Condominium Design and Pricing:
A Case Study in Consumer Trade-off Analysis

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Introduction

The concept of utility has been a familiar one to economists for over a century. Much of economics is based on a theory of buyer behavior in which the consumer is thought to allocate his resources so as to maximize his person utility. In the later 19th century, it was fashionable among economists to attempt to assign numerical values to individuals' utilities for various quantities of goods. Finding those efforts lacking in predictive power, they have tended to abandon efforts to quantify utilities. However, the basic concept, the idea of the rational consumer, has remained.

It is possible that the consumer is unaware of the numerical values of his utilities, but that they may be revealed through his choices among product concepts which are varied in systematic ways.

This study is a practical application of the economists' traditional theory of buyer behavior. The study was based on a simple model which assumes:

- Consumers can supply their rank orders of preference for various combinations of attributes that characterize the features of a product or service they intend to purchase.
- Computational techniques recently available allow us to solve for a set of numbers for each consumer which adequately reproduce his rank orders of preference and which appear, therefore, to have the properties of utilities.
- Finally, a consumer's choice from among several products or services can be predicted by combining his utilities for the attributes which characterize each good and determining which have the greatest utility for that individual.

This study was a cooperative project of Market Facts and a major builder. Because of this joint investment in the data and its analysis, some of the findings can be discussed; however, much of the data has been rescaled to protect the client's interests.

The Problem

The builder is currently developing a major residential complex on a unique 38-acre site, across the Hudson River from midtown Manhattan. When completed, the development will contain six high-rise buildings containing about 4,000 condominium homes along with extensive recreational facilities.

Each thirty-one story building will consist of six different types of units. These are described in Figure 1 together with the range of prices for each type of unit in the first building. The price of a unit depends not only on its size, but also on its height and the direction of the view.

Figure 1

PRICE SCHEDULE FOR BUILDING ONE

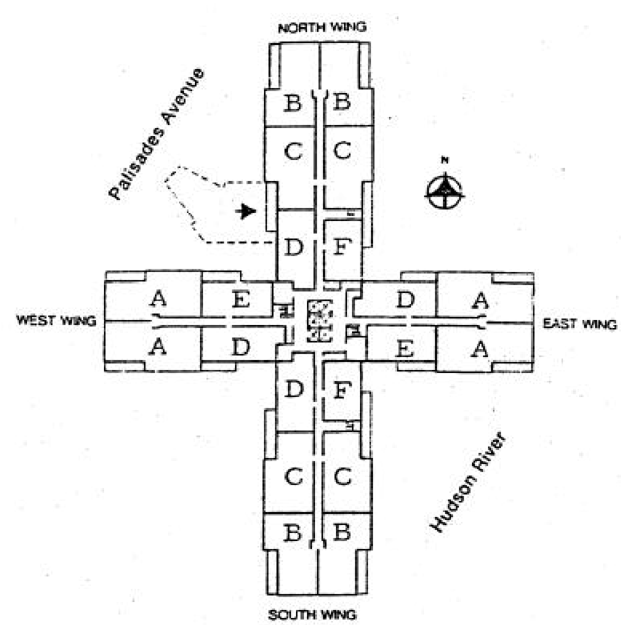
Plan A 3-bedroom, 3-bath corner apartment/home $64,500 Lobby floor $78,700 31st floor	**Plan D** 2-bedroom, 2-bath apartment/home $46,000 Lobby floor $56,050 31st floor
Plan B 2-bedroom, 2-bath corner apartment/home $56,500 Lobby floor $68,000 31st floor	**Plan E** 2-bedroom, 1½-bath convertible apartment/home $39,500 Lobby floor $49,600 31st floor
Plan C 2-bedroom, 2-bath deluxe apartment/home $52,000 Lobby floor $65,200 31st floor	**Plan E** 1-bedroom apartment/home $35,000 Lobby floor $40,100 31st floor

The view of New York City across the river to the east contrasts sharply with the undramatic view of New Jersey to the west.

The floors above the first are identical with twenty apartments on each floor as shown in Figure 2.

The 614 units in the first building were priced in accordance with the developer's experience on other condominium projects. The larger the unit, the better its view, the more expensive is its price.

Figure 2
TYPICAL FLOOR IN BUILDING ONE



The results of the first few weeks of sales for the first building are shown below:

Table 1

SALES IN BUILDING ONE AS OF JANUARY 31, 1972

	Number of Units	
	Sold	**Available**
3-Bedroom (A)	13	124
2-Bedroom (B)	19	122
2-Bedroom (C)	25	122
2-Bedroom (D)	12	123
2-Bedroom (E)	19	62
1-Bedroom (F)	55	61
River View	121	338
No River View	22	276
TOTAL	143	614

Of the 276 unites without a view only 22 or about 8% had been sold. Of the 338 units with a view, 121 or 36% had been sold. Some units were only selling on the lower floors, others only on the upper floors. The one-bedroom units were virtually sold out, while most of the three-bedroom units remained unsold.

Management realized it had pricing problems and adjusted the floor and view premiums in an attempt to create more realistic prices. However, the sales during the following months continued to be uneven. Cumulative sales through the end of July are shown in Table 2.

Table 2 SALES IN BUILDING ONE AS OF JULY 31, 1972		
	Number of Units	
	Sold	**Available**
3-Bedroom (A)	43	124
2-Bedroom (B)	71	122
2-Bedroom (C)	75	122
2-Bedroom (D)	53	123
2-Bedroom (E)	51	62
1-Bedroom (F)	61	61
River View	248	338
No River View	106	276
TOTAL	354	614

At that time, almost 60% of the building was sold, a figure which would have been most acceptable to management if the sales had been evenly distributed throughout the building. But the were not. The two smallest units, E and F, were virtually sold out, while others remain unwanted. Seventy percent of the sales were units with a view across the river. It seemed as though the building might tip into the river.

The builder had already begun plans for a second building in the complex and needed a pricing formula which would provide a more even sellout of the building.

The Study

Accordingly, a study was undertaken which would utilize the model outlined earlier. The plan of the study was to:

- Locate previous and prospective buyers of various-sized units in the development.
- Collect from these respondents their rank orders of preference for condominium apartments having differing combinations of view, floor height, unit size, and price.
- Calculate each respondent's theoretical utilities for the various levels of each attribute characterizing a condominium.
- Construct a mathematical model to simulate the sell-out of a specified building under varying pricing formulae.

- Find a set of prices which would cause the building to sell out as evenly possible.

Questionnaire Design and Field Survey

It was decided that any apartment in the building could be characterized by a combination of the relatively few levels for the four variables to be measured. Further, certain levels were not applicable to all respondents and a respondent interested in a unit of a specified size was questioned only on those which were relevant to him. The levels of the attributes are shown in Table 3. Each of the four “floors” studied actually represented about eight floors in the building.

Approximately two hundred respondents were selected from among visitors to the model units of the development site and from among previous buyers returning to the development office to select various decorating options.

Table 3

LEVELS OF ATTRIBUTES MEASURED IN SURVEY

Attribute			**Levels**		
Floor:	28th	20th	12th	4th	
View:	View of River		No View of River		
Purchase Price:	$46,000 $49,000	$52,000 $55,000	$59,000 $64,000	$66,000 $73,000	$74,000 $82,000
Unit Type:	Plan A Plan B		Plan C Plan D		Plan E Plan F

The tasks given the respondent were simple. A sample page from the questionnaire is shown below:

Figure 3

SAMPLE QUESTIONNAIRE PAGE

You could have an apartment with a view...

And could be on the...	Toward the Hudson River	Away from the Hudson River
28th Floor		
20th Floor		
12th Floor		
4th Floor		

Here the respondent is asked to imagine eight possible apartments, each differing only in floor and view. If he could have any of the eight, which would be his first choice? Most respondents placed a 1 in the upper-left box. Now if that unit were unavailable, which would be his choice? This procedure was repeated until the respondent had provided his rank orders of preference for all eight units. Using such a ranking procedure, each of the four attributes was compared to each other.

In addition to the trade-off data just described, standard demographic and classificatory data were collected.

By merely tabulating the survey results the client was provided with a type of data unique to the housing industry which provided answers to questions such as:

- Would people rather live in a large unit with no view or a smaller one with a view?
- What proportion of people interested in one-bedroom apartment would be willing to pay an extra $25 a month for a second bedroom?
- Would people be willing to move the twenty-eighth floor to the twelfth in order to keep the view across the river?

Computation of Utilities

Direct examination of the trade-off data, however, allows only two attributes to be compared at a time. Since each apartment unit is characterized by four attributes it is desirable to compute "utilities" for each level of each attribute so that these may be combined to predict each respondent's choice from among various types of apartments.

The computational procedure used is similar to pairwise nonmetric factor analysis and has been described in detail in a paper by Johnson.[1] A short example will suffice to explain the technique here. Suppose a respondent has given us ranked data as shown in Figure 4.

Figure 4

SAMPLE QUESTIONNAIRE PAGE

You could have an apartment with a view...

And could be on the...	Toward the Hudson River	Away from the Hudson River
28th Floor	1	4
20th Floor	2	5
12th Floor	3	7
4th Floor	6	8

[1] Richard M. Johnson: *Trade-off Analysis: A Method for Quantifying Consumer Values* (Market Facts, Inc., Chicago, 1972).

The procedure solved for a number for each and one for each of the two types of views. These numbers are determined so that their products have the same (or nearly the same) rank order as the original data. An example is given below.

Figure 5

PAIRWISE PRODUCTS OF UTILITIES

		View	**No View**
		.7	**.3**
28^{th} Floor	.4	.28 (1)	.12 (4)
20^{th} Floor	.3	.21 (2)	.09 (5)
12^{th} Floor	.2	.14 (3)	.06 (7)
4^{th} Floor	.1	.07 (6)	.03 (8)

It can be readily seen that these numbers have the same rank order as the original data. This is not always the case. When an attribute is compared to several others, the respondent may be inconsistent in his preferences so that no set of numbers can be found which will fit the data perfectly.

We required a measure of how well the utilities fit the data. An appropriate statistic is Kendall's tau, which involves a count of the pairs of ranks which are in the right order and those which are in the wrong order. Tau is the difference between two such proportions or

$$\text{tau} = \frac{\text{number of rights} - \text{number of wrongs}}{\text{number of rights} + \text{number of wrongs}}$$

In the case of the above example, tau has a value of 1.0. A tau of 0.0 would indicate no order relationship between the predicted value and the data.

Figures 6 – 11 show the six trade-off matrices supplied by an actual respondent. This respondent happened to be a married man with higher than average income with no children who had been looking for anew home for about three months.

In the first matrix, he tells us his preference for the river view totally dominates his preference for floor height. (See Figure 6)

Figure 6

FIRST TRADE-OFF MATRIX: FLOOR VS. VIEW

You could have an apartment with a view...

And could be on the...	Toward the Hudson River	Away from the Hudson River
28th Floor	1	5
20th Floor	2	6
12th Floor	3	7
4th Floor	4	8

In the second matrix we see that although we was willing to give up in floor height to keep that important view, he is not willing to pay an extra $60 a month to have it. (See Figure 7)

Figure 7

SECOND TRADE-OFF MATRIX: VIEW VS. PRICE

You could get an apartment at this price...

And could have a view...	$52,000 ($440 per month*)	$59,000 ($500 per month*)	$66,000 ($560 per month*)	$74,000 ($625 per month*)
Toward the Hudson River	1	3	5	7
Away from the Hudson River	2	4	6	8
*Monthly cost includes all payments. Taxes, maintenance, principal and interest on a 30-year, 7½% mortgage with 20% down.				

From the next matrix we learn he would prefer to give up the river view rather than to live in the small two-bedroom apartment with a view. (See Figure 8)

Figure 8

THIRD TRADE-OFF MATRIX: VIEW VS. UNIT TYPE

You could have this apartment...

And could have a view...	Plan B (2-bedroom, 2-bth deluxe corner apartment)	Plan C (2-bedroom, 2-bath deluxe apartment)	Plan D (2-bedroom, 2-bath apartment)	Plan E (2-bedroom, 1½-bath convertible apartment)
Toward the Hudson River	1	2	3	7
Away from the Hudson River	4	5	6	8

In the fourth trade-off matrix, unit price is traded off against unit type. Again there is a total rejection of Plan E. Plan C at $52,000 is preferred to Plan D at $52,000 and so on. (See Figure 9)

Figure 9

FOURTH TRADE-OFF MATRIX: PRICE VS. UNIT TYPE

You could have this apartment...

And pay this price....	Plan B (2-bedroom, 2-bth deluxe corner apartment)	Plan C (2-bedroom, 2-bath deluxe apartment)	Plan D (2-bedroom, 2-bath apartment)	Plan E (2-bedroom, 1½-bath convertible apartment)
$52,000 ($440 per month*)	1	4	9	13
$59,000 ($500 per month*)	2	5	10	14
$66,000 ($560 per month*)	3	7	11	15
$74,000 ($625 per month*)	6	8	12	16

The next ranking sheet shows that this respondent preferred Plan B on any floor except the 4th. If that were not available he would prefer Plan C, again ruling out the 4th floor. He does prefer Plans B and C on the 4th floor to either Plan D or Plan E on any floor.

Figure 10

FIFTH TRADE-OFF MATRIX: FLOOR VS. UNIT TYPE

You could have this apartment...

And could be on the....	Plan B (2-bedroom, 2-bth deluxe corner apartment)	Plan C (2-bedroom, 2-bath deluxe apartment)	Plan D (2-bedroom, 2-bath apartment)	Plan E (2-bedroom, 1½-bath convertible apartment)
28th Floor	1	4	9	13
20th Floor	2	5	10	14
12th Floor	3	7	11	15
4th Floor	6	8	12	16

In the last matrix, we see he would prefer to spend $59,000 and live on the 28th or 20th floors rather than to spend $52,000 and live on the 4th floor.

Figure 11

FIFTH TRADE-OFF MATRIX: FLOOR VS. PRICE

You could have this apartment...

And could be on the....	$52,000 ($440 per month*)	$59,000 ($500 per month*)	$66,000 ($560 per month*)	$74,000 ($625 per month*)
28th Floor	1	4	9	13
20th Floor	2	5	10	14
12th Floor	3	7	11	15
4th Floor	6	8	12	16

These data were supplied to the utility calculating program with the results shown in Table 4.

Table 4

EXAMPLE OF A RESPONDENT'S UTILITIES

Attribute	Level	Utility	Attribute	Level	Utility
Floor:	28^{th}	.315	Price:	$52,000	.738
	20^{th}	.311		$59,000	.217
	12^{th}	.271		$66,000	.035
	4^{th}	.103		$74,000	.010
View:	River View	.769	Unit:	Plan B	.471
	No View	.231		Plan C	.403
				Plan D	.125
				Plan e	.001

$$\text{tau} = \frac{441 - 3}{444} = \frac{438}{444} = .986$$

When these utilities are cross-multiplied and their products rank ordered, we find that the respondent's data were correctly predicted for four of the six matrices. There were three pairwise errors of prediction in the remaining two matrices. The calculation of the resulting tau of .986 is show.

How typical was the respondent of the sample? Table 5 shows the distribution of tau for the sample.

Table 5

DISTRIBUTION OF TAU

	Respondents	
Tau	**No.**	**%**
1.000	25	13.3
.950 - .999	51	27.1
.900 - .949	56	29.8
.850 - .899	27	14.4
.800 - .849	17	9.0
.400 - .799	12	6.4

An arbitrary cutoff was made, and ten respondents whose taus were less than .775 were eliminated from further analysis. Our sample respondent was at the 79th percentile.

Modeling the Building Sellout

The first way the utilities were employed was to test the model by a simulation to "predict" the sellout of the first building. For the purpose of the model, we viewed the building as consisting of the six types of unit, with or without a view, on one of four floor levels. Thus there were 48 different combination of apartment configuration (6 x 2 x 4 = 48).

Appropriate prices for each of these units were obtained using the client's pricing schedule. Each respondent's utility for each apartment configuration was then computed by multiplying together his utilities for the levels of the attributes comprising the particular unit. An example, using the utilities for the respondent seen earlier, shows his utilities for eight of the possible 48 units.

Table 6

RESPONDENT'S UTILITIES FOR SELECTED APARTMENTS

	Apartment Configuration				Utilities	Overall Utility
1	B Unit	View	12th floor	$66,000	.471 x .769 x .271 x .035 =	.0034
2	B Unit	No View	20th floor	$59,000	.471 x .231 x .311 x .217 =	.0073
3	C Unit	View	4th floor	$59,000	.403 x .769 x .103 x .217 =	.0069
4	C Unit	No view	28th floor	$59,000	.403 x .231 x .315 x .217 =	.0064
5	D Unit	View	28th floor	$52,000	.125 x .769 x .315 x .738 =	.0223
6	D Unit	No view	20th floor	$52,000	.125 x .231 x .311 x .738 =	.0066
7	E Unit	View	12th floor	$52,000	.001 x .769 x .271 x .738 =	.0002
8	E Unit	No view	20th floor	$52,000	.001 x .231 x .311 x .738 =	.0001

Note that the first unit shown, which would have been the most attractive of these if cost were not an issue, has a relatively low overall utility. The apartment with the greatest appeal is the fifth unit shown, combining the lowest price with a view and having an acceptable floor plan on a floor above the fourth.

In most cases, the price levels from which utilities were calculated did not correspond exactly to actual market prices for the units. In these cases, interpolation was used to estimate a respondent's utilities for market prices.

A respondent would theoretically be most likely to purchase that type of unit for which his utility is the highest. However, that unit might be sold out when he is ready to buy;

in such a case, we would expect him to purchase that apartment for which his utility was the second highest. However, if all but a few types of units had sold out and those remaining had very low utilities for a particular respondent, it seems quite likely that he would buy elsewhere rather than purchase such a unit. It was therefore necessary to estimate how far down in his choice hierarchy of possible units an individual would be likely to make a purchase. Various possibilities were computed and compared against the actual sellout of the first building. While solutions were not particularly sensitive to the value chosen, the assumption that an individual would be willing to purchase any of the three units for which he had the highest utility did provide the best fit to the data.

The marginal total are shown below.

Table 7

ACTUAL VS. PREDICTED SELLOUT OF BUILDING ONE

	Sellout	
Units	**Predicted**	**Actual (7-31-72)**
3-Bedroom (A)	42	43
2-Bedroom (B, C, D, E)	253	250
1-Bedroom (F)	59	61
View	248	248
No View	106	106
28^{th} Floor	53	
20^{th} Floor	85	
12^{th} Floor	110	
4^{th} Floor	106	

Although data by floor were not available, the client confirmed the fact that more units had been sold on the lower floors. While the model performed satisfactorily in predicting the marginal totals, as shown, it did less well in predicting the sellout of units with specified sizes, prices, and views. The client attributed much of this error to the changes that were made in the pricing schedule during the first seven months of sales. It was therefore decided to accept the model and proceed to explore sellout rates as a function of pricing schedules for the second building.

Determining an Optimal Price Schedule for Building Two

The second building's configuration is quite different from that of the first. Because of its location on the site, fewer units will have a view across the river. There will also be fewer three-bedroom (A) units, and more of the larger two-bedroom units (B, C, D). The next step of the analysis was to assume an initial set of prices for the different types of units in the new building and input prices to the model. The outcome of this simulation is shown in Table 8.

Table 8

PREDICTED SELLOUT OF BUILDING TWO

Units	**Predicted by Model**	**Target**	**Error**
28th Floor	134	169	-35
20th Floor	192	169	+23
12th Floor	182	169	+13
4th Floor	170	169	+1
View	326	310	+16
No View	352	366	-14
Floor Plan A	51	62	-11
Floor Plan B	209	184	+25
Floor Plan C	115	184	-69
Floor Plan D	132	123	+9
Floor Plan E	29	31	-2
Floor Plan F	142	92	+50

This initial pricing schedule did even a poorer job than Table 8 indicates. When the results of the simulation were examined in greater detail, comparing the predicted sellout with the target, we found errors such as: the model predicted the sale of 41 B units on the "28th floor" without a view, but only 15 were available; the model predicted the sale of only 11 units on the same "28th floor" with a view out of a total 31 available. A useful measure of the error of prediction is the root mean square, a weighted average error. For the forty-four types of units in the simulation, the root mean square error was 12.7 units.

A number of judgmental attempts were made to create a better pricing schedule which would reduce this error and provide a more even sellout. These were not only time-consuming, but mostly unproductive as well.

Accordingly, we decided to let the model search for a set of prices that would theoretically sell the building out evenly. An iterative procedure was used that simply increased slightly the prices of those units where predicted sales exceeded the number available and decreased the prices of those units which were not predicted to sell well enough.

The model did not find a set of prices that performed perfectly, though it did converge on an adequate solution. The results are shown in Table 9.

Table 9

FINAL PREDICTED SELLOUT OF BUILDING TWO

Units	**Predicted by Model**	**Target**	**Error**
28th Floor	160	169	-9
20th Floor	177	169	+8
12th Floor	166	169	-3
4th Floor	175	169	+6
View	306	310	-4
No View	372	366	+6
Floor Plan A	42	62	-20
Floor Plan B	187	184	+3
Floor Plan C	176	184	-8
Floor Plan D	117	123	-6
Floor Plan E	42	31	+11
Floor Plan F	114	92	+22

For the detailed list of 44 types of units, the root mean square is 3.0. This is about 75% reduction in error, and appears to be as low a value as is possible with the limited sample size and the integer nature of the predictions.

All that remained was to formalize these prices through the creation of a corresponding formula to price all 676 units in the new building. This was done by solving for a set of base prices for each unit, and premium adjustments for floor and view which corresponded most closely to the theoretically optimal prices.

Conclusion

The only real test of the model will be how evenly the new building does sell out. Our predictions are on record.

In addition to pricing a building, the data can be used as an input to planning the configuration of future buildings. We should theoretically be able to determine whether certain units should be built only with or without a view, or only on certain floors.

The applications of this model are obviously not limited to housing. The model has also been used to study intercity travel, the market for sophisticated office equipment, the operation of urban mass transit systems, as well as in the areas of financial services and government regulation.