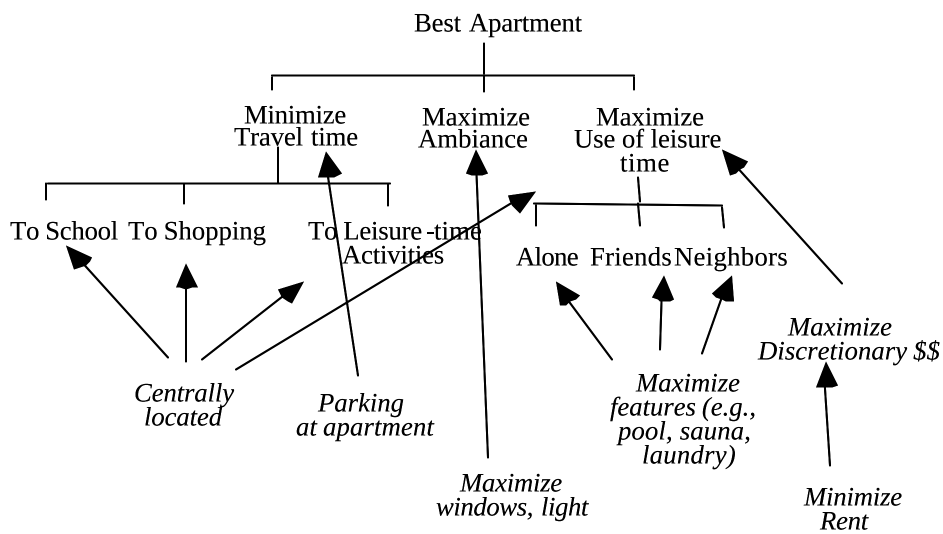
Solutions

3.1. Fundamental objectives are the essential reasons we care about a decision, whereas means objectives are things we care about because they help us achieve the fundamental objectives. In the automotive safety example, maximizing seat-belt use is a means objective because it helps to achieve the fundamental objectives of minimizing lives lost and injuries. We try to measure achievement of fundamental objectives because we want to know how a consequence “stacks up” in terms of the things we care about.

Separating means objectives from fundamental objectives is important in Chapter 3 if only to be sure that we are clear on the fundamental objectives, so that we know what to measure. In Chapter 6 we will see that the means-objectives network is fertile ground for creating new alternatives.

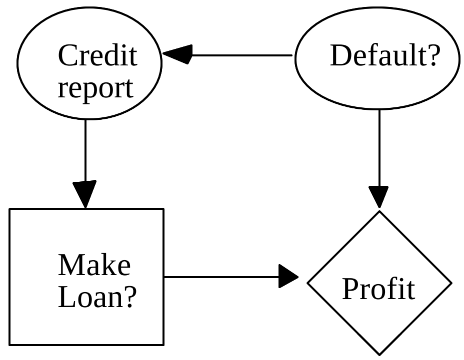
3.2. Answers will vary because different individuals have different objectives. Here is one possibility. (Means objectives are indicated by *italics*.)



3.3. A constructed scale for “ambiance” might be the following:

Best	Many large windows. Unit is like new. Entrance and landscape are clean and inviting with many plants and open areas.
--	Unit has excellent light into living areas, but bedrooms are poorly lit. Unit is clean and maintained, but there is some evidence of wear. Entrance and landscaping includes some plants and usable open areas but is not luxurious.
--	Unit has one large window that admits sufficient light to living room. Unit is reasonably clean; a few defects in walls, woodwork, floors. Entrance is not inviting but does appear safe. Landscaping is adequate with a few plants. Minimal open areas.
--	Unit has at least one window per room, but the windows are small. Considerable wear. Entrance is dark. Landscaping is poor; few plants, and small open areas are not inviting.
Worst	Unit has few windows, is not especially clean. Carpet has stains, woodwork and walls are marred. Entrance is dark and dreary, appears unsafe. Landscaping is poor or nonexistent; no plants, no usable open areas.

3.4. It is reasonable in this situation to assume that the bank’s objective is to maximize its profit on the loan, although there could be other objectives such as serving a particular clientele or gaining market share. The main risk is whether the borrower will default on the loan, and the credit report serves as imperfect information. Assuming that profit is the only objective, a simple influence diagram would be:

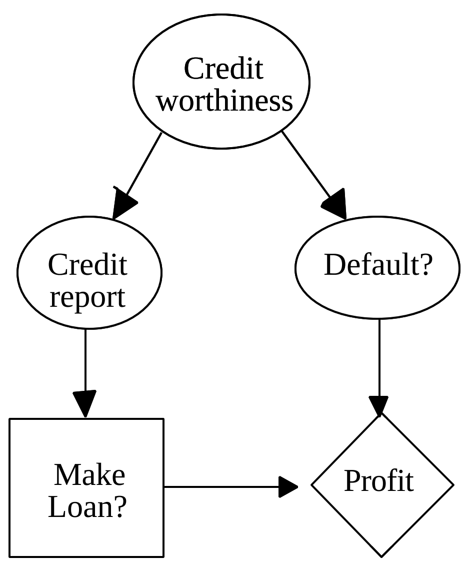


Note the node labeled "Default." Some students may be tempted to call this node something like "Credit worthy?" In fact, though, what matters to the bank is whether the money is paid back or not. A more precise analysis would require the banker to consider the probability distribution for the amount paid back (perhaps calculated as NPV for various possible cash flows).

Another question is whether the arrow from "Default" to "Credit Report" might not be better going the other way. On one hand, it might be easier to think about the probability of default given a particular credit report. But it might be more difficult to make judgments about the likelihood of a particular report without conditioning first on whether the borrower defaults.

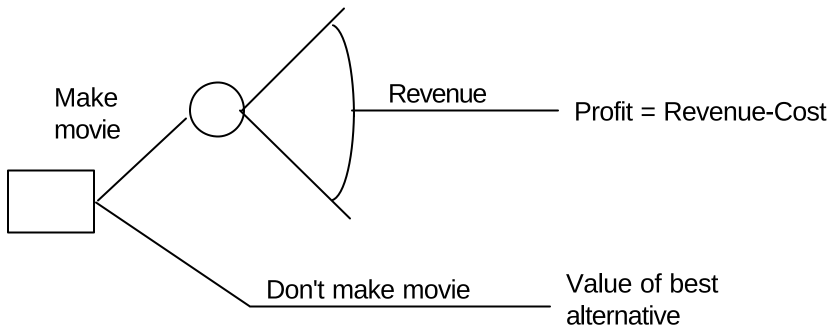
Also, note that the "Credit Report" node will probably have as its outcome some kind of summary measure based on many credit characteristics reported by the credit bureau. It might have something like ratings that bonds receive (AAA, AA, A, and so on). Arriving at a summary measure that passes the clarity test could be difficult and certainly would be an important aspect of the problem.

If the diagram above seems incomplete, a "Credit worthiness" node could be included and connected to both "Credit report" and "Default":



Both of these alternative influence diagrams are shown in the Excel file "Problem 3.4.xls". Two different types of arcs are used in the diagrams: 1) value only and 2) value and timing, and these are explained on page 94 in the text. A value influence type influences the payoff calculation and a timing type exists if the outcome precedes that calculation chronologically (or is known prior to the event).

3.5. This is a range-of-risk dilemma. Important components of profit include all of the different costs and revenue, especially box-office receipts, royalties, licensing fees, foreign rights, and so on. Furthermore, the definition of profits to pass the clarity test would require specification of a planning horizon. At the specified time in the future, all costs and revenues would be combined to calculate the movie's profits. In its simplest form, the decision tree would be as drawn below. Of course, other pertinent chance nodes could be included.



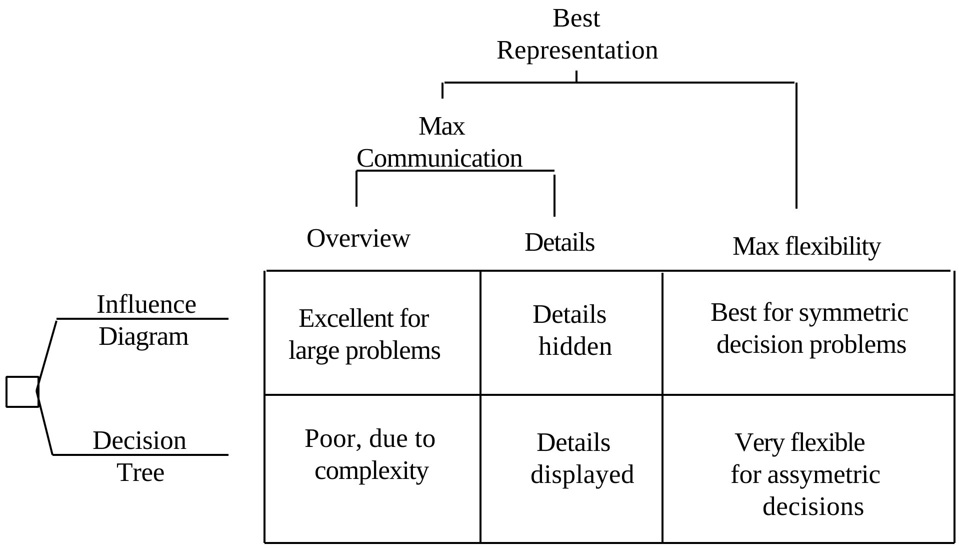
The revenue for the movie is drawn as a continuous uncertainty node in the above decision tree. Continuous distributions can be handled two ways in PrecisionTree either with a discrete approximation (see Chapter 8 in the text) or with simulation (see Chapter 11 in the text). This decision tree with a discrete approximation of some sample revenue values is shown in the Excel file "Problem 3.5.xls". A potentially useful exercise is to have the students alter the sample values to see the effect on the model and specifically the preferred decision.

3.6.

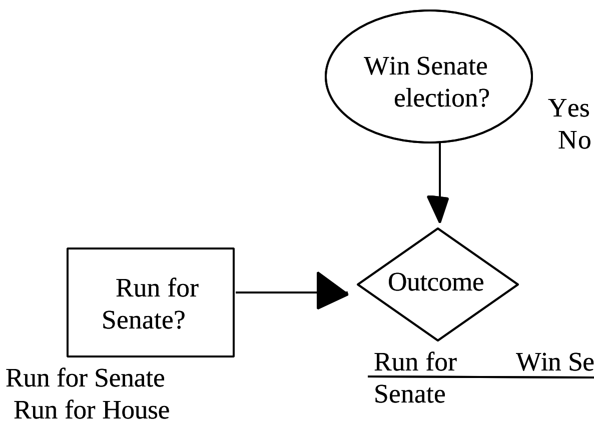
	Influence Diagrams	*Decision Trees*
Strengths	Compact Good for communication Good for overview of large problems	Display details Flexible representation
Weaknesses	Details suppressed	Become very messy for large problems

Which should he use? I would certainly use influence diagrams first to present an overview. If details must be discussed, a decision tree may work well for that.

3.7. This problem can be handled well with a simple decision tree and consequence matrix. See Chapter 4 for a discussion of symmetry in decision problems.

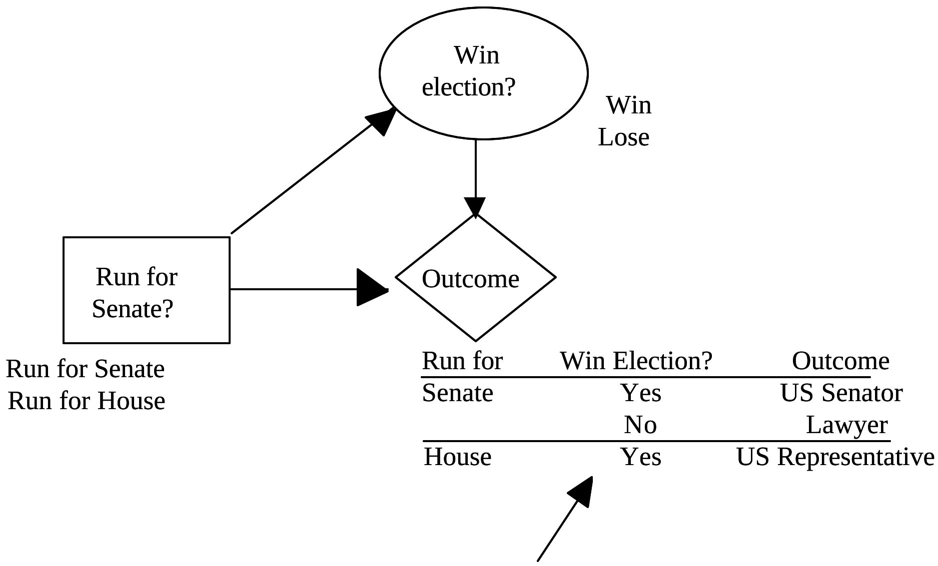


3.8.



Run for	Win Senate?	Outcome
Senate	Yes	US Senator
	No	Lawyer
House	Yes	US Representative
	No	US Representative

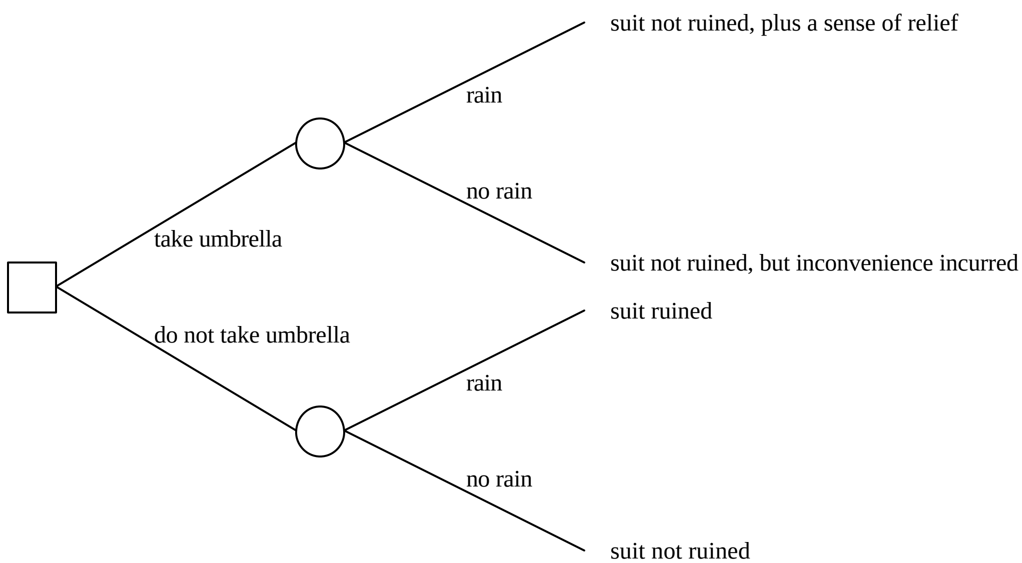
Note that the outcome of the "Win Senate" event is vacuous if the decision is made to run for the house. Some students will want to include an arc from the decision to the chance node on the grounds that the chance of winning the election depends on the choice made:



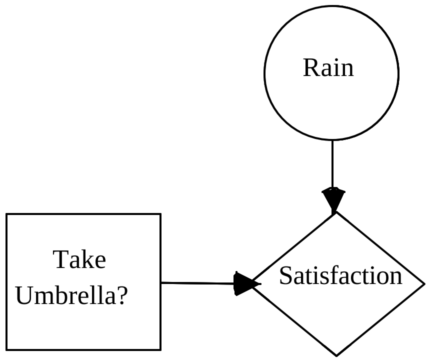
Note that it is not possible to lose the House election.

The arc is only to capture the asymmetry of the problem. To model asymmetries in an influence diagram, PrecisionTree uses structure arcs. When a structural influence is desired, it is necessary to specify how the predecessor node will affect the structure of the outcomes from the successor node. By using a structure arc, if the decision is made not to run for the senate, the "Win election?" node is skipped. This influence diagram is shown in the Excel file "Problem 3.8.xls".

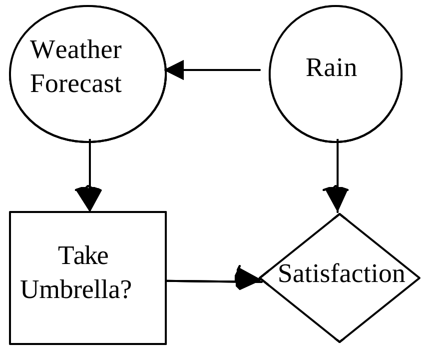
3.9. (Thanks to David Braden for this solution.) The following answers are based on the interpretation that the suit *will* be ruined if it rains. They are a good first pass at the problem structure (but see below).



(A) Decision tree



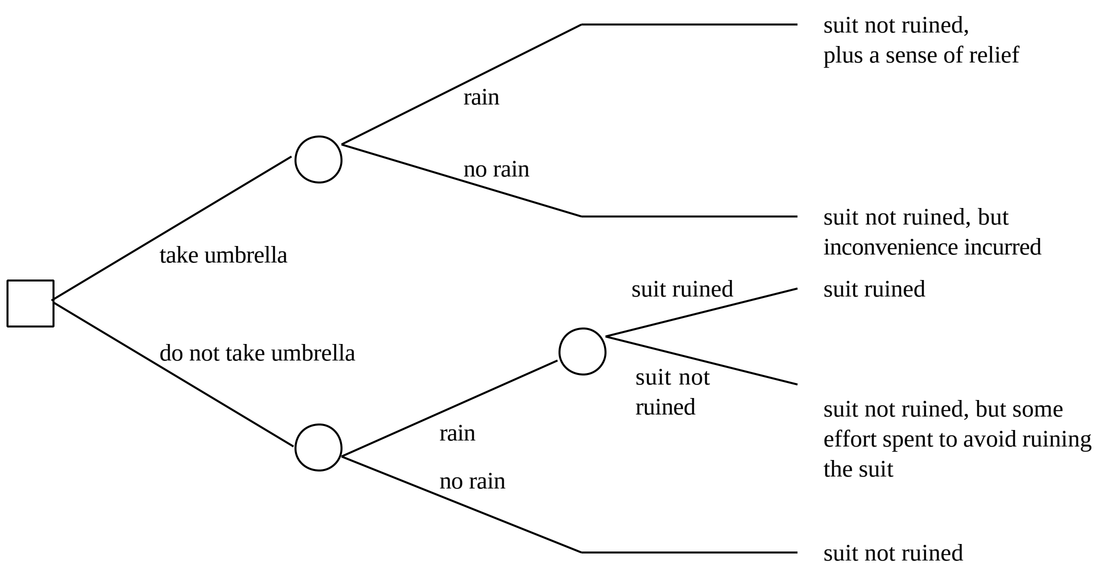
(B) Basic Risky Decision



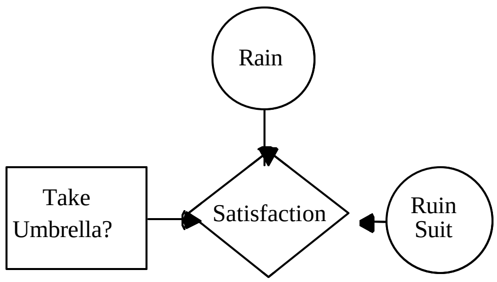
(C) Imperfect Information

The Excel solution "Problem 3.9.xls" shows a realization of this problem assuming the cost of the suit is $200, the cost of the inconvenience of carrying an umbrella when it is not raining is $20, the probability of rain is 0.25, and the weather forecaster is 90% accurate.

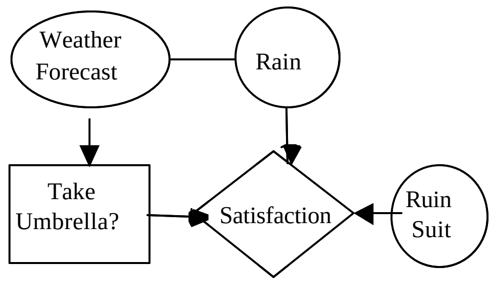
Note that the wording of the problem indicates that the suit *may* be ruined if it rains. For example, the degree of damage probably depends on the *amount* of rain that hits the suit, which is itself uncertain! The following diagrams capture this uncertainty.



(A) Decision tree



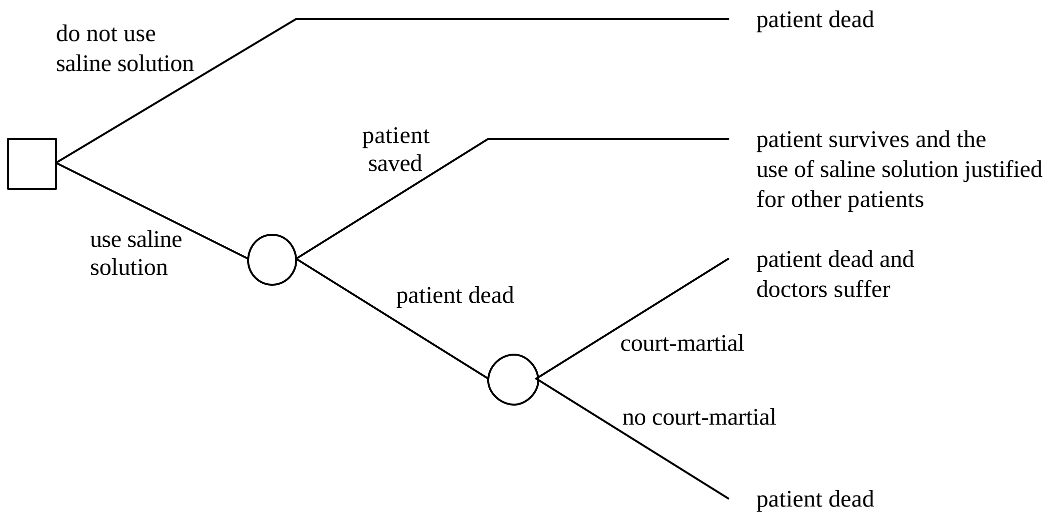
(B) Basic Risky Decision



(C) Imperfect Information

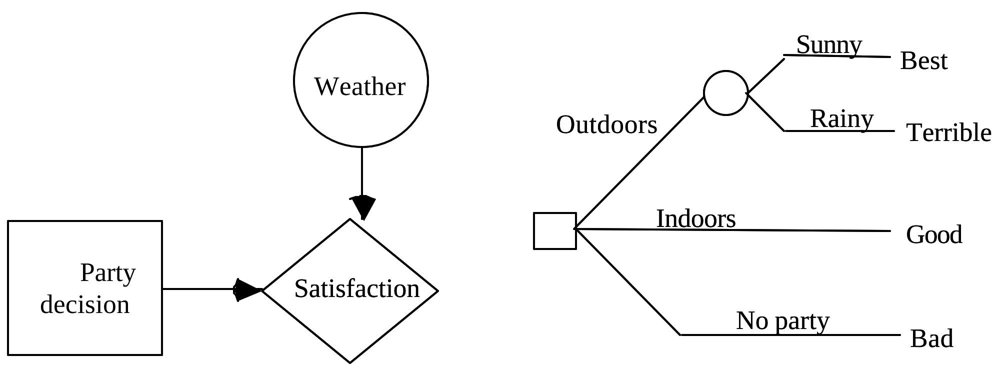
3.10. (Thanks to David Braden for this solution.)

The decision alternatives are (1) use the low-sodium saline solution, and (2) don't use the low-sodium saline solution. The uncertain variables are: (1) The effect of the saline solution, consequences for which are patient survival or death; (2) Possibility of court-martial if the saline solution is used and the patent dies. The possible consequences are court-martial or no court-martial. The decision tree:



This decision tree is drawn in the Excel file "Problem 3.10.xls".

3.11. a.

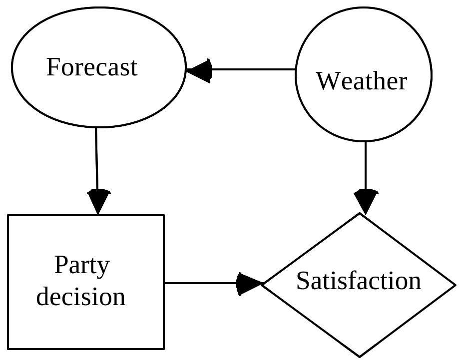


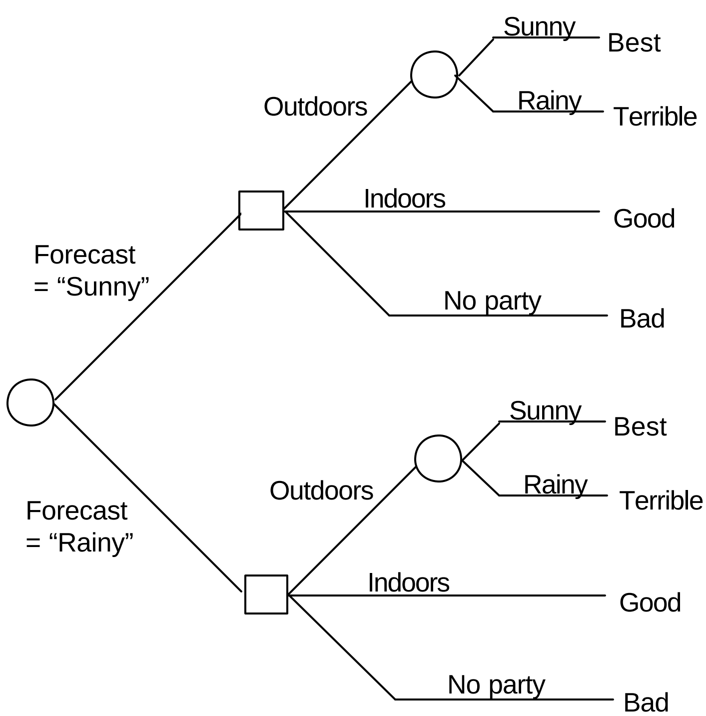
This influence diagram is drawn in the Excel file "Problem 3.11.xls" with some sample values assumed (on a utility scale, a sunny party outside is worth 100, an indoors party is worth 80, no party is worth 20, a party outside in the rain is worth 0, and the probability of rain is 0.3). A structure only arc is added in the file between party decision and weather to include the asymmetries to skip the weather uncertainty if the decision is made to have no party or have one indoors.

The second worksheet in the file shows the default decision tree created by the "Convert to Tree" button on the influence diagram settings dialog box. (Click on the name of the influence diagram "Problem 3.11a" to access the influence diagram settings. The Convert to Decision Tree button creates a decision tree from the current influence diagram. This can be used to check the model specified by an influence diagram to insure that the specified relationships and chronological ordering of nodes are correct. Conversion to a decision tree also shows the impacts of any Bayesian revisions made between nodes in the influence diagram.

Once a model described with an influence diagram is converted to decision tree, it may be further edited and enhanced in decision tree format. However, any edits made to the model in decision tree format will not be reflected in the original influence diagram.

b. The arrow points from "Weather" to "Forecast" because we can easily think about the chances associated with the weather and then the chances associated with the forecast, given the weather. That is, if the weather really will be sunny, what are the chances that the forecaster will predict sunny weather? (Of course, it is also possible to draw the arrow in the other direction. However, doing so suggests that it is easy to assess the chances associated with the different forecasts, regardless of the weather. Such an assessment can be hard to make, though; most people find the former approach easier to deal with.)





The influence diagram including the weather forecast is shown in the third worksheet and the associated default decision tree created by the "Convert to Tree" function is shown in the fourth worksheet. Additionally, we assumed that the weather forecaster is 90% accurate.

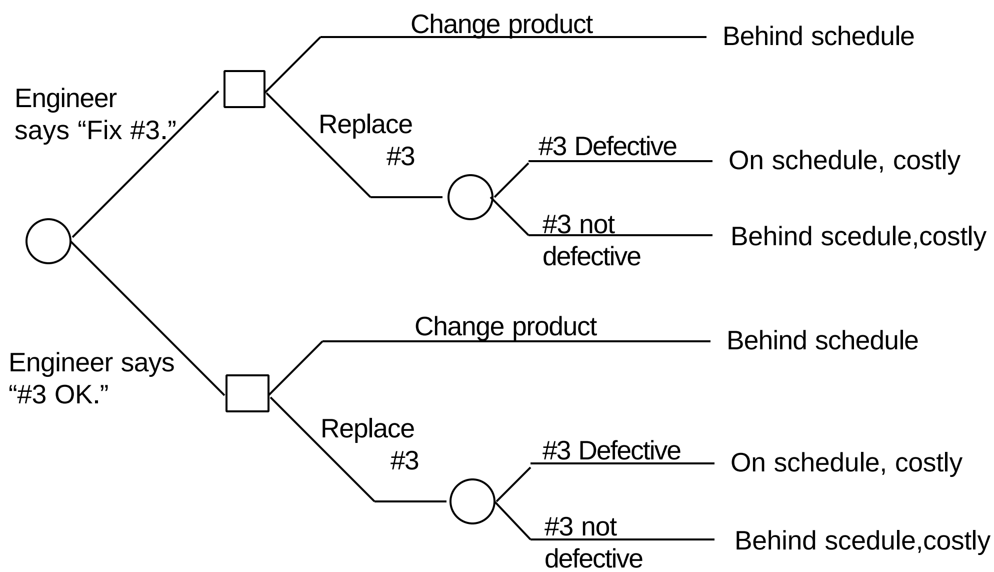
3.12. The outcome "Cloudy," defined as fully overcast and no blue sky, might be a useful distinction, because such an evening outdoors would not be as nice for most parties as a partly-cloudy sky. Actually, defining "Cloudy" to pass the clarity test is a difficult task. A possible definition is "At least 90% of the sky is cloud-covered for at least 90% of the time."

The NWS definition of rain is probably not as useful as one which would focus on whether the guests are forced indoors. Rain could come as a dreary drizzle, thunderstorm, or a light shower, for instance. The drizzle and the thunderstorm would no doubt force the guests inside, but the shower might not.

One possibility would be to create a constructed scale that measures the quality of the weather in terms that are appropriate for the party context. Here are some possible levels:

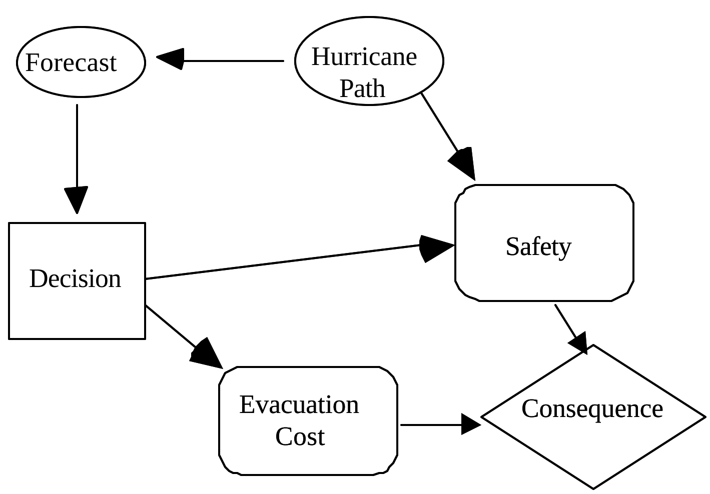
(Best)	Clear or partly cloudy. Light breeze. No precipitation.
--	Cloudy and humid. No precipitation.
--	Thunderclouds. Heavy downpour just before the party.
--	Cloudy and light winds (gusts to 15mph). Showers off and on.
(Worst)	Overcast. Heavy continual rain.

3.13.



This decision tree is drawn in the Excel file "Problem 3.13.xls".

3.14.



Note that Evacuation Cost is high or low depending only on the evacuation decision. Thus, there is no arc from Hurricane Path to Evacuation Cost.

This influence diagram is drawn in the Excel file "Problem 3.14.xls". Since PrecisionTree allows only one payoff node per influence diagram, the "Safety" and "Evaluation Cost" nodes are represented by calculation nodes. A calculation node (represented by a rounded blue rectangle) takes the results from predecessor nodes and combines them using calculations to generate new values. These nodes can be used to score how each decision either maximizes safety or minimizes cost.

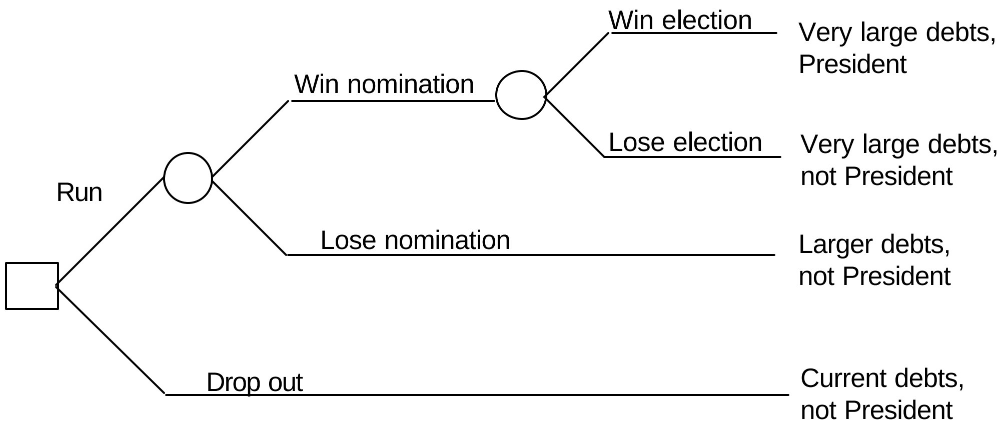
The constructed scale for safety is meant to describe conditions during a hurricane. Issues that should be considered are winds, rain, waves due to the hurricane's storm surge, and especially the damage to buildings that these conditions can create. Here is a possible constructed scale:

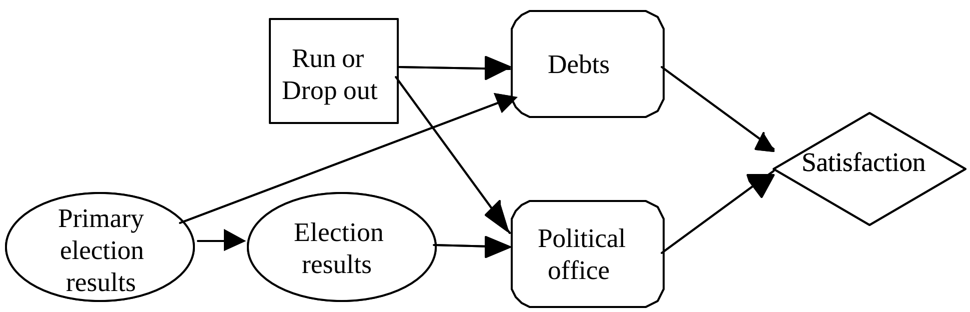
(Best)	Windy, heavy rain, and high waves, but little or no damage to property or infrastructure. After the storm passes there is little to do beyond cleaning up a little debris.
--	Rain causes minor flooding. Isolated instances of property damage, primarily due to window breakage. For people who stay inside a strong building during the storm, risk is minimal. Brief interruption of power service.
--	Flooding due to rain and storm surge. Buildings within 100 feet of shore sustain heavy damage. Wind strong enough to break many windows, but structural collapse rarely occurs. Power service interrupted for at least a day following the storm.
--	Flooding of roads and neighborhoods in the storm's path causes areas with high property damage. Many roofs are severely damaged, and several poorly constructed buildings collapse altogether. Both electrical power and water service are interrupted for at least a day following the storm.
(Worst)	Winds destroy many roofs and buildings, putting occupants at high risk of injury or death. Extensive flooding in the storm's path. Water and electrical service are interrupted for several days after the storm. Structural collapse of older wood-frame buildings occurs throughout the region, putting occupants at high risk.

3.15. Answers to this question will depend largely on individual preferences, although there are some typical responses. Some fundamental objectives: improve one's quality of life by making better decisions, help others make better decisions, improve career, graduate from college, improve one's GPA (for one who is motivated by grades). Some means objectives: satisfy a requirement for a major, improve a GPA (to have better job opportunities), satisfy a prerequisite for another course or for graduate school. Note that "making better decisions" is itself best viewed as a means objective because it can provide ways to improve one's life. Only a very few people (academics and textbook writers, for example), would find the study of decision analysis to be its own reward!

The second set of questions relates to the design of the course and whether it is possible to modify the course so that it can better suit the student's objectives. Although I do not want to promote classroom chaos, this is a valuable exercise for both students and instructor to go through together. (And the earlier in the term, the better!) Look at the means objectives, and try to elaborate the means objectives as much as possible. For example, if a class is primarily taking the course to satisfy a major requirement, it might make sense to find ways to make the course relate as much as possible to the students' major fields of study.

3.16. The main source of uncertainty is whether he will win the election. Conflicting objectives include reducing his debts versus becoming President. Of course, many different structures are possible, depending on exactly what elements of the decision are taken into account. Here are some possibilities:

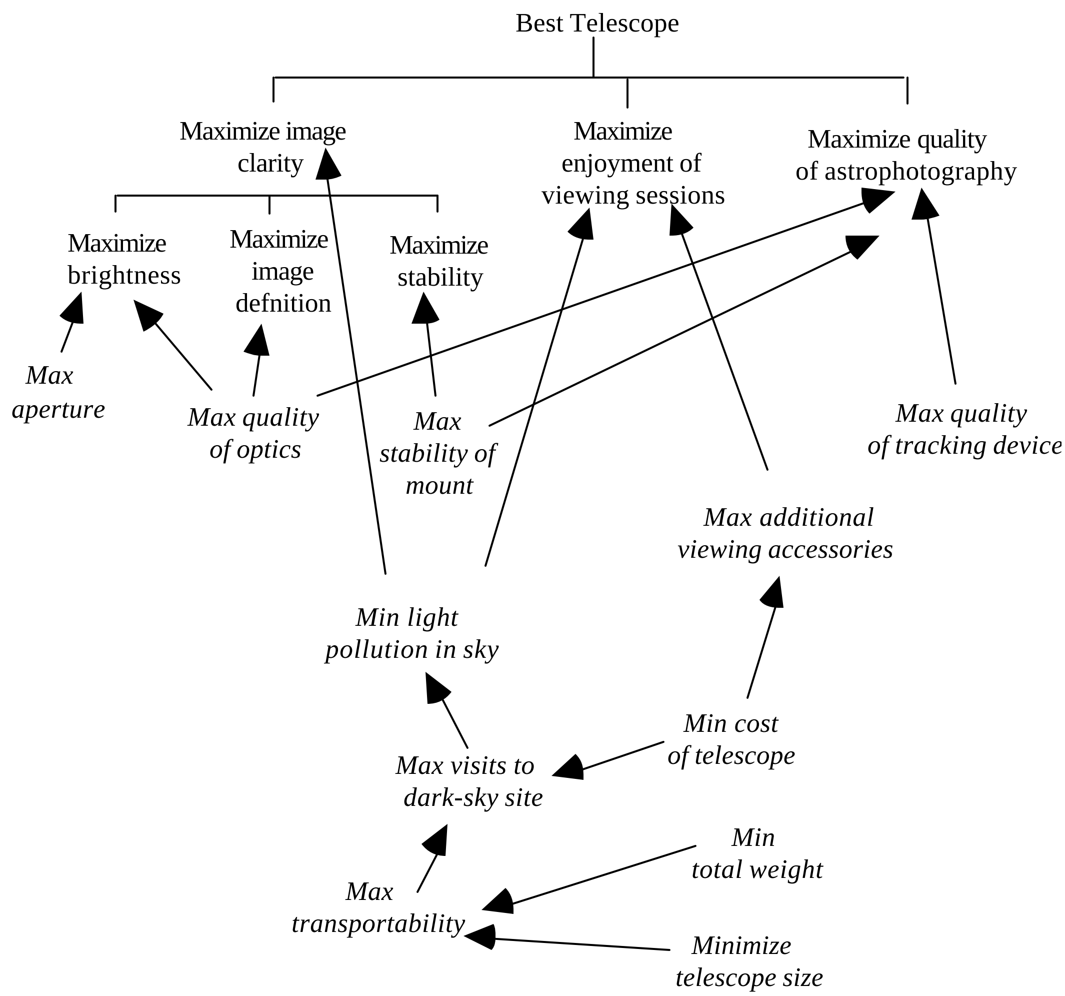




This decision tree and corresponding influence diagram are drawn in the Excel file "Problem 3.16.xls".

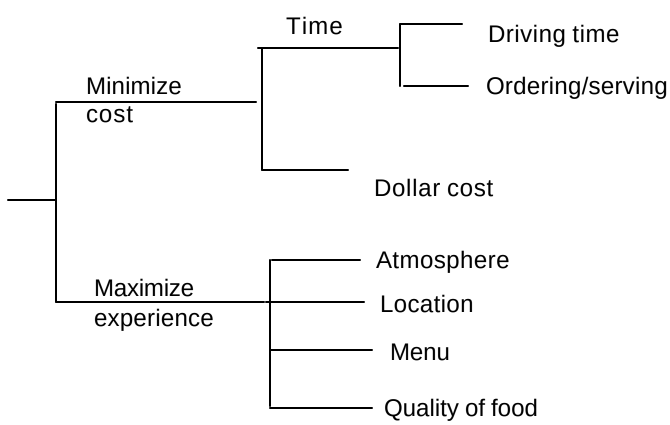
3.17. Here are my fundamental-objectives hierarchy and means-objective network (italics) in the context of purchasing or building a telescope. The diagram does provide insight! For example, many astronomers focus (so to speak) on image quality, and so there is a tendency to overemphasize aperture and quality of eyepieces. But for me, an important issue is enjoying myself as much as possible, and that can mean taking the telescope out of the city. All of the means objectives related to "Maximize enjoyment of viewing sessions" (which is intended to capture aspects other than enjoying the quality of the images viewed) push me toward a smaller, lighter, less expensive telescope. Thus, it is arguable that the basic question I must ask is whether I just want to get out at night and enjoy seeing a few interesting sights, or whether my interest really is in seeing very faint objects with as much clarity as possible.

Of course, the creative solution would be to find an inexpensive and highly transportable telescope with large aperture, excellent optics, and very stable mount. Unfortunately, such a telescope doesn't exist; all of the desired physical features would lead to a very expensive telescope!

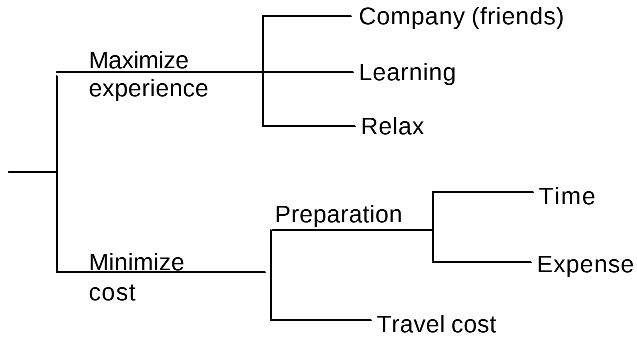


3.18. Objectives are, of course, a matter of personal preferences, and so answers will vary considerably.

a. Here is an objectives hierarchy for the decision context of going out to dinner:

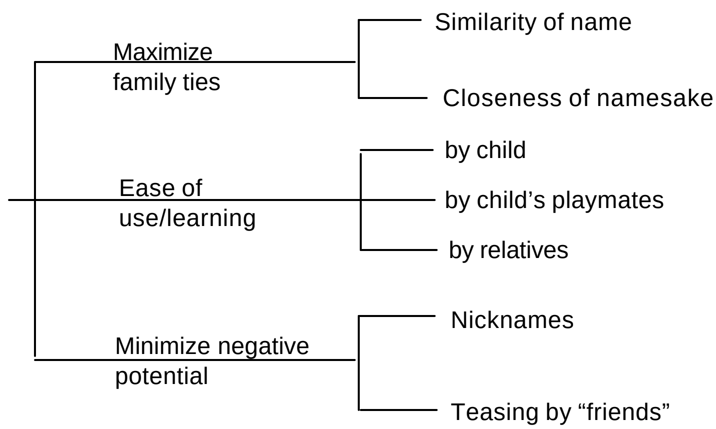


b. A simple hierarchy for deciding from among different trips:



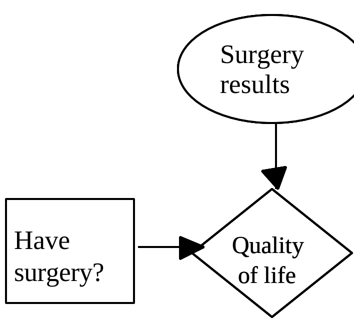
Some means objectives might be going to a particular kind of resort; maximizing time spent shopping, golfing, or on the beach; maximizing nights spent in youth hostels; using a travel agent (to reduce time spent in preparation); maximizing time in a foreign country (to maximize language learning, for example).

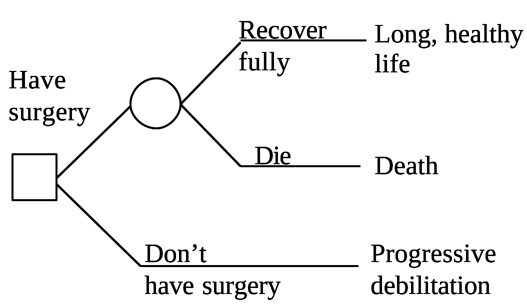
c. Here is a possible fundamental-objectives hierarchy for choosing a child's name:



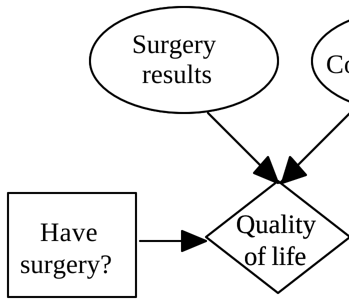
3.19. Responding to this question requires considerable introspection and can be very troubling for many students. At the same time, it can be very enlightening. I have had students face up to these issues in analyzing important personal decisions such as where to relocate after graduation, whether to make (or accept) a marriage proposal, or whether to have children. The question, "What is important in my life?" must be asked and, if answered clearly, can provide the individual with important insight and guidance.

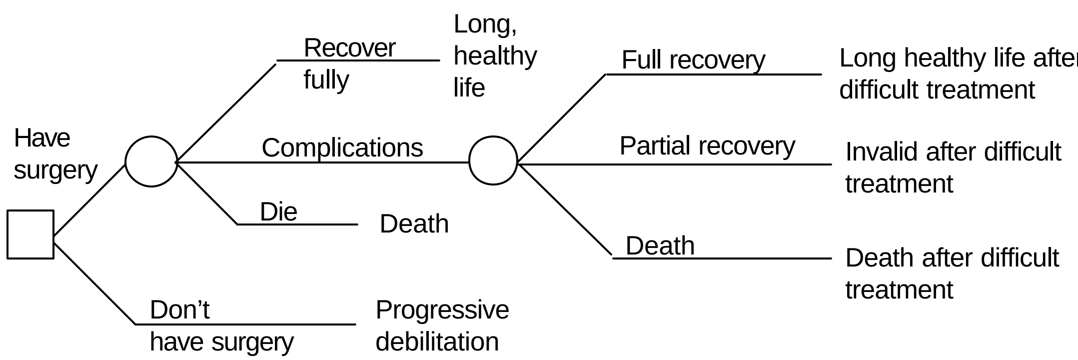
3.20. a. These influence diagrams and decision trees are drawn in the Excel file "Problem 3.20.xls".





b.





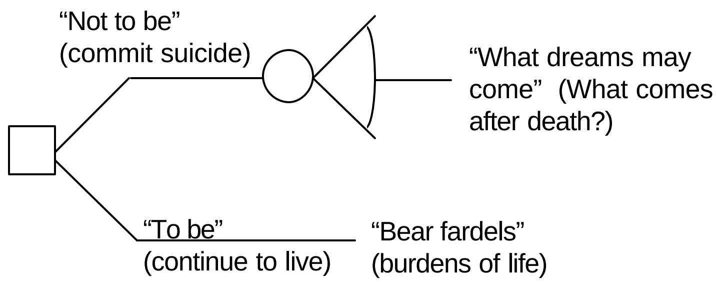
Given the possibility of complications and eventual consequences, the surgery looks considerably less appealing.

c. Defining this scale is a personal matter, but it must capture important aspects of what life would be like in case complications arise. Here is one possible scale:

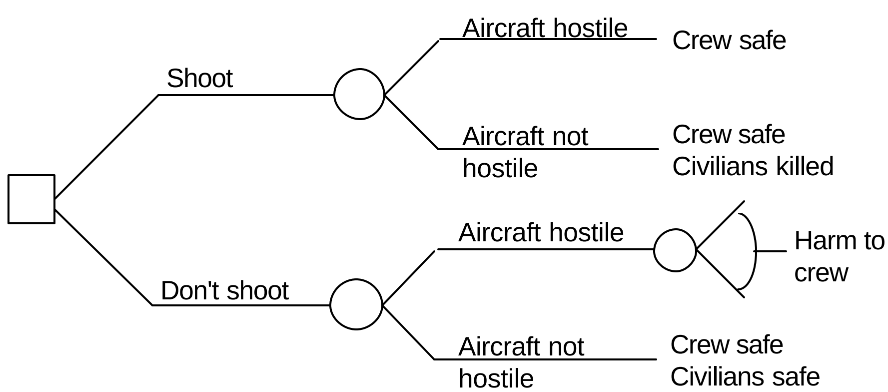
(Best)	No complications. Normal, healthy life.
--	Slight complications lead to minor health annoyances, need for medication, frequent visits. Little or no pain experienced. Able to engage in most age-appropriate activities.
--	Recovery from surgery requires more than two weeks of convalescence. Pain is intense but intermittent. Need for medication is constant after recovery. Unable to engage in all age-appropriate activities.
--	Recovery requires over a month. Chronic pain and constant need for medication. Confined to wheelchair 50% of the time.
(Worst)	Complete invalid for remainder of life. Restricted to bed and wheelchair. Constant pain, sometimes intense. Medication schedule complicated and occasionally overwhelming.

3.21. This question follows up on the personal decision situation that was identified in problem 1.9.

3.22 This decision tree is drawn in the Excel file "Problem 3.22.xls".



3.23. This decision tree is drawn in the Excel file "Problem 3.23.xls".



Rogers's most crucial objectives in this situation are to save lives, those of his crew and of any civilians who are not involved. It is not unreasonable to consider objectives of saving his ship or improving the relationship with Iran, but in the heat of action, these were probably not high on Rogers' list.

The risk that Rogers faces is that the blip on the radar screen may not represent a hostile aircraft. The main trade-off, of course, is the risk to his crew versus possibly killing innocent civilians.

As usual, there are a lot of ways this decision tree could be made more elaborate. For example, a "Wait" alternative might be included. The tree above assumes that if the decision is to shoot, the incoming aircraft would be hit (generally a safe assumption these days), but one might want to include the possibility of missing.

3.24. This is a straightforward calculation of NPV. Assuming that all the cash flows happen at the ends of the years, the following table shows the cash flows:

Cash Flows Year	Stop	Continue No Patent	Continue Patent License	Continue Patent Develop Dem. High	Continue Patent Develop Dem. Med	Continue Patent Develop Dem. Low
0	0	0	0	0	0	0
1	0	-2	-2	-2	-2	-2
2	0	0	0	0	0	0
3	0	0	5	-5	-5	-5
4	0	0	5	-5	-5	-5
5	0	0	5	11	6.6	3
6	0	0	5	11	6.6	3
7	0	0	5	11	6.6	3
8	0	0	0	11	6.6	3
9	0	0	0	11	6.6	3

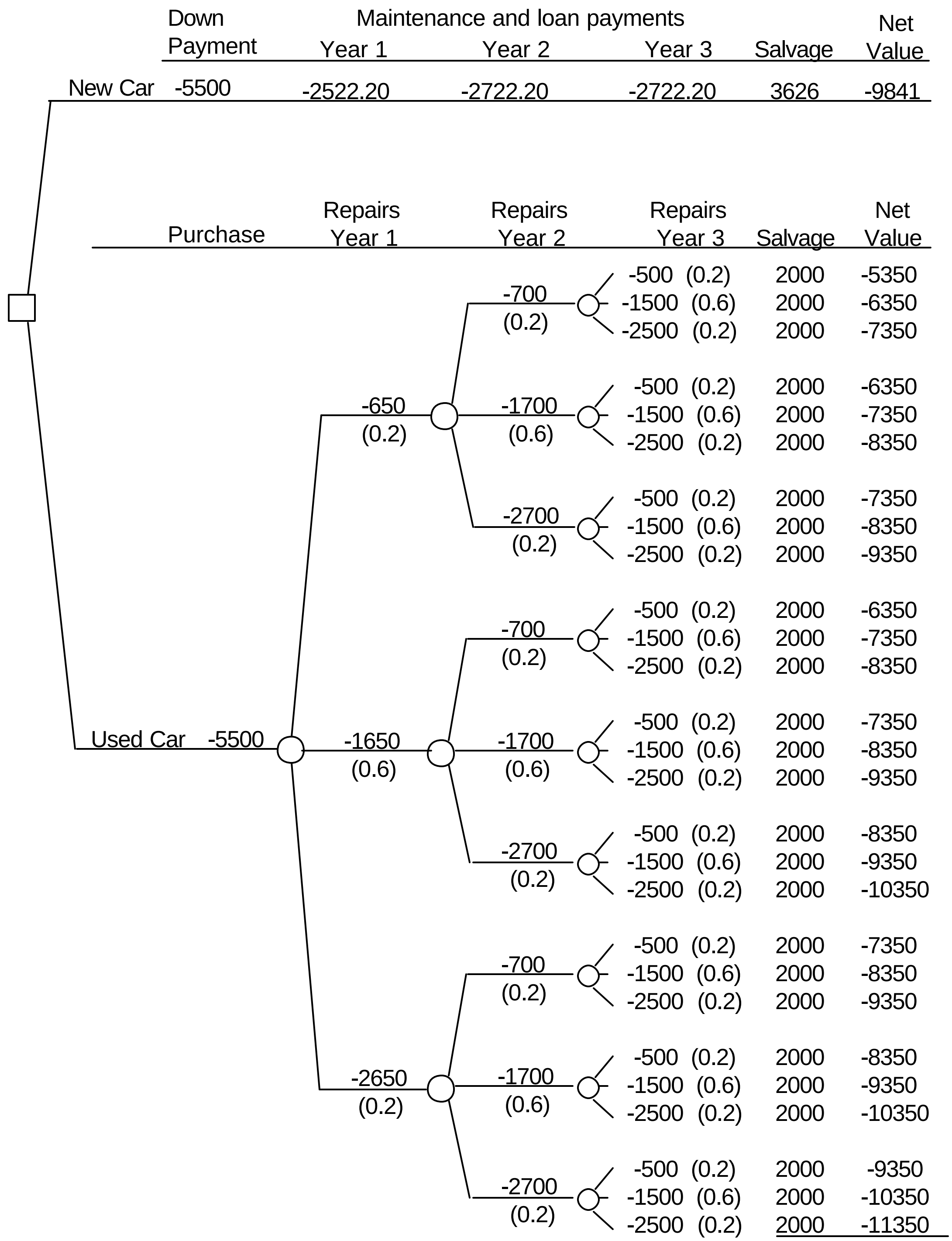
Present values are calculated by applying the appropriate discount rate to each cash flow; the discount rate is $\frac{1}{1.15^i}$ for the cash flows in year i. Finally, NPV is the sum of the present values. Also, the NPV function in Excel can be used for the calculations as shown in the Excel file "Problem 3.24.xls".

Present Values Year	Discount Factor	Stop	Continue No Patent	Continue Patent License	Continue Patent Develop Dem. High	Continue Patent Develop Dem. Med	Continue Patent Develop Dem. Low
0	1	0.00	0.00	0.00	0.00	0.00	0.00
1	0.8696	0.00	-1.74	-1.74	-1.74	-1.74	-1.74
2	0.7561	0.00	0.00	0.00	0.00	0.00	0.00
3	0.6575	0.00	0.00	3.29	-3.29	-3.29	-3.29
4	0.5718	0.00	0.00	2.86	-2.86	-2.86	-2.86
5	0.4972	0.00	0.00	2.49	5.47	3.28	1.49
6	0.4323	0.00	0.00	2.16	4.76	2.85	1.30
7	0.3759	0.00	0.00	1.88	4.14	2.48	1.13
8	0.3269	0.00	0.00	0.00	3.60	2.16	0.98
9	0.2843	0.00	0.00	0.00	3.13	1.88	0.85
NPV		**0.00**	**-1.74**	**10.93**	**13.20**	**4.76**	**-2.14**

In file "Problem 3.24.xls", the decision tree references the NPV calculations to demonstrate the process of choosing to continue or stop development. The ability to build these trees in Excel and reference cells as done in this problem makes this a powerful program. The payoff for each branch of the tree is a formula that corresponds to the correct cell in the NPV calculations worksheet.

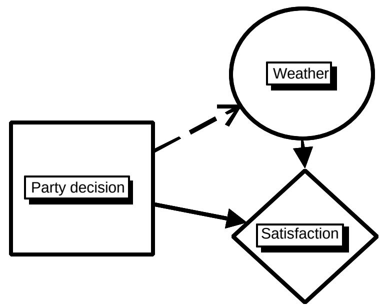
Alternative assumptions can be made about the timing of the cash flows. For example, it would not be unreasonable to believe that the expenses must be paid at the beginning of the year and that revenue arrives at the end of the year. The most realistic scenario, however, is that all cash flows are evenly spread out over the year for which they are specified.

3.25. This decision tree is relatively complex compared to the ones that we have seen so far. Buying the new car does not involve any risk. However, the used car has an uncertainty each year for the next three years. The decision tree is shown below. Note that it is also possible to calculate the NPVs for the ends of the branches; the natural interest rate to use would be 10%, although it would be best to use a rate that reflects what you could earn in another investment. This decision tree representation does not discount the values.

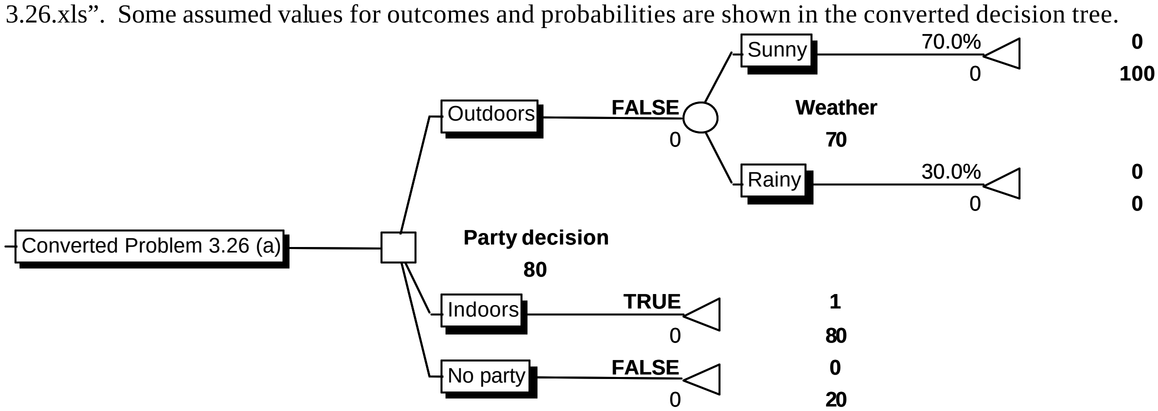


Two Excel files are included for this problem: one with discounting ("Problem 3.25.xls") and one without discounting that corresponds to the above decision tree ("Problem 3.25 alt.xls"). The decision trees are implemented with a payoff formula. The payoff formula is specified in the decision tree settings dialog box. The formula sums the values (costs) incurred through each path of the decision tree, and in "Problem 3.25.xls" discounts the values appropriately according to the chosen interest rate. Changing the interest rate in cell B4 does not automatically update the formula calculations. In order to update the decision tree calculations, you need to open the decision tree settings dialog box.

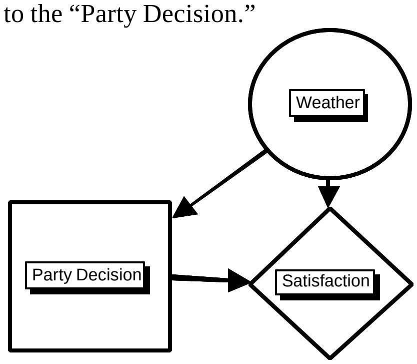
3.26a. The influence diagram from Exercise 3.11(a) is shown here drawn in PrecisionTree.

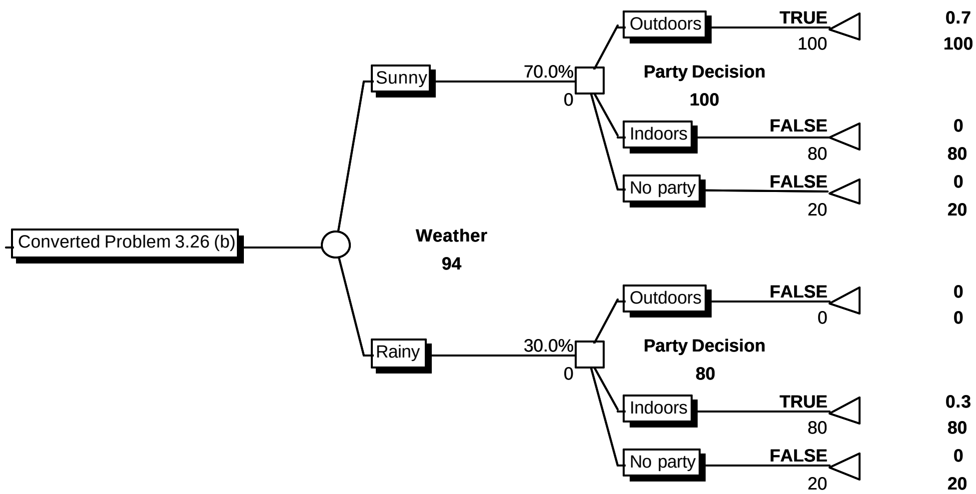


In order for the "Convert To Tree" button to automatically adjust for the asymmetries, a structure arc is needed from "Party Decision" to "Weather" (represented by the dotted arrow). This influence diagram and the corresponding converted decision tree are shown in the first two worksheets in the Excel file "Problem 3.26.xls". Some assumed values for outcomes and probabilities are shown in the converted decision tree.

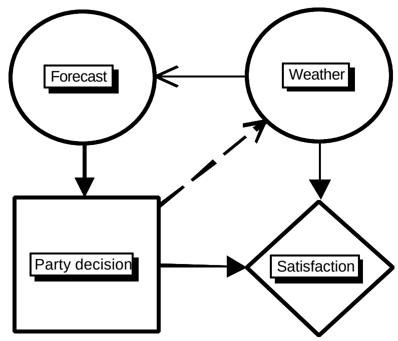


b. Adding the arrow from "Weather" to "Party Decision" means that the information regarding the weather is known before the time of the decision. Therefore, in the Converted Decision Tree, the "Weather" chance events will appear in the tree prior to the "Party Decision."





c.



If the arrow went from "Party" to "Forecast", then you would have to make the party decision before you got the forecast. If an arrow started at "Forecast" and went to "Weather", we would be stating that somehow the forecast influences the weather.