CHAPTER 10

Solutions to Chapter-End Problems

A. Key Concepts

Benefits and Costs:

10.1 Some examples:

Cost/Benefit	**How measured**
Noise pollution/people wake up	Public complaints—hard to quantify
Snowplow damage to roads/property	Observation of damage
Fewer accidents/towing	Difference in number by experiment
Visible demonstration of taxes being used	Political benefit only
Snow in people's driveways	Cost of removal

10.2 Some examples:

Cost/Benefit:	**How measured:**
Cost of maps, etc	as incurred
Telephone costs	as incurred
Insurance	as incurred
More tourist stay in province/state	survey effectiveness
Tourists more likely to return	survey effectiveness
Attractions/hotels get advertising	survey source of customers
Tourist have good impression	survey, but hard to quantify
Healthy to stop and stretch/picnic	hard to measure

Benefit-cost Ratios:

10.3 **(a)** BCR = 17 000 000/(5 000 000 + 6 000 000) = 1.546
(b) BCRM = (17 000 000 – 5 000 000)/6 000 000 = 2

10.4 **(a)** BCR(A) = 19 000 000/(5 000 000 + 5 000 000) = 1.9
BCR(B) = 15 000 000/(8 000 000 + 1 000 000) = 1.667

(b) BCRM(A) = (19 000 000 – 5 000 000)/5 000 000 = 1.667
BCRM(B) = (15 000 000 – 8 000 000)/1 000 000 = 7

(c) BCR(A–B) = (19 000 000 – 15 000 000)/(10 000 000 – 9 000 000) = 4

(d) PW(A) = 19 000 000 – 5 000 000 – 5 000 000 = 9 000 000
PW(B) = 15 000 000 – 8 000 000 – 1 000 000 = 6 000 000

(e) The preferred project is A, whether one uses net present worth or BCR. Both projects are found to have acceptable BCRs. Ranking from the greatest to least PW(costs) requires calculation of the BCR for A–B. The value is greater than one, so the increment is preferred, and so project A is preferred. Note that the value of the BCR for B–A would be numerically identical, also 4.

10.5 **(a)** BCR(A) = 17 000 000/(5 000 000 + 6 000 000) = 1.545
BCR(B) = 17 000 000/(11 000 000 + 1 000 000) = 1.417

(b) BCRM(A) = (17 000 000 – 5 000 000)/6 000 000 = 2
BCRM(B) = (17 000 000 – 11 000 000)/1 000 000 = 6

(c) BCR(B–A)
= (17 000 000 – 17 000 000)/(12 000 000 – 11 000 000) = 0

(d) PW(A) = 17 000 000 – 5 000 000 – 6 000 000 = 6 000 000
PW(B) = 17 000 000 – 11 000 000 – 1 000 000 = 5 000 000

(e) The preferred project is A, whether one uses net present worth or BCR. The incremental BCR is calculated for B–A since B has the greatest PW(costs). The BCR of zero results from equal benefits, so project A, with the lower PW(costs), is chosen.

10.6 **(a)** BCR(A) = 17 000 000/(5 000 000 + 6 000 000) = 1.545
BCR(B) = 15 000 000/(8 000 000 + 3 000 000) = 1.364

(b) BCRM(A) = (17 000 000 – 5 000 000)/6 000 000 = 2
BCRM(B) = (15 000 000 – 8 000 000)/3 000 000 = 2.333

(c) BCR(A–B)
= (17 000 000 – 15 000 000)/(11 000 000 – 11 000 000) = not defined

(d) PW(A) = 17 000 000 – 5 000 000 – 6 000 000 = 6 000 000
PW(B) = 15 000 000 – 8 000 000 – 3 000 000 = 4 000 000

(e) With an undefined incremental BCR resulting from equal costs, we chose the project with the greater PW of benefits, project A.

Market Failure:

10.7 Air pollution is an example of market failure because people who drive cars or own polluting companies benefit from the inexpensive transportation or inexpensive production of goods. However, many people are negatively affected by the air pollution. The costs to these people, and to our health system, probably exceed pollution prevention costs.

Economic regulation by government: already being done by regulations governing emission controls for cars and factories; pedestrian-only zones in cities, alternating driving days, plant shutdowns.

Monetary incentives or deterrents: subsidized mass transit, gas taxes; pollution fines.

Seeking compensation in courts: permitting suits against air pollution. Note, however, who would sue whom here? The reason for market failure is that there are large numbers of drivers who dump into the air, and large numbers of persons who are adversely affected. It is not worth the while for those who are adversely affected to do much about dumping since the costs of seeking compensation would exceed any compensation. This might be overcome by class action suits. The large number of persons adversely affected would have to form a coalition. This might be difficult. The coalition would have to identify and sue all the individuals who dump.

Government provision of goods and services: government-run mass transit, e.g., GO train in Toronto.

10.8 Overfishing is an example of market failure because individual fishers benefit from taking the available fish. However, all fishers, and society at large, suffer because insufficient stock remains to restore the supply.

Economic regulation by government: already being done by regulations governing fish quotas, fishing licenses.

Monetary incentives or deterrents: payments to displaced fishers, subsidies to economic development of fishing communities.

Seeking compensation in courts: perhaps can be applied to action against native or foreign fishers.

Government provision of goods and services: government restocking programs, international treaties.

10.9 Where there is only one family affected by the Smiths' trees, the Smiths' refusal to top their trees does not imply that there is market failure. The Smiths refusal of the Browns' compensation offer means that the trees are worth more to the Smiths than the view is worth to the Browns. There would be a social loss if the trees were cut.

Where there are 4 families affected by the Smiths' trees the situation is not simple. The affected families would have to agree to share cost of inducing the Smiths to top their trees. The bargaining over sharing the cost may be difficult. It is possible that the total value of the view for all 4 families exceeded the value the tall trees to the Smiths. In this case, there would be market failure.

A reduction in biodiversity might cause a loss for many people, possibly for everyone on earth. All these individuals could not form a voluntary coalition to bargain with the forest companies to get them to change their cutting practices. Even if no individual sustained a large cost from a reduction in biodiversity, the total value of costs may exceed the value of clear cutting to forest companies. In this case, there would be market failure.

10.10 The technical changes reduce the need for regulation. Regulation was important when scale economies made single supplier provision of these services more efficient than multiple supplier provision. Single suppliers had monopoly power that they could have exploited. Regulation was used to prevent excessive prices, and to maintain quality standards in these industries. The existence of multiple suppliers means that the potential for monopolistic exploitation of consumers is reduced.

MARR in Government Projects:

10.11 The MARR on government projects is determined by the opportunity cost of the funds invested in the project. We usually assume that funds come from the private sector. In the private sector, the funds could come from either consumption or from investment. The tax on investment income makes the return to savers lower than the actual physical return. That is, the rate at which individuals are willing to give up current consumption to make an investment is lower than the rate the investment returns. The opportunity cost, therefore, is between the before-tax and the after-tax rates earned on investments.

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10.13 The MARR on government projects is determined by the opportunity cost of the funds invested in the project. We usually assume that funds come from the private sector. The actual dollar return on investments in the private sector rises with an expectation of inflation. Therefore, the actual dollar MARR for government projects also rises.

B. Applications

10.14 **(a)** If Plant B and Plant C met Plant A's performance of 10 cl/kilogram, Plant B would reduce dumping by 5 cl/kg and Plant C by 8 cl/kg. Total reduction in dumping would be 5(11 000) + 8(8000) = 119 000 kg per day.

The cost for Plant B would be
(0.06 + 0.06 + 0.063 + 0.068 + 0.075)(11 000) = $3586

The cost for Plant C would be
(0.25×7 + 0.375)(8000) = $17 000

The total cost of best practice regulation is $20 586 per day.

(b) A tax of $0.20 per centilitre dumped would cause Plant A to reduce dumping by 5 cl/kg. Plant B would reduce by 6 cl/kg. Plant C would choose not to reduce dumping and to pay the tax.

Total reduction in dumping would be 5(17 000) + 6(11 000) = 151 000 cl per day.

(c) The cost for Plant A would be
(0.02 + 0.032 + 0.048 + 0.1 + 0.18)(17 000) = $6460 per day

The cost for Plant B would be
(0.06 + 0.06 + 0.063 + 0.068 + 0.075 + 0.193)(11 000) = $5709 per day.

10.15 The value of the benefit to consumers has two parts: (1) the benefit due to the lower price on power that is consumed even at the high price, and (2) the benefit due to the increased consumption. The value of the lower price on existing consumption is: 0.02(9 000 000) = $180 000.

The value of increased consumption is given by the value to users less their cost. The value per unit to users can be approximated by a point half way between the old and new price. The value must be at least $0.05/kwh, otherwise there would be no new consumption. It must be less than $0.07/kwh, otherwise the higher consumption would have existed even with the higher price.

We get [(0.07+0.05)/2 – 0.05](12 250 000 – 9 000 000) = $32 500

The total benefit is then 180 000 + 32 500 = $212 500.

10.16 **(a)** The benefit to travellers has two parts: (1) the benefit of the zero price on crossings that would be made at $1.50 per crossing, and (2) the benefit of increased crossings. These increased crossings are valued at $0.75 per crossing—half way between the $1.50 value and zero. This gives

	Total	Lower price	Increased use
Benefit to users ($/year)	112 500	90 000	22 500

(b) The owners would lose their profits. These are (Price – Cost)×(Use). This comes to $30 000 per year.

(c) The taxpayers incur the cost of building and maintaining the bridge. This is $85 000/year.

(d) (Annual benefits – Annual costs) = –$2500

(e) The situation would be made worse by charging a toll. This would transfer money from travellers to taxpayers with no net gain or loss to society as a whole. It would also reduce use. Under the assumption that use entails no cost, this reduction in use is a pure loss.

10.17 **(a)** Amount saved = 200(2)(75)(5.5)(52) = $8 580 000 per year

(b) You could survey similar locations for an estimate.

(c) You could, for example, find the average cost of the highway per kilometre per year, then divide by the average number of cars per kilometre to work out the cost per car per kilometre. In addition, to capture the benefits of reducing congestion, you could estimate the cost of a traffic jam and the amount traffic jams would be marginally reduced by the removal of one car.

10.18 *Costs*:

There would have to be specialized equipment for collecting, sorting and processing the various types of newspaper, cardboard and cans. This information could be obtained by finding out what equipment would have to be purchased and what facilities built. Price estimates could then be obtained.

There will be costs associated with recycling boxes and composters for each household. These costs could be estimated by finding the number of households and the number and type of containers used by each.

There would also be costs borne by each household for separating the waste. These costs could be estimated by determining how much time is necessary to separate waste each week, and by multiplying by an appropriate wage. If some householders feel that the cost is negligible, it may be valid to reduce the total cost by an appropriate amount.

Benefits:

The newspaper, paper and cans can be sold. These benefits could be estimated by finding out the approximate waste for each category generated by each house on a weekly basis, determining how much of it can be sold and then finding the market price for recycled materials.

The landfill site will fill more slowly, so there is a reduced cost associated with land acquisition and site management. By determining the volume of material sold and the amount of "wet" compostable material, analysts can infer the reduction in waste being brought to the landfill site on a weekly basis. This could be converted into a yearly amount and then an estimate made of the cumulative volume saved over the life of the landfill.

There may be a reduction in tipping fees as well, which can be determined by the forecasted reduction in volume of waste brought to the landfill site weekly.

10.19 (1) Reduced school cleaning and maintenance. This is partly a real benefit, and partly a transfer. It’s a benefit to the extent that the resources used for cleaning and maintenance, mostly labour, have good alternative uses on the off day. In this case, tax payers receive the benefit. It’s a transfer from workers to taxpayers to the extent that the workers do not have good alternatives for the off days.

(2) Reduced use of school buses on the off day. This is partly a real benefit, and partly a transfer. It’s a benefit to the extent that the resources involved in school bus use have good alternative uses on the off day. Just keeping the buses in the garage yields some saving in resources. Tax payers receive the benefit. It’s a transfer from workers, drivers and others, to taxpayers to the extent that the workers do not have good alternatives for the off days.

(3) Reduction in driving to school by parents, students and staff on the off day. This is a real benefit received by those who avoid driving. There may also be some benefits in reduced road crowding and reduced pollution. These are received by other drivers and by the population as a whole.

(4) Reduction in public transportation use on the off day. This is a real benefit to those who don’t have to use the transit system. If the public transit system is crowded, there will be some benefit to other users in

reduced crowding. There will also be a transfer from the owners of the transit system to those who don't have to use transit on the off days.

(5) Some high school students and school staff will seek part-time work for the off day. We have to distinguish between those who continue to have the same number of school hours, and those like bus drivers and cleaning staff whose hours are reduced. For those who continue to have the same number of total hours, there is a real benefit. This arises if having a whole day off as opposed to shorter days permits better use of the off time. The benefit will be received by whoever can make better use of the day off. This is not limited to those who seek part-time work. For those whose hours are reduced, whether or not there is a benefit, loss or a wash depends on the alternative opportunities for their time.

(6) Reduced absences by students and staff. This is mainly because some required personal activities could be scheduled for the off day. This is a real benefit received by students if reduced absence increases effectiveness.

(7) Reduced subsidized school lunch requirements. This is a transfer from students and their families to taxpayers.

(8) Greater need for day care on the off day for working parents. About a third of elementary schools could be opened for day care. The costs would be covered by fees. This is a cost that would be borne mainly by the working parents.

(9) Learning by elementary students may be reduced because of their limited attention spans. This is a real cost borne by the students and their families.

(10) Lower school taxes. This is just a transfer to school tax payers. The real effects have been counted already.

10.20 **(a)** We can compare the incremental benefit to the incremental cost.

Benefit/year = (10 km/trip)(2.5/km)(400 000 trips) = 10 000 000 Pesos

The incremental cost per year of the tunnel route over the base of the mountain route (in millions of Pesos) is:

Cost/year = 240 (A/P, 10%, 40) + 0.4
= 240 (0.10266) + 0.4
= 24.542240 + 0.4 = 24.9424 million Pesos

The incremental benefit of the tunnel route over the base of the mountain route is less than half the incremental cost. Therefore, based on the information given, we recommend the base of the mountain route.

(b) The analysis does not take into account the value of time saved for travellers.

(c) We have 14 942 400 Pesos/year to make up with the value of time savings. At 400 000 trips per year, this is about 37.4 Pesos per trip to save 6 minutes per trip. This implies a value of time of about 370 Pesos/hour. We would need to know more about the travellers to say with confidence if this amount is too large to be reasonable for the opportunity cost of travellers' time.

(d) A toll would be mainly a transfer from travellers to tax payers. It would also reduce the value of the tunnel route if waiting for the toll to be paid were required. A toll would not cause a recommendation in favour of the river route to change.

10.21 **(a)** Under equal emission reduction Old Gloria's cost will be U$50 + U$45 = U$95. New Gloria's cost will be U$40 + U$30 = U$70. The total cost will be U$165.

(b) A tax on odour emission above U$25/(1000 OU/day) and below U$30/(1000 OU/day) will induce Old Gloria to reduce emission by 2000 OU/day and New Gloria to reduce by 5000 OU/day. The cost of this will be U$50/day for Old Gloria and U$105/day for New Gloria.

(c) If the two plants are offered a similar amount, say U$27(1000 OU/day) to reduce emission, Old Gloria will find it worthwhile to reduce emission be 2000 OU/day. New Gloria will find it worthwhile to reduce emission by 5000 OU/day.

10.22 **(a)** The following are social benefits of the bridge:

1. Reduction in operating and maintenance costs
2. Reduction in vehicle operating costs
3. Reduction in driver and passenger time cost
4. Reduction in accident cost

The only incremental cost of the bridge is its first cost.

(b) Some of the revenue lost by roadside business on the present road is due to the greater vehicle operating cost on the present road. The reduction in vehicle operating cost is already reflected in a separate category. Presumably the rest of the revenue will go elsewhere. This will offset the reduction of revenues to roadside businesses. There is a transfer, but not a cost or benefit. The toll is also just a transfer. This last is an approximation based on the assumption that the cost of collecting the toll is about the same as the cost of the government raising revenue in other ways.

(c) The table assumes that traffic over the bridge will be the same with or without the toll. The toll is likely to reduce traffic over the bridge.

(d) If the toll caused a diversion of traffic from the bridge to the present road, social benefits would be reduced. The benefits from lower vehicle costs, time costs and accident costs would all be less.

10.23 If the only losses from floods were borne by land owners, the increase in the value of the land should reflect the reduction in flood losses. One wonders why the two numbers are not the same. Does this mean that the land owners do not capture the benefit of reduced flood losses?

10.24 **(a)** We must compute the present worth of costs. First costs are given as \$3 750 000. Operating and maintenance costs for each year of operation are 7500 + 0.25q, where q is the number of crossings. The number of crossings at zero toll is 11 000. Thus, annual operating and maintenance costs are 7500 + 0.25(11 000) = \$10 250.

We then get the present worth of this as of the end of year 1. Then we bring that figure back to the start of year 1. The present worth of operating and maintenance costs are \$84 582.

We must get the present worth of the annual benefits. Annual benefits were given in the text as \$498 750. We get the present worth of these benefits as of the end of year 1. We then bring this back to the start of year 1. The present worth of the benefits is \$4 115 612.

The net present worth is then \$281 031.

(b) BCR = 4 115 612/(3 750 000 + 84 582) = 1.073

(c) BCRM = (4 115 612 – 84 582)/3 750 000 = 1.075

10.25 **(a)**

	Road improvement ($)	**New buses ($)**
First cost	15 000 000	4 500 000
PW(operating & maintenance costs)	5 000 000	2 000 000
Estimated increased land value	26 000 000	18 000 000
Parking garage	4 000 000	
Net PW	2 000 000	1 500 000

BCR (garage as cost)	1.083	1.091
BCR (garage as reduction in benefit)	1.1	

(b) Garage as cost:
BCR(road–bus) = (26 – 18)/(24 – 16.5) = 1.067

Garage as benefit reduction:
BCR(road–bus) = (22 – 18)/(20 – 16.5) = 1.143

(c) The benefit-cost ratio of the difference is greater than 1 under either assumption. This is consistent with the road improvement having a greater present worth than the bus project.

10.26 Tax collections are not a benefit since the gain to taxpayers at large is offset by the increased payments by the farmers who pay the higher taxes. The increased crop value and the increased land value are the same thing stated in two ways. The increased land value should approximately equal the present worth of the increased crops. One should use only one of these values to avoid double counting.

10.27 **(a)** BCR = AW(benefits)/AW(costs)
= (150 000)/[1 750 000(A/P, 5%, 20) + 20 000] = 0.935

(b) BCR = AW(benefits)/AW(costs)
= (150 000 – 20 000)/[1 750 000(A/P, 5%, 20)] = 0.926

(c) The most they would be willing to pay is $1 620 000 as seen from the summary of spreadsheet calculations.

Price ($)	BCR
1 000 000	1.620
1 200 000	1.350
1 400 000	1.157
1 620 000	1.000
1 800 000	0.900
2 000 000	0.810

10.28 BCR = AW(benefits)/AW(costs) = (150 000)/[500 000(A/P, 9%, 8)]= 1.66

The project is worthwhile.

10.29 **(a)** BCR = AW(benefits)/AW(costs)
= (175 000 + 50 000)/[1 500 000(A/P, 5%, 10) + 8000] = 1.11

(b) BCRM = [AW(benefits)-AW(operating costs)]/AW(capital costs)
= (175 000 + 50 000 – 8000)/[1 500 000(A/P, 5%, 10)] = 1.17

(c) Both the BCR and the BCRM have ratios exceeding 1, and thus the project appears to be a good economic choice.

10.30 **(a)** Current dumping of BOD5 is 20 000(1.0) + (9000)(1.5) = 33 500 kg/day. If both plants limited their dumping to 0.81kg/steer, dumping would be (29 000)(0.81) = 23 490 kg/day.

The cost of this reduction is as follows:

Plant A must reduce their dumping by 1.0 – 0.81 = 0.19kg/steer.
Plant B must reduce their dumping by 1.5 – 0.81 = 0.69kg/steer.

Plant A: [(1.5)(0.1) + (2.4)(0.09)](20 000) = RUB 7320/day
Plant B: [(4.5)(0.5) + (10.5)(0.1) + (13.5)(0.09)](9000) = RUB 40 620 /day

The total cost is $47 940/day.

(b) If there were a tax of $4.8 per kilogram dumped, Plant A would reduce dumping by 0.3 kilograms per steer since, beyond that amount, it would cost Plant A more to reduce the BOD5 than the taxes saved. Similarly, Plant B would reduce dumping by 0.5 kilograms per steer. See the answer for parts (c) and (d) for further explanation.

The total reduction in BOD5 would be:

Plant A: 0.3(20 000) = 6000 kg/day.
Plant B: 0.5(9000) = 4500 kg/day.

The cost would be

Plant A: (1.5+2.4+3.6)(0.1)(20 000) = $15 000/day
Plant B: (4.5)(0.5)(9000) = $20 250/day

The total is $35 250/day. This is a lower total cost than with regulation and the reduction in the amount dumped is greater.

(c) & (d) The reductions in the amounts dumped would be the same under the subsidy scheme as under the tax. Therefore, the costs would be the same. The behaviour would be the same because it would cost Plant A less than $4.8 per kilogram to reduce dumping by 0.3 kilograms per steer. Greater reductions would cost more than $4.8 per kilogram. It would cost Plant B less than $ 4.8 per kilogram to reduce dumping by 0.5 kilograms per steer. Greater reductions would cost more than $4.8 kilograms per steer. Avoiding paying tax that the company would otherwise pay (at $4.8/kg) is a benefit equivalent to gaining a subsidy (at $4.8/kg).

(e) The tax and subsidy schemes encourages Plant A, which has lower cost of reducing BOD5, to reduce dumping more than Plant B, which has higher costs.

C. More Challenging Problems

10.31 **(a)** We first get the present worth of benefits under the toll. The benefit has two parts: (1) the value of a lower cost to visit the park for visits that would take place without the bridge, and (2) the value of increased visits.

The bridge cuts the cost of a visit from \$290 to \$237.50. With the toll the cost of a visit to a traveller falls from \$290 to \$244.50. The annual benefit to travellers from the lower cost on existing visits is 8 000×(290 – 244.5) = \$364 000. We must add to this the toll that is paid on existing visits, \$56 000. This is a benefit to taxpayers. Notice that the total benefit for existing visits is \$420 000 = 364 000 + 56 000. This is the same result that we got in the text for the annual benefit on existing visits. The toll has taken a benefit from travellers and transferred it to taxpayers. The final social benefit from a lower cost on existing visits, which is the sum of gains by travellers and taxpayers, is unaffected by the toll.

The annual benefit from increased visits is given by the average value per increased visit times the increase in the number of visits per year. This is given by [(290 – 244.5)/2 + 244.5]×(10 600 – 8000) = \$694 850. The traveller sees a cost of \$244.50 per visit. But \$7 of this goes to taxpayers. The actual cost of these extra visits is \$237.5 per visit. We could either compute the cost using the \$244.50 and then have a benefit to taxpayers, or we could work with the actual cost of \$237.50. We have worked with the actual cost. This is given by (10 600 – 8000)(237.50)= \$617 500.

The total annual benefit from the bridge with the toll is \$77 350 for the increased visitors plus \$420 000 for the existing visitors, equalling \$497 350.

We must get the present worth of the annual benefits. We get the present worth of the annual benefits as of the end of year 1. We then bring this back to the start of year 1. The present worth of the benefits is \$4 104 060.

We now get costs. The costs consist of first cost and operating and maintenance costs. First costs are given as \$3 750 000. Operating and maintenance costs for each year of operation are 7500 + 0.25q, where q is the number of crossings. The number of crossings at the \$7 toll is 10 600. Annual operating and maintenance costs are \$10 150. We then get the present worth of operating and maintenance costs as of the end of year 1.

Then we bring that figure back to the start of year 1. The present worth of operating and maintenance cost is $83 756.32.

The net present worth then is $4 104 060 – 3 750 000 – 83 756.32 = $270 303.50. This is about $10 000 less than without the toll.

(b) The benefits of increased use have been reduced by the toll because the increase in use is less than with no toll. The toll itself is neither a social benefit nor a cost. It is a cost to users and a benefit to taxpayers. These cancel out.

10.32 **(a)** The tax payments are

A: $66.67(25 – 16.67) = $555.55/day
B: $66.67(20 – 8.33) = $777.77/day
Total = $1333.33/day

(b) Total cost for A is $1111.11/day. For B, $1055.56/day.

(c) Under regulation the only costs were BOD5 removal costs. These were $450/day for A and $400/day for B. Thus, taxation by itself leaves both A and B worse off.

(d) A total benefit of $1322.21 per day divided equally between the two plants would leave A no worse off and B better off. This is a bit less than the tax collection of $1333.33/day.

10.33 **(a)** Pool:
BCR = AW(benefits)/AW(costs)
= 450 000/[2 500 000(A/P, 5%, 25) + 300 000] = 0.909

This is not acceptable.

Tennis courts:
BCR = AW(benefits)/AW(costs)
= 60 000/[200 000(A/P, 5%, 8) + 20 000] = 1.178

The tennis courts are preferable.

(b) BCRM = [AW(benefits) – AW(operating costs)]/AW(capital costs)

Pool:
BCRM = (450 000 – 300 000)/[$2 500 000(A/P, 5%, 25)] = 0.769

This is not acceptable.

Tennis courts:
BCRM = (60 000 – 20 000)/[200 000(A/P, 5%, 8)] =1.293

The tennis courts are preferable.

10.34 **(a) & (b)** The benefits are reflected in the increased land values, and in the increased crop values. If the land owners capture all the benefits of the increased crop values and there are no other effects on land prices the increase in land values should equal the present worth of the increased crop values. We should not count both increased land values and increased crop values. When you compute the present worth of increased crop values, remember that the benefits start in year 2. Tax collections are a transfer from land owners to taxpayers as a whole. They are neither a benefit nor a cost.

Road use costs have two components, the time value of drivers and the cost of operating the vehicles. Computation of the cost due to time value of drivers assumes that drivers traverse the entire road, 24 km for Route A and 16 km for Route B. We get the time spent on a trip by dividing the number of kilometres on a route by the speed in km/h. The annual cost is simply the time multiplied by the value of time and by the number of vehicles per year. For example, for Route A we have (24/100)$\times$15$\times$1 000 000 = 3 600 000 as the annual value of travel time. Recall that benefits start in year 2 when computing road use costs.

Costs (in $000s)	Route A	Route B	Computation
Construction cost	53 400	75 000	a
PW(O&M cost)	464.38	348.28	b
PW(resurface after 10 years)	1 086.53	823.66	c
PW(road costs)	54 951	76 171.94	d = a + b + c
PW(road use costs: vehicle time)	27 862.57	27 862.57	e
PW(road use costs: vehicle use)	55 725.15	44 580.12	f
PW(total cost)	138 539	148 615	g = d + e + f
PW(increased crop value)	104 484.6	139 312.8	h
Net PW	–34 054.12	–9301.83	i = h – g
PW(tax collection increase)	6278.48	8371.30	
BCR(road use costs as cost)	0.754	0.937	= h/g
BCR(road use costs as reduction in benefit)	0.38	0.878	= (h – e – f)/d

(c) The benefit-cost ratios are consistent in that they are less than one no matter how they are computed.

(d) Neither road should be built. The benefit-cost ratios are less than one. The present worth is negative.

10.35 Dam Construction:
P_1 = –300 000 – 750 000(P/F, 15%, 1) – 1 500 000(P/F, 15%, 2)

$= –300\ 000 – 750\ 000(0.86957) – 1\ 500\ 000(0.75614)$
$= –2\ 086\ 388$

Dam Operating and Maintenance:
$P_2 = –30\ 000(P/A, 15\%, 50)(P/F, 15\%, 2)$
$= –30\ 000(6.6605)(0.75614)$
$= –151\ 088$

Flood Damage and Irrigation benefits:
$P_3 =(182\ 510 + 200\ 000)(P/A, 15\%, 50)(P/F, 15\%, 2)$
$= 382\ 510(6.6605)(0.75614)$
$= 1\ 926\ 424$

$PW_{dam} = P_1 + P_2 + P_3 = –2\ 086\ 388 – 151\ 088 + 1\ 926\ 424 = –311\ 052$

Recreation Construction:
$P_4 = –50\ 000(P/F, 15\%, 2) – 20\ 000[(P/F, 15\%, 12) + (P/F, 15\%, 22) + (P/F, 15\%, 32) + (P/F, 15\%, 42)]$
$= –50\ 000(0.75614) – 20\ 000(0.18691+ 0.04620 + 0.01142 + 0.00298)$
$= –42\ 757$

Recreation Operating and Maintenance:
$P_5 = –15\ 000(P/A, 15\%, 50)(P/F, 15\%, 2)$
$= –15\ 000(6.6605)(0.75614)$
$= –75\ 544$

Recreation benefits:
$i° = (1 + i)/(1 + g) – 1 = 1.15/1.0325 – 1 = 0.1138$

$(P/A, 3.25\%, 11.38\%, 50)$
$= [(1 + i°)^N – 1]/[i°(1 + i°)^N][1/(1 + g)]$
$= (1.1138^{50} – 1)/[0.1138(1.1138)^{50}](1/1.0325)$
$= 8.472$

$P_6 = 27\ 600(P/A, 3.25\%, 11.38\%, 50)(P/F, 15\%, 2)$
$= 27\ 600(8.472)(0.75614)$
$= 176\ 806$

$PW_{rec} = P_4 + P_5 + P_6 = –42\ 757 – 75\ 544 + 176\ 806 = 58\ 505$

$PW_{dam+rec} = –311\ 052 + 58\ 505 = –252\ 547$

The present worths are negative at a 15% MARR for both projects. It is not possible to state, with certainty, what the correct MARR is. The MARR is based on the assumption that all funds for this project are taken from private investment that has a pre-tax return of 15%. A next step could be to find the highest value of MARR for which the present worth is positive. If this is “close” to 15%, the project may be justified by other non-quantitative factors that have not been discussed.

10.36 The combination of projects, 2, 6, 7 and 8, maximizes the number of life-years saved within the constraint of $660 000 000. This is in spite of this not using all of the permitted $660 000 000. This may be found by experimenting with different combinations. A useful device for guiding these experiments is to compute the number of life-years saved per dollar for each project. These are shown below.

Project	Total cost ($s)	Life years saved (per year)	Total cost per life year saved ($s)
1. Flashing lights	18 000 000	14	1 285 714
2. Flashing lights and gates	30 000 000	20	1 500 000
3. Widen bridge #1	48 000 000	14	3 428 571
4. Widen bridge #2	28 000 000	10	2 800 000
5. Widen bridge #3	44 000 000	18	2 444 444
6. Pole density reduction	120 000 000	96	1 250 000
7. Runaway lane #1	240 000 000	206	1 165 049
8. Runaway lane #2	240 000 000	156	1 538 462

10.37 All computations are for one kilometre.

(a) The present worth of road widening costs per kilometre has two parts, the first cost and the present worth of the annuity equivalent to operating and maintenance costs. These sum to $243 078.

(b) We get the reduction in the number of accidents when 6-metre lanes are replaced with 7.5-metre lanes. This reduces the number of accidents to 4.5 accidents per km per year. We multiply this by the cost per accident. This gives an annual value. We then get the present worth of this annuity. The present worth is $102 117.

(c) Note that if we considered only material costs, the net present worth would be negative since costs from part (a) exceed the benefit of the reduction in material damages from part (b). To get the minimum value for avoiding a serious personal injury, we find the reduction in the number of serious injuries. This is 0.45 accidents per kilometre per year. We then get the annual worth of the difference between \$243 078 and \$102 117. This is \$15 529. We divide 0.45 into \$15 529. The answer is \$34 510.

10.38 **(a)** The present worths (in millions of Yuan) are:

PW(A) = –200 + (26.4 – 2.4)(P/A,10%,25) = –200 + (26.4 – 2.4)(9.077) = 17.84
PW(B) = –256 + (33.6 – 2.4)(9.077) = 27.2
PW(C) = –416 + (56.8 – 4.0)(9.077) = 63.28

Project C is the best choice.

(b) BCR(A) = (26.4×9.077)/(200 + 2.4×9.077) = 239.6/221.76 = 1.080
BCR(B) = (4.2×9.077)/(32 + 0.3×9.077) = 304.96/277.76 = 1.098
BCR(C) = (7.1×9.077)/(52 + 0.5×9.077) = 515.6/452.32 = 1.140

(c) First consider the increment from Project A to Project B:

BCR(B–A) = [(33.6 – 26.4)×9.077]/[(256 – 200) + (2.4 – 2.4)×9.077] = 9.6

Since the ratio is greater than 1, B is better than A. Now consider the increment from Project B to Project C:

BCR(C–B) = [(56.8 – 33.6)×9.077]/[416 – 256 + (4 – 2.4)×9.077] = 9.68

This confirms that Project C is the best choice.

(d) We can see that the additional first cost does not change the best project choice because the present worth of Project C, now 39 280 000 Yuan, remains the highest. But if we look at the new benefit-cost ratio of Project C, we find that it is less than that of Project B.

BCR(revised) = 515.6/476.32 = 1.082

However, the incremental BCR from B to C remains greater than one.

BCR(C–B) = [(56.8 – 33.6)×9.077]/[416 + 24 – 256 + (4 – 2.4)×9.077] = 1.06

10.39 The incremental cost of starting with the 4-lane road
= 12 000 000 – 18 000 000(P/F, i, 10) + 10 000(P/A, i, 10)

For years 1-5, there is time savings of 0.25 – 0.2 = 0.05 hours per car with the 4-lane road alternative, which translates to \$2 savings per car. Similarly, for years 6-10, there is \$3.43 savings per car with the 4-lane road alternative.

The incremental benefit of starting with the 4-lane road is:
{[5000 + 200(A/G, i, 5)](2) + [6000 + 200(A/G, i, 5)](3.43)(P/ F, i, 5)}
$\times$(P/A, i, 5)

(a) For MARR = 5%:

P(cost)
= 12 000 000 – 18 000 000(P/F, 5%, 10) + 10 000(P/A, 5%, 10)
= 12 000 000 – 18 000 000(0.61391) + 10 000(7.7217)
= 12 000 000 – 11 050 380 + 77217
= 1 026 837

P(benefit)
= {[5000 + 200(A/G, 5%, 5)](2)
+ [6000 + 200(A/G, 5%, 5)](3.43)(P/ F, 5%, 5)}$\times$(P/A, 5%, 5)
= {[5000 + 200(1.90011)](2)
+ [6000 + 200(1.90011)](3.43)(0.78353)}(4.31431)
= 10 760 + 17 146(4.31431)
= 84 733

The incremental benefit of the 4-lane road does not exceed the incremental cost with the MARR = 5%.

(b) For MARR = 20%:

P(cost)
= 12 000 000 – 18 000 000(P/F, 20%, 10) + 10 000(P/A, 20%, 10)
= 12 000 000 – 18 000 000(0.16151) + 10 000(4.1925)
= 12 000 000 – 2 907 180 + 41 925
= 9 134 745

P(benefit)
= {[5000 + 200(A/G, 20%, 5)](2)
+ [6000 + 200(A/G, 20%, 5)](3.43)(P/ F, 20%, 5)}$\times$(P/A, 20%, 5)
= {[5000 + 200(1.6405)](2)
+ [6000 + 200(1.6405)](3.43)(0.40188)}(2.9906)
= 10 656 + 8723(2.9906)
= 36 743

The incremental benefit of the 4-lane road does not exceed the incremental cost with the MARR =20%.

(c) It is reasonable to assume that the opportunity cost of funds for the used in the road upgrading is between 5% and 20%. If the alternative to upgrading the road is private consumption, the opportunity cost is 5%.

Private individuals deciding between consumption and saving face a choice between the return on a safe investment like a government savings bond, at 5%, and the benefit of consumption now. If the alternative to upgrading the road is private investment, the opportunity cost is what could be earned before tax on that investment, 20%. At either 5% or at 20%, the immediate building of the 4-lane road is not preferred.

10.40 **(a)** Equivalent annual cost of Alternative A (in $000s) at 5%:
= 420(A/P, 0.05, 15) + 52.5 = 420(0.09634) + 52.5 = 92.96

Equivalent annual cost of Alternative B (in $000s) at 5%:
= 315(A/P, 0.05, 15) + 74 = 315(0.09634) + 74 = 104.35

(b) Equivalent annual cost of Alternative A (in $000s) at 20%:
= 420(A/P, 0.20, 15) + 52.5 = 420(0.21388) + 52.5 = 142.33

Equivalent annual cost of Alternative B (in $000s) at 20%:
= 315(A/P, 0.20, 15) + 74 = 315(0.21388) + 74 = 141.37

(c) Alternative A has lower equivalent annual cost at 5%. Project B has marginally lower equivalent annual cost at 20%. For B to be preferred, we would have to assume that virtually all of the resources used in the project came from private investment. That over a third of the cost for the project will come from increased dumping fees suggests that at least some of the resources will be from reduced private consumption. Alternative A is, therefore, preferred.

10.41 **(a)** The social benefits are a reduction in the health costs associated with exposure and the reduced environmental costs that accrue when the ban takes place. The costs are calculated using the base case of having the controls in place. The social costs are the lost value of the pesticide use to its users and to the manufacturer.

(b) No, although it might seem so initially. The social costs and benefits of the ban both need to be computed starting from the same base-case. Since the benefits were computed comparing the ban to the pre-existing regulations, the costs must be computed on this basis as well. The social benefits to users and to the producers lost due to the ban already account for the costs of production and compliance, so reduction in production and compliance costs should not be treated as a savings.

Notes for Case-in-Point 10.1

1-3) All of these questions depend on the judgement of the student.

Notes for Mini-Case 10.1

1) Too high a level of carbon allowances will not cause any abatement in emissions.

2) An open-market auction is preferable because it is more efficient. If companies could sell to one another, there is no guarantee that the price will reflect the system-wide cost of emissions reductions.

3) Potential shortcomings of the use of regulators relate to the fact that individual regulators could be bribed, or may not enforce the system by levying the fines. If fines are not sufficiently high, companies do not have an incentive to reduce their emissions.

4) Emissions taxes result in a uniform rate of payment for emissions across companies. Although taxes may be simple in principle, they do not recognize that different companies will face different costs to reduce emissions. In this way, it can be said to be less efficient than a trading system.

Solutions to All Additional Problems

Note: Solutions to odd-numbered problems are provided on the Student CD-ROM.

10S.1

We are committed to doing one of the two plans, so we just need to look at the B/C ratio of one compared to the other. Taking the single tunnel as the default, we get an immediate benefit of $200 000 by building a half-capacity tunnel. Then in ten years we get a further benefit of $4000. In twenty years, we can either consider that we get a benefit of $4000 and a cost of $400 000, or we can lump these together as a net cost of $396 000. This choice will affect the numerical value of the B/C ratio, but not whether it is greater or less than 1. Then in the thirtieth and fortieth years we get a cost of $12 000 each time.

So the present worth of the benefits is $\$200\ 000 + \$4000 / (1+i)^{10} = \$202\ 455$, and the present worth of the costs is

$\$396\ 000 / (1+i)^{20} + \$12\ 000 / (1+i)^{30} + \$12\ 000(1+i)^{40} = \$149\ 250 + 2776 + 1704 = \$153\ 730$.

Thus the B/C ratio is greater than 1, and the half-capacity tunnel is the better investment.

10S.2
We can eliminate U and V immediately, since they have B/C<1. Of the remainder, P has the largest B/C ratio; T is the most expensive with B/C>1, and P is the cheapest with B/C>1.

However, to decide which we should choose, we do not use any of these facts. Rather, we start with the proposal that we do P, then calculate the B/C ratios for each possible upgrade. Only the upgrade to R has B/C>1, so we do that. Then we consider the B/C ratios for upgrading from R. All these are less than 1, so we go with R.

10S.3

The most important point in this question is choosing the right time frame. Although the longest time period mentioned in the question is ten years, choosing this as the study period will give a biased result, over-estimating the effect of the initial cost. All the alternatives considered have a long life, and since the interest rate is 5%, cash flows several decades in the future will still have a significant present value. So the simplest and most reasonable assumption is to take an infinite time frame, and use capitalized costs.

Finding the present worth of each option:

1. Bridge
PW = 10 000 000 + 500 000 / 0.05 = 20 000 000

2. Tunnel
Initial cost is more than the total cost for the bridge, so this can be ruled out.

3. Ferries
Consider this as a series of payments, each consisting of the initial cost of the ferry plus its capitalised lifetime cost. The biennial interest rate is about 0.1.

PW = (2 500 000 + 200 000/0.05)(*P/A*,0.1,5)
=6 500 000 × 3.79 = 24 635 000

4. Hovercraft
Present worth = 1 500 000 + 500 000/0.05 + (2 000 000
+ 500 000/0.05)(*P/F*,0.05,5)
= 11 500 000 + 12 000 000 × 0.8
= 21 100 000

So of these options, the bridge looks the best, though the hovercraft is close enough that it might be worth considering if other considerations are important.

10S.4

Since the unknown is an equivalent annual cost, we should calculate the equivalent annual cost for each option, using a 30-year study period. We assume that no periodic maintenance is done in the final year. For the bridge, we have (all figures in millions of rand):

EUAC(bridge) = $(A/P,0.08,30) \times (17 + 1(P/A,i_6,4) + 3(P/A,i_{10},2) + 4(P/F,0.08,15)) + 0.3$

EUAC(tunnel) = $(A/P,0.08,30) \times (24 + 2(P/F,0.08,10) + 2(P/F,0.08,20)) + x$
This can then be solved for x. Note that i^6 and i^{10} are the effective interest rates for 6- and 10-year periods respectively.

We note that $i^6 = 1.056–1 = 0.34$ and $i^{10} = 1.0510−1 = 0.63$

So EUAC(bridge) = (0.0888) ×(17 + 1(2.029) + 3(0.99) + 4(0.3152)) + 0.3
= 2.3655

EUAC(tunnel) = (0.0888) × (24 +2(0.4632) + 2(0.2145)) + x
= 2.2516 + x

From which we deduce that *x*=0.1139, implying that up to R 113 900 could be spent on annual maintenance of the tunnel before the bridge became the preferred option.

10S.5

We take an infinite study period, so we consider the capitalised value of all continuing costs and benefits. To deal with the increase in health cost savings over the first 10 years, we sum the present worths of an annual saving of 20 over 10 years, an arithmetic gradient of 2 over 10 years, and a continuing annual saving of 40, starting in 10 years:

PW (Health costs) = 20(P/A,0.05,10) + 2(A/G,0.05,10)(P/A,0.05,10)
+ 40 / 0.05(P/F,0.05,10)
= 20(12.462) + 2(7.9030)(12.462) + 800(0.6139)
= 937

PW(Storm cost savings) = 50 / 0.05(P/F,0.05,20) = 1000(0.3769) = 376.9

PW(reduced highway wear) = 5 / 0.05 = 100

PW(reduced building damage) = 10 / 0.05 = 200

Thus the total present value of the benefits, in millions of yen, is:

937 + 377 + 100 + 200 = 1614

To deal with the shrinking reduction in export costs over the first 15 years, we sum the present worths of an annual cost of 20 over 15 years, a negative arithmetic gradient of 1 over 15 years, and a continuing annual cost of 5, starting in 15 years:

PW(export reduction) = 20(P/A,0.05,15) – 1(A/G,0.05,15)(P/A,0.05,15)
+ 5 / 0.05(P/F,0.05,15)

= 20(10.380) – 1(6.0973)(10.380) + 100(0.4810)

= 207.6 – 63.3 + 48.1 = 192.4

PW(Increased food prices) = 20 / 0.05 = 400

PW(Administrative costs) = 10 + 5 / 0.05 = 110

Total Present worth of costs = 702.4

Hence, cost/benefit ratio = 1614 / 702 = 2.3. This is greater than 1, so on the basis of these figures, the tax should be implemented.

10S.6

The amount the company will save each year by replacing a truck is:
Money saved / year = 500 × 50 × 150 × 0.5 = ¥1 875 000
Cost of new truck = ¥9 000 000

So payback time is 4.8 years.
The IRR is the solution to

9 000 000 – 1 875 000(P/A,i,5) = 0

which is equivalent to

(P/A,i,5) = 4.8. This corresponds to an IRR of just less than 3%.

After the tax and the subsidy are introduced, the money saved per year increases to
$500 \times 50 \times 200 \times 0.5 =$ ¥2 500 000, and the first cost is reduced to ¥8 000 000. So the payback time is now 3.2 years, and the IRR is given by $(P/A,i,5) = 3.2$, corresponding to an IRR of about 15.5%.

If the company's MARR is lower than 3%, it will replace the trucks even without the tax and subsidy, and if its MARR is above 15.5%, it will not replace them in any case. However, for a company MARR in the range 3−15.5%, the government action will make a difference.