[ I wrote this several months ago (the week that Richard Branson announced his venture, in case you couldn't guess) for a colleague who wanted to know how to use Excel's finance functions, and used it as the basis of a short training class last week. I've found it useful twice, so I'm posting it because it may be useful to others. I appreciate any comments. Phil ]

A venture is an activity undertaken for the purpose of making money: you invest money in the venture, in the expectation that the venture will return money to you. A venture can be as simple as a roadside lemonade stand operated by two giggling seven-year old girl scouts or as complicated as Richard Branson hiring rocket scientists to build a vehicle to take paying tourists to the edge of space. In either case, before starting, a wise venturer will consider whether the returns will exceed the investment, by an amount sufficient to make the effort worth the risk of failure. The branch of human knowledge that studies ventures is known as finance, and one of the primary tools that finance uses in this study is known as discounted cash flow analysis. This note describes a little bit of finance theory, illustrates the tools of discounted cash flow analysis, and teaches a few tricks of using Excel spreadsheets.

To keep the discussion simple, we'll eschew outer space and consider the example of a roadside lemonade stand. Our venturers, Anne and Kate, intend to operate a lemonade stand in front of their house daily during the twelve weeks of summer vacation from school, so they can have a little bit of spending money during the subsequent school year. They expect to sell one pitcher (half a gallon, or six large glasses) each evening at a price of 25¢ per glass, plus an extra pitcher on Saturday afternoon; they will sell an extra four pitchers of lemonade on Independence Day. It will cost them $1 to make a pitcher of lemonade, including the cost of six disposable cups and the water and ice that Mom supplies; Mom will also charge them $1 per week for rent. At the beginning of the season, Dad will help them build a lemonade stand, at a cost of $20; because the stand is subject to sun, rain and wind, Anne and Kate will discard it at the end of the summer. The girls will also spend $5 for a pitcher and spoon, which they will resell to Mom for the original $5 at the end of the summer. All these expectations are summarized in this table:

| Week | Stand | Sales | Lemon | Rent | Cash Flow |
|---|---|---|---|---|---|
| 0 | 25 | | | | -25 |
| 1 | | 12 | 8 | 1 | 3 |
| 2 | | 12 | 8 | 1 | 3 |
| 3 | | 12 | 8 | 1 | 3 |
| 4 | | 12 | 8 | 1 | 3 |
| 5 | | 12 | 8 | 1 | 3 |
| 6 | | 18 | 12 | 1 | 5 |
| 7 | | 12 | 8 | 1 | 3 |
| 8 | | 12 | 8 | 1 | 3 |
| 9 | | 12 | 8 | 1 | 3 |
| 10 | | 12 | 8 | 1 | 3 |
| 11 | | 12 | 8 | 1 | 3 |
| 12 | -5 | 12 | 8 | 1 | 8 |
| | 20 | 150 | 100 | 12 | 18 |

The initial investment is $25, total revenue is $150, variable costs for lemonade, cups, ice and water are $100, fixed costs for rent are $12, and net cash flow, calculated as revenue minus variable cost, fixed cost, and initial investment plus investment recapture is $18. Thus, this venture passes the first analysis, that the net cash flow is positive.

The concept of interest is familiar to everyone with a bank account. The basic idea is that a dollar in hand today is worth more than a dollar in the future; the value of that dollar increases simply due to the passage of time, since it can be put to use to earn more money. Economists call that concept the time-value of money. Finance theorists know the concept as the cost of capital, from the old concept that the four elements of value are land, labor, capital and entrepreneurial ability, which cost, respectively, rent, wages, interest, and profit. Numerical analysts generally refer to the concept as the discount rate. Whatever the name, the basic idea behind discounted cash flow analysis is to equalize all the various cash flows over time to the same point in time, eliminating the time-value of money from the calculation.

The venture's net present value is computed by using the cost of capital to equalize the

time-value of money to the beginning of the venture. For instance, if the lemonade stand's cost of capital is 2% per week, the $3 cash flow (sales of $12, less $8 for lemonade and $1 rent to Mom) during the first week is more valuable than the $3 cash flow during the tenth week; the $3 from the first week is worth $2.94 at the beginning of the project ($2.94 would earn interest of 6¢, calculated as $2.94 times 2%), but $3 from the tenth week is worth only $2.46.

Interest calculations are tricky. The basic formula for simple interest is I = P * R * T, interest equals principal times rate times time, but since interest is earned in subsequent periods on the interest already earned in the current period -- the new principal in the second period is the old principal from the first period plus the interest earned in the first period -- the effect of simple interest is compounded over time; the formula for compound interest is PV = FV * (1 + R) ^ N, where PV is the present value, FV is the future value, R is the interest rate, and N is the number of periods. Thus, $3, discounted at 2% for ten periods, will have a present value of $2.46, calculated as 3 / (1 + 0.02) ^ 10. The sum of the discounted cash flows for all periods, $12.44, is the net present value, as shown in the table below:

| Week | Current Cash Flow | Discounted Cash Flow |
|---|---|---|
| 0 | -25 | -25.00 |
| 1 | 3 | 2.94 |
| 2 | 3 | 2.88 |
| 3 | 3 | 2.83 |
| 4 | 3 | 2.77 |
| 5 | 3 | 2.72 |
| 6 | 5 | 4.44 |
| 7 | 3 | 2.61 |
| 8 | 3 | 2.56 |
| 9 | 3 | 2.51 |
| 10 | 3 | 2.46 |
| 11 | 3 | 2.41 |
| 12 | 8 | 6.31 |
| NPV | | 12.44 |

Excel provides a built-in function to compute the net present value. The discounted present value of future cash flows at a 2% cost of capital is given by the formula =NPV (2%,F3:F14), which is $37.44; subtracting the initial $25 investment (it doesn't have to be discounted to the beginning of the venture because no time passes) gives a net present value of $12.44. The table below shows the net present value at a variety of interest rates; note that the net present value equals the cumulative cash flow when the discount rate is zero:

| Rate | NPV |
|---|---|
| 0% | 18.00 |
| 1% | 15.09 |
| 2% | 12.44 |
| 3% | 10.04 |
| 4% | 7.86 |
| 5% | 5.87 |
| 6% | 4.05 |
| 7% | 2.38 |
| 8% | 0.85 |
| 9% | -0.55 |
| 10% | -1.84 |
| 11% | -3.02 |
| 12% | -4.12 |

The relationship between cost of capital and present value is inverse; as the cost of capital increases, the present value decreases. Eventually, the cost of capital increases enough to make the net present value negative. The crossover point is important; in fact, the crossover point, which is 8.6% in the above example, is known in finance theory as the internal rate of return. In Excel, the internal rate of return can be calculated with the formula =IRR(F2:F14); note that unlike NPV, IRR must include the initial cash flow in the specified range.

Another measure of a venture's finances is the payback period, which comes in two flavors, simple and discounted. Let's look again at the cash flow table:

| Week | Current Cash Flow | Cumulative Cash Flow | Simple Payback |
|---|---|---|---|
| 0 | -25 | -25 | |
| 1 | 3 | -22 | 1.0 |
| 2 | 3 | -19 | 1.0 |
| 3 | 3 | -16 | 1.0 |
| 4 | 3 | -13 | 1.0 |
| 5 | 3 | -10 | 1.0 |
| 6 | 5 | -5 | 1.0 |
| 7 | 3 | -2 | 1.0 |
| 8 | 3 | 1 | 0.7 |
| 9 | 3 | 4 | 0.0 |
| 10 | 3 | 7 | 0.0 |
| 11 | 3 | 10 | 0.0 |
| 12 | 8 | 18 | 0.0 |
| Total | 18 | | 7.7 |

The cumulative cash flow becomes positive midway through the eighth week; this point is known as the simple payback period. Unfortunately, Excel provides no built-in function to compute the simple payback period, so we must do it ourselves. The simple payback period can be calculated by entering the formula =IF(G3<0,1,IF(G2<0,-G2/F3,0)) in cell H3, copying the formula down through cell H14, and entering the formula =SUM(H3:H14) in cell H15.

Let's take a look at that formula. Our goal is to put a one in each week where the cumulative cash flow remains negative, a zero in each week where the cumulative cash flow is positive, and a calculation of the partial week in the week where the cumulative cash flow crosses over from negative to positive. The nested IFs identify negative weeks, positive weeks, and the crossover week, and the ratio calculates the fraction of the crossover week that is negative. Note that this method only works if the cumulative cash flow eventually becomes positive.

Another way to make that calculation uses an array formula. Type the formula =INDEX (A3:A14-G3:G14/F3:F14,SUM(IF(G3:G14<=0,1,0))+1), but instead of pressing the enter key, hold down the control and shift keys and press the enter key while keeping the control and shift keys down. The simple payback period of 7.7 will magically appear, and the formula as it appears in the formula box will be surrounded with curly braces.

If you've never used array formulas before, get ready for some magic. Array formulas are entered with the control-shift-enter key-combination, and perform an iterative calculation over a contiguous range of cells.

Let's start with the part of the formula that reads A3:A14-G3:G14/F3:F14. There are three ranges in that formula; let's call them arrays instead of ranges. Each array consists of twelve cells, each corresponding to one another. We can write the three arrays like this:

A3:A14 { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12}

F3:F14 { 3, 3, 3, 3, 3, 5, 3, 3, 3, 3, 3, 8}

G3:G14 {-22, -19, -16, -13, -10, -5, -2, 1, 4, 7, 10, 18}

Because the formula is an array formula entered with control-shift-enter, it operates on the members of the array as they correspond individually. The formula for each element of the array is A-G/F, and the result of the array formula is another array (as an example, the first element of the result array is calculated as 1-(-22/3), which is 8.3):

{8.3, 8.3, 8.3, 8.3, 8.3, 7, 7.7, 7.7, 7.7, 7.7, 7.7, 9.75}

We'll come back to that array in a moment. But first, let's look at the part of the formula that reads IF(G3:G14<=0,1,0). This is another array formula, using the range G3:G14 as its only array. The result of that array formula is the array

{1,1,1,1,1,1,1,0,0,0,0,0}

That array is wrapped in a SUM function, like this:

SUM({1,1,1,1,1,1,1,0,0,0,0,0})

The sum is 7 (the single number seven, not an array). Now we can consider the INDEX function. With all of its arguments evaluated, the entire array formula looks like this:

INDEX({8.3, 8.3, 8.3, 8.3, 8.3, 7, 7.7, 7.7, 7.7, 7.7, 7.7, 9.75}, 8)

The INDEX formula counts to the eighth element of the array (the offset is eight because we want the first positive element, not the last negative element). The value of that element, which is 7.7, is displayed as the result of the array formula. Note again that this method only works if the cumulative cash flow eventually becomes positive.

We've already seen two methods to calculate the simple payback period, one based on the sum of a range of nested-if formulas and one based on an array formula. A third method is to use Excel's macro language, Visual Basic for Applications (generally referred to by the acronym VBA) to write the PAYBACK function that Microsoft omitted from Excel. If you've never programmed before, don't worry; we'll go through every step slowly.

You can see the VBA editor by pressing the Alt-F11 key in Excel. Click on the Insert | Module menu, and type the following program in the code window:

```
Function Payback(CashFlows As Range) As Double
    Dim CumCashFlow As Double
    Dim Index As Integer
    CumCashFlow = CashFlows(1).Value
    Index = 1
    Do While Index < CashFlows.Count
        If CumCashFlow + CashFlows(Index + 1) >= 0 Then
            Payback = Index - CumCashFlow / _
                      CashFlows(Index + 1) - 1
            Exit Function
        End If
        Index = Index + 1
        CumCashFlow = CumCashFlow + CashFlows(Index)
    Loop
    Payback = 1 / 0
End Function
```

Check your typing carefully; any error will cause the function to fail. Now go back to the spreadsheet and enter the formula =PAYBACK(F2:F14). The familiar result, 7.7, will appear. If, instead, you are thrown back to the VBA editor, correct the error highlighted in yellow, reset the project by clicking Run | Reset, return to the spreadsheet, and re-calculate the PAYBACK formula. Unlike the two previous methods, using the PAYBACK function will cause a #VALUE! error to appear if the cumulative cash flow never becomes positive.

Let's look back at the function. The first line declares CashFlows as a range of cells that is input to the Payback function, which returns a number (double refers to double-precision arithmetic, which is used by Excel). The two Dim statements declare temporary memory locations used in the function: CumCashFlow will accumulate the cash flows from each period and Index is the number of the period currently being considered. CumCashFlow is set to the first value in the CashFlows input range, which is the initial investment, and Index is set to 1, representing the initial investment.

The Do While iterates through the CashFlows input range, stopping at the end of the CashFlows range. If the next cash flow CashFlows(Index+1) will cause the cumulative cash flow to become positive, the partial period is calculated, the result is assigned to the function, and the function exits. Otherwise, the cumulative cash flow and index are updated and the loop iterates.

If the cumulative cash flow never becomes positive, the loop will fail to exit early and the Payback function will return an error, the result of division by zero. Thus, this is the safest of the three methods for calculating the simple payback period, because the

other two fail if the cumulative cash flow never becomes positive.

We said before that there are two flavors of payback period, simple and discounted. Let's take one more look at the cash flow table:

| Week | Current Cash Flow | Discounted Cash Flow | Cumulative Discounted Cash Flow |
|---|---|---|---|
| 0 | -25 | -25.00 | -25.00 |
| 1 | 3 | 2.94 | -22.06 |
| 2 | 3 | 2.88 | -19.18 |
| 3 | 3 | 2.83 | -16.35 |
| 4 | 3 | 2.77 | -13.58 |
| 5 | 3 | 2.72 | -10.86 |
| 6 | 5 | 4.44 | -6.42 |
| 7 | 3 | 2.61 | -3.81 |
| 8 | 3 | 2.56 | -1.25 |
| 9 | 3 | 2.51 | 1.26 |
| 10 | 3 | 2.46 | 3.72 |
| 11 | 3 | 2.41 | 6.13 |
| 12 | 8 | 6.31 | 12.44 |

We previously discussed the time-value of money. In this table, we discount each of the cash flows by the cost of capital. The discounted payback period can be calculated in exactly the same way as the simple payback period using either of the first two methods, except that it uses the discounted cash flow instead of the current cash flow; assuming a 2% cost of capital as shown above, the discounted payback period is 8.5 weeks. The PAYBACK function must change to take an interest rate, as follows:

```
Function Payback(CashFlows As Range, _
    Optional Rate As Double = 0) As Double
    Dim DiscountRate As Double
    Dim DiscCashFlow As Double
    Dim CumCashFlow As Double
    Dim Index As Integer
    DiscountRate = 1 + Rate
    CumCashFlow = CashFlows(1).Value
    Index = 1
    Do While Index < CashFlows.Count
        DiscCashFlow = CashFlows(Index + 1) / DiscountRate
        If CumCashFlow + DiscCashFlow >= 0 Then
            Payback = Index - CumCashFlow / _
                      DiscCashFlow - 1
            Exit Function
        End If
        DiscountRate = DiscountRate * (1 + Rate)
        Index = Index + 1
        CumCashFlow = CumCashFlow + DiscCashFlow
    Loop
    Payback = 1 / 0
End Function
```

Note that the discounted payback period will equal the simple payback period if the cost of capital is zero. The second version of the PAYBACK function takes advantage of that fact so that the same function can be used for either simple or discounted payback, using an optional Rate argument that defaults to zero.

That concludes our discussion of the discounted cash flow analysis of a venture. But it misses one important element: risk. We assumed that we knew how many pitchers of lemonade Anne and Kate could sell. But what if their actual sales are higher or lower than the projected sales? Either possibility introduces risk. There are techniques for analyzing risk, but we'll save that discussion for another day.

By the way, Anne and Kate decided that $18 wasn't enough of a return for their effort, and they spent the summer in the swimming pool. They must be smarter than any dusty old finance textbook!