A Brain-Friendly Guide

Head First Data Analysis

A learner's guide to big numbers, statistics, and good decisions

Predict your raise with linear regression

Sell more toys by optimizing your business model

Experiment to discover who your customers *really* are

Overcome your cognitive biases

Load important statistical concepts directly into your brain

Clean messy data for efficient analysis

O'REILLY®

Michael Milton

3 optimization

Take it to the max

We all want more of something.

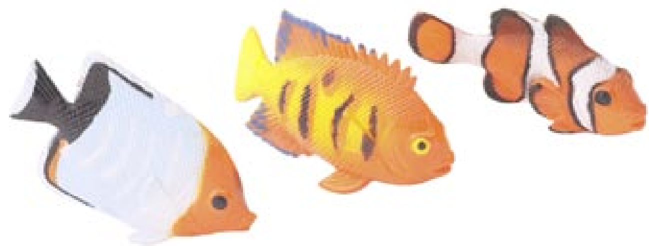
And we're always trying to figure out how to get it. *If* the things we want more of—profit, money, efficiency, speed—can be represented numerically, then chances are, there's an tool of data analysis to help us tweak our *decision variables,* which will help us find the **solution** or *optimal point* where we get the most of what we want. In this chapter, you'll be using one of those tools and the powerful spreadsheet **Solver** package that implements it.

You're now in the bath toy game

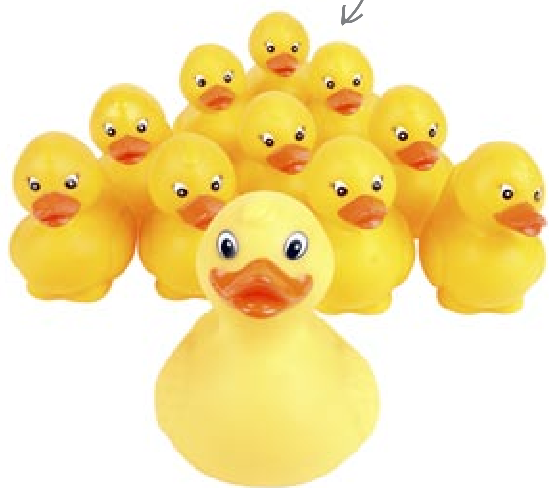
You've been hired by Bathing Friends Unlimited, one of the country's premier manufactures of rubber duckies and fish for bath-time entertainment purposes. Believe it or not, bath toys are a serious and profitable business.

They want to make more money, and they hear that managing their business through data analysis is all the rage, so they called you!

The rubber fish is an unconventional choice, but it's been a big seller.



Some call it the classic, some say it's too obvious, but one thing is clear: the rubber ducky is here to stay.



You have demanding, discerning customers.

Sharpen your pencil

Here's an email from your client at Bathing Friends Unlimited, describing why they hired you.

From: Bathing Friends Unlimited
To: Head First
Subject: Requested analysis of product mix

Dear Analyst,

We're excited to have you!

We want to be as profitable as possible, and in order to get our profits up, we need to make sure we're making the right amount of ducks and the right amount of fish. What we need you to help us figure out is our ideal *product mix*: how much of each should we manufacture?

Looking forward to your work. We've heard great things.

Regards,

BFU

Here's what your client says about what she needs.

What ***data*** do you need to solve this problem?

....

....

....

....

....

....

Sharpen your pencil Solution

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BFU

What ***data*** do you need to solve this problem?

First of all, it'd be nice to have data on just how profitable ducks and fish are. Is one more profitable than the other? But more than that, it'd be nice to know what other factors constrain the problem. How much rubber does it take make these products? And how much time does it take to manufacture these products?

Your Data Needs Up Close

Take a closer look at what you need to know. You can divide those data needs into two categories: **things you can't control**, and things you can.

These are things you can't control.

- How profitable fish are
- How much rubber they have to make fish
- How much rubber they have to make ducks
- How profitable ducks are
- How much time it takes to make fish
- How much time it takes to make ducks

And the basic thing the client wants you to find out in order to get the profit as high as possible. Ultimately, the answers to these two questions you **can control**.

These are things you can control.

- How many fish to make
- How many ducks to make

You need the hard numbers on what you can and can't control.

Constraints limit the variables you control

These considerations are called **constraints**, because they will define the parameters for your problem. What you're ultimately after is *profit*, and finding the right product mix is how you'll determine the right level of profitability for next month.

But your options for product mix will be ***limited*** by your constraints.

These are your actual constraints for this problem.

From: Bathing Friends Unlimited
To: Head First
Subject: Potentially useful info

Dear Analyst,

Great questions. Re rubber supply: we have enough rubber to manufacture 500 ducks or 400 fish. If we did make 400 fish, we wouldn't have any rubber to make ducks, and vice versa.

We have time to make 400 ducks or 300 fish. That has to do with the time it takes to set the rubber. No matter what the product mix is, we can't make more than 400 ducks and 300 fish if we want the product on shelves next month.

Finally, each duck makes us $5 in profit, and each fish makes us $4 in profit. Does that help?

Regards,

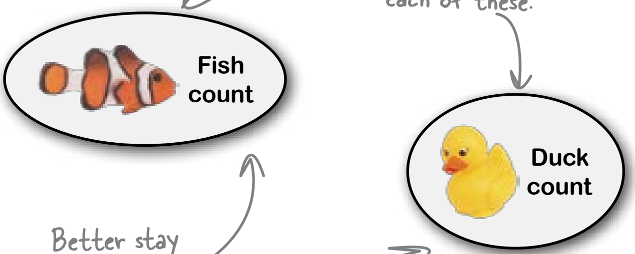
BFU

Decision variables are things you can control

Constraints don't tell you how to maximize profit; they only tell you what you *can't* do to maximize profit.

Decision variables, on the other hand, are the things you ***can*** control. You get to choose how many ducks and fish will be manufactured, and as long as your constraints are met, your job is to choose the combination that creates the most profit.

You get to choose the values for each of these.



Better stay within your constraints!

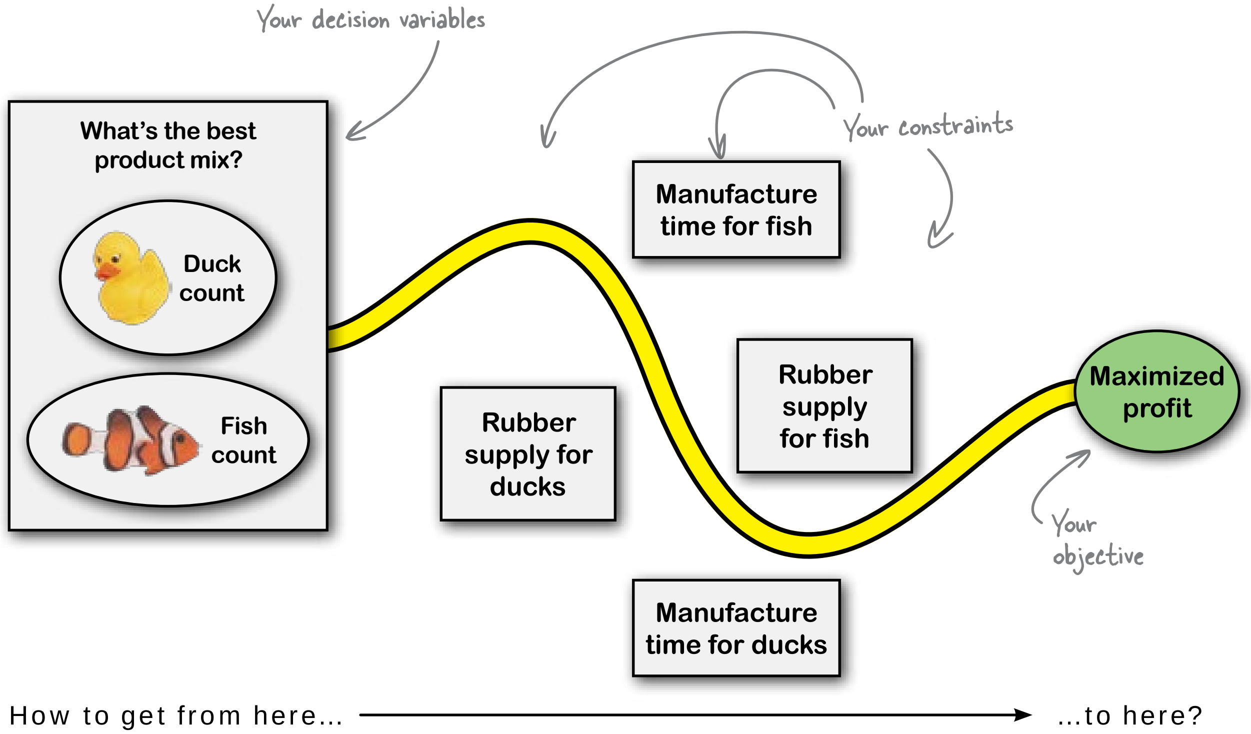
BRAIN POWER

So, what do you think you ***do*** with constraints and decision variables to figure out how to maximize profit?

You have an optimization problem

When you want to get as much (or as little) of something as possible, and the way you'll get it is by changing the values of other quantities, you have an **optimization problem**.

Here you want to maximize *profit* by changing your decision variables: the number of ducks and fish you manufacture.



But to maximize profit, you have to stay within your constraints: the manufacture time and rubber supply for both toys.

To solve an optimization problem, you need to combine your decision variables, constraints, and the thing you want to maximize together into an **objective function**.

Find your objective with the objective function

The **objective** is the thing you want to maximize or minimize, and you use the **objective function** to find the optimum result.

Here's what your objective function looks like, if you state it algebraically:

Each "c" refers to a constraint.

Each "x" refers to a decision variable.

"P" is your objective: the thing you want to maximize.

$$c_1x_1 + c_2x_2 = P$$

Some optimization problems have more elaborate objective functions.

Don't be scared! All this equation says is that you should get the highest P (profit) possible by multiplying each decision variable by a constraint.

Your constraints and decision variables in this equation combine to become the profit of ducks and fish, and those together form your objective: the total profit.

Here's c_1x_1

And here's c_2x_2

You want your objective to be as high as you can get it.

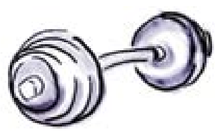
duck profit

+

fish profit

= Total Profit

All optimization problems have constraints and an objective function.

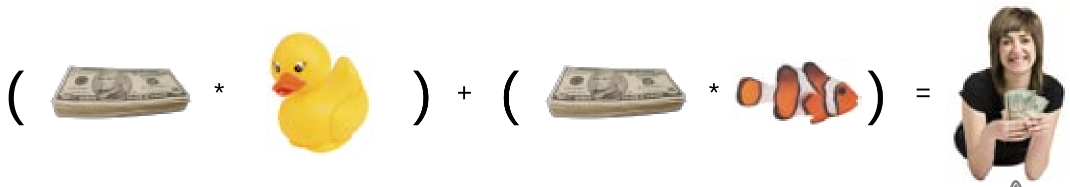


BRAIN BARBELL

What specific values do you think you should use for the constraints, c_1 and c_2?

Your objective function

The constraints that you need to put into your objective function are the **profit for each toy**. Here's another way to look at that algebraic function:



Here's your client from Bathing Friends Unlimited.

The profit you get from selling fish and ducks is equal to the profit per duck multiplied by the number of ducks plus the profit per fish multiplied by the number of fish.

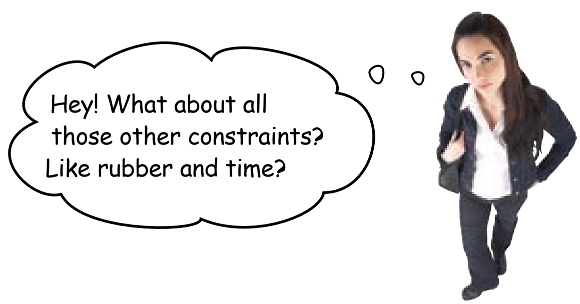
$$\underbrace{(\text{profit per duck} * \text{count of ducks})}_{\text{Total duck profit.}} + \underbrace{(\text{profit per fish} * \text{count of fish})}_{\text{Total fish profit.}} = \text{Profit}$$

Now you can start trying out some product mixes. You can fill in this equation with the values you know represent the profit per item along with some hypothetical count amounts.

This is what your profit would be if you decide to make 100 ducks and 50 fish.

$$(\$5 \text{ profit} * 100 \text{ ducks}) + (\$4 \text{ profit} * 50 \text{ fish}) = \$700$$

This objective function projects a \$700 profit for *next month*. We'll use the objective function to try out a number of other product mixes, too.



Show product mixes with your other constraints

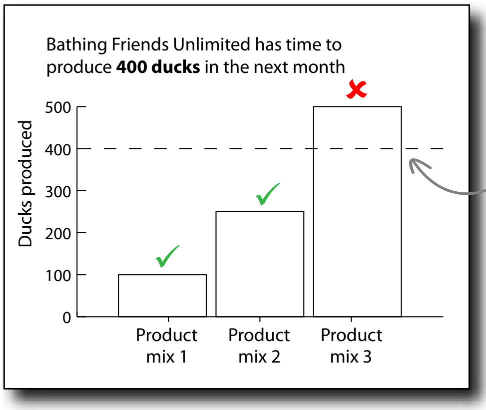
Rubber and time place limits on the count of fish you can manufacture, and the best way to start thinking about these constraints is to envision different hypothetical **product mixes**. Let's start with the constraint of *time*.

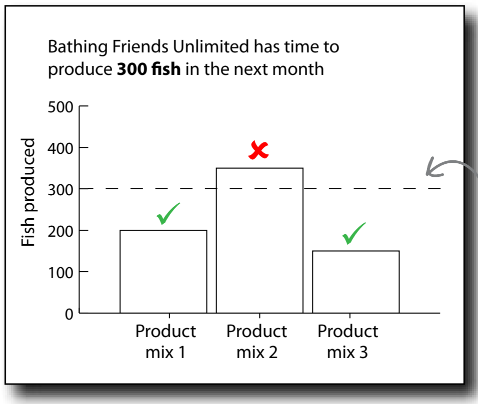
Here's what they say about their time constraint.

> ducks, and vice versa.
>
> **We have time to make 400 ducks or 300 fish. That has to do with the time it takes to set the rubber. No matter what the product mix is, we can't make more than 400 ducks and 300 fish if we want the product on shelves next month.**
>
> **Finally, each duck makes us $5 in profit,**

A hypothetical "Product mix 1" might be where you manufacture 100 ducks and 200 fish. You can plot the time constraints for that product mix (and two others) on these bar graphs.

This line shows the maximum number of ducks you can produce.

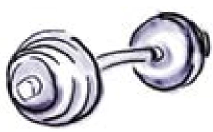




This line shows how many fish you have time to produce.

Product mix 1 doesn't violate any constraints, but the other two do: product mix 2 has too many fish, and product mix 3 has too many ducks.

Seeing the constraints in this way is progress, but we need a better visualization. We have yet more constraints to manage, and it'd be clearer if we could view them **both** on a single chart.

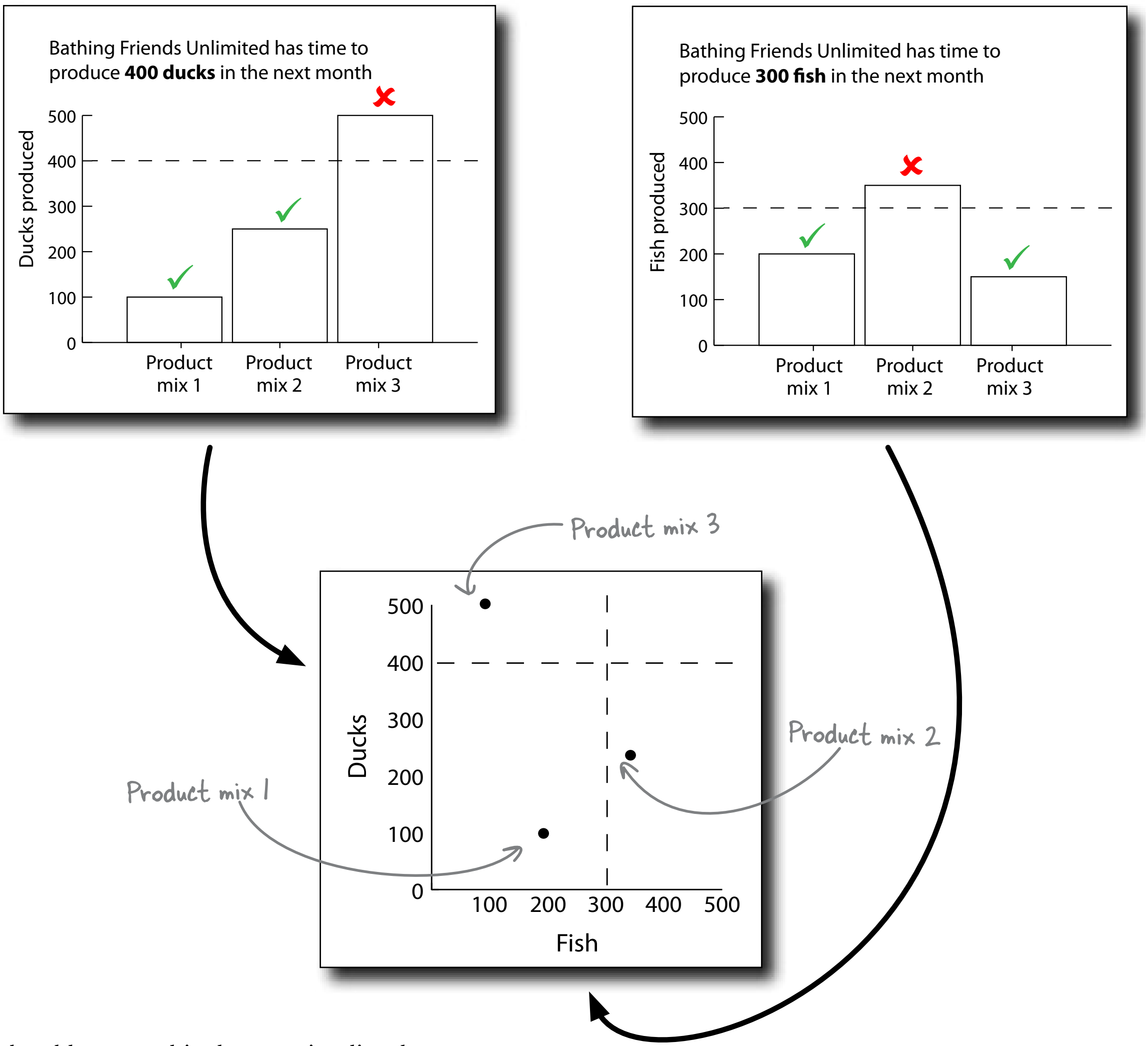


BRAIN BARBELL

How would you visualize the constraints on hypothetical product mixes of ducks *and* fish with one chart?

Plot multiple constraints on the same chart

We can plot both time constraints on a single chart, representing each product mix with a dot rather than a bar. The resulting chart makes it easy to **visualize both time constraints together**.



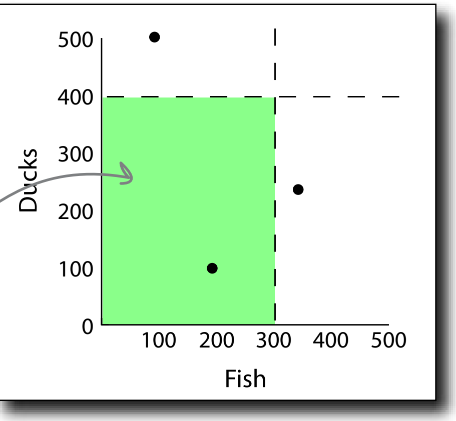
We'll also be able to use this chart to visualize the rubber constraints. In fact, you can place **any number of constraints** on this chart and get an idea of what product mixes are possible.

Your good options are all in the feasible region

Plotting ducks on a y-axis and fish on an x-axis makes it easy to see what product mixes are *feasible*. In fact, the space where product mixes are within the constraint lines is called the **feasible region**.

When you add constraints to your chart, the feasible region will change, and you'll use the feasible region to figure out which point is *optimal*.

This is the feasible region.



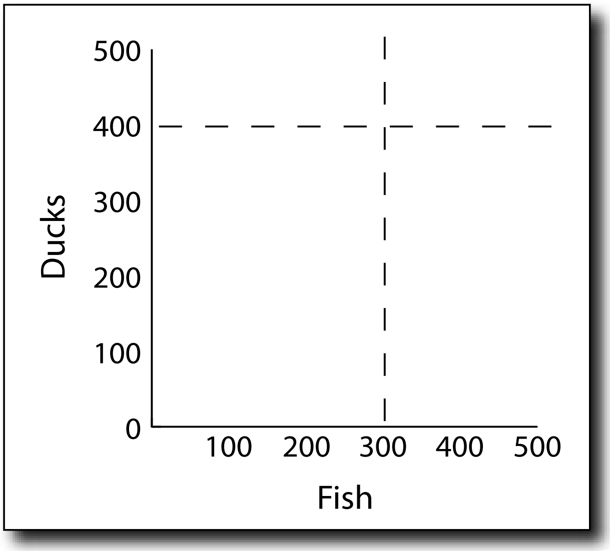
Sharpen your pencil

Let's add our other constraint, which states how many fish and ducks can be produced given the quantity of rubber they have. Bathing Friends Unlimited said:

Each fish takes a little more rubber to make than each duck.

Great questions. Re rubber supply: we have enough rubber to manufacture 500 ducks or 400 fish. If we did make 400 fish, we wouldn't have any rubber to make ducks, and vice versa.

You have a fixed supply of rubber, so the number of ducks you make will limit the number of fish you can make.



1. Draw a point representing a product mix where you make 400 fish. As she says, if you make 400 fish, you won't have rubber to make any ducks.
2. Draw a point representing a product mix where you make 500 ducks. If you made 500 ducks, you'd be able to make zero fish.
3. Draw a line through the two points.

Sharpen your pencil Solution

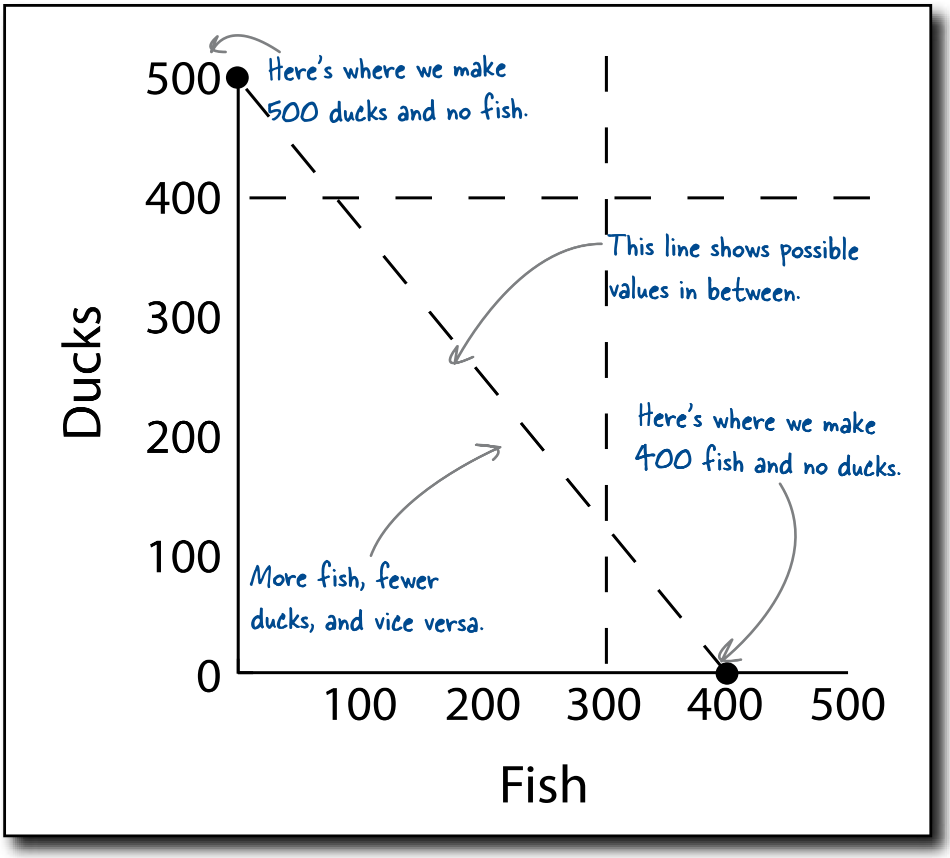
How does the new constraint look on your chart?

1. Draw a point representing a product mix where you make 400 fish. As she says, if you make 400 fish, you won't have rubber to make any ducks.

2. Draw a point representing a product mix where you make 500 ducks. If you made 500 ducks, you'd be able to make zero fish.

3. Draw a line through the two points.

Great questions. Re rubber supply: we have enough rubber to manufacture 500 ducks or 400 fish. If we did make 400 fish, we wouldn't have any rubber to make ducks, and vice versa.



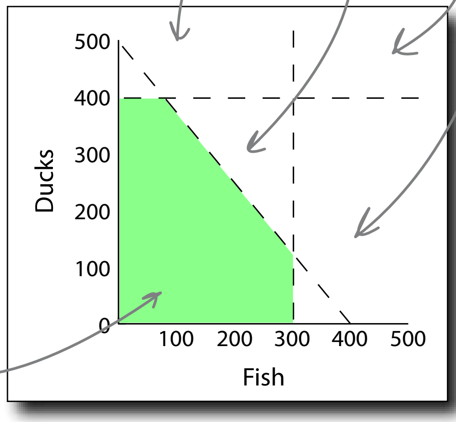
Your new constraint changed the feasible region

When you added the rubber constraint, you **changed the shape** of the feasible region.

Before you added the constraint, you might have been able to make, say, 400 ducks and 300 fish. But now your rubber scarcity has ruled out that product mix as a possibility.

You can't use duck/fish combinations that exist in any of these spaces.

Your potential product mixes all need to be inside here.



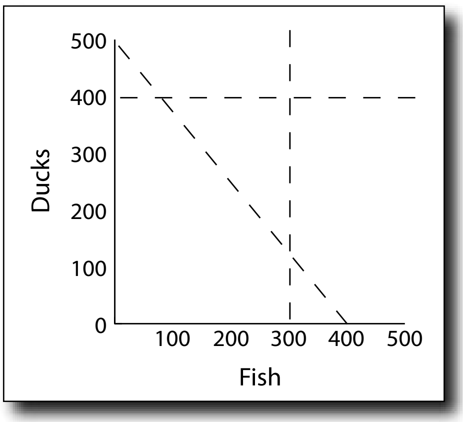
Sharpen your pencil

Here are some possible product mixes.

Are they inside the feasible region?
Draw a dot for each product mix on the chart.

How much profit will the different product mixes create?
Use the equation below to determine the profit for each.

Draw where each product mix goes on the chart.



300 ducks and 250 fish

Profit: ....

100 ducks and 200 fish

Profit: ....

50 ducks and 300 fish

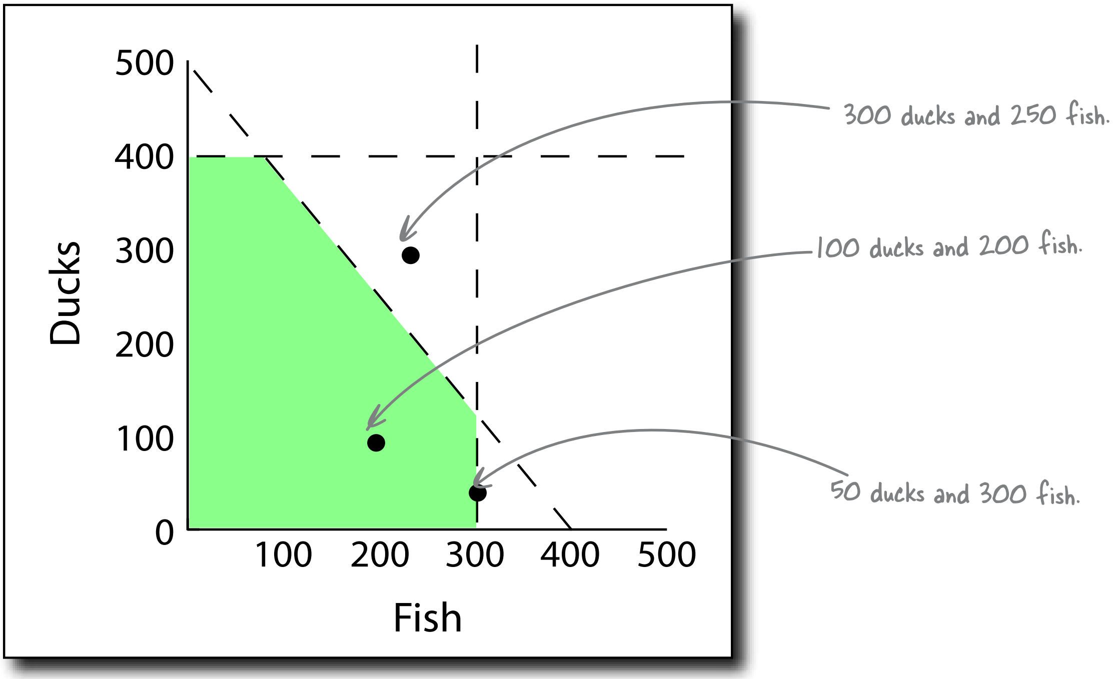
Profit: ....

Use your objective function to determine profit.

($5 profit * count of ducks) + ($4 profit * count of fish) = Profit

Sharpen your pencil Solution

You just graphed and calculated the profit for three different product mixes of ducks and fish. What did you find?



300 ducks and 250 fish.

Profit: ($5 profit*300 ducks)+($4 profit*250 fish) = $2500

Too bad this product mix isn't in the feasible region.

100 ducks and 200 fish.

Profit: ($5 profit*100 ducks)+($4 profit*200 fish) = $1300

This product mix definitely works.

50 ducks and 300 fish.

Profit: ($5 profit*50 ducks)+($4 profit*300 fish) = $1450

This product mix works and makes even more money.

Now all you have to do is try every possible product mix and see which one has the most profit, right?

You don't have to try them all.

Because both Microsoft Excel and OpenOffice have a handy little function that makes short order of optimization problems. Just turn the page to find out how…

Your spreadsheet does optimization

Microsoft Excel and OpenOffice both have a handy little utility called **Solver** that can make short order of your optimization problems.

If you plug in the constraints and write the objective function, Solver does the algebra for you. Take a look at this spreadsheet, which describes all the information you received from Bathing Friends Unlimited.

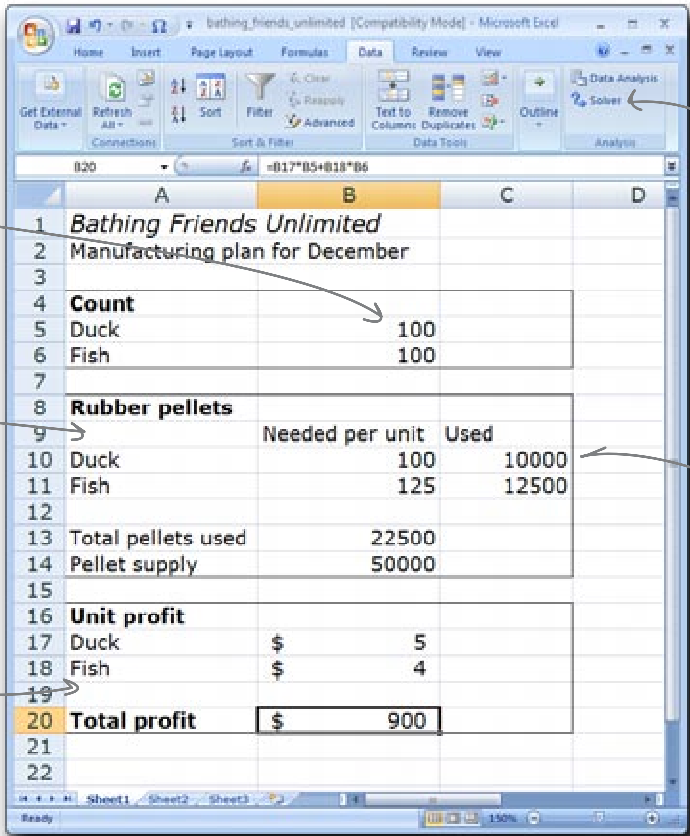
Load this!

www.headfirstlabs.com/books/hfda/bathing_friends_unlimited.xls

These cells show a product mix where you manufacture 100 ducks and fish each.

This box shows your rubber supply.

This box shows your profit.



Here's Solver.

If you make 100 ducks at 100 rubber pellets per duck, you use 100,000 pellets.

There are a few simple formulas on this spreadsheet. First, here are some numbers to quantify your rubber needs. The bath toys are made out of rubber pellets, and cells `B10:B11` have formulas that calculate how many pellets you need.

Second, cell `B20` has a formula that multiplies the count of fish and ducks by the profit for each to get the total profit.

Take a look at Appendix iii if you use OpenOffice or if Solver isn't on your Excel menu.

Try clicking the Solver button under the Data tab. What happens?

Sharpen your pencil

Let's take a look at the Solver dialogue box and figure out how it works with the concepts you've learned.

Draw an arrow from each element to where it goes in the Solver dialogue box.

Rubber and time

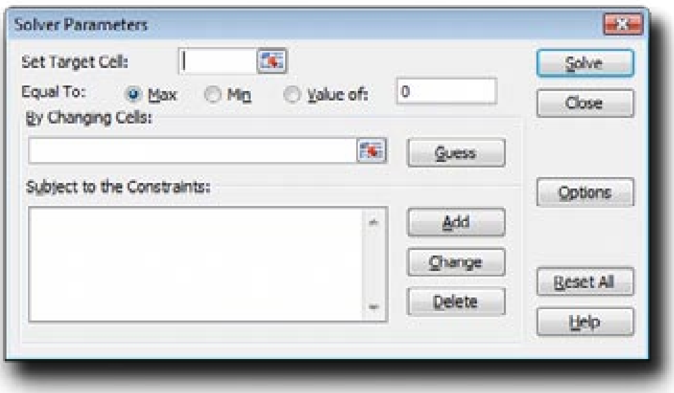
Decision Variables

Constraints

Objective

The number of ducks to make

Profit



Draw an arrow from each element to where it should go on the Solver.

Where do you think the **objective function** goes?

....

....

Sharpen your pencil Solution

How do the spaces in the Solver dialogue box match up with the optimization concepts you've learned?

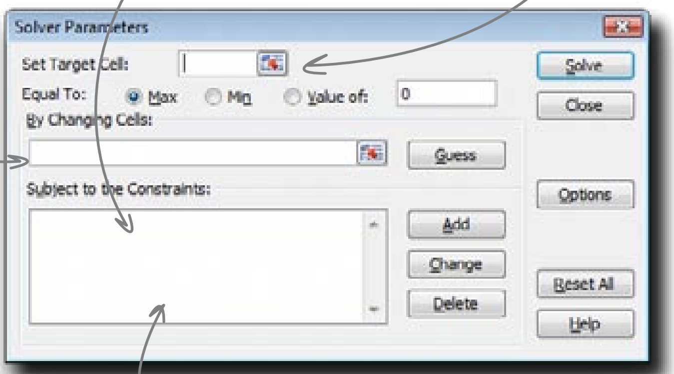
Draw an arrow from each element to where it goes in the Solver dialogue box.

Decision variables

Constraints

Objective

Excel calls your objective the Target Cell.



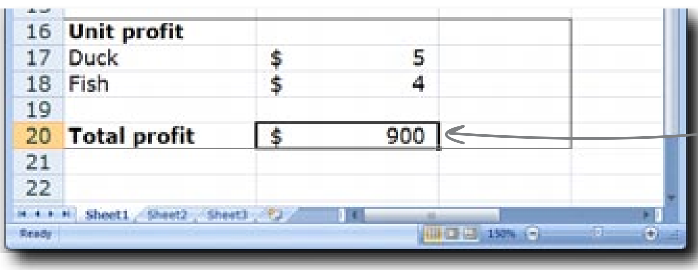
The decision variables are the values you will change to find your objective.

Constraints go in the constraints box... no big surprise there!

Where do you think the **objective function** goes?

The objective function goes in a cell on the spreadsheet and returns the objective as the result.

The objective that this objective function calculates is the total profit.



The objective function is in this cell.

Test Drive

Now that you've defined your optimization model, it's time to plug the elements of it into Excel and let the Solver do your number crunching for you.

1. Set your target cell to point to your objective function.

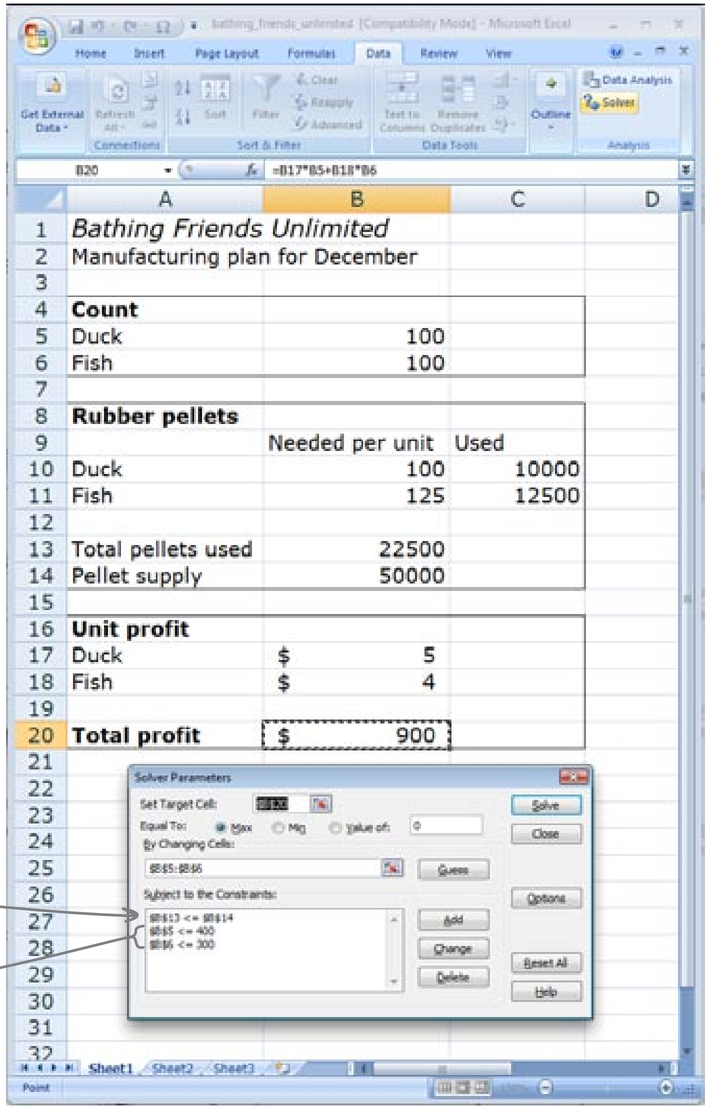
2. Find your decision variables and add them to the Changing Cells blank.

3. Add your constraints.

4. Click Solve!

Here's your rubber constraint.

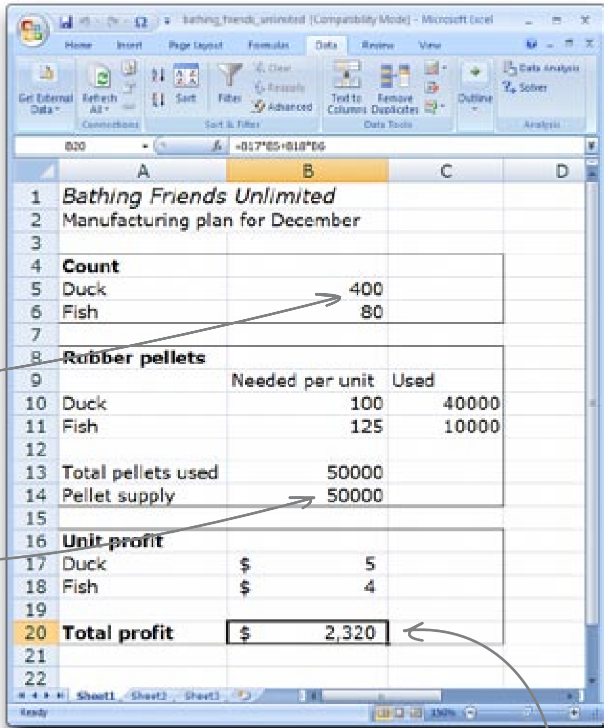
Don't forget your time constraints!



What happens when you click Solve?

Solver crunched your optimization problem in a snap

Nice work. Solver took all of about a millisecond to find the solution to your optimization problem. If Bathing Friends Unlimited wants to maximize its profit, it need only manufacture 400 ducks and 80 fish.



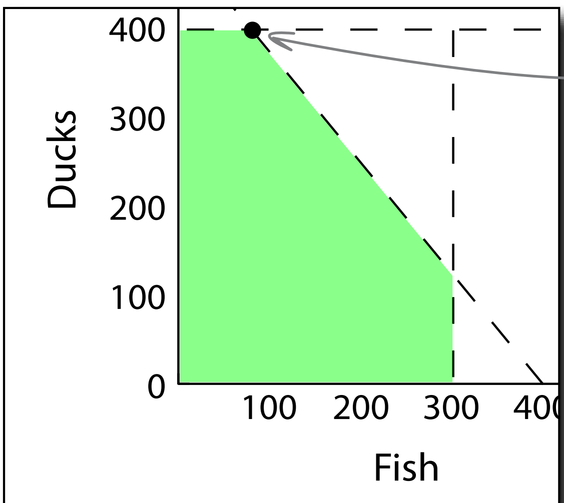
	A	B	C
1	*Bathing Friends Unlimited*		
2	Manufacturing plan for December		
3			
4	**Count**		
5	Duck	400	
6	Fish	80	
7			
8	**Rubber pellets**		
9		Needed per unit	Used
10	Duck	100	40000
11	Fish	125	10000
12			
13	Total pellets used	50000	
14	Pellet supply	50000	
15			
16	**Unit profit**		
17	Duck	$ 5	
18	Fish	$ 4	
19			
20	**Total profit**	$ 2,320	

Solver tried out a bunch of Count values and found the ones that maximize profit.

Looks like you're using all your rubber, too.

Here's the profit you can expect.

What's more, if you compare Solver's result to the graph you created, you can see that the precise point that Solver considers the best is on the outer limit of your feasible region.



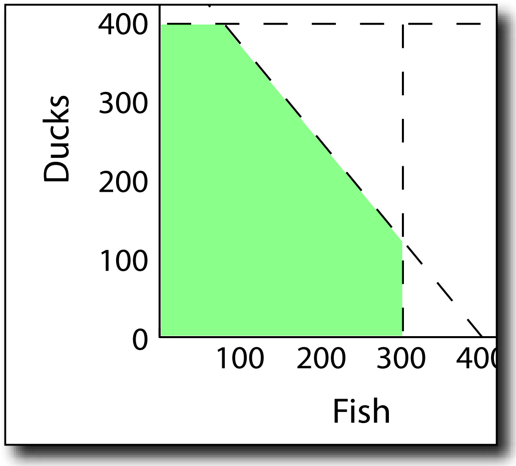
Here's your solution.

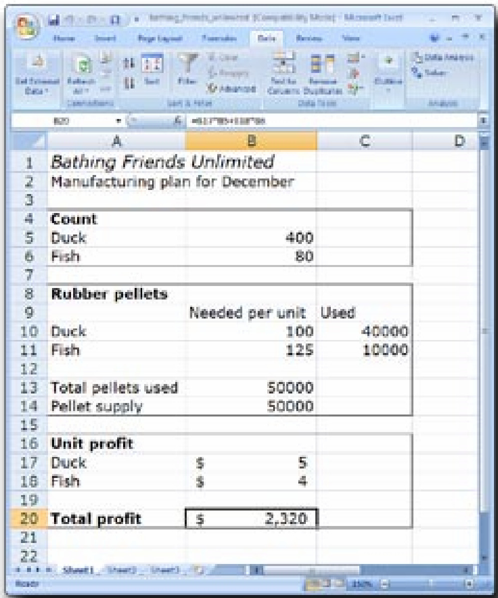
Looks like great work. Now how did you get to that solution again?

Better explain to the client what you've been up to...

Sharpen your pencil

How would you explain to the client what you're up to? Describe each of these visualizations. What do they mean, and what do they accomplish?





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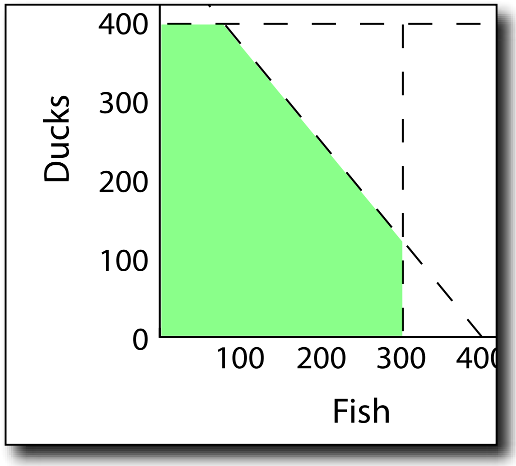
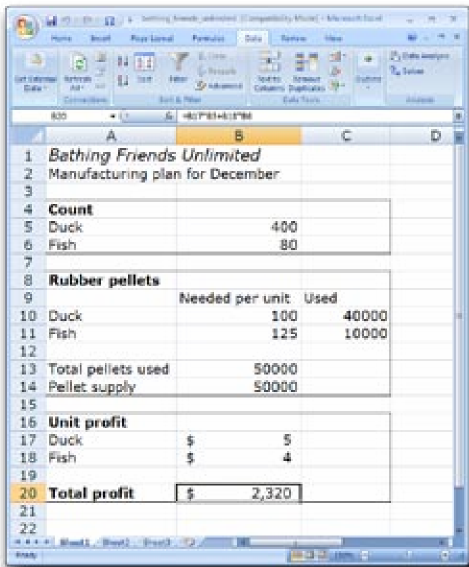
16	**Unit profit**		
17	Duck	$ 5	
18	Fish	$ 4	
19			
20	**Total profit**	$ 2,320	
21			
22			

Sharpen your pencil Solution

How did you interpret your findings to your client?



The shaded part of this graph shows all the possible duck/fish product mixes given our constraints, which are represented by the dashed lines. But this chart does not point out the solution itself.



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15			
16	**Unit profit**		
17	Duck	$ 5	
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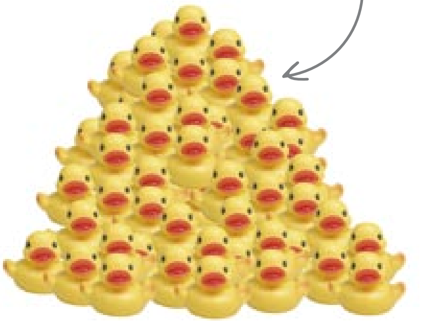
19			
20	**Total profit**	$ 2,320	
21			
22			

This spreadsheet shows the product mix computed by Excel to be the optimum. Of all possible product mixes, manufacturing 400 ducks and 80 fish produces the most profit while staying inside our constraints.

Profits fell through the floor

You just got this note from Bathing Friends Unlimited about the results of your analysis…

There are lots of ducks left over!



From: Bathing Friends Unlimited
To: Head First
Subject: Results of your "analysis"

Dear Analyst,

Frankly, we're shocked. We sold all 80 of the fish we produced, but we only sold 20 ducks. That means our gross profit is only $420, which you might realize is way below the estimate you gave us of $2,320. Clearly, we wanted something better than this.

We haven't ever had this sort of experience before with our duck sales, so for the moment we're not blaming you for this until we can do our own internal evaluation of what happened. You might want to do your own analysis, too.

Regards,

BFU

This is pretty **bad news**. The fish sold out, but no one's buying the ducks. Looks like you may have made a mistake.

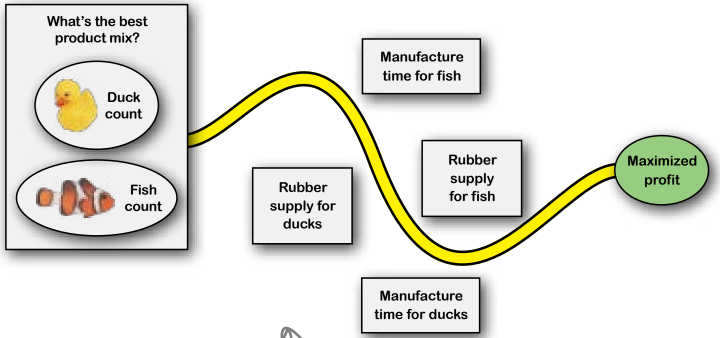
I want to see your explanation.

How does *your model* explain this situation?

Your model only describes what you put into it

Your model tells you how to maximize profits only **under the constraints you specified.**

Your models approximate reality and are never perfect, and sometimes their imperfections can cause you problems.



There's a lot more to reality than this model.

But does it matter?

It's a good idea to keep in mind this cheeky quote from a famous statistician:

"All models are wrong, but some are useful."

– George Box

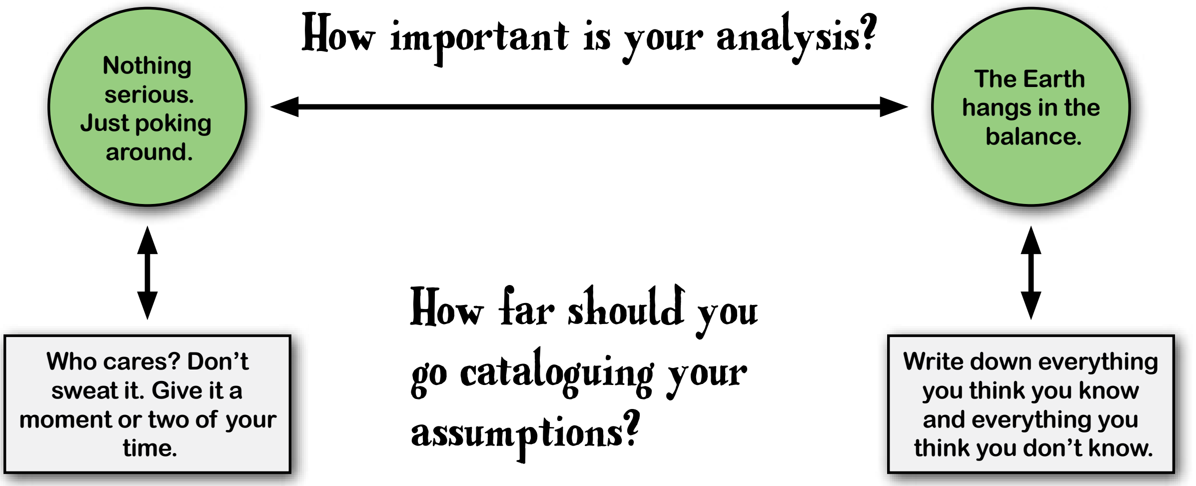
Your analytical tools inevitably simplify reality, but if your **assumptions** are accurate and your data's good the tools can be pretty reliable.

Your goal should be to create the ***most useful models*** you can, making the imperfections of the models unimportant relative to your analytical objectives.

Calibrate your assumptions to your analytical objectives

You can't specify all your assumptions, but if you miss an important one it could ruin your analysis.

You will always be asking yourself how far you need to go specifying assumptions. It depends on how important your analysis is.



Sharpen your pencil

What assumption do you need to include in order to get your optimization model working again?

Sharpen your pencil Solution

Is there an assumption that would help you refine your model?

There's nothing in the current model that says what people will actually buy. The model describes time, rubber, and profit, but in order for the model to work, people would have to buy everything we make. But, as we saw, this isn't happening, so we need an assumption about what people will buy.

there are no Dumb Questions

Q: What if the bad assumption were true, and people *would* buy everything we manufactured? Would the optimization method have worked?

A: Probably. If you can assume that everything you make will sell out, then maximizing your profitability is going to be largely about fine-tuning your product mix.

Q: But what if I set up the objective function to figure out how to maximize the amount of ducks and fish we made overall? It would seem that, if everything was selling out, we'd want to figure out how to make more.

A: That's a good idea, but remember your constraints. Your contact at Bathing Friends Unlimited said that you were limited in the amount of fish and ducks you could produce by both time and rubber supply. Those are your constraints.

Q: Optimization sounds kind of narrow. It's a tool that you only use when you have a single number that you want to maximize and some handy equations that you can use to find the right value.

A: But you can think of optimization more broadly than that. The optimizing mentality is all about figuring out what you want and carefully identifying the constraints that will affect how you are able to get it. Often, those constraints will be things you can represent quantitatively, and in that case, an algebraic software tool like Solver will work well.

Q: So Solver will do my optimizations if my problems can be represented quantitatively.

A: A lot of quantitative problems can be handled by Solver, but Solver is a tool that specializes in problems involving *linear programming*. There are other types of optimization problems and a variety of algorithms to solve them. If you'd like to learn more, run a search on the Internet for **operations research**.

Q: Should I use optimization to deal with this new model, will we sell people what they want?

A: Yes, if we can figure out how to incorporate people's preferences into our optimization model.

Exercise

Here's some historical sales data for rubber fish and ducks. With this information, you might be able to figure out why no one seemed interested in buying all your ducks.

Load this!

www.headfirstlabs.com/books/hfda/historical_sales_data.xls

Is there a pattern in the sales over time that hints at why ducks didn't sell well last month?

....

....

....

....

This sales data is for the whole rubber toy industry, not just BFU, so it's a good indicator of what people prefer to buy and when they prefer to buy it.

Do you see any month-to-month patterns?

Here's the most recent month, when everything went wrong.

	A	B	C	D	E
1	Month	Year	Fish	Ducks	Total
2	J	2006	71	25	96
3	F	2006	76	29	105
4	M	2006	73	29	102
5	A	2006	81	29	110
6	M	2006	83	32	115
7	J	2006	25	81	106
8	J	2006	35	89	124
9	A	2006	32	91	123
10	S	2006	25	87	112
11	O	2006	21	96	117
12	N	2006	113	51	164
13	D	2006	125	49	174
14	J	2007	90	34	124
15	F	2007	91	30	121
16	M	2007	90	30	120
17	A	2007	35	97	132
18	M	2007	34	96	130
19	J	2007	34	97	131
20	J	2007	43	105	148
21	A	2007	38	105	143
22	S	2007	119	43	162
23	O	2007	134	45	179
24	N	2007	139	58	197
25	D	2007	148	60	208
26	J	2008	103	37	140
27	F	2008	37	106	143
28	M	2008	34	103	137
29	A	2008	45	114	159
30	M	2008	40	117	157
31	J	2008	37	113	150
32	J	2008	129	48	177
33	A	2008	127	45	172
34	S	2008	137	45	182
35	O	2008	160	56	216
36	N	2008	125	175	300
37	D	2008	137	201	338

Exercise Solution

What do you see when you look at this new data?

Is there a pattern in the sales over time that hints at why Ducks didn't sell well last month?

Duck sales and fish sales seem to go in opposite directions. When one's up, the other's down. Last month, everyone wanted fish.

	Month	Year	Fish	Ducks	Total
2	J	2006	71	25	96
3	F	2006	76	29	105
4	M	2006	73	29	102
5	A	2006	81	29	110
6	M	2006	83	32	115
7	J	2006	25	81	106
8	J	2006	35	89	124
9	A	2006	32	91	123
10	S	2006	25	87	112
11	O	2006	21	96	117
12	N	2006	113	51	164
13	D	2006	125	49	174
14	J	2007	90	34	124
15	F	2007	91	30	121
16	M	2007	90	30	120
17	A	2007	35	97	132
18	M	2007	34	96	130
19	J	2007	34	97	131
20	J	2007	43	105	148
21	A	2007	38	105	143
22	S	2007	119	43	162
23	O	2007	134	45	179
24	N	2007	139	58	197
25	D	2007	148	60	208
26	J	2008	103	37	140
27	F	2008	37	106	143
28	M	2008	34	103	137
29	A	2008	45	114	159
30	M	2008	40	117	157
31	J	2008	37	113	150
32	J	2008	129	48	177
33	A	2008	127	45	172
34	S	2008	137	45	182
35	O	2008	160	56	216
36	N	2008	125	175	300
37	D	2008	137	201	338

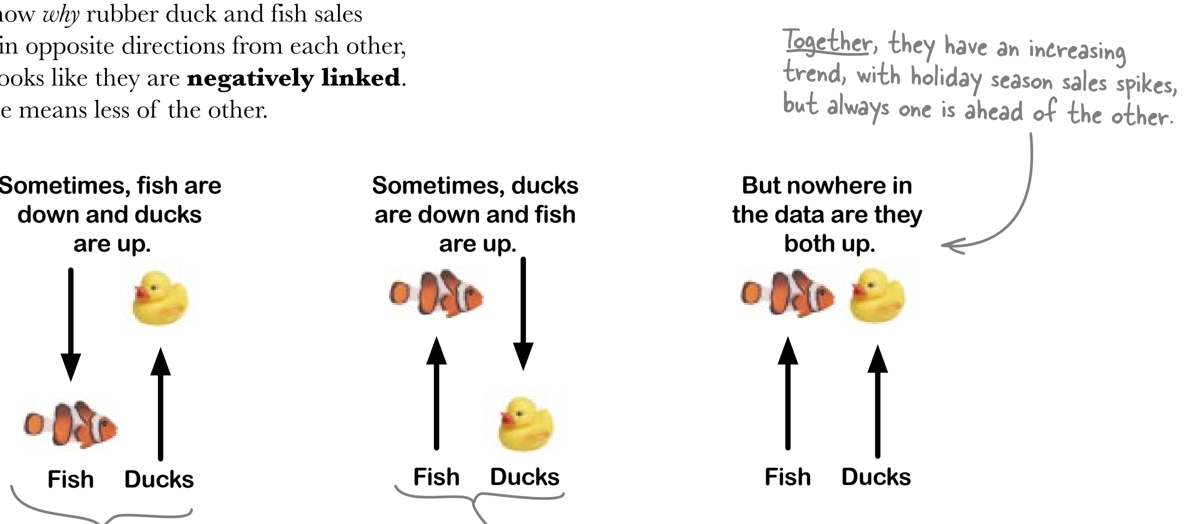
There are big drops in sales every January.

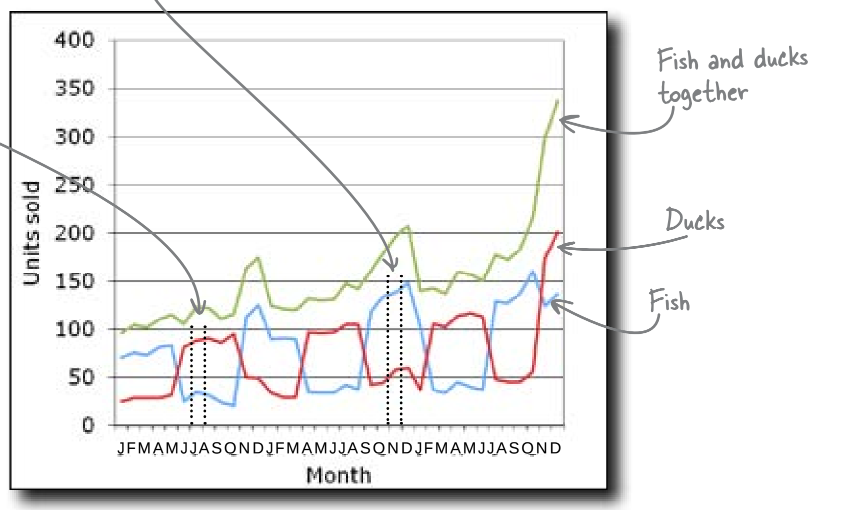
Here's switch, where ducks sell well and then fish jump ahaead..

Here's another switch!

Watch out for negatively linked variables

We don't know *why* rubber duck and fish sales seem to go in opposite directions from each other, but it sure looks like they are **negatively linked**. More of one means less of the other.





Don't assume that two variables are **independent** of each other. Any time you create a model, make sure you specify your assumptions about how the variables relate to each other.

BRAIN POWER

What sort of constraint would you add to your optimization model to account for the negatively linked fish and duck sales?

Long Exercise

You need a new constraint that **estimates demand** for ducks and fish for the month in which you hope to sell them.

1 Looking at the historical sales data, estimate what you think the highest amount of sales for ducks and fish will be next month. **Assume** also that the next month will follow the trend of the months that precede it.

	Month	Year	Fish	Ducks	Total
2	J	2006	71	25	96
3	F	2006	76	29	105
4	M	2006	73	29	102
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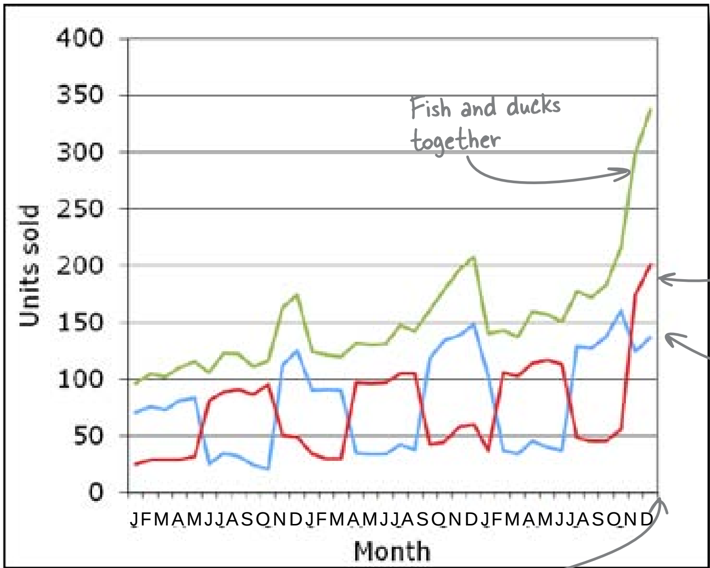
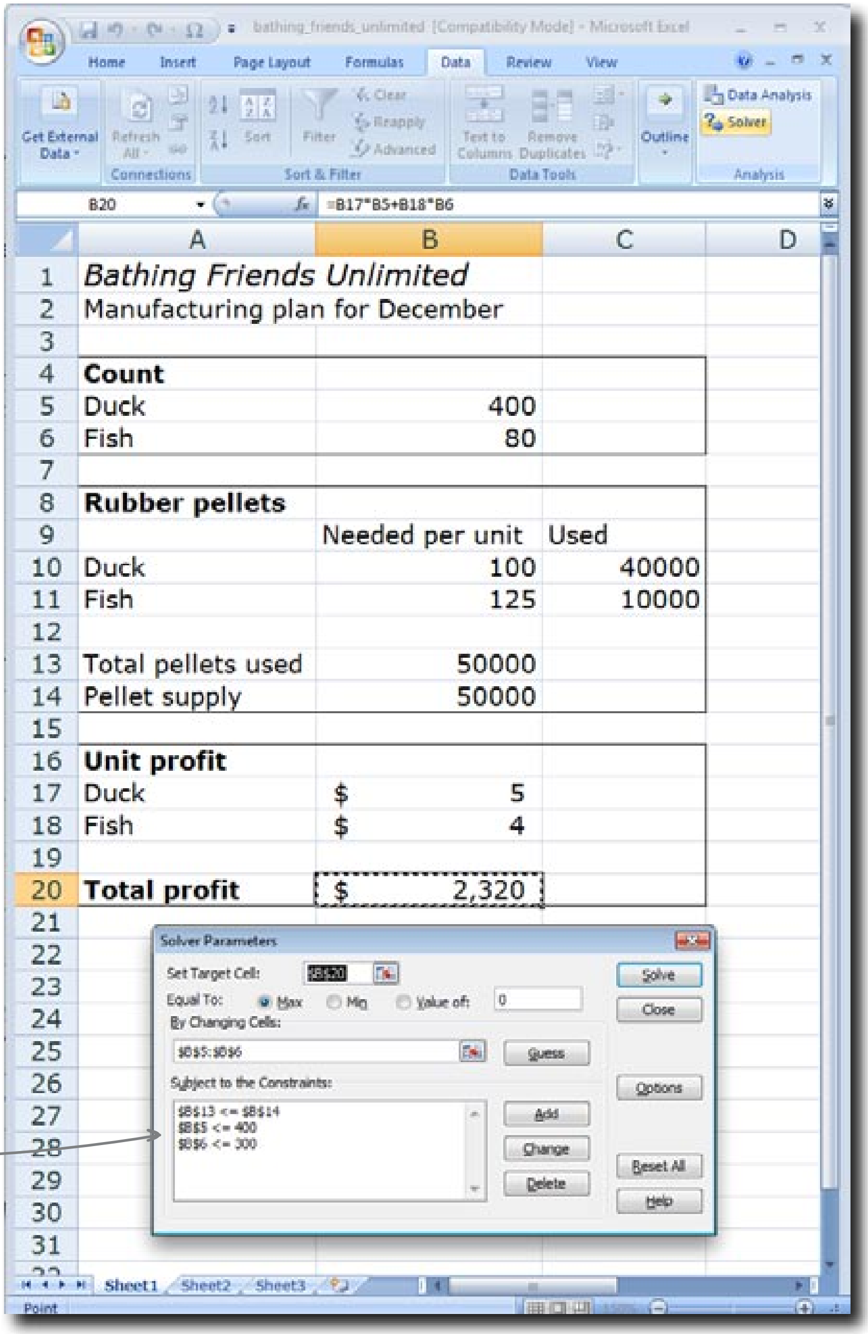


What usually happens after December to bath toy sales?

Which toy do you think will be on top next month?

2 Run the Solver again, adding your estimates as new constraints. For both ducks and fish, what do you think is the **maximum number** of units you could hope to sell?

None of these elements have changed, so you can leave the spreadsheet itself as is.

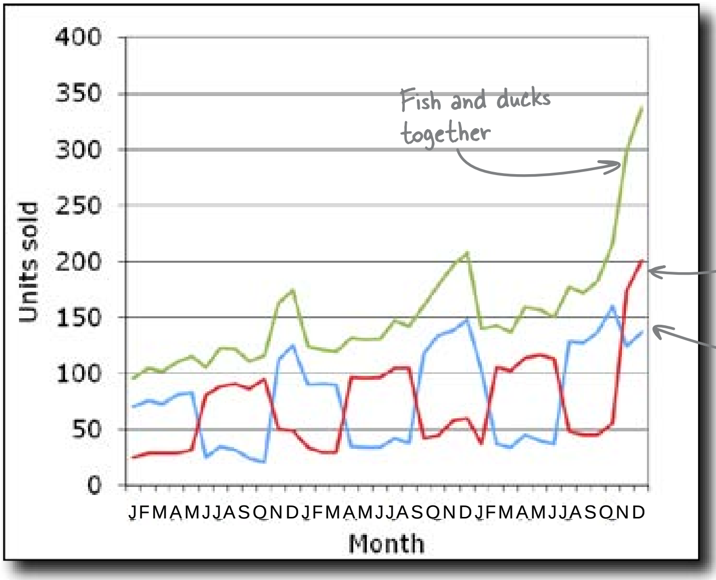


You want to change your constraints in this box.

Long Exercise Solution

You ran your optimization model again to incorporate estimates about rubber duck and fish sales. What did you learn?

1 Looking at the historical sales data, estimate what you think the highest amount of sales for ducks and fish will be next month. **Assume** that the next month will be similar to the months that preceded it.



We should prepare for a big drop in January sales, and it looks like ducks will still be on top.

We probably won't be able to sell more than 150 ducks.

Ducks

Fish

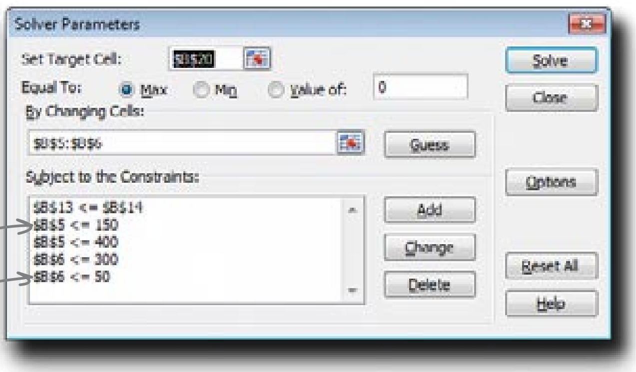
We probably won't be able to sell more than 50 fish.

2 Run the Solver again, adding your estimates as new constraints. For example, if you don't think that more than 50 fish will sell next month, make sure you add a constraint that tells Solver not to suggest manufacturing more than 50 fish.

Here are your new constraints.

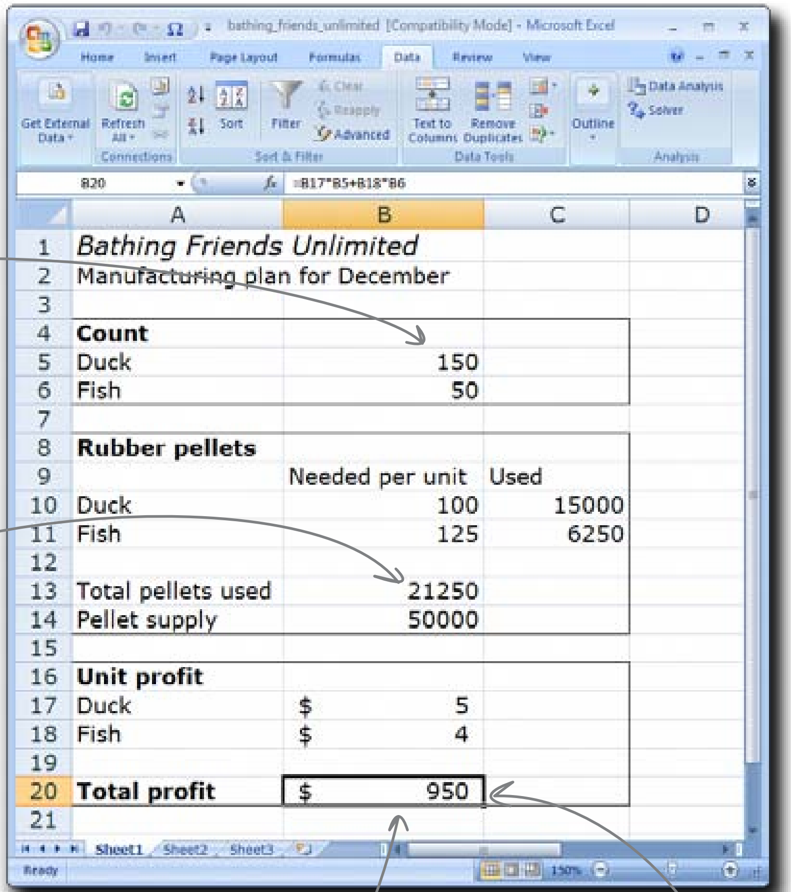
Ducks

Fish



Your specific numbers may vary a little... these are estimates after all.

Here's what Solver returned:



	A	B	C	D
1	*Bathing Friends Unlimited*			
2	Manufacturing plan for December			
3				
4	**Count**			
5	Duck	150		
6	Fish	50		
7				
8	**Rubber pellets**			
9		Needed per unit	Used	
10	Duck	100	15000	
11	Fish	125	6250	
12				
13	Total pellets used	21250		
14	Pellet supply	50000		
15				
16	**Unit profit**			
17	Duck	$ 5		
18	Fish	$ 4		
19				
20	**Total profit**	$ 950		
21				

Here's your product mix for next month.

Looks like you won't need to use anywhere near all your rubber.

Here's the profit estimate for next month.

It's not as large as last month's estimate, but it's a lot more reasonable!

Your new plan is working like a charm

The new plan is working brilliantly. Nearly every duck and fish that comes out of their manufacturing operation is sold immediately, so they have no excess inventory and every reason to believe that the profit maximization model has them where they need to be.

Not too shabby

From: Bathing Friends Unlimited
To: Head First
Subject: Thank you!!!

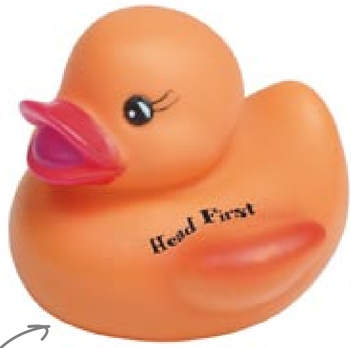
Dear Analyst,

You gave us *exactly* what we wanted, and we really appreciate it. Not only have you optimized our profit, you've made our operations more intelligent and data-driven. We'll definitely use your model for a long time to come. Thank you!

Regards,

BFU

P.S. Please accept this little token of our appreciation, a special Head First edition of our timeless rubber duck.



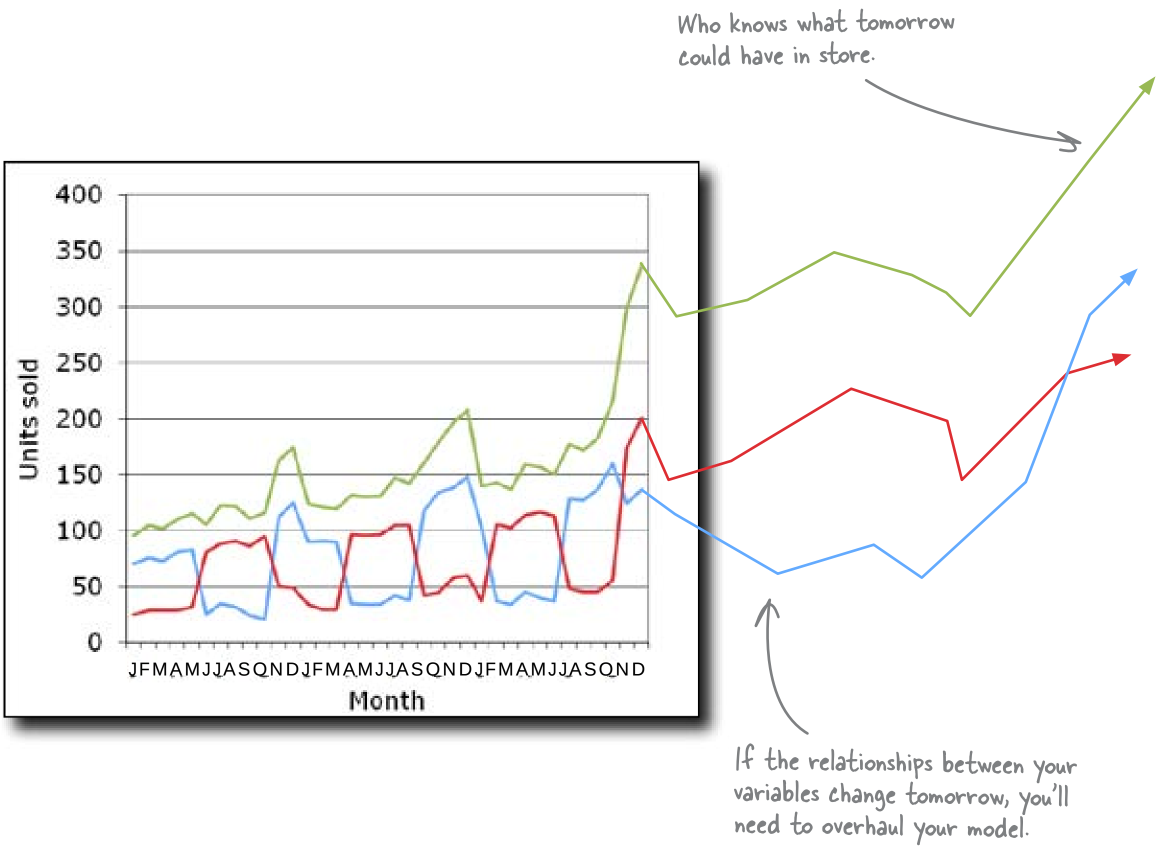
Enjoy your duck!

Good job! One question: the model works because you got the relationship right between duck demand and fish demand. But what if that relationship changes? What if people start buying them together, or not at all?

Your assumptions are based on an ever-changing reality

All your data is observational, and you don't know what will happen in the future.

Your model is working now, but it might break suddenly. You need to be ready and able to reframe your analysis as necessary. This perpetual, iterative framework is what analysts do.



Be ready to change your model!