Chapter 16. Case #5 (draft, review copy)
Managing a Feebate Program for Cleaner Vehicles

Imagine you have been asked to design an incentive program to promote the sale of cleaner vehicles in your city. And if you take on this job, you will be asked to manage the feebate program. This is quite an offer, and you are wondering whether to accept it.

Your city is huge, with over a million new cars sold each year. Most of them burn gasoline and release harmful pollutants into the air shed. Your job is to shift the sales toward cleaner vehicles. The market place has been changing rapidly, and consumers now have dramatically different choices including electric vehicles, hybrid-electric vehicles and vehicles fueled with compressed natural gas. You are convinced that purchase price incentives are the key to shifting consumer choices. You believe a large rebate could encourage the purchase of electric cars and other alternative-fueled vehicles. But your program is suppose to be self-financing, so how do you pay for the rebates?

One answer is feebates. A fee would be imposed on the purchase of new vehicles with high pollution, and the revenues from the fees would cover the cost of rebate. Imagine that you have proposed the feebate idea, and the top officials are willing to go with your judgment. But they remind you that millions of new cars are sold each year, so the cash flow for rebates could be enormous. They want to know if you can guarantee that the cash coming in from fees will balance the cash flow for rebates. And they ask what you propose to do if the cash flows are not in balance.

These are difficult questions, and you aren't sure how to answer them. Wisely, you turn to system dynamics to build your understanding. System dynamics has its roots in control theory, so you know it is well suited for problems of controllability. You identify yourself as the initial client for a modeling study. If you can design a good policy for managing feebates, you will want to use modeling to explain your policy to the top officials. For their benefit, as well as your own, it is useful include a control panel to promote interactive simulation and discussion.

This chapter leads you through the development of such a model. Supporting information and the Vensim and Stella models are available on the book's website (BWeb). The chapter concludes with a set of exercises to let you experiment with fees and rebates. A second set of exercises challenges you to expand and improve the model.

Background on Urban Air Pollution

Air pollution in America's urban areas became a highly publicized issue in the 1960s. The first emission standards were established in 1965. They were followed by the Clean Air Act of 1970. It established stricter standards to take effect in 1975 to protect human health. Unfortunately, the air in many of our urban areas remains unhealthy over two decades after the original 1975 target date.

The most visible sign of the continuing failure was the smog in our dirtiest cities. Smog is tropospheric ozone. It is formed by a photochemical reaction between hydrocarbons (HC) and the oxides of nitrogen (NO_x) in the presence of heat and sunlight. Gordon (1991, 62) reported that "more than 100 of the cities in the US are choking on smog, and roughly half of all Americans live in areas that exceed the ozone standard at least once a year." The air pollution problems in America's urban areas have persisted for many decades even though the pollutants themselves are quickly dissipated in the atmosphere. The persistence of urban air pollution stems from our continued use of polluting technologies on the ground.

One of the biggest polluters is the automobile. Gordon reported that there were 187 million cars and light trucks or vans on the road in 1989, roughly 1.5 vehicles for every working American. The transportation sector was said to be responsible for two-thirds of the nation's carbon monoxide (CO) emissions and around 40% of the nation's HC and NO_x emissions. Transportation was also responsible for 30% of the nation's CO2 emissions. The tail pipe emissions from a conventional gasoline vehicle include HC, NO_x and CO. HC and NO_x are the precursors to ozone. CO is a heavier pollutant which becomes highly concentrated in transportation corridors and causes headaches and stress on the heart.

Each of these pollutants is subject to emissions standards set by the state agencies. If the population of vehicles continues to grow, the responsible agencies will have to adopt more and more expensive measures to lower emissions sufficiently to bring the air shed into compliance. Some air districts have issued extremely detailed plans with hundreds of control measures along with their costs per pound of emission reduction. The marginal control measures in such plans are an indication of the cost associated with emissions over the life of a CV. The BWeb explains the cost of a CV in a polluted air shed in southern California in the late 1990s:

115 pounds of HC @ $8 plus
133 pounds of NO_x @ $12 plus
1,346 pounds of CO @ $5

for a total cost of over $9,000. In other words, a conventional vehicle's lifetime emissions would force the air district to call on industries, municipalities and residents to spend over $9,000 to achieve compensating reductions elsewhere in the air shed.

The Value of Electric Vehicles

Sperling (1988, 1995) and Gordon (1991) describe the prospects for improving urban air pollution by changing the mix of vehicles. Rather than continued reliance on conventional vehicles burning gasoline or diesel fuels, they envision a future with a wide array of choices. The vehicles of the future might be fueled by gasoline, ethanol, methanol, compressed natural gas or electricity. Electric vehicles (EVs) are one of the more intriguing technologies because they offer the prospects for zero emissions. Indeed, EVs are sometimes called ZEVs or zero emission vehicles, and a major debate was underway in California during the 1990s about government regulations for ZEVs. California regulators stepped back from the strict production requirement. General Motors Corporation produced the EV-1, the first generation of commercially produced electric vehicles in the U.S. The GM EV-1 effort was not sustained, and the vehicles sold during the 1990s were removed from operation as their leases expired. However, interest in EVs is growing again due to a combination of concerns over urban air pollution, the skyrocketing price of gasoline and the dangerous accumulation of CO2 in the atmosphere.

The increased attention on EVs make them a good point of focus for this chapter. We'll pay close attention to the comparison of an EV with a CV. The attributes for both vehicles are taken from the mid 1990s, as explained in the 1st edition of *Modeling the Environment* (BWeb). The fuel prices will be taken from that period as well. And let's proceed with the $9,000 estimate of the value of an EV relative to a CV.

Joe questions the $9,000 estimate

Joe raises his hand to ask about the hidden emissions for an EV. He suspects the EV batteries would be recharged each night so the vehicles would be ready for the next day's commute. That electricity could come from burning fossil fuels, so there would be emissions to the atmosphere. Shouldn't these emissions be counted against the EV?

This is a good question, one that is frequently asked in the classroom. And Joe is right about the electricity generation --- it would typically occur during night-time hours. For the electric system in the western USA, the marginal generators would be fueled by natural gas. The BWeb explains that the gas-fired generation would add some NO_x to the atmosphere, thus contributing to the formation of smog. When the NO_x emissions are evaluated at 12 $/pound, they could add $300 to the cost of the EV. The relative value of an EV would be reduced from $9,000 to $8,700.

Many students have the same concern as Joe because they have become cautious about new technologies. But for some reason, students often do not ask the corresponding question about the existing vehicles: *what about the hidden emissions for a CV?* These are the emissions associated with the production of gasoline at the refinery and the distribution of gasoline at the retail station. These emissions are often forgotten, but they are not hidden. Indeed, they are often in plain sight (i.e., when you are filling your gas tank on a hot day). These emissions add around $1,300 to the cost of the CV (BWeb).

The cost of a CV (relative to an EV) is now $9,000 minus $300 plus $1,300 for a total of $10,000. $10,000 is a round number that is easy to remember. It will serve as a target for the feebate modeling in this chapter.

The Case for Feebates

Feebates are appealing because they would work to supplement the market forces that create the supply and demand for vehicles. With current market forces, the $10,000 extra cost of a CV is largely ignored by consumers. With feebates, however, this cost could be brought to the consumer's immediate attention by setting the fee and rebate to total $10,000. For example, the CV fee might be set at $2,000 and the EV rebate at $8,000. Consumers would be free to chose whichever vehicle best meets their needs, and manufacturers would be free to produce the most profitable mix of vehicles. The market would now operate with feedback to the participants on the environmental impacts of their decisions.

Feebates are also appealing because they would promote new technologies without requiring the program administrator to play favorites. Feebate programs could be implemented in a fuel neutral and a technology neutral manner. Each vehicle could be evaluated solely in terms of its emissions in the air shed, and the feebates could be adjusted accordingly. Any clean vehicle would qualify for a rebate; any dirty vehicle would be subject to a fee.

The Challenge of Feebates

Feebates are appealing, but could they be managed in a pragmatic manner? Suppose that the CVs and EVs are the only vehicle choices, and we elect to set the CV fee at $2,000 and the EV rebate at $8,000. We hope that the fees collected from the sale of CVs will provide the financing for the EV rebates. We announce the feebate for a given model year and wait to watch the market response. Perhaps the market will respond with 80% CVs and 20% EVs. If 80 out of 100 buyers purchase the CV despite the $2,000 fee, we would collect $160,000 in fees. The other 20 buyers receive an $8,000 rebate, so total rebates would be $160,000. This example shows the ideal situation – the cash flows are in balance, and the program may be described as self financing. Self financing is another reason for the popularity of feebates -- they could be operated in a revenue neutral manner so as to avoid the “tax label” (which is unpopular in the US).

Now, consider a slight variation on the ideal situation. Suppose the market responds with a 70% - 30% mix of CVs - EVs. For every 100 new car purchasers, we would collect $140,000 in fees, but we would be obligated for $240,000 in rebates. The program would be $100,000 out of balance for every 100 new cars sold. Think of the consequences with 1 million new cars sold every year -- the feebate program would be out of balance by one billion dollars per year!

At this point, you are probably thinking that you could avoid this problem by setting the feebate to account for the 70% - 30% market shares. You might keep the fee at $2,000 but lower the rebate to $4,667. Or you might set the fee to $1,000 and the rebate at $2,333. Both of these examples abandon the goal of keeping the sum of the fee and rebate at $10,000. But suppose our focus is to get the cash flow into balance. These two examples aim to do so by setting the rebate at 2.33 times the fee. This makes sense because the CV market share is expected to be 2.33 times larger than the EV market share. However, these examples presuppose that you can accurately forecast the 70% - 30% market shares.

Unfortunately, there is little reason to believe that you could develop a reliable forecast of market shares. Your efforts would be hampered by major uncertainties in describing consumer behavior and equally important uncertainties in describing the attributes of the vehicles to be offered for sale. If we are to seriously consider a feebate program, we must face the fact that the administrator will not have a crystal ball to forecast future market shares.

Since the cash flow will be frequently out of balance, so it makes sense to operate with a balancing account. (We'll start with $100 million in the account.) We should expect to see years when fees exceed rebates, so the balancing account will grow. And there will be years when the rebates exceed the fees, so the balance in the account will decline. We wish to know if the fees and rebates could be adjusted to control the fund balance reasonably close to zero. This is the main purpose of the model. Along the way, it will also shed light on the mix of vehicles in operation and their emissions.

The model is explained below in work-book style, as if you are working along on your own computer. The modeling will be in Stella, but the BWeb provides the Vensim equivalents. We'll be dealing with five types of vehicles, so it makes sense to take advantage of Stella's arrays feature. You'll use the array editor to create a dimension called V with five elements for each of the vehicle types.

The Vehicles Sector

Fig. 16.1 shows the portion of the model devoted to the accumulation of vehicles in the air shed. These variables have been combined using Stella's sector tool. The conveyor stock is assigned to cars in operation. The stock is increased by sales and reduced by retirements. The retirements are based on a 10-year lifetime for all five types of vehicles. Cars are measured in millions; sales and retirements are in millions of cars per year. Let's assume that there are 10 million cars at the start of the simulation, and all of them are CVs. The initial value of this stock should be set to spread the 10 million evenly across the conveyor (exercise 14-1).

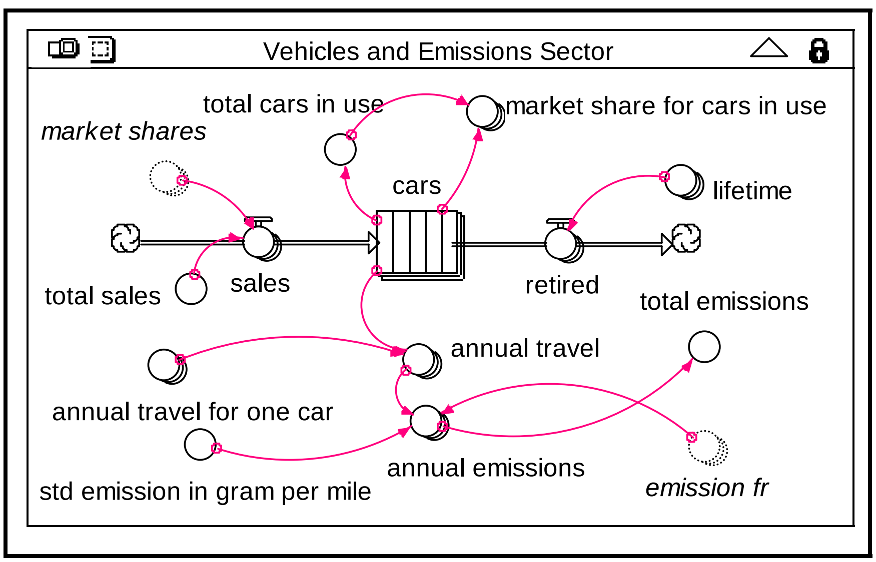

Fig. 16.1. The vehicles and emissions sector.

The sales is an array flow which is the product of the total sales and the market share for each of the five types of vehicles. Fig. 16.1 shows the market shares as a shadow variable because it is part of another sector. You can test the vehicle sector by specifying the market shares as shown in Table 16.1. Set the total sales to begin at 1.6 million/year and to grow exponentially at 0.047/yr (see the EXP function in Fig. 14.16.)

Set the model to simulate from 2000 to 2016 with DT at $1/4^{th}$ of a year. You should have total sales of 3.4 million vehicles/yr by the end of the simulation. The total vehicles in operation will grow from 10 million to nearly 27 million during the simulation. You should see 1.55 million EVs in operation at the end of the simulation.

Vehicle Type	Element Name	Emissions Fraction	Market Share
Conventional	CV	1.00	52%
Electric	EV	0.00	6%
Hybrid-Electric	HEV	0.37	8%
Compressed Nat. Gas	CNG	0.42	22%
Alcohol	AL	0.81	12%

Table 16.1. Vehicle information.

Now, set the annual travel for a single car at 10,000 miles/year and the annual travel as the product of the number of cars and the annual travel. The simulation begins with 10 million CVs, so annual travel is 100 billion miles/year. The standard emissions refers to the 0.25 grams of HC emissions expected from a CV per mile of travel. Annual emissions from 100 billion miles/yr would be 25 billion grams/yr. This the same as 25 thousand metric tons/yr, so we will measure annual emissions in thousands of metric tons of HC per year. The emissions fractions for each vehicle type are listed in Table 16.1. The electric vehicle is a ZEV, so its fraction is zero. The HEV is the next cleanest with HC emissions at 37% of the standard value assigned to a CV.

You should be able to build the vehicles sector from the information given so far. Run this sector on its own and check that total emissions grows to just over 50 thousand metric tons/yr by the end of the simulation.

Market Shares from a Discrete-Choice Model

Consumer choice between different types of vehicles could be influenced by a wide range of vehicle attributes such as purchase price, color, add-on options and your dealer's reputation. For this chapter, we'll draw on a vehicle choice modeling by researchers from the University of California (Bunch 1992). They modeled consumer choice based on six attributes that would cover the main differences between conventional and alternative vehicles. Table 16.2 shows the six attributes, along with the assumed values for this chapter. The first two attributes deal with the cost to purchase and operate the vehicle. The purchase prices range from $15,000 for a CV to $27,000 for an HEV. (Remember, these are numbers from the mid 1990s.) Fuel cost ranges from 2.7¢/mile for a CNG to 6.4 ¢/mile for a HEV.

Now, suppose we were dealing with consumers who focus solely on the costs. The first two attributes would tell the whole story. We might combine these two attributes into a total, effective cost of each vehicle. To illustrate, suppose we knew that consumers weight future fuel costs as if they expected to use their vehicle for 60,000 miles of total, discounted travel. In this case, the total, effective cost of a CV would be $15,000 for plus $2,820 (i.e. 60,000 miles @ 4.7¢/mile). The total, effective cost would be $17,820. We might then compute the corresponding cost of each of the other vehicles and compare the costs. But what would be do with the comparison? Would we award 100% of the market to the vehicle with the lowest cost? This might make sense if the winning vehicle were thousands of dollars less expensive. But what if it were only a few hundred dollars less expensive?

Attributes	CV	EV	HEV	CNG	AL
1. price	$15,000	$25,000	$27,000	$20,000	$18,000
2. fuel cost (¢/mile)	4.7	5.3	6.4	2.6	7.2
3. range (miles)	450	100	200	200	250
4. emissions fraction	1.00	0.00	0.37	0.42	0.81
5. fuel availability	1.00	0.50	1.00	0.25	0.20
6. horse power	121	65	85	115	134

Table 16.2. Attributes of five types of vehicles.

It's not immediately clear how we should calculate market share, even when we concentrate solely on the cost attributes. The market share simulation is made even more complicated by the presence of non-monetary attributes like horsepower. Most readers are familiar with horsepower, and most would prefer a car with more power (everything else held equal). Data on consumer purchases of cars with different horsepower might tell us how much more a consumer is willing to pay to buy a more powerful vehicle. We have such data for conventional vehicles, but we lack data for the alternative vehicles. And we also lack sales data on how consumer choice is shaped by attributes like range and emissions. How are we to proceed if there is no sales data to support a theory of consumer choice among vehicles?

The researchers from the University of California dealt with this problem with a mail-back survey of 700 people in southern California (Bunch 1992). The people were presented with choices between many different types of vehicles whose attributes spanned a wide range of values. Their choice of vehicles was then explained with a statistical model that has proven useful in discrete choice. The model is known as a multi-nominal logit model (BWeb). The market share for a particular vehicle (v) among 5 competing types of vehicles uses the exponential (exp) function as follows.

$$MSv = {\exp Uv}\Big/{\sum_{i=1}^{5} \exp Ui}$$

The U is sometimes described as the utility of a vehicle. This is an abstract term which is not easily interpreted. But for now, think of greater utility meaning greater overall attractiveness and a higher market share. Table 16.3 shows the Stella equations to implement the multi-nomial logit equation. The variables are grouped in a market shares sector shown in Fig. 16.2. The utility for each vehicle is the sum of utilities from the six attributes. The coefficients were estimated statistically from the stated preference survey. A single coefficient means that the stated preferences were well explained with a linear relationship. Two coefficients were used when a nonlinear expression provided a better explanation of the stated preferences.

```
market_shares[V] = numerator[V]/denominator
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numerator[V] = exp(U[V])
denominator = ARRAYSUM(numerator[*])
U[V] = U1[V]+U2[V]+U3[V]+U4[V]+U5[V]+U6[V]
U1[V] = coef_1*purchase_price[V]/1000
U2[V] = coef_2*fuel_cost[V]
U3[V] = coef_3A*(range[V]/100) + coef_3B*((range[V]/100)^2)
U4[V] = coef_4A*emission_fr[V]+coef_4B*emission_fr[V]^2
U5[V] = coef_5A*fuel_availability[V]+coef_5B*fuel_availability[V]^2
U6[V] = coef_6*horse_power[V]
coef_1 = -.143
coef_2 = -.175
coef_3A = 2.06
coef_3B = -.303
coef_4A = -3.08
coef_4B = 1.53
coef_5A = 2.24
coef_5B = -.956
coef_6 = .00796
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Table 16.3 Stella equations for the market share calculation.

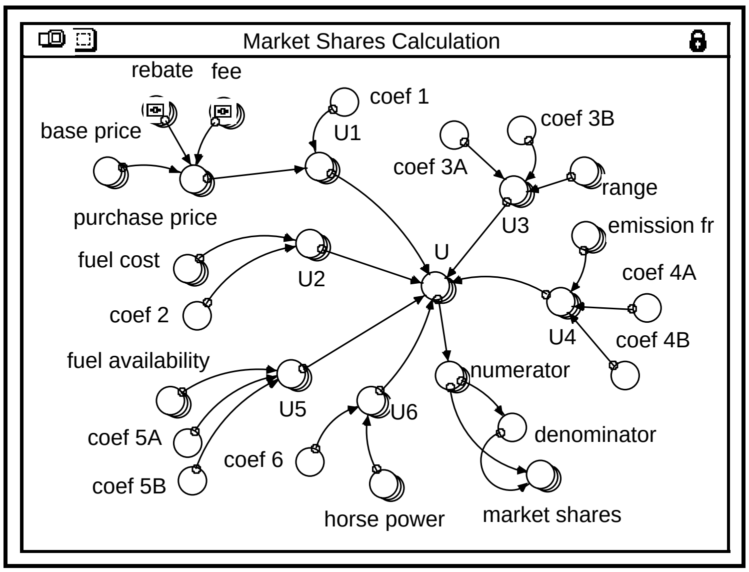

Fig. 16.2 The market shares sector.

The multi-nomial logit model has become well established in estimating discrete choice with multiple attributes (BWeb). Although the equations are suitable for statistical estimation, they do not lend themselves to easy interpretation. Inserting these equations into a spreadsheet will help us to experiment with the numbers. Table 16.4 and 16.5 show the spreadsheet (BWeb) to focus on competition between a CV and an EV. (The other three vehicles are ignored for clarity.) The utility of a CV is calculated as 0.86391. The utility of the EV turns out to be a negative number: -1.3471. This may look bad for the EV, but they would still capture some of the market:

MS_{EV} = 0.2599/(2.3724 + 0.2599) which turns out to be 10%.

A 10% market share turns out to be quite plausible if the competition is limited to CVs and EVs. Indeed, a 10% EV market share figured prominently in the ZEV debate during the 1990s (BWeb).

Attributes	coefficients			Utilities
price in thousands of $	-0.143	15.0	U1(CV)=	-2.145
fuel cost in cents/mile	-0.175	4.7	U2(CV)=	-0.8225
range in hundreds of miles	2.060	4.5		
range squared	-0.303	20.3	U3(CV)=	3.13425
emissions fraction	-3.080	1.0		
emission fraction squared	1.530	1.0	U4(CV)=	-1.55
fuel availability	2.240	1.0		
fuel availability squared	-0.956	1.0	U5(CV)=	1.284
horsepower	0.00796	121.0	U6(CV)=	0.96316
U (CV) =				0.86391
e^U				2.372419

Table 16.4. Spread sheet check for the CV.

Attributes	coefficients			Utilities
price in thousands of $	-0.143	25.0	U1(EV)=	-3.575
fuel cost in cents/mile	-0.175	5.3	U2(EV)=	-0.9275
range in hundreds of miles	2.060	1.0		
range squared	-0.303	1.0	U3(EV)=	1.757
emissions fraction	-3.080	0.0		
emission fraction squared	1.530	0.0	U4(EV)=	0
fuel availability	2.240	0.5		
fuel availability squared	-0.956	0.3	U5(EV)=	0.881
horsepower	0.00796	65.0	U6(EV)=	0.5174
U (EV)=				-1.3471
e^U				0.259993

Table 16.5. Spread sheet check for the EV.

The spread sheet makes it easy to conduct multiple experiments with different assumptions on the vehicles. If we increase the range of an EV to 200 miles, for example, the EV market share increases from 10% to 26%. Returning the range to 100 miles and lowering the price of the EV to $17,000 will deliver the same result – the market share increases to 26%. These experiments tell us that an extra 100 miles of range is worth $8,000. This is one of the tradeoffs implicit in the responses of the 700 folks who participated in the stated preference survey. You can experiment with the spread sheet to find other tradeoffs that were in the minds of the participants in the survey. The reasonableness of these tradeoffs is what makes the market share calculations suitable for the feebate modeling exercise.

You should be able to build the market share sector from the information provided so far. Run the model, and you should see the market shares listed in Table 16.1.

Cash Flow and the Control Panel

Fig. 16.3 shows the third sector of the model. The balance in the feebate fund is initialized at $100 million. The fund is fed by fees collected, and it is drained by rebates paid. The third flow is the interest earned or charged. The interest rate is 0.10/yr which means the fund will accumulate interest earnings at 10%/year. However, if the fund goes into the red, there will be interest charges at the rate of 10%/year. The fee and rebate are marked with the slider icon, so you know these will be set on the control panel. The sales is a ghosted variable from the vehicles sector. The equations for the this final sector are listed in Table 16.7

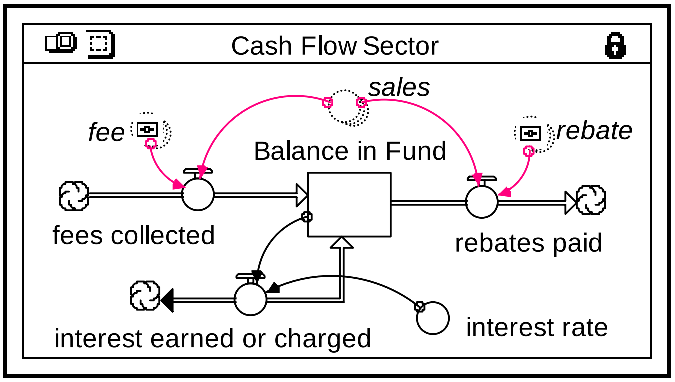

Fig. 16.3. The cash flow sector.

Balance_in_Fund(t) = Balance_in_Fund(t - dt) +
(fees_collected + interest_earned_or_charged - rebates_paid) * dt
INIT Balance_in_Fund = 100
fees_collected = fee[CV]*sales[CV]+fee[AL]*sales[AL]
interest_earned_or_charged = Balance_in_Fund*interest_rate
rebates_paid = rebate[EV]*sales[EV]+rebate[HEV]*sales[HEV]+rebate[CNG]*sales[CNG]
interest_rate = .10

Table 16.7. Stella equations for the cash flow sector.

The feebates model is formed by the three sectors in Fig. 16.1, 16.2 and 16.3. The downloadable model contains some extra "display" variables that make time graphs on the control variable easier to understand. Fig 16.4 shows the control panel on the BWeb downloadable model. An example of a display variable is the "Target is zero by the year 2016."

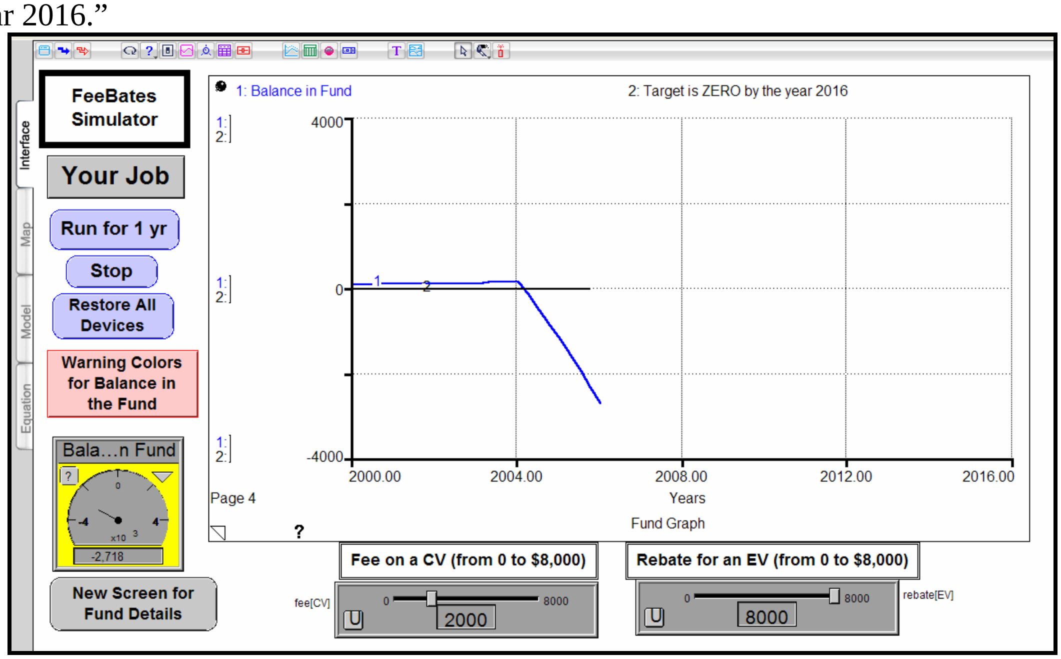

Fig. 16.4. Control panel results with a $2,000 fee and a $8,000 rebate.

The simulation in Fig. 16.4 begins with no fee or rebate. The market shares will match the values in Table 16.1, and the balance in the fund will grow from $100 million to $148 million due to interest earnings. The simulation advances one year at a time on the assumption that the feebate manager can elect to change feebates on an annual basis. This simulation imposes a $2,000 fee on CVs and allows an $8,000 rebate on EVs starting in 2004. (There are no fees or rebates on the AL, CNG or HEVs to keep the example simple.) These incentives cause the CV share of the new sales to fall from 52% to 40%,. The EVs market share increases from 6% to 18%. This is a good result so far. You have tripled the market share for EVs, and the sum of the fee and rebate is $10,000 so consumers feel the environmental value of an EV.

There are no changes in vehicle attributes or in fuel costs during the simulation, so these new market shares will remain in place as long as you keep the fee and rebate fixed. These incentives are held in place for two years in this simulation, and the fund is deeply in the red. The “Balance in Fund” warning light has turned yellow to draw your attention to the fact that the current balance has fallen below $2 billion in the red. Indeed, the current balance is a negative $2,718 million at this point in the simulation. This policy would put the state $2.7 billion in the red in just two years!

The control panel is designed with the idea that the feebate manager should be given considerable latitude in controlling the fund. The specific limits are plus or minus $4 billion. For example, if you let the fund go more than $4 billion in the red, Stella will ask for your resignation. And if you let the fund accumulate more than $4 billion, you will be fired for diverting too much money out of the economy. These are arbitrary limits. Perhaps you ill find that you can control the cash flows quite successfully. In this case, you could reassure the top officials that the fund balance will be maintained within plus or minus $1 billion. However, it may turn out that large swings in the fund balance are inevitable. In this case, you should warn the top officials that even the best fund manager will need wide latitude in managing the fund.

These are some of the possible conclusions to be drawn from the exercises. This chapter is written as a work-along chapter where you learn by building and experimenting on your own computer. You have come a long way if you have constructed the feebate model on your own computer. But much of the learning is waiting in the exercises. They will guide you through a typical process of experimentation and model improvement. By the end of the exercises you should know whether to accept the job as feebate manager.

Exercises

This chapter includes two sets of exercises. The first five exercises make use of the BWeb model. You’ll work on the interface layer to simulate the existing model under a wide variety of conditions. The second set of exercises call for changes in the underlying structure of the model. You’ll make the changes on the map and model layers of the software and then simulate the new model to learn if you can achieve better control of feebates.

Exercise 16-1. Verify the Stella model: Down load the Stella model and verify you get the market shares in Table 16.1 without fees or rebates. Verify that total emissions grow to just under 50 thousand metric tons by 2016. Then verify the results in Fig. 16.4.

Exercise 16-2. Verify the Vensim model. The BWeb provides a Vensim version using the PLE (free) version of the software. The PLE does not support arrays, so we assign separate variables as shown in Fig. 16.5. Run the model for the entire simulation to verify the market shares in Table 16.1 and that total emissions growing to just under 50 thousand metric tons.

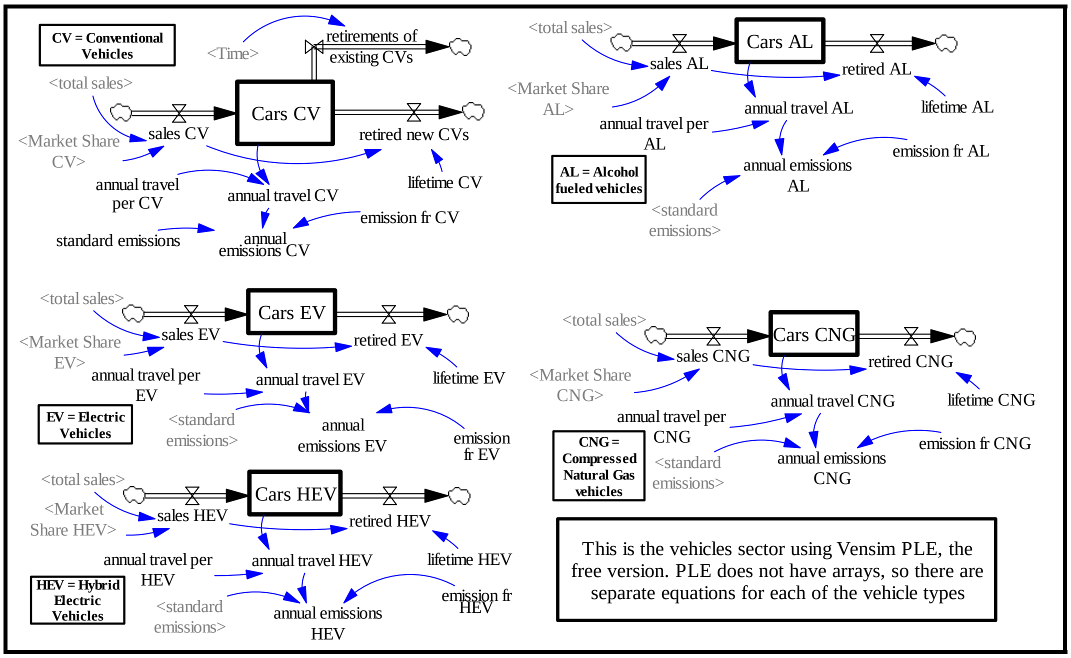

Fig. 16.5. The vehicles sector view in the Vensim PLE model of feebates.

Exercise 16-3. Feebate policy continued: Recreate the results in Fig. 16.4 with the Stella model. Then continue the simulation for another two years with the same feebate values to learn how Stella can fire a feebate manager. Then recreate Fig. 16.4 and adopt a new feebate starting in the year 2006. Aim for a fee and rebate that bring the fund close to zero by the year 2016. And see if you can accomplish this with the sum of the fee and rebate fixed at $10,000.

Exercise 16-4. Explore feebates policies: Experiment with any combination of fees and rebates over the 16-year time period and aim to bring the balance close to zero by the end of the simulation. Your main goal is to avoid getting fired, so be sure to keep the fund balance within the prescribed limits. Your other goals are to lower total emissions as much as possible by 2016. It would also be nice if the sum of the CV fee and the EV rebate were to add to $10,000. And if you impose a fee on AL vehicles, set the fee to reflect the AL emissions factor. Similarly, take the emission factors for CNG and HEVs, into account when allowing rebates for these vehicles. This is an open-ended exercise. The only restrictions are that the fees and rebates can not exceed $8,000. Also, you will simulate one year at a time, so these incentives must remain in effect for at least one year. Otherwise, you are free to devise any policy that will do the best job in lowering emissions. Remember that you are practicing for the job of feebate manager, so you need a feebate policy that can be explained to the top officials.

Exercise 16-5. Feebates strategy paper: Write a strategy paper about your best feebate policy. The paper should be addressed to the top officials who have asked you to design the feebate program. The paper should inform them on the likely swings in the feebate fund over time. It should also make them aware of the reduction in emissions that might be achieved by 2016. Explain the conditions under which you would accept the job as feebate manager.

Modeling Exercises

Exercise 16-6 Endogenous feebate control: The fees and rebates are exogenous inputs controlled by sliders on the interface layer. Now that you have arrived at a good policy, it is useful to convert the fees and rebates to endogenous variables. The challenge is to alter the model so these incentives respond continuously over time to the changing conditions in the market. With endogenous incentives, we could run the model on auto-pilot. The fees and rebates would be adjusted automatically, freeing our time to explore a wide range of simulations with changes in assumptions about vehicles and consumers. Fig. 16.6 illustrates one example of how this might be done. This is a causal loop diagram, but there are no loops unless we count the dashed lines. These are added to depict the decisions by a student who watched the balance in the fund to set the CV fee and the EV rebate. If the fund becomes too big, the student lowered the CV fee and raised the EV rebate. This policy would create two negative feedback loops. They are labeled fee control and rebate control, but the ? warn us that this only one possible way of thinking about feebate control. Your job is to implement your own feebate policy so it can be tested on auto-pilot.

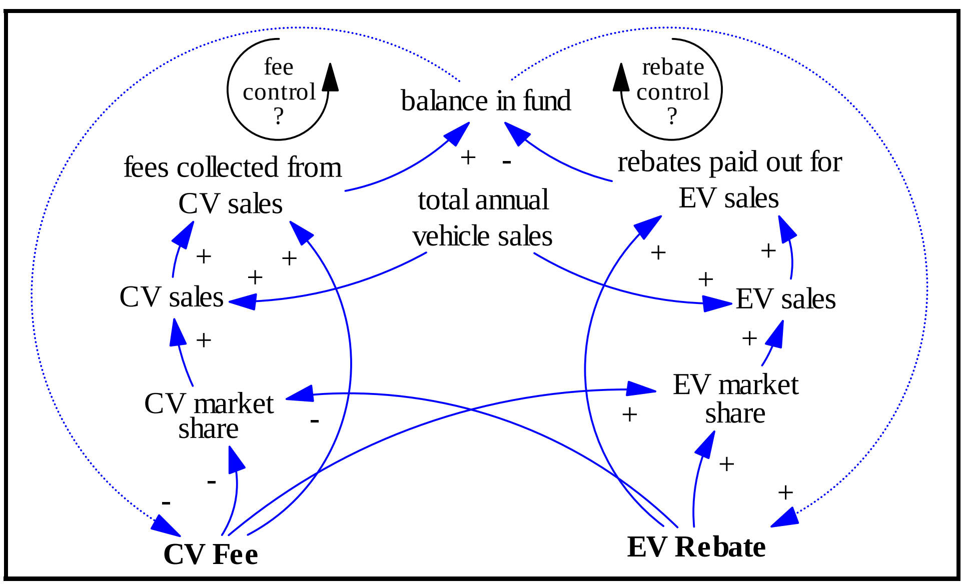

Fig. 16.6 Dashed lines to represent an example of fee and rebate control.

Exercise 16-7 Run the new model on auto-pilot: Run your new model with constant conditions to verify that you get similar results to your best policy in Exercise 16.4. (Your results will be somewhat different since the fees and rebates are now subject to continuous adjustments.)

Exercise 16-8. Stability test with better EVs: Introduce a major change to make EVs more attractive. For example, you might increase the range of an EV from 100 to 150 miles in the year 2012. Then simulate the model on auto-pilot to see if you feebate policy can control the fund within the prescribed limits.

Exercise 16-9. Feebates with a different environmental values: The $10,000 estimate of the environmental value of the EV is from the mid 1990s. If the estimate were repeated today, it could be much lower due to lower emissions from the newer CVs. On the other hand, the value of an EV would increase if we include the cost associated with CO2 emissions from the CV. Now, did your endogenous feebate policy maintain the sum of the fee and rebate to $10,000? If so, use your model to test the same feebate policy with the sum of the fee and rebate maintained at $5,000.

Exercise 16-10. Fees and rebates for all vehicles: The previous exercises focus on EVs and CVs to learn about controllability. But the producers of AL, CNG and HEVs will ask for fair treatment, so we should search for a general policy for feebates. Suppose the AL and CV are assigned a fee because of their high emissions. Rebates will be allowed for CNG, HEV and EVs. If possible, set the relative value of the fees and rebates to reflect the emission fractions in Table 16-1. Run the new model with your endogenous policy on fees and rebates. Can you control the fund within the prescribed limits?

Exercise 16-11. Expand to include fuel efficiencies: The fuel cost is an exogenous input measured in ¢/mile. Expand the model to specify the fuel cost and efficiency for both the EV and the EV. The CV fuel cost is $1.29 per gallon and the efficiency is 27.5 miles per gallon. The EV fuel cost is 5.3 ¢/kwh and the efficiency is 1 mile/kwh. Run the new model to verify you get the fuel costs in Table 16.2 and the market shares in Table 16.1.

Exercise 16-12. Impact of lower electric rates: Use the model from Exercise 16-11 to simulate the change in EV market shares if the electricity price is cut from 5.3 ¢/kwh to 2 ¢/kwh. How many more EVs are in use in the year 2016 with the lower rates?

Exercise 16-13. Impact of a gasoline tax : Use the model from Exercise 16-11 to simulate the change in market shares if the state imposes a 1 $/ gallon tax on gasoline. How many fewer CVs are in use in the year 2016 with the tax? How many more EVs are in use?

Exercise 16-14. Gas tax feeds the fund: Suppose the tax revenues generated in the previous exercise are fed into the state fund (the fund shown in Fig. 16.3). This would build the balance allowing for larger rebates for cleaner vehicles. Expand the model from the previous exercise to allow for gasoline tax revenues to contribute to the state fund. (To keep the calculation simple, ignore the gasoline consumed by the HEVs.) Your tax revenues will come from the CVs. The simulation begins with 100 billion miles of annual CV travel @ 27.5 miles/gallon. The gasolinue consumption is 3.64 billion gallons/year. A $1 per gallon tax would quickly run the fund above $4 billion, so remove the plus or minus $4 billion limits in the Stella model.

Exercise 16-15. Are TaxBates easier or more difficult to control? Let's coin the term "TaxBates" to stand for a program to promote the sale of cleaner vehicles through rebates financed by a gasoline tax as well as fees. Experiment with the model from the previous exercise to find an appropriate combination of a gasoline tax, CV fee and EV rebates to lower the emissions in the air shed. How do the financial challenges of operating a taxbate program compare with the problems of a feebate program?

Exercise 16-16. Interface for a TaxBates control model: Expand the interface in Fig. 16.4 by adding a new slider to control the size of the gasoline tax to be used in a taxbate program. Add any new screens and buttons that will help a newcomer use your model to explore the dynamics of a taxbate program. Test your best taxbate program with the stability test of Exercise 16-8.

Exercise 16-17. Revised version of the strategy paper: Revise the strategy paper from Exercise 16-5 to include what you have learned from the endogenous modeling of feebates and the experiments with a taxbate policy. Conclude with the conditions under which you would accept the job a fund manager.