

# Civil and Environmental Systems Engineering | (2nd Edition)

Chapter 9, Problem 9E

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## Problem

Land purchase and 'limited site work' for power plant. Private utilities must obtain many federal, state, and local permits before constructing a coal-fired electric generating plant. In most cases, the key permit is from the federal agency responsible for writing the environmental impact statement [or the plant. Assume that a utility estimates the probability of the permit being denied as 0.2 and of being approved 0.8.

As part of the decision-making process, the utility must determine whether it is worthwhile purchasing land for the plant and if purchased, whether *limited site work* is to occur, all before the permit decision is made by the federal agency. If the land is purchased, it is usually done anonymously through a real estate representative before any permits are applied for, in order to avoid possibly having to buy at a premium from sellers who may be reluctant to sell their land for a power plant, and to avoid eminent domain proceedings that might be necessary later. If the land is purchased, a further decision must be made during the permitting process as to whether *limited site work* (clearing, grubbing road work, etc.) is to be carried out all at the utility's risk. *The incentive to begin site work is to advance any subsequent construction process thereby saving interest costs and avoiding inflated future construction costs. The danger in buying the land and doing site work is that if the permit is later denied the land would have to be sold usually at a loss to the utility.*

For a particular case assume that the utility can immediately buy the necessary 100 acres of land for \$1000 per acre, or that it could invest this money and have \$1,20,000 accumulated at the time of the agency's decision on the permit (the latter amount is thus the opportunity cost of the land purchase to the utility). If the land were purchased, the utility could also clear the site for an additional \$100,000, again expressed as the opportunity cost at the time of the agency's permit decision. If the agency's decision were to deny the permit, the utility could sell the cleared land for \$1000 per acre (Zero appreciation in real terms), or the cleared land for \$500 per acre. By clearing the land, the utility could advance its construction schedule and save \$300,000 in interest and differential inflation costs if the permit were approved.

Alternatively, the utility could wait and purchase the land only if and when the agency approved the permit. In this case the land would cost \$1400 per acre. Also since the utility would have to negotiate directly with the landowners (or possibly go through eminent domain proceedings), the construction schedule would be delayed, causing a loss of \$300,000 in interest and inflation costs. In any case, if the permit is denied, the utility would have to do something else to secure the necessary power, but it is assumed that there is no cost or benefit in so doing.

(a) Should the utility immediately buy the land or not and if purchased should 'limited site work' be carried out or not? Draw the complete decision tree and determine the optimal action and associated expected savings.

(b) Increase the probability of permit denial by tenths (to 0.3, 0.4, etc.) and determine the probability levels at which it would first become best not to clear the land and best not to buy the land immediately.

## Step-by-step solution

### Step 1 of 18

Use decision theory to decide whether the utility should invest in buying land or not.

Consider all the possibilities for the utility to make a decision. List the possible possibilities:

• **Case A:** Buy a land for power plant construction.

◦ **Case A:** Do limited site work to avoid future inflated construction cost before agency approves permit.

◦ **Case B:** Do not start limited site work before agency approves permit.

• **Case B:** Do not buy land for power plant construction.

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### Step 2 of 18

#### Case I:

Consider buying a land for the construction of the power plant. There are two possibilities for the utility to make a decision: to start the limited site work before the approval of the agency and not to start the limited site work before the approval of the agency. Select the option which produces highest savings as the best optimal saving in buying a land for the construction of the power plant.

[Comment](#)

### Step 3 of 18

#### Case A:

Consider starting limited site work to avoid future inflated construction cost before agency approves permit.

Determine the net cost of buying a land, starting the limited site work, and the agency denies the permit using the relation:

$$(NC)_{\text{Denied}} = C_{\text{Land}} + C_{\text{Self Land}} + C_{\text{LSW}} + C_{\text{Do something}}$$

Here,  $(NC)_{\text{Denied}}$  is the net cost of buying a land, starting the limited site work, and the agency denies the permit;  $C_{\text{Land}}$  is the opportunity cost in buying the land;  $C_{\text{Self Land}}$  is the cost achieved in selling of the cleared land;  $C_{\text{LSW}}$  is the cost of limited site work; and  $C_{\text{Do something}}$  is the cost of doing something else.

Substitute  $-\$1,200,000$  for  $C_{\text{Land}}$ ,  $\$500,000$  for  $C_{\text{Self Land}}$ ,  $-\$100,000$  for  $C_{\text{LSW}}$ , and  $\$0$  for  $C_{\text{Do something}}$ :

$$(NC)_{\text{Denied}} = (-\$1,200,000) + \$500,000 + (-\$100,000) + \$0$$

$$(NC)_{\text{Denied}} = -\$800,000$$

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### Step 4 of 18

Determine the net cost of buying a land, starting the limited site work, and the agency approves the permit using the relation:

$$(NC)_{\text{Approved}} = C_{\text{Land}} + C_{\text{Avoided Land}} + C_{\text{LSW}} + C_{\text{Savings}}$$

Here,  $(NC)_{\text{Approved}}$  is the net cost of buying a land, starting the limited site work, and the agency approves the permit;  $C_{\text{Land}}$  is the opportunity cost in buying the land;  $C_{\text{Avoided Land}}$  is the cost achieved in avoiding buying land after the agency approves the permit;  $C_{\text{LSW}}$  is the cost of limited site work; and  $C_{\text{Savings}}$  is the cost of saving achieved in interest and differential inflation cost.

Substitute  $-\$1,200,000$  for  $C_{\text{Land}}$ ,  $\$1,400,000$  for  $C_{\text{Avoided Land}}$ ,  $-\$100,000$  for  $C_{\text{LSW}}$ , and  $\$300,000$  for  $C_{\text{Savings}}$ :

$$(NC)_{\text{Approved}} = (-\$1,200,000) + \$1,400,000 + (-\$100,000) + \$300,000$$

$$(NC)_{\text{Approved}} = \$400,000$$

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### Step 5 of 18

Determine the savings in buying a land and starting the limited site work using the relation:

$$S_{\text{Clear}} = ((NC)_{\text{Approved}} \times P_{\text{Approved}}) + ((NC)_{\text{Denied}} \times P_{\text{Denied}})$$

Here,  $S_{\text{Clear}}$  is the savings in buying a land and starting the limited site work;  $(NC)_{\text{Approved}}$  is the net cost of buying a land, starting the limited site work, and the agency approves the permit;  $(NC)_{\text{Denied}}$  is the net cost of buying a land, starting the limited site work, and the agency denies the permit;  $P_{\text{Approved}}$  is the probability of permit being approved; and  $P_{\text{Denied}}$  is the probability of permit being denied.

Substitute  $-\$180,000$  for  $(NC)_{\text{Denied}}$ ,  $0.2$  for  $P_{\text{Denied}}$ ,  $\$400,000$  for  $(NC)_{\text{Approved}}$ , and  $0.8$  for  $P_{\text{Approved}}$ :

$$S_{\text{Clear}} = (\$400,000 \times 0.8) + (-\$180,000 \times 0.2)$$

$$S_{\text{Clear}} = \$160,000$$

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### Step 6 of 18

#### Case B:

Consider limited site work, to avoid future inflated construction cost, is not started before agency approves permit.

Determine the net cost of buying a land, not starting the limited site work, and the agency denies the permit using the relation:

$$(NC)_{\text{Denied}} = C_{\text{Land}} + C_{\text{Self Land}} + C_{\text{Do something}}$$

Here,  $(NC)_{\text{Denied}}$  is the net cost of buying a land, not starting the limited site work, and the agency denies the permit;  $C_{\text{Land}}$  is the opportunity cost in buying the land;  $C_{\text{Self Land}}$  is the cost achieved in selling of the unclear land; and  $C_{\text{Do something}}$  is the cost of doing something else.

Substitute  $-\$1,200,000$  for  $C_{\text{Land}}$ ,  $\$1,000,000$  for  $C_{\text{Self Land}}$ , and  $\$0$  for  $C_{\text{Do something}}$ :

$$(NC)_{\text{Denied}} = (-\$1,200,000) + \$1,000,000 + \$0$$

$$(NC)_{\text{Denied}} = -\$200,000$$

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### Step 7 of 18

Determine the net cost of buying a land, not starting the limited site work, and the agency approves the permit using the relation:

$$(NC)_{\text{Approved}} = C_{\text{Land}} + C_{\text{Avoided Land}} + C_{\text{Savings}}$$

Here,  $(NC)_{\text{Approved}}$  is the net cost of buying a land, not starting the limited site work, and the agency approves the permit;  $C_{\text{Land}}$  is the opportunity cost in buying the land;  $C_{\text{Avoided Land}}$  is the cost achieved in avoiding buying land after the agency approves the permit;  $C_{\text{LSW}}$  is the cost of limited site work; and  $C_{\text{Savings}}$  is the cost of saving achieved in interest and differential inflation cost.

Substitute  $-\$1,200,000$  for  $C_{\text{Land}}$ ,  $\$1,400,000$  for  $C_{\text{Avoided Land}}$ , and  $\$0$  for  $C_{\text{Savings}}$ :

$$(NC)_{\text{Approved}} = (-\$1,200,000) + \$1,400,000 + \$0$$

$$(NC)_{\text{Approved}} = \$200,000$$

[Comment](#)

### Step 8 of 18

Determine the savings in buying a land and not starting the limited site work using the relation:

$$S_{\text{Unclear}} = ((NC)_{\text{Approved}} \times P_{\text{Approved}}) + ((NC)_{\text{Denied}} \times P_{\text{Denied}})$$

Here,  $S_{\text{Unclear}}$  is the savings in buying a land and starting the limited site work;  $(NC)_{\text{Approved}}$  is the net cost of buying a land, not starting the limited site work, and the agency approves the permit;  $(NC)_{\text{Denied}}$  is the net cost of buying a land, not starting the limited site work, and the agency denies the permit;  $P_{\text{Approved}}$  is the probability of permit being approved; and  $P_{\text{Denied}}$  is the probability of permit being denied.

Substitute  $-\$200,000$  for  $(NC)_{\text{Denied}}$ ,  $0.2$  for  $P_{\text{Denied}}$ ,  $\$200,000$  for  $(NC)_{\text{Approved}}$ , and  $0.8$  for  $P_{\text{Approved}}$ :

$$S_{\text{Unclear}} = (\$200,000 \times 0.8) + (-\$200,000 \times 0.2)$$

$$S_{\text{Unclear}} = \$120,000$$

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### Step 9 of 18

Determine the savings in buying a land for the power plant construction by comparing the savings obtained in starting limited site work and not starting limited site work and selecting the highest saving amount as the savings in buying a land.

$$S_{\text{Buy land}} = \text{Highest of } \{S_{\text{Clear}}, S_{\text{Unclear}}\}$$

Here,  $S_{\text{Buy land}}$  is the savings in buying a land for the power plant construction,  $S_{\text{Clear}}$  is the savings in buying a land and starting the limited site work, and  $S_{\text{Unclear}}$  is the savings in buying a land and starting the limited site work.

Substitute  $\$160,000$  for  $S_{\text{Clear}}$  and  $\$120,000$  for  $S_{\text{Unclear}}$ :

$$S_{\text{Buy land}} = \text{Highest of } \{\$160,000, \$120,000\}$$

$$S_{\text{Buy land}} = \$160,000$$

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### Step 10 of 18

#### Case II:

Consider not buying the land for the construction of the power plant.

Determine the net cost in not buying a land and the agency denies the permit using the relation:

$$(NC)_{\text{Denied}} = C_{\text{Land}} + C_{\text{Do something}}$$

Here,  $(NC)_{\text{Denied}}$  is the net cost in not buying a land and  $C_{\text{Do something}}$  is the cost of doing something else.

Substitute  $\$1,200,000$  for  $C_{\text{Land}}$  and  $\$0$  for  $C_{\text{Do something}}$ :

$$(NC)_{\text{Denied}} = \$1,200,000 + \$0$$

$$(NC)_{\text{Denied}} = \$1,200,000$$

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### Step 11 of 18

Determine the net cost in not buying a land and the agency approves the permit using the relation:

$$(NC)_{\text{Approved}} = C_{\text{Avoided Land}} + C_{\text{Buy Land}} + C_{\text{Loss}}$$

Here,  $(NC)_{\text{Approved}}$  is the net cost of buying a land, starting the limited site work, and the agency approves the permit;  $C_{\text{Avoided Land}}$  is the opportunity cost of the land;  $C_{\text{Buy Land}}$  is the cost in buying land after the agency approves the permit; and  $C_{\text{Loss}}$  is the cost of loss caused due to interest and differential inflation cost.

Substitute  $\$1,200,000$  for  $C_{\text{Avoided Land}}$ ,  $-\$1,400,000$  for  $C_{\text{Buy Land}}$ , and  $-\$300,000$  for  $C_{\text{Loss}}$ :

$$(NC)_{\text{Approved}} = \$1,200,000 + (-\$1,400,000) + (-\$300,000)$$

$$(NC)_{\text{Approved}} = -\$500,000$$

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### Step 12 of 18

Determine the savings in buying a land and starting the limited site work using the relation:

$$S_{\text{Start buy land}} = ((NC)_{\text{Approved}} \times P_{\text{Approved}}) + ((NC)_{\text{Denied}} \times P_{\text{Denied}})$$

Here,  $S_{\text{Start buy land}}$  is the savings in not buying a land;  $(NC)_{\text{Approved}}$  is the net cost of buying a land, starting the limited site work, and the agency approves the permit;  $(NC)_{\text{Denied}}$  is the net cost of buying a land, starting the limited site work, and the agency denies the permit;  $P_{\text{Approved}}$  is the probability of permit being approved; and  $P_{\text{Denied}}$  is the probability of permit being denied.

Substitute  $\$1,200,000$  for  $(NC)_{\text{Denied}}$ ,  $0.2$  for  $P_{\text{Denied}}$ ,  $-\$500,000$  for  $(NC)_{\text{Approved}}$ , and  $0.8$  for  $P_{\text{Approved}}$ :

$$S_{\text{Start buy land}} = (-\$500,000 \times 0.8) + (\$1,200,000 \times 0.2)$$

$$S_{\text{Start buy land}} = -\$160,000$$

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### Step 13 of 18

Determine whether the utility should buy the land for the construction of the power plant or not by comparing the savings in buying the land and not buying the land and select the highest saving.

$$S_{\text{Optimal}} = \text{Highest of } \{S_{\text{Buy land}}, S_{\text{Start buy land}}\}$$

Here,  $S_{\text{Optimal}}$  is the saving achieved in implementing the best strategy,  $S_{\text{Buy land}}$  is the savings in buying a land for the power plant construction, and  $S_{\text{Start buy land}}$  is the savings in not buying a land.

Substitute  $\$160,000$  for  $S_{\text{Buy land}}$  and  $-\$160,000$  for  $S_{\text{Start buy land}}$ :

$$S_{\text{Optimal}} = \text{Highest of } \{\$160,000, -\$160,000\}$$

$$S_{\text{Optimal}} = \$160,000$$

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### Step 14 of 18

Draw the decision tree to determine the optimal action as in Figure (1).



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### Step 15 of 18

(a)

The optimal action is **to buy a land and start a limited site work**.

The expected saving in buying a land and performing a limited site work is **\$160,000**.

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### Step 16 of 18

(b)

Similarly, calculate the saving if the denial probability is raised to 0.3 and approval probability of 0.7 as in Figure (2).



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### Step 17 of 18

Draw the decision tree for a raised denial probability of 0.4 and approval probability of 0.6 as in Figure (3).



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### Step 18 of 18

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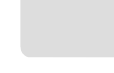
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not starting the limited site work is **\$80,000**

The best optimal choice if the probability of denial is raised to 0.4 would be **not to buy a land** and the cost of saving would be **€180,000**.

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