of life and business, our electrical systems become critical components of infrastructure that deserve such preservation efforts. Even within such extreme events, the electrical infrastructure is key to such emergency related entities as police stations, fire stations, hospitals, and 911 facilities. For example, Florida Power and Light (FPL) has stated they want to improve the overall resiliency of the electrical system for their customers and will invest nearly $500M over a three-year period towards this effort (starting in 2013). They hope that such efforts will help to prevent storm-related outages, as well as speed restoration following severe weather.

Water infrastructure directly impacts public health and the environment. Decisions in this area must take into consideration the affect storms have on the availability of safe drinking water and eliminating the possibility that wastewater threaten public health. As well, we need to keep in mind that much of the infrastructure was built long ago and in locations that today may be somewhat questionable when evaluating their resiliency to such storms. Therefore, when considering upgrades and major innovations, it is important to consider the possibility of relocating facilities further from shorelines. Such consideration of “safe locations” should be incorporated into the zoning laws of cities to affect future projects.

When looking at these types of issues from an economic perspective, how does one assign value to such issues as “down-time” both during and after the storm, drinking water availability, environmental impact, and loss of human life? This inability makes it difficult to talk about what actions and expenditures are justifiable from an economic perspective.

1-54

Basis: 1,000 pieces

Individual Assembly: $32.00 × 2.7 hours × 1,000 = $86,400	$86.40/unit
Team Assembly: 5 × $22.00 × 0.8 hours × 1,000 = $88,000	$88.00/unit

Individual Assembly is less expensive.

1-55

a) Each firm will save the expenses of two trips:
Saving = 2 [$275.00 + (2 × 90 miles) ($1.20/mile)] = $982.00/week

b) Considering that the travel of an empty truck is still business travel:
Saving = 2 [$275.00 + (2 × 90 miles) ($1.20 + $0.20/mile)] = $1,054.00/week

1-56

3,600 gallon capacity = 3,600 gallons/7.48 gal/ft^3 = 481.3 cubic ft. capacity

Let: L = tank length in feet
d = tank diameter in feet

The volume of a cylindrical tank equals the end area × length:
Volume = $(\pi/4)\, d^2 L = 481.3\ ft^3$
$L = (481.3 \times 4)/(\pi d^2)$

The total surface area is the two end areas + the cylinder surface area:
$S = 2\,(\pi/4)\, d^2 + \pi\, d\, L$

Substitute in the equation for L:
$S = (\pi/2)\, d^2 + \pi\, d\, [(481.3 \times 4)/(\pi\, d^2)]$
$= (\pi/2)\, d^2 + 1{,}925.13 d^{-1}$

Take the first derivative and set it equal to zero:
$dS/dd = \pi\, d - 1{,}925.13 d^{-2} = 0$
$\pi\, d = 1{,}925.13/d^2$
$d^3 = 1{,}925.13/\pi = 612.79$
$d = 8.5$ ft

Substitute back to find $L = (481.3 \times 4)/(\pi\, d^2) = 1{,}925.13/(\pi (8.5)^2) = 8.5$ ft

<u>Tank diameter = 8.5 ft and Tank length = 8.5 ft</u>

1-57

	A	B	C	D	E	F
4	Time Period	Daily Sales in Time Period	Cost of Groceries	Hours in Period	Wage Cost for Period	Hourly Profit
5	0600–0700	$40	$26	1.0	$23	-$9
6	0700–0800	$70	$46	1.0	$23	$2
7	0800–0900	$120	$78	1.0	$23	$19
8	0900–1200	$400	$260	3.0	$69	$24
9	1200–1500	$450	$293	3.0	$69	$30
10	1500–1800	$500	$325	3.0	$69	$35
11	1800–2000	$600	$390	2.0	$46	$82
12	2000–2200	$200	$130	2.0	$46	$12
13	2200–2300	$50	$33	1.0	$23	-$6
14	2300–2400	$85	$55	1.0	$23	$7
15	2400–0100	$40	$26	1.0	$23	-$9

Hourly Profit = (Daily Sales – Cost of Groceries – Wage Cost)/Hours in Period

The first profitable operation is in 0700–0800 time period. In the evening the 2200–2300 time period is unprofitable, but next hour's profit barely covers the loss.

Conclusion: Open at 0700, close at 2200. Given the low profit level in the first hour, it would be wise to monitor the first hour to be sure it is a profitable period.

1-58

Itemized expenses: $0.325/mile × 15,000 miles + $3,650 = $8,525
Based on Standard Mileage Rate: $0.545/mile × 15,000 miles = $8,175

Itemized expenses produces a larger reimbursement than using standard mileage.

Breakeven: Let x = mileage at which both methods yield the same amount.

x = $3,650/($0.545 – $0.325) = 16,591 miles

1-59

The car can be driven: 25 mpg*20 gal = 500 miles
Three options exist:

1. Return it with a full gas tank. So we must pay for gas to fill it up at market rate of $3.50/gallon.
2. Return it without filling it and pay $5.75/gallon. So company fills the tank and we pay their rate of $5.75/gallon.
3. Accept a fixed price of $60 for the gas

a) Drive 150 miles:
Consumed: 150 miles/25 mpg = 6 gallons
Option 1 Cost: 6 gal * $3.5/gal = $21.00
Option 2 Cost: 6 gal * $5.75/gal = $34.50
Option 3 Cost: $60
Option 1 is best.

b) Drive 300 miles:
Consumed: 300 miles/25 mpg = 12 gallons
Option 1 Cost: 12 gal * $3.50/gal = $42.00
Option 2 Cost: 12 gal * $5.75/gal = $69.00
Option 3 Cost: $60
Option 1 is best.

c) Drive 450 miles:
Consumed: 450 miles/25 mpg = 18 gallons
Option 1 Cost: 18 gal * $3.50/gal = $63.00
Option 2 Cost: 18 gal * $5.75/gal = $103.50
Option 3 Cost: $60
Option 3 is best.

d) Considering our time to fill 20 min at $15/hr will add $5 to the cost of option 1 in each case.
Drive 150 miles: Option 1 Cost is $26 – Option 1 remains the best option
Drive 300 miles: Option 1 Cost is $47 – Option 1 remains the best option
Drive 400 miles: Option 1 Cost is $68 – Option 3 remains the best option

1-60

Total Cost = Cost of Gas + Cost of Time Spent on the Road
= (Miles Driven/Miles per gal)(Cost/gal) + (Miles Driven/Speed)*(Cost/hr)
= (Miles Driven)[(Cost/gal)/(Miles per gal) + (Cost/hr)/(Speed)]

a) Cost (60 mph) = (525 miles) [($3/gal)/(29mpg)+($18/hr)/(60mph)] = $211.81
Cost (70 mph) = (525 miles) [($3/gal)/(25mpg)+($18/hr)/(70mph)] = $198.00

$/gal	$/hr	Speed	MPG	Cost of Gas	Cost of Time	Total Cost
$3	$18	60	29	$54.31	$157.50	$211.81
$3	$18	70	25	$63.00	$135.00	**$198.00**
$4	$12	60	29	$72.41	$105.00	$177.41
$4	$12	70	25	$84.00	$90.00	**$174.00**
$5	$9	60	29	$90.52	$78.75	**$169.27**
$5	$9	70	25	$105.00	$67.50	$172.50

a) Driving at 70 mph is cheaper
b) Driving at 70 mph is cheaper
c) Driving at 60 mph is cheaper
d) Worksheet is given below.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	525	Distance											
2	29	MPG at		60	mph								
3	25	MPG at		70	mph								
4	Formula for cell D9			=$A$1*B9/$A$2									
5	Formula for cell E9			=$A$1*A9/C9									
6	Formula for cell F9			=D9+E9									
7													
8	$/hr	$/gal	Speed	Cost of Gas	Cost of Time	Total Cost		$/hr	$/gal	Speed	Cost of Gas	Cost of Time	Total Cost
9	$6	$2	60	$36.21	$52.50	$88.71		$6	$2	70	$42.00	$45.00	$87.00
10	$6	$3	60	$54.31	$52.50	$106.81		$6	$3	70	$63.00	$45.00	$108.00
11	$6	$4	60	$72.41	$52.50	$124.91		$6	$4	70	$84.00	$45.00	$129.00
12	$6	$5	60	$90.52	$52.50	$143.02		$6	$5	70	$105.00	$45.00	$150.00
13	$9	$2	60	$36.21	$78.75	$114.96		$9	$2	70	$42.00	$67.50	$109.50
14	$9	$3	60	$54.31	$78.75	$133.06		$9	$3	70	$63.00	$67.50	$130.50
15	$9	$4	60	$72.41	$78.75	$151.16		$9	$4	70	$84.00	$67.50	$151.50
16	$9	$5	60	$90.52	$78.75	$169.27		$9	$5	70	$105.00	$67.50	$172.50
17	$12	$2	60	$36.21	$105.00	$141.21		$12	$2	70	$42.00	$90.00	$132.00
18	$12	$3	60	$54.31	$105.00	$159.31		$12	$3	70	$63.00	$90.00	$153.00
19	$12	$4	60	$72.41	$105.00	$177.41		$12	$4	70	$84.00	$90.00	$174.00
20	$12	$5	60	$90.52	$105.00	$195.52		$12	$5	70	$105.00	$90.00	$195.00
21	$15	$2	60	$36.21	$131.25	$167.46		$15	$2	70	$42.00	$112.50	$154.50
22	$15	$3	60	$54.31	$131.25	$185.56		$15	$3	70	$63.00	$112.50	$175.50
23	$15	$4	60	$72.41	$131.25	$203.66		$15	$4	70	$84.00	$112.50	$196.50
24	$15	$5	60	$90.52	$131.25	$221.77		$15	$5	70	$105.00	$112.50	$217.50
25	$18	$2	60	$36.21	$157.50	$193.71		$18	$2	70	$42.00	$135.00	$177.00
26	$18	$3	60	$54.31	$157.50	$211.81		$18	$3	70	$63.00	$135.00	$198.00
27	$18	$4	60	$72.41	$157.50	$229.91		$18	$4	70	$84.00	$135.00	$219.00
28	$18	$5	60	$90.52	$157.50	$248.02		$18	$5	70	$105.00	$135.00	$240.00

1-61

Area A: Preparation Cost = $2 \times 10^6 \times \$9.40 = \$18{,}800{,}000$

Area B: Difference in Haul
0.60 × 5 miles = 3.0 miles
0.20 × –2 miles = –0.4 miles
0.20 × 0 = 0 miles
Total = 2.6 miles average additional haul

Cost of additional haul/load = 2.6 mi/25 mph × \$210/hr = \$21.84

Since truck capacity is 20 m^3:
Additional cost/cubic yard = \$21.84/20 m^3 = \$1.0924/m^3

For 14 million cubic meters:
Total Cost = $14 \times 10^6 \times \$1.092 = \$15{,}288{,}000$

Area B with its lower total cost is preferred.

1-62

Profit = Income – Cost
= PQ – C
where: $PQ = 475Q - 0.25Q^2$
$C = 48Q + 22{,}500$

Profit = $427Q - 0.25Q^2 - 22{,}500$
$d(\text{Profit})/dQ = 427 - 0.50Q = 0$

Solve for Q:
$Q = 427/0.5 = 854$ units/year

$d^2(\text{Profit})/dQ^2 = -0.50$

The negative sign indicates that profit is maximum at Q equals 854 units/year.
Answer: Q = 854 units/year

1-63

Quantity Sold/Week	Selling Price	Income	Cost	Profit
300	$1.20	$360	$225	$135
600	$0.90	$540	$450	$90
1200	$0.80	$960	$756	$204
1800	$0.66	$1,188	*$990	$198
1800	$0.66	$1,188	**$960	$228
2300	$0.52	$1,196	$1,104	$92

* buy 1,800 packages at $0.55 each

** buy 2,000 packages at $0.48 each (if we sell more than the 1800, then we will improve our profit further). The $228 profit is if we just sell 1800 units.

	A	B	C	D	E	F	G	H	I
1	Quantity Sold/Week	Selling Price	Income	Cost	Profit				
2	300	$1.20	$360	$225	$135				
3	600	$0.90	$540	$450	$90				
4	1200	$0.80	$960	$756	$204				
5	1800	$0.66	$1,188	$990	$198				
6	1800	$0.66	$1,188	$960	$228				
7	2300	$0.52	$1,196	$1,104	$92				
8									
9	Formula in cell C2 is		=A2*B2						
10	Formula in cell D2 is		=IF(A2<1000,A2*0.75,IF(A2<1500,A2*0.63,IF(A2<2000,A2*0.55,A2*0.48)))						
11	Formula in cell E2 is		=C2-D2						
12	Formula in cell D6 is		=2000*0.48	(Buy 2000 and sell or discard 250 of them)					

Conclusion: Based on just the 5 quantity levels, best profit ($204) is obtained at 1200 packages. However, if we buy 2000 units at $0.55 each, and just sell 1800 at $0.66 each, our profit goes up to $228. We can sell the extras for even more profit.

1-64

	A	B	C	D	E	F
1	50	Total Number of Rooms				
2	$16	Actual Cost/room				
4			Net	Outcome		
5	Alternative	Price	Income per Room	Occ. Rate	No. Rooms	Net Income
6	1	$65	$49	100%	50	$2,450
7	2	$72	$56	93%	46	$2,576
8	3	$79	$63	82%	41	$2,583
9	4	$86	$70	68%	34	$2,380
10	5	$78	$62	72%	36	$2,232
11	6	$85	$69	65%	32	$2,208
12	7	$92	$76	62%	31	$2,356
13	8	$99	$83	54%	27	$2,241
14						
15	Formula C6	=B6-$A$2		Formula F6	=C6*E6	
16	Formula E6	=INT(D6*$A$1)				

To maximize net income, Jim should advertise and charge $79 per night.

1-65

Let t = time from the present (in weeks)
Volume of apples at any time = (1,000 + 120t − 20t) = (1000 – 100t)
Price at any time = $30.00 − $1.50t

Total Cash Return (TCR) = (1,000 + 100t) ($30 – $1.50t)
$= \$30{,}000 + \$1{,}500t - \$150t^2$

This is a minima–maxima problem.
Set the first derivative equal to zero and solve for t.

$dTCR/dt = \$1{,}500 - \$300t = 0$

$t = \$1{,}500/\$300 = 5$ weeks

$d^2TCR/dt^2 = -300$

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

At t = 5 weeks:
Total Cash Return (TCR) = $30,000 + $1,500(5) – $150(5)^2 = $33,750

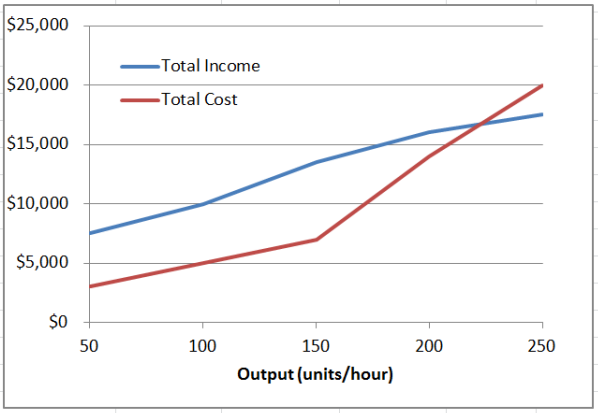
b) Worksheet:

	A	B	C	D	E
1	Using the TCR equation from above				
2					
3	Formula in cell B6	=30000+1500*A6-150*A6^2			
4					
5	**Week**	**TCR**			
6	0	$30,000			
7	1	$31,350			
8	2	$32,400			
9	3	$33,150			
10	4	$33,600			
11	5	$33,750	Max Profit		
12	6	$33,600			
13	7	$33,150			
14	8	$32,400			
15	9	$31,350			
16	10	$30,000			

1-66

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:

	A	B	C	D	E	F
1	Output Units/Hour	Sales Price	Total Income	Total Cost	Net Profit	
2	50	$150	$7,500	$3,000	$4,500	
3	100	$100	$10,000	$5,000	$5,000	
4	150	$90	$13,500	$7,000	**$6,500**	
5	200	$80	$16,000	$14,000	$2,000	
6	250	$70	$17,500	$20,000	-$2,500	



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

1-67

(a) If each offer has the same weight (33.33%) we get:

	A	B	C	D	E
1		Job	Family	Livability	
2	Weight	33.33%	33.33%	33.33%	
3	Offer				Total
4	A	4	9	5	6.0
5	B	8	5	4	5.7
6	C	6	3	8	5.7
7					
8			=SUMPRODUCT($B$2:$D$2,B4:D4)		

Select offer A.

(b) Holding the *livability* weight constant, and incrementing weights by whole percent values (no fractional change), the family weight would need to be **at least 39%** for use to select offer A.

	A	B	C	D	E
1		Job	Family	Livability	
2	Weight	41%	39%	20%	
3	Offer				Total
4	A	4	9	5	6.2
5	B	8	5	4	6.0
6	C	6	3	8	5.2

(c) Holding the *family* weight constant, and incrementing weights by whole percent values (no fractional change), the family weight would need to be **at least 39%** for use to select offer C.

	A	B	C	D	E
1		Job	Family	Livability	
2	Weight	22%	30%	48%	
3	Offer				Total
4	A	4	9	5	6.0
5	B	8	5	4	5.2
6	C	6	3	8	6.1

1-68

(a) If academics is weight 40% and cost at 60%, then the "Second" university is best with the total weights of each as shown below.
(Formula cell D4: =SUMPRODUCT($B$2:$C$2,B4:C4)

	A	B	C	D
1		Ranking	Cost	
2	Weight	40%	60%	
3	School			Total
4	First	5	7	6.2
5	Second	7	6	6.4
6	Third	10	3	5.8

(b) If the academic ranking is rated at 60%, then the "Third" university is best with the total weights of each as shown below.

	A	B	C	D
9		Ranking	Cost	
10	Weight	60%	40%	
11	School			Total
12	First	5	7	5.8
13	Second	7	6	6.6
14	Third	10	3	7.2

1-69

A number of possible problems exist that students may choose. If they have trouble identifying one you may suggest such ideas as: the purchase of a computer or car. These are items that they should easily be able to identify some criteria of interest to them.

1-70

When considering the environment and sustainability within engineering design a firm will keep in mind the social, environment, and economic aspects of the problem. When thinking about the environment, one needs to keep in mind such factors as the impact on resources such as air quality, water quality, plants and animals. These are all impacted by the facilities we build, as well as the materials and processes we utilize. You may find lists that contain such sustainability factors such as: social, government, political, organizational, environmental, technical, financial, etc. When thinking of sustainability, we need to be concerned with economic affordability, community acceptance, and regulatory compliance.