Product, Sub-Market and Market Demand

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Introduction

Some number of years ago, preparing a cost estimate was quite a bit easier in many respects. Requirements for government programs were drawn up by their respective program offices. Contractors who wanted the work came up with proposed designs to meet those requirements. Contracts were awarded to those who came up with the cheapest satisfactory design.

In large measure, those times are behind us. No longer can contractors count on government program offices to spell out their requirements. Much more often than before, the government will no longer define the best designs. Moreover, they often will not specify how much they are ultimately willing to pay for their new programs. Increasingly, the contractors themselves are being asked to come up with the best design possible for the monies available.

This new direction mimics what happens in the private sector in every market every day. No single entity dictates to a manufacturer the capacity of the next passenger plane, or the speed of the next air freighter, or the number of commercial helicopters that must be made to satisfy the market. With the cost of developing large programs ranging into the billions, guessing incorrectly about market demand has potentially devastating consequences.

However, with some diligent research and statistical analysis, there is no need to guess about markets of interest. Markets have limitations, as the monies placed within them, and responses, as measured by their behavior when presented changes in price and the attributes of the products offered for sale. These market features may be observed and depicted empirically. The results of such work permit the determination of statistically significant responses to the differences in the attributes of products offered for sale to the buyers within markets, as well as the product, sub-market and demand curves applicable to them.

Methodology

This paper is an extension of previous work by the author on the same aircraft markets (Howarth 2005 1-3, 2006 1-3). In this case we'll examine and determine how to derive a demand curve for a market, along with those for the sub-markets and products within it. Manufacturer's websites are a primary source of information here, as they often provide the product attributes, prices and their historical and projected sales. Failing complete information there, various free websites or subscription-based services such as those offered by Teal Group Corporation, Forecast International and Jane's Information Group are used to augment the data. Curves on a single plane are calculated the Microsoft Excel regression tool, while Value response surfaces are computed via stepwise regression using the CO$TAT module within Tecolote Research's ACEIT suite.

Classical Demand

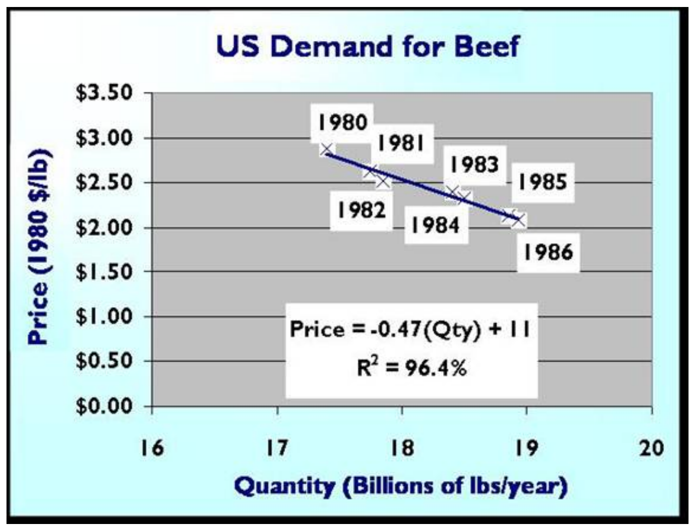
Summarizing what had been long observed, Paul Samuelson noted that "the quantity of a good that people will buy at any one time depends on price; the *higher* the price charged for an article, the *less* the quantity of it people will be willing to buy, and other things being equal, the lower its market price, the more units of it will be demanded. This relationship between price and quantity bought is called…the demand curve" (Samuelson, 1973).

Often, when hypothetical depictions of demand curves are called for, the price and quantity relationship for a commodity such as wheat or corn will be entertained. Real world observations of such behaviors can be found in the marketplace, as shown in Figures 1 and 2 below (Schroeder, 1998) (Buzby and Farah, 2006).

Figure 1: Beef Consumed

Year	US Beef Consumption (Billions of lbs./year)	1980 Price ($/lb)
1980	17.4	$2.88
1981	17.7	$2.62
1982	17.8	$2.51
1983	18.4	$2.39
1984	18.5	$2.32
1985	18.8	$2.13
1986	18.9	$2.08

Figure 2: US Beef Demand Curve 1980-86



Over a seven year period, from 1980 to 1986, the amount of red beef consumed in the United States steadily increased as the price for it steadily decreased.

The aggregate demand curve in Figure 2 is

$$\text{Price} = -\$0.47(\text{Quantity}) + \$11/\text{pound} \qquad (1)$$

Where:

Price = Price per pound in 1980 dollars
Quantity = Billions of pounds of US beef consumed per year

The relationship described in Equation 1 suggests there is an inverse linear relationship between price and quantity, confirming our understanding that as prices fall, quantities purchased increases, verified by an R^2 of 96.4% (The R^2, or coefficient of determination, is the ratio of the variation of the dependent variable explained by a regression equation over the total variation of the dependent variable. A perfectly correlated regression equation has an R^2 of 1; an equation with no predictive ability has an R^2 of 0. The adjusted R^2, which we'll use later, allows comparisons between regressions with differing numbers of independent variables). However, as we'll see below, many if not most demand curves demonstrate a logarithmic or log-linear quality, given enough range in price. It seems possible, if not probable, that what we are seeing in Figure 2 is a local linearization of a curve that is ultimately non-linear. In any event, we exit the study of the beef market armed with statistically significant support of the original hypothesis, which is that high prices decrease quantities purchased, and vice versa.

Market Demand for Products with Multiple Attributes

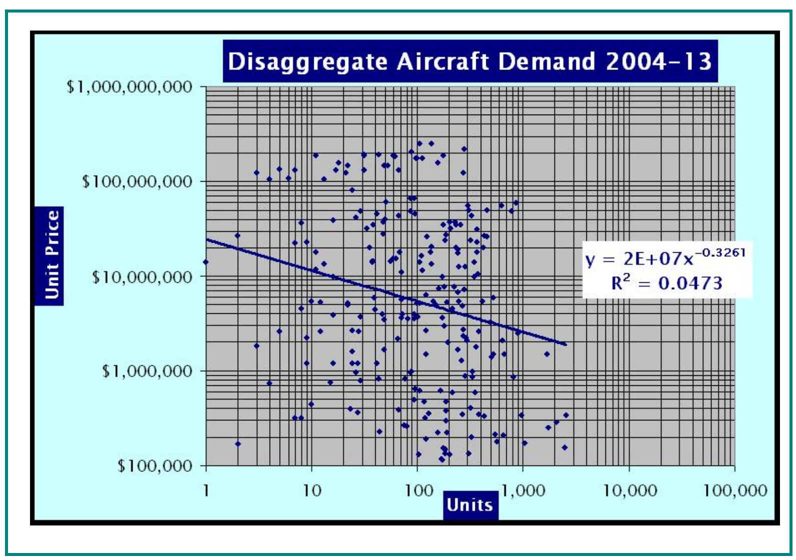
New aircraft for sale have a number of different attributes which distinguish them from other vehicles in the market. They vary by the number of passengers or pounds of payload they can carry, the speeds at which they can operate, their ability to land vertically or on water and the number of engines they employ, along with many other features. Consider then, the entire market for new civil aircraft, some 233 models ranging from piston-powered vehicles as small as the Cessna 172R to jumbo jet airliners as large as the Airbus A380, with helicopters, regional airliners and air freighters included in the mix as well, priced from $100,000 to $250 million, for the decade running from January 1, 2004 to December 31, 2013 (with the model names removed to protect the database) (Forecast International, 2004, Teal Group Corporation, 2004).

The entrants in this market have a projected sales figure for the decade, as well as predicted prices, with several models as shown in Figure 3, and the entire group of 233 quantity-price points each representing a model in Figure 4.

Figure 3: Sample Data

Aircraft	2004 2013 Qty	Price 04$
Model 1	281	$900,000
Model 2	295	$2,100,000
Model 3	71	$3,700,000
Model 4	92	$3,600,000
Model 5	81	$3,600,000
Model 6	191	$2,000,000
Model 7	11	$18,000,000

Figure 4: Aircraft Quantity-Price Points



The aggregate demand curve in Figure 4 is

$$\text{Price} = 2E{+}07\ (\text{Quantity})^{-0.3261} \qquad (2)$$

Where:

Price = Predicted Price per Aircraft in 2004
Quantity = Number of Planes purchased from 2004 to 2013

The R^2 for Equation 2 is only 4.7%, which is clearly not usable. Note that the aircraft market, with all of the variations of products that it offers to its buyers, does not behave in the same manner in the same manner as that for the beef market, which has substantially fewer variations.

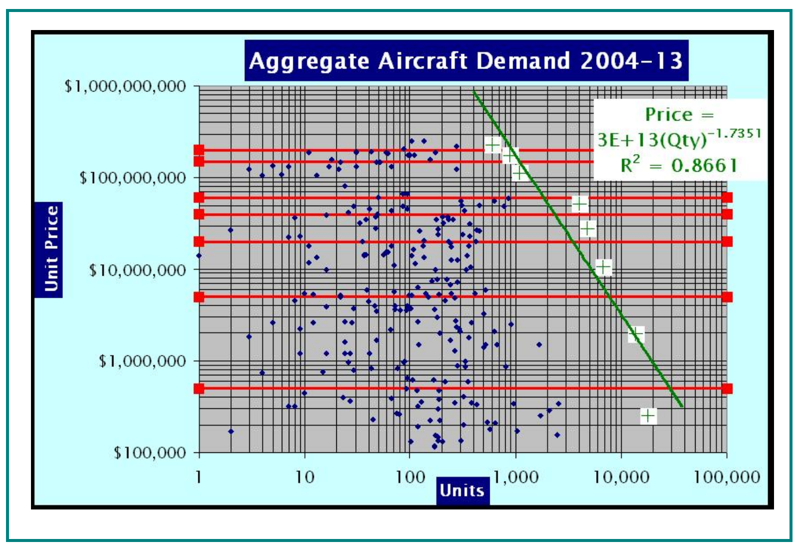
At this juncture, given the seeming lack of correlation in the data, we might well throw up our hands and move on to another problem. However, with some simple manipulation of the data, we can discover the impact of price on the quantities sold.

In Figure 5, we collect the total quantities sold within certain price ranges. Within each range, we total up the revenue for that segment and divide that by the number of aircraft within that same segment to get a figure for the total quantities sold and the average price per unit. For example, below a price tag of $500,000, we discover there are 17,716 vehicles predicted to be sold over the decade running from 2004 to 2013. When we divide the total revenue in the segment by the number of vehicles within in it, we find that that segment has an average price of about $260,000. This, then, is an ordered pair, 17,716, $260,000, which shows up as a white box with a green plus sign through it in the lower right hand corner of the chart in Figure 6

Figure 5: Data Bins

Price Range in 04$M	Qty	Ave 04$M
x <= $0.5	17,716	$0.26
$0.5 < x <= $5.0	13,571	$1.98
$5.0 < x <= $20.0	6,707	$10.49
$20.0 < x <= $40.0	4,770	$28.00
$40.0 < x <= $60.0	3,971	$51.74
$60.0 < x <= $150.0	1,091	$112.91
$150.0 < x <= $200.0	888	$175.94
x > $200.0	599	$228.39

Figure 6: 2004-13 Aggregate Demand



We continue this process to find the number of vehicles to be for over $500,000 but less than equal to $5 million (13,571 vehicles at an average price of $1.98 million), those over $5 million but less than $20 million, (6,707 vehicles, average price $10.49 million) and so on, until we have captured eight distinct bands according to price.

With these eight points, we can run a regression and we find that the aggregate demand in Figure 6 is

$$\text{Price} = 3E{+}13\,(\text{Quantity})^{-1.7351} \qquad (3)$$

Where:
Price = Predicted Price per Aircraft in 2004
Quantity = Number of Planes purchased per bin from 2004 to 2013

In this newer way of looking at demand, we now have a usable equation for aggregate demand, as the R^2 here is 86.6%. Using this curve, we can characterize the market response to changes in price for all 233 models within it simultaneously.

Since used aircraft are a substitute for new aircraft, and they are not included in this projection, we would rightly suppose that if used aircraft were added to the database, they would cost less than their identical new counterparts. This would have the effect of adding more price-quantity points to the lower end of the scale, which would certainly flatten the curve and may well improve it correlation. Importantly as well, the number of aircraft in the market, along with the number projected to be added to the market, gives a measure of the anticipated saturation within it. This, as we might guess, could be useful. We'll address that a bit later.

Sub-Market Demand

Within the larger aircraft market there are several sub-markets. The buyers of personal aircraft, designed primarily for individual owners, form a sub-market. Individuals and companies that buy business jets support another sub-market, and airlines that purchase large commercial aircraft yet another. Each sub-market, by its very nature, has a more limited scope and price range than the entire market. Because of that, it may be useful to examine these sub-markets individually.

Figure 7: Regional Aircraft

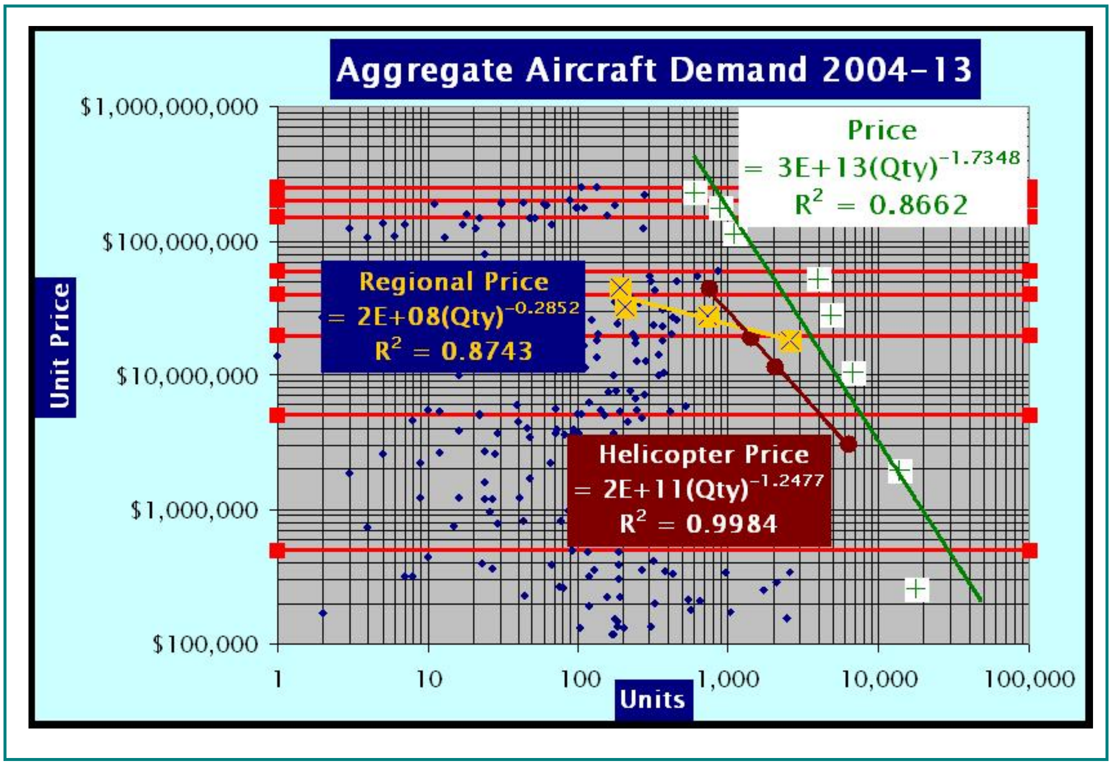
Price Range in 04$M	Qty	Ave 04$M
x <= $25	2,532	$18.31
$25 < x <= $30	717	$27.43
$30 < x <= $40	204	$32.08
x > $40	191	$45.00

Figure 8: Helicopters

Price Range in 04$M	Qty	Ave 04$M
x <= $7.5	6,373	$3.02
$7.5 < x <= $15	2,043	$11.39
$15 < x <= $25	1,424	$19.15
x > $25	751	$43.63

Consider the markets for regional aircraft and helicopters in Figures 7 and 8, respectively. With quantity and price figures pulled for each sub-market from the same database used for the analysis in Figures 3 through 6 above, we now have price bins for two distinct elements within the larger total market. In the case of regional aircraft, as shown in Figure 7, in the lowest end of the price range, for aircraft priced less than or equal to $25 million, we have 2532 vehicles identified for sale for the decade running from the beginning of 2004 to the end of 2013, at an average price of $18.31 million. Continuing on in that same Figure, we see that we 717 vehicles over $25 million but less than or equal to $30 million, at an average of $27.43 million, 204 vehicles priced over $30 million but less than or equal to $40 million at an average of $32.08 million, and 191 vehicles in the price category over $40 million, at an average price of $45 million. When we perform the same kind of analysis for Vertical Takeoff and Landing (VTOL), or helicopter demand, and both it and the demand for regional aircraft to our original demand curve, we get a broader view of the market for aircraft as presented in Figure 9.

Figure 9: Demand for the Regional and Helicopter Sub-Markets



With the data above, we can run regressions and we find that the regional aircraft and helicopter aggregate demand curves in Figure 9 respectively are

Regional Price = 2E+08 $(\text{Quantity})^{-0.2852}$ (4)
Helicopter Price = 2E+11 $(\text{Quantity})^{-1.2477}$ (5)

Where:
Price = Predicted Price per Aircraft in 2004
Quantity = Number of Planes purchased per bin from 2004 to 2013

Figure 9 reveals that both the regional and helicopter sub-markets have their own identifiable statistically significant demand curves, which in turn make up part of the total market demand curve, which is statistically significant as well. Given that going to a lower level in the analysis may have been of use to us already, we may want to go a step further and see if we can make some sense of what forces are at work for demand at the product level.

Product Demand

Before we attempt to characterize product demand, perhaps we should try to gain a better understanding of what the buyers want in a product. Warren Buffet once commented that "Price is what you pay. Value is what you get." Mr. Buffet made the strong suggestion that there is a correlation between value and price. Intuitively, we know this to be true. How might we go about trying to verify that statistically?

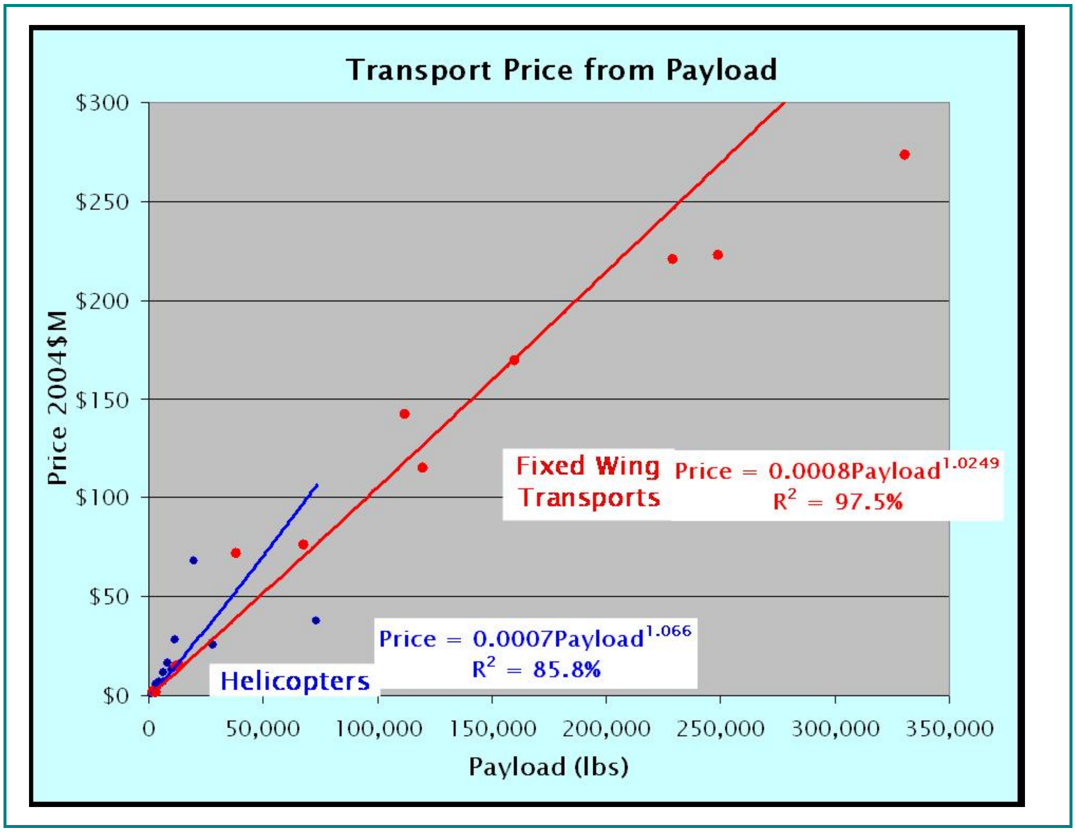
Let us suppose for a moment that there are many things that might be valued in a product. How could we characterize these attributes? Perhaps the easiest way of going about this task is to determine the broad categories of traits that consumers look for when buying just about anything. While not all of us have bought an aircraft, we most likely have flown in one or more of them and can determine what we like in them. And, after all, if we don't like the planes, how are airlines going to entice us to ride in them? More within more consumers budgets are personal and laptop computers. When we stop to think about what is similar in how purchases of aircraft and computers are made, we are more struck with the similarities of the two processes, rather than the differences.

Aircraft, for example, have a certain capacity. Typically it is measured by the number of passengers it can carry, or its payload capability, as measured by weight or volume. Notice that computers have capacities too, often measured in the amount of memory they possess. All other things being equal, a plane that goes faster than another is more valuable. So it is with computers, where, in a given time period, computers with faster processing times fetch more money than those with slower processing. Portability is important to purchasers of planes, as they will favor a plane that can land in the many more available small fields and landing pads rather a vehicle restricted to a few of the longest fields available. The ability to easily move one's computer about is important as well, as a small laptop with a given memory and processing speed will always fetch more than a comparable desktop. And, to get back to the topic at hand, that of demand, it seems reasonable to believe that given a greater number of airliners at hand rather than fewer, an airline might feel it reaching a sort of satiation in regards to its purchases, in the same manner as we might imagine, say, a school might once it had a computer for every student attending it, and, in each case, the potential buyers would be less likely to pay what had been the full previous price for the articles in question.

In order to move beyond a simple heuristic notion of value, we'll have to employ some statistics on a database to gain a deeper understanding of the workings of a market. Suppose we wanted to make some new hybrid vehicle that could take off vertically, move fairly quickly, and land on water. To that end, we'll select 34 models of the aircraft database already mentioned, to include all of the models that employ some sort of freighter designation, as well as all of the helicopter models within it. As we've already seen in the wider analysis, the lightest fixed wing aircraft in this subset, the Cessna Caravan Amphibian, is economically related to the largest fixed wing aircraft in this subset, the Airbus A380 freighter. Within the helicopter portion of database, we incorporate vehicles as small as the Eurocopter EC-120 to those as large as the Sikorsky S-92, and to round out the breadth of the vertical take-off and landing craft, add in the Bell Augusta BA-609, which offers added cruise speed as a product of its tilt-rotor configuration.

As a first cut into the data we may want to see if, say, payload capacity alone could be used to explain price. This would cut down on our work if we can satisfactory answers using this method. We employ this method in Figure 10, where the blue points, ordered pairs representing the payloads and prices of the helicopters in our database are compared to the red points, the corresponding ordered pairs for the fixed wing transports we are considering.

Figure 10: Transport Price Predicted by Payload Capacity



In Figure 10, we calculate the sustainable price in millions of 2004 dollars from the payload capacity for each of our two sets, helicopters and fixed wing transports.

We discover that

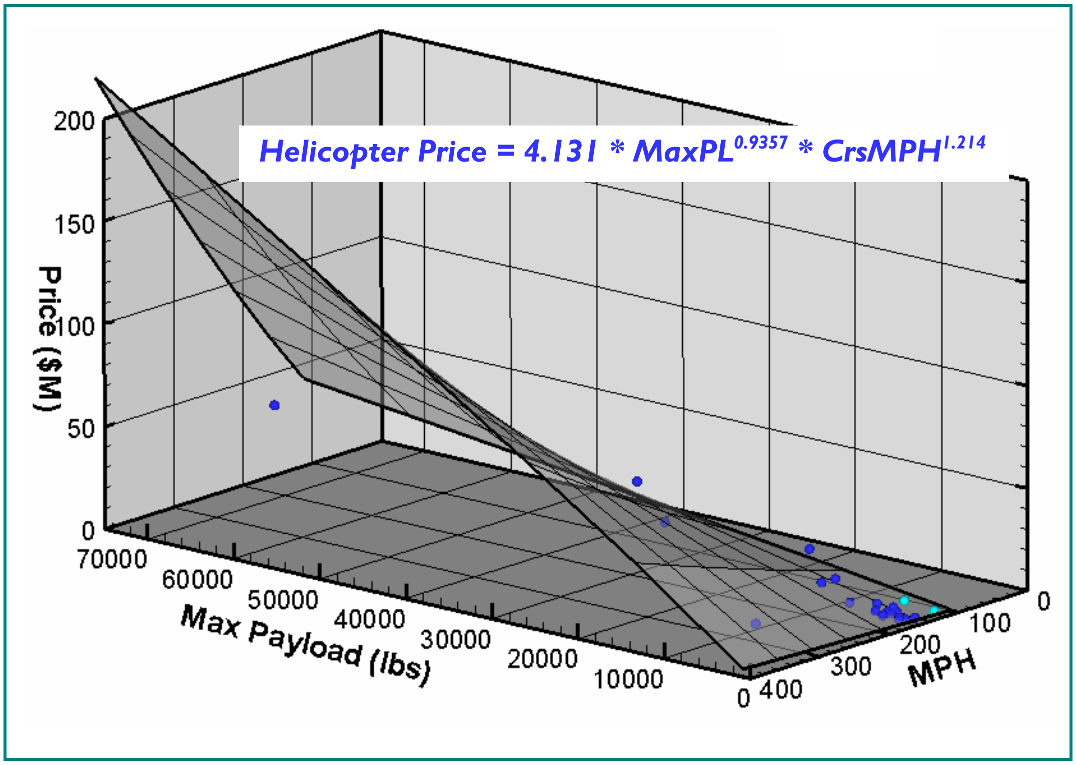
Helicopter 2004 Median Price (in Millions) $= 0.0007 * \text{Payload}^{1.066}$ (6)

Fixed Wing Transport 2004 Median Price (in Millions) $= 0.0008 * \text{Payload}^{1.0245}$ (7)

Each of Equations 6 and 7 provide acceptable R^2, 85.8% and 97.5%, respectively, but we wonder if we might be able to do better given that the correlation for helicopters is not very high and neither equation considers more than one term.

To that end we plot the payload capacity of helicopters, as an "x" value, along with the maximum cruise speed in miles per hour, as a "y" value, to see if we can predict speed, which then becomes a "z" value (represented by Price as currency). We use the same blue points to represent our helicopters as we did before, but note that we have a pair of them that can land on water, which we depict with light blue points. After we do that, we run a multiple stepwise regression on the data, adding speed as an independent variable to the payload term we already considered, to try to predict price, our dependent term, in Figure 11.

Figure 11: Helicopter Price from Payload Capacity and Cruise Speed



In Figure 11, we now use two independent variables where we were using one. Our new equation to explain helicopter cost is

Helicopter Price Median Price (in 2004$) = 4.131 * $\text{MaxPayload}^{0.9357}$ * $\text{CrsMPH}^{1.214}$ (8)

Equation 8 offers a better adjusted R^2, at 89.5%, than our single variable R^2 that we had in equation 6 when we tried to predict helicopter price using only payload. Importantly, this equation has a T-Statistic probability value of 1.000 for its payload term, and 0.994 for its cruise speed term. Both independent variables, then, clearly influence the helicopter price.

We do the same type of effort for fixed wing transports in Figure 12, where we try to predict their prices from payload and speed as well. Just as with Figure 11, we are using both the payload values and cruise speed values to predict the sustainable price in the market.

In Figure 12, we find that

Fixed Wing Median Price (in 2004$) = 6.654 * $\text{MaxPayload}^{0.7274}$ * $\text{CrsMPH}^{1.324}$ (9)

Equation 9 has an adjusted R^2 of 97.4%, which does not represent an improvement from our equation 7, in which payload alone explained fixed wing transport cost with an R^2 of 97.5%. Also important are the T-Statistic probability values associated with Equation 9, which at 0.987 is fine for payload, but which at 0.776 for speed is a little less than we would like.

We might take notice that the number of engines varies widely for this set. At least one vehicle has four engines, and at least one has one engine. Additionally, it is worth noting that one of the vehicles is amphibious.

Figure 12: Fixed Wing Price from Payload Capacity and Cruise Speed

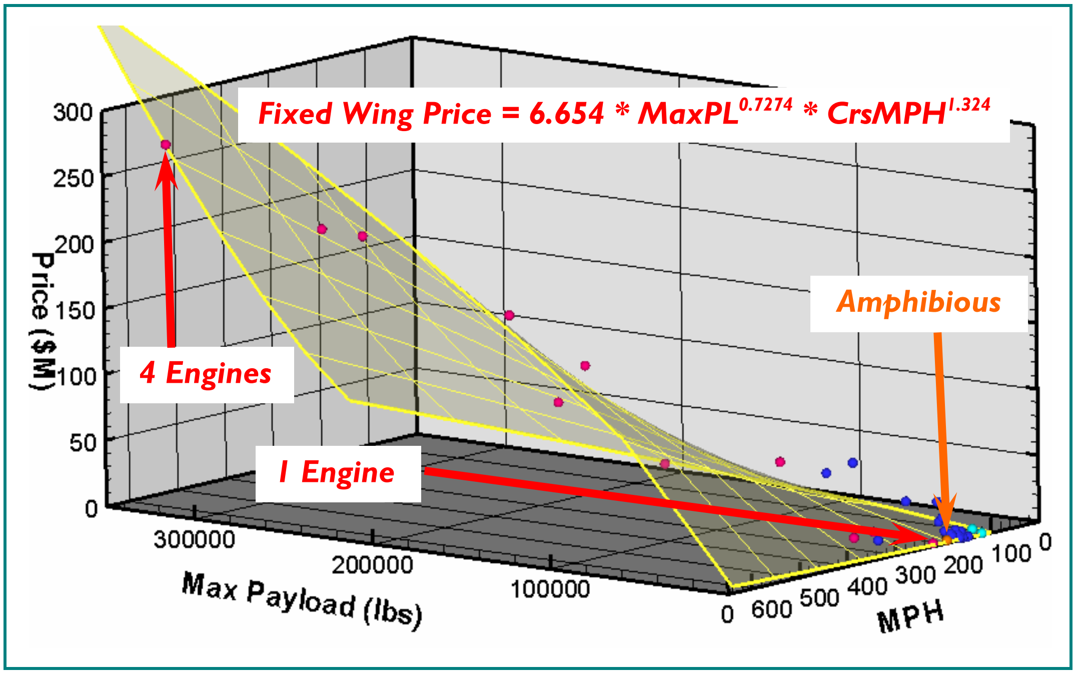
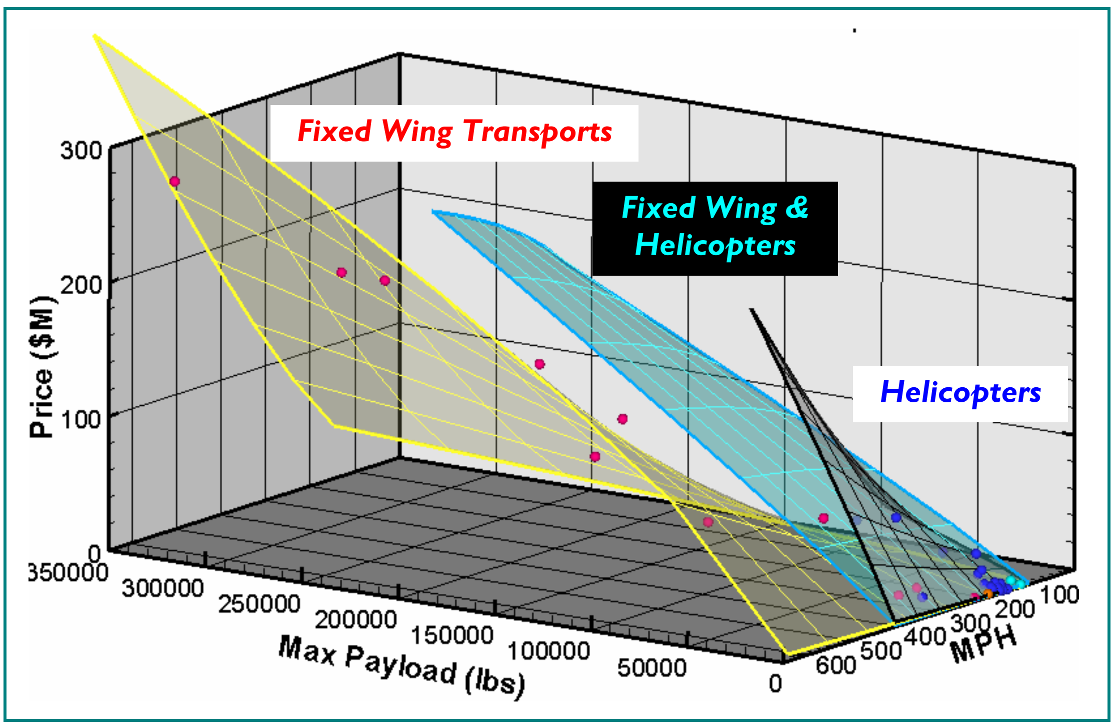


Figure 13: All Vehicle Prices from Payload Capacity and Cruise Speed



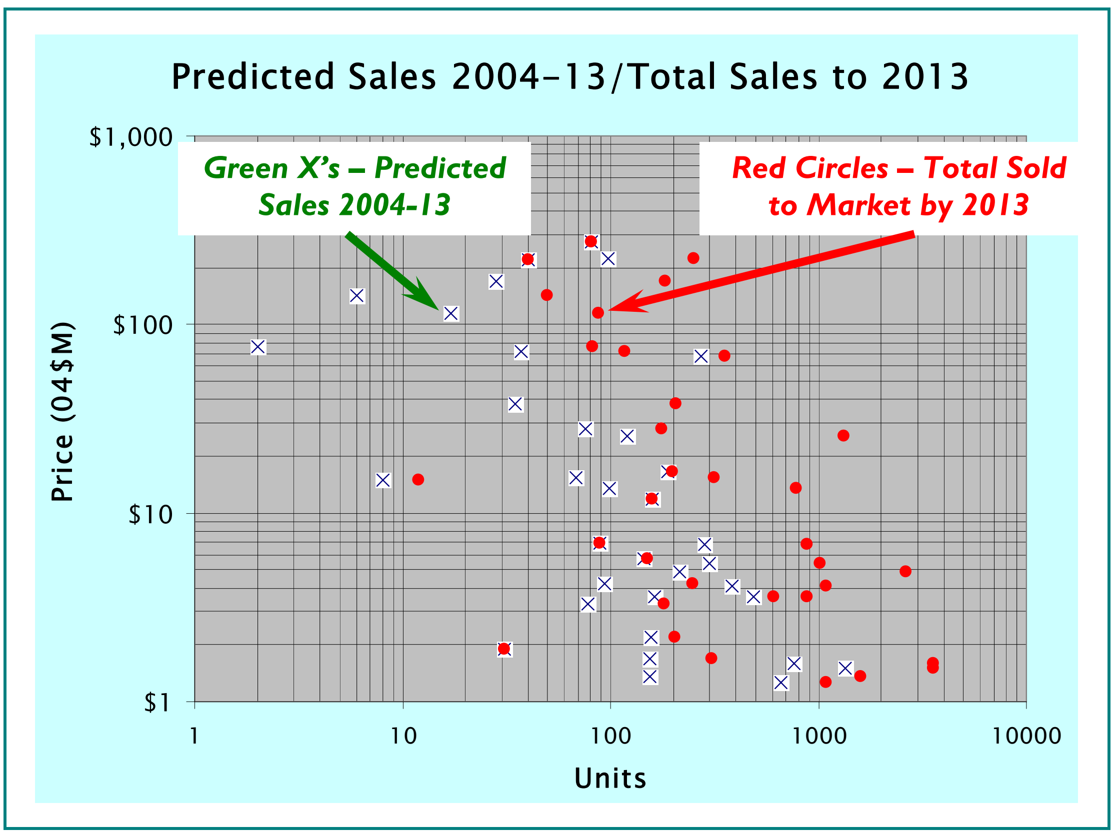
If we attempt to simply split the difference, as in Figure 13, and estimate the impact of payload and speed on all of the vehicles, we get the light blue surface.

Transport Vehicle Median Price (in 2004$) = 617 * $MaxPayload^{0.9282}$ * $CrsMPH^{0.2368}$ (10)

Equation 10, representing the light blue surface in Figure 13, has a satisfactory adjusted R^2 of 94.6%, but while its T-Statistic Probability value for payload is more than acceptable at 1.000, that same value for cruise speed is only 0.615. Thus, it would be hard to use this equation based on that poor t-statistic. Since we intuitively know that speed is likely very important to value in aircraft transports, we decide to employ other methods to see if we navigate around this problem.

Since helicopters command more money than fixed wing transports for the same capabilities (note that the black value response surface for helicopters, in Figure 13, is higher at all payloads and speeds that the yellow value response surface for fixed wing transports), we will employ a dummy variable for helicopters (1 = Fixed Wing Transport, 2 = Helicopter). We suspect a similar relationship exists for amphibious craft; that is, all other attributes being equal, we expect a vehicle that can take off from water or land might be worth more than one that can only take off from land, and assign a dummy variable for amphibians (1 = No Water Landing Capability, 2 = Water Landing Capable). We also expect that having more engines might be worth something to buyers as a measure of safety, and will introduce that as an independent variable.

Figure 14: Total Number of Vehicles Sold to the Market by 2013



Finally, we note that in addition to the units predicted to be sold over the course of 2004-13 (the white boxes with green "x's" in Figure 14, we might want to account for the units already sold to the market. Those units add to those predicted for sale over 2004-2013, and give the red circles in Figure 15. These units provide a measure of market saturation by the end of 2013.

Performing multiple stepwise regressions upon these attribute we discover that the following equation may be used to predict value:

$$\text{Estimated 2004 Median Price} = 16.26 * MaxPL^{0.719} * CrsMPH^{1.15} * Helo^{1.22} * Engs^{0.635} * WtrLnd^{0.705} * Units^{(-0.067)} \quad (11)$$

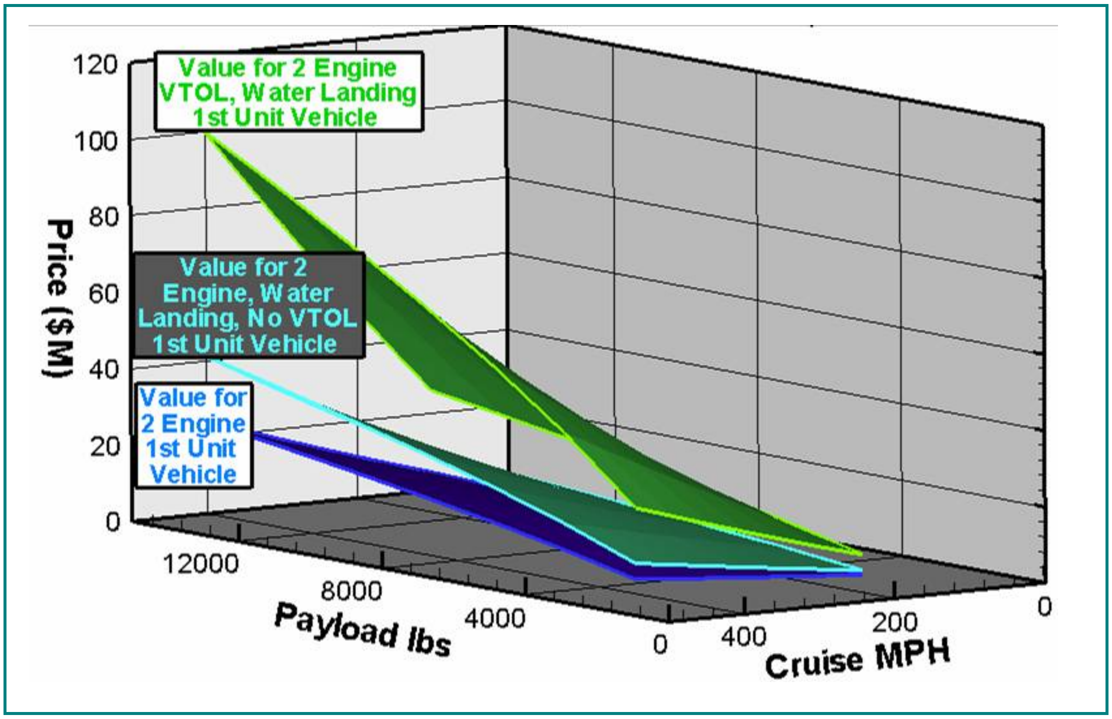
Where:

Estimated Median Price = Predicted Price per Aircraft in 2004 Dollars
MaxPL = Maximum Vehicle Payload in Pounds
CrsMPH = Maximum Vehicle Cruise Speed in Miles per Hour
Helo = Dummy Variable for VTOL ability (1 = Fixed Wing, 2 = VTOL capable)
Engs = Number of Engines on the Vehicle
WtrLand = Dummy Variable for Water Landing (1 = No Water Landings, 2 = Amphibious)
Units = Number of Units Anticipated in the Market by 2013 (those already built by the end of 2003, plus those predicted to be built from the beginning of 2004 to the end of 2013)

The F-Statistic for Equation 11 is 177.4, while the Pearson's Correlation Coefficient squared value is 93.4%, meaning this is a statistically significant equation from which we can estimate the market value of our hypothetical aircraft.

The T-Statistics for Payload, Cruise Speed, VTOL capability, Number of Engines and Water Landing capability are 1.000, 0.999, 0.999, 0.995 and 0.961, respectively. All of these features are significant contributors to the ultimate value of any air vehicle.

Figure 15: Value Response Surfaces Relate to Vehicle Attributes



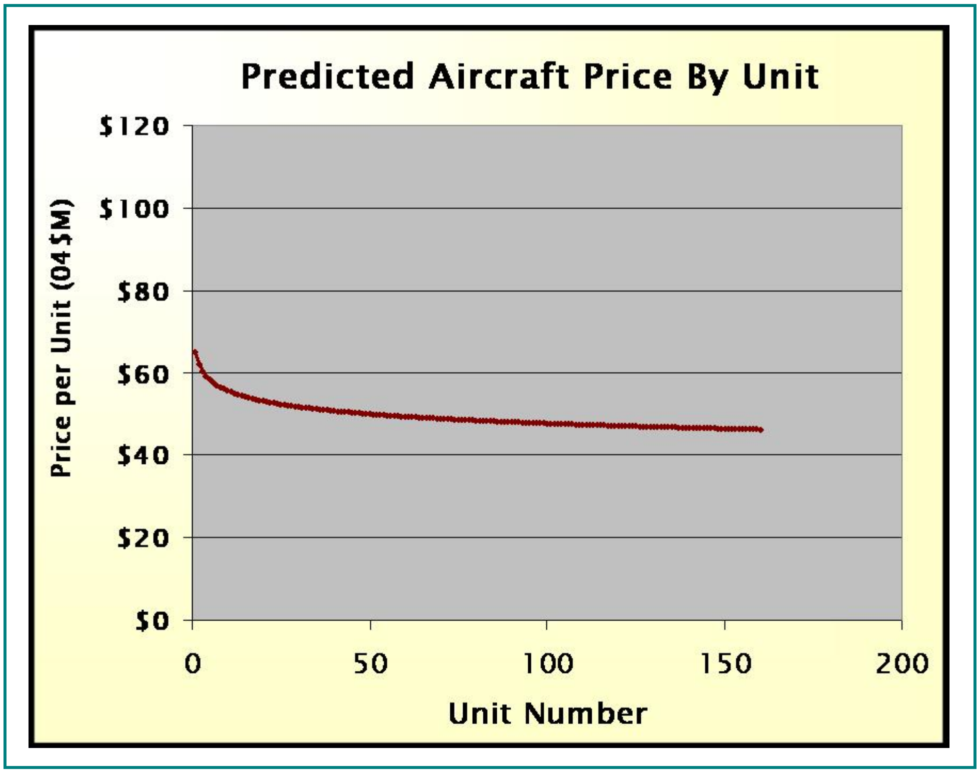
The impact of model features is revealed in Figure 15. In the lowest surface, we populate Equation 11 with a range of payload weights and possible cruise speeds. To this particular case we further describe it as the first vehicle of an entirely new model series (we set the Units variable value to 1), one that cannot take off vertically (we set the Helo variable value to 1), cannot take off from the water (we set the WtrLand variable value to 1) and which has 2 Engines (we set the Engs variable value to 2).

If we take the same hypothetical vehicle and now make it amphibious (by changing our setting on the WtrLand variable to 2), we get the middle surface. Note that for all equivalent speeds and payloads, a vehicle that can land on water is worth more than one that cannot.

If we take the vehicle we hypothetically created in the previous paragraph and now give it the ability to take off vertically (by changing the value on Helo variable from 1 to 2), we get the upper surface. Note that this vehicle is worth more than all others, for all equivalent payloads and cruising speed.

Less important to the value of a given aircraft model is the number of units of it in the marketplace. This is borne out by "Units" T-Statistic, which, at 0.796, is much lower than the other five other attributes. Forecast International, in 2004, having examined the prospects for the 233 aircraft models above mentioned, predicted sales of nearly 50,000 vehicles for the decade running from January 1, 2004 and ending December 31, 2013. These vehicles will add to a market already brimming with tens of thousands of aircraft by the end of 2003. In a market where unit sales for the vast majority of models run less than 1000 for an entire decade, the impact of one vehicle's sales figures do less to affect its price than its other highly valued attributes. The impact of saturation, as we would expect, is in the right direction: the more vehicles sold, the lower the supportable price.

Figure 16: Predicted Sustainable Unit Price of Hypothetical Aircraft



The impact of more units sold of our very own hypothetical model is shown in Figure 16. Using the uppermost value response surface from Figure 15, we have postulated a vehicle that has 2 engines, can take off vertically as well as from the water (as can all hypothetical vehicles on that surface) and that has an additional pair of specific attributes: 1) it can carry 9,000 pounds of payload and it 2) has a maximum cruise speed of 400 miles per hour.

Therefore:

At Unit 1, Estimated 2004 Median Price = $16.26 * 9000^{0.719} * 400^{1.15} * 2^{1.22} * 2^{0.635} * 2^{0.705} * 1^{(-0.067)}$ = $65.0 Million (11A)

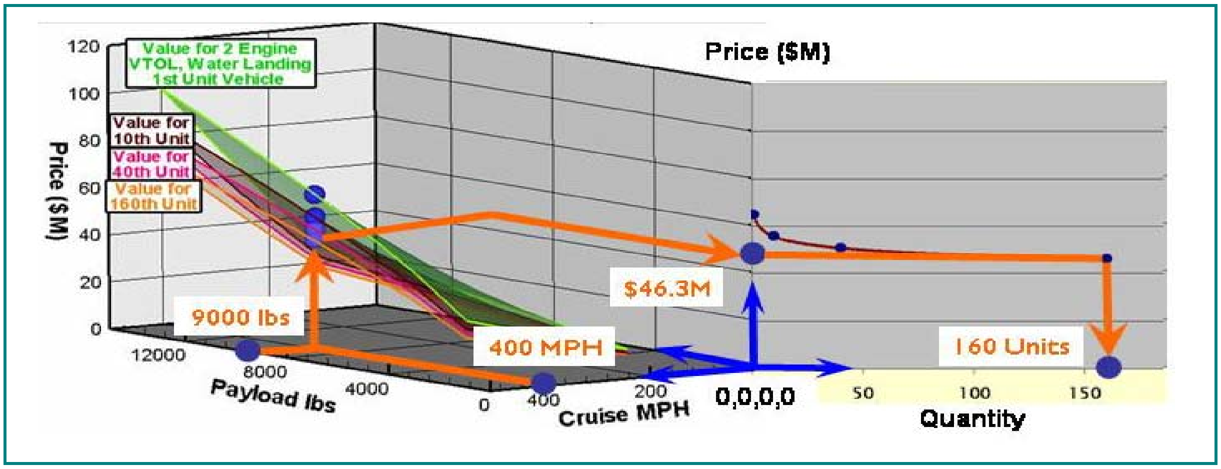
At Unit 160, Estimated 2004 Median Price = $16.26 * 9000^{0.719} * 400^{1.15} * 2^{1.22} * 2^{0.635} * 2^{0.705} * 160^{(-0.067)}$ = $46.3 Million (11B)

Figure 16 contains the values from equations 11A and 11B, and all unit values in between.

The Law of Value and Demand

If we examine the Demand Curve and Value Space at the same time, we notice that they share a common axis, that of currency. Moreover, since there are no negative quantities or capacities or speeds (or, to carry this idea further, no negative numbers of engines), it is possible to fairly abut each region to the other along the currency axis, as shown in Figure 12.

Figure 17: Value Space and the Demand Plane Share the Currency Axis



The Value Space on the left contains three now familiar axes, those of speed (as of Maximum Cruise Speed, in Miles per Hour), capacity (as of Maximum Payload, in Pounds) and currency (as in 2004 dollars). In the particular case at hand, we have additionally required our hypothetical vehicle to have several other attributes; specifically, we have mandated that it have exactly 2 engines, and be able to take off vertically and from the water. The descending surfaces, from the top to the bottom, reflect the projected market value falling as more units of this model are introduced into the market. At 160 units, the lowest Value Response Surface depicted is in operation. If we, as imagined producers of a new air vehicle, decide to make it cruise at a speed of 400 miles per hour, and haul a maximum payload of 9,000 pounds, we have selected attributes for it. These collective attributes, the 160th unit of a two engine vehicle that can take off vertically and from the water and that can cruise at 400 miles per hour and carry a maximum of 9000 pounds, are valued by the market as the blue sphere immediately above the left-most arrowhead on the lowest value response surface shown. This value translates across to the currency axis, as shown by the line leading from the previous point to the one where the resulting value translates into a price of $46.3 million along the currency axis. This price, in turn, dictates how many vehicles can be sold, as by the right angled line leading from the $46.3 million price point to the projected sales figure of 160 units.

These values are part of the 4D+ (pronounced “four-dee-positive”) Coordinate System that applies to every market. These coordinates are called out in this order: Valued Attribute A, Valued Attribute B, Price, Quantity. Placed together, these values form ordered quads (as opposed to ordered pairs or ordered triples). In the case at hand, our dimensions are capacity, speed, currency and quantity, and the ordered quad that represents our hypothetical plane is 9000 (payload pounds), 400 (cruise speed miles per hour), $46.3 million, 160 (units), respectively. While several attributes may affect product price (as for our hypothetical aircraft, which is influenced by payload capacity, cruise speed, the number of engines it possesses and its ability to take off and land vertically and on water), only two attributes are assigned axes. Modification of value response surfaces beyond those used for Valued Attributes A and B comes with the selection of constants for those other attributes (as Valued Attributes C, D and E, etc), as shown in Figure 15.

Initially, it was thought (Howarth, 2005 1-3, 2006 1-3) that the 4D+ Coordinate System applied only to products with many different attributes such as the aircraft considered here, and that simpler products, such as commodity items such as wheat or water, were subject to other less complicated market structures. It is now easy to recognize that these same forces apply to every market, though the valued attributes common to a given market or group of markets may not be the same in others.

The United States Department of Agriculture (USDA) expects the average price of wheat to be $4.30 per bushel for the 2007 and 2008 season (USDA, 2007). At an average of 13.5% moisture content, a bushel of wheat weighs 60 pounds (Hining, et. al., 1987). This works out to just over $0.07/pound for unprocessed wheat. A supermarket chain advertises 25 pounds of all purpose flour at $6.99 (about $0.28/pound) or two pounds of a different brand for $1.79 (about $0.90/pound), while a pound of bread at the same store can run from run from $1.69 for a one pound loaf of wheat bread to $3.49 for a one pound loaf of low carbohydrate organic bread (Albertsons, 2007). The degree to which wheat is finished makes a difference in its value, which in turn determines its price. Pound for pound, bushels of wheat fetch less than wheat flour which fetch less than bread (all of which relates to the ease of use). Packaging makes a difference as well, as consumers are willing to buy larger amounts for breaks in the price per pound (all of which relates to portability). Brand recognition has a value for consumers of wheat products, as does the degree to which the product in question is perceived to be healthy or void of impurities (a measure of safety, as for organic breads). Clearly, then, given enough data, it is possible to draw a 4D+ Coordinate System for wheat products market. Quite certainly, based on the anecdotal evidence presented and our previous observations and intuition it exists.

In the United States, the average price for a cubic meter of water is $0.66, which, at 264.2 gallons per cubic meter, works out to $0.0025/gallon (Clark II, 2007). Reclaimed or reused water sells for about 30% less than that (Global Water Intelligence Team, 2005). At the supermarket, bottled water can go from $0.89/gallon for the store brand in a one gallon container with the store name on it, to $10.24/gallon for a brand name water product in a 20 ounce container to $13.95/gallon for a pack of 16 ounce containers of flavored name brand water with protein in it (Albertsons, 2007). As with wheat, the degree to which the water is processed dictates its price, as does its packaging, taste, health benefits and brand recognition. This market, then, has a 4D+ coordinate system associated with it.

Any market is subject to the effects of tampering, be it price ceilings or floors, or quantity limits or minimums, or subsidies or tariffs or quotas or a host of other economic and legislature restrictions. In a market such as that for aircraft, technical restrictions may additionally be at play. The forces of the market, however, that of those individuals who are buying the products the market offers to them, are always at work. If products are offered at prices which exceed the value the market places upon them, the market will either buy less of them than their suppliers expected of their customers or, if given high enough prices, buy none at all. Products that are priced below what the market supports will find either shortages or secondary resale markets appear, or both. Suppliers only can make money only when they keep their costs below sustainable prices.

While the structure of every snowflake is different, the structure of every market is the same.

We are thus led to this overarching principal applicable to any and all markets:

The Law of Value and Demand:
Attributes determine Value which determines Price which determines Quantity Demanded.

Conclusions

Markets have quantity-price points, as ordered pairs, which represent the historic or projected quantities sold or to be sold and the actual or envisioned prices sustained for each of the products within them over a period of time. Infrequently, simple regressions through these data points will yield statistically significant representative demand curves that describe the relationship between product prices and quantities sold. More often than not, in order to gain a statistically significant relationship between prices and quantities, it will be necessary to group the products within markets into groups according to price, and then calculate the total quantity and average price within each group. Often this same procedure can be repeated for smaller segments, or sub-markets within larger markets.

Individual products within larger markets sustain their prices through their attributes, only one of which is their quantity sold, which is a measure of saturation. Products may have several attributes. It is the markets' response to product attributes that determines product prices. Product prices, in turn, determine quantities sold.

Value space and the demand plane meet at the currency axis, forming the 4D+ Coordinate System.

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Biography

Doug Howarth is the lead of Lockheed Martin's Advanced Development Projects Parametric Estimating group. Doug has held a number of supervisory positions at Lockheed Martin and has acted as the F-117A Manufacturing Program Manager. A member of Advanced Development Projects for over 27 years, Doug has been a Parametric Analyst for 13 years, specializing in buoyant and partially buoyant vehicles, as well as Unmanned Air Vehicles and various classified and unclassified platforms. His paper, "Profit as an Independent Variable: The Case of Business Aircraft," was published in the Winter 2007 edition of *The Journal of Parametrics*. In addition to making numerous presentations to ISPA, Doug has presented papers to the American Institute of Aeronautics and Astronautics (AIAA), the Institute of Electrical and Electronic Engineers (IEEE) and the Society of Automotive Engineers (SAE). Doug graduated from Washington State University in 1977, with a Bachelor of Arts in Economics.