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To: MetroScope Work Group August 16, 2005

From: Sonny Conder

Subject: Some Properties of MetroScope Gen 3.0 Residential Model

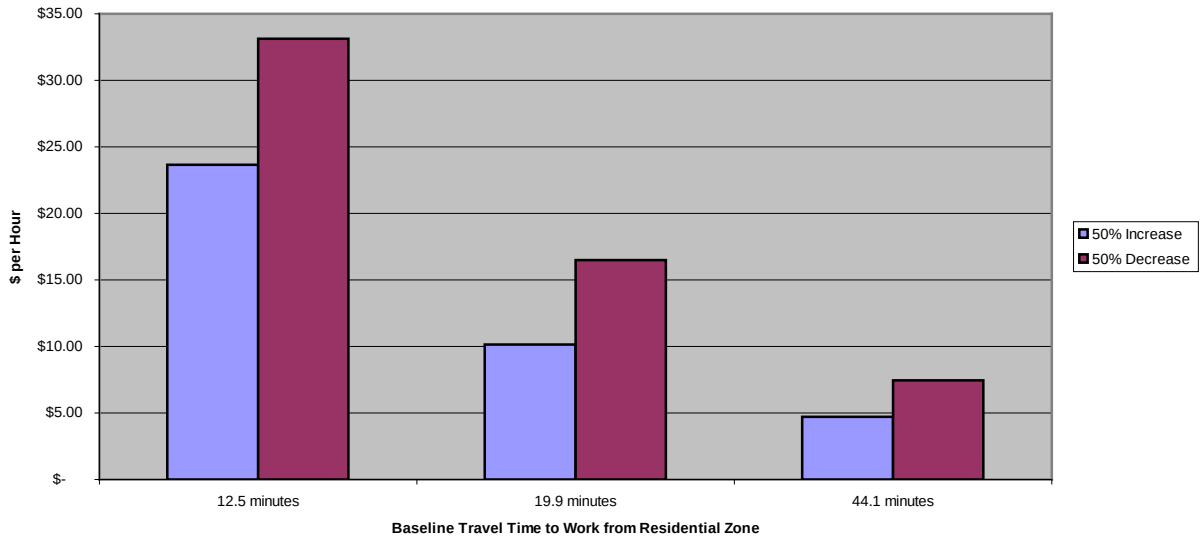
Mill in *Critique of Pure Reason* makes the point that deductive reason cannot yield any insight that was not there in the first place. You are necessarily limited to the information explicit and implicit in your initial premises. That may indeed very well be. However, in my personal simulation model building experience it is almost always amazing to discover what you have included that you did not know about. My recent sensitivity testing with the Gen 3.0 version of the MetroScope model only serves to underscore past experience. A few of the revealed properties are of general interest to others so I thought I would discuss a couple of them.

Variations in the Value of Time

The first of these is the model yields estimates of the value of time. Understand that there is no value of time component within the model but nevertheless it is possible to manipulate the model to yield just such estimates. Doing so produces estimates of the value of time by household that vary with household type, housing choice type and location. More on this later but first an explanation of how we do it. We have deliberately specified the model demand equations such that there occurs a tradeoff between housing price and travel time to work. If we change travel time, we are able to calculate how much housing price would have to change to compensate for the changed travel time. For instance, if travel time between a work zone and a residential zone drops by 20%, the number of people living in the residential zone increases. What we do is calculate the increase in house price necessary to reduce the number of people living in the zone to its level prior to the drop in travel time. What this amounts to in economic parlance is the construction of an "indifference curve". An indifference curve defines a line along which varying amounts of two commodities exactly substitute for one another. In this case a given class of households value a 10 minute commute and a $360,000 house exactly the same as a 20 minute commute and a $320,000 house. Once we have that basic information we can annualize the housing price difference and compare that to the annual household difference in commute hours the result from the travel time change. This calculation produces an hourly value of time for the household.

Figure 1 below displays several value of time calculations for CBD workers living 12.5, 19.9 and 44.1 minutes from work. To simplify for exposition purposes Figure 1 limits the comparison to one household class living in an identical owner occupied single family residence in three different locations.

Figure 1: Implicit Value of Time from Residential Model - OSFD Derived Values for Moderate Income Household by Travel Time to Work in the CBD



Most notable from Figure 1 is that the value of time changes dramatically as we move from close in locations to more remote locations (Battleground at 44.1 minutes). Keep in mind this is a value of time computation for an identical class of households located in an identical housing unit; only location changes. Using additional data depicted on Exhibit One (attached at back) we observe that a moderate income household is willing to pay $459,000 for a house located 12.5 minutes from the CBD. If the house were located 6 minutes from the CBD the same income class would be willing to pay $494,000 for the house. If it were moved out to almost 19 minutes, the equivalent house value would drop to $433,000. Annualizing the house price difference and dividing through by the annual amount of household hours saved or expended by the travel time change, yields the hourly estimate of the household's value of time. In the case above it ranges from $24 per hour to $33 per hour for the 12.5 minute travel time to $5 to $7 per hour for the 44 minute travel time. Keep in mind this result applies to what we consider for modeling purposes to be identical households.

So how could this be? One group of supposedly identical households values time very highly while other members of the same set value it at a fairly low amount. There are basically 2 reasons for this wide distribution of preferences. First, though we have but one class of households, this is an aggregate distribution containing thousands of members. Consequently, the preferences of the individual households within the class do indeed reveal a wide range of levels. Secondly, the specific amount a household budgets in travel time versus housing consumption is a complex consideration involving more or less wage income, time available for other activities, preference for public versus private space, housing versus transportation investments, etc. Rather than attempt to model the details of these many household budget choices, the model accepts a fairly wide dispersion of preferences among any particular household class.
Figure 2 below depicts value of time data by Income – Consumption class and by location.

Figure 2: Implicit Value of Travel Time - OSFD Derived Values by Income and Travel Time to Work

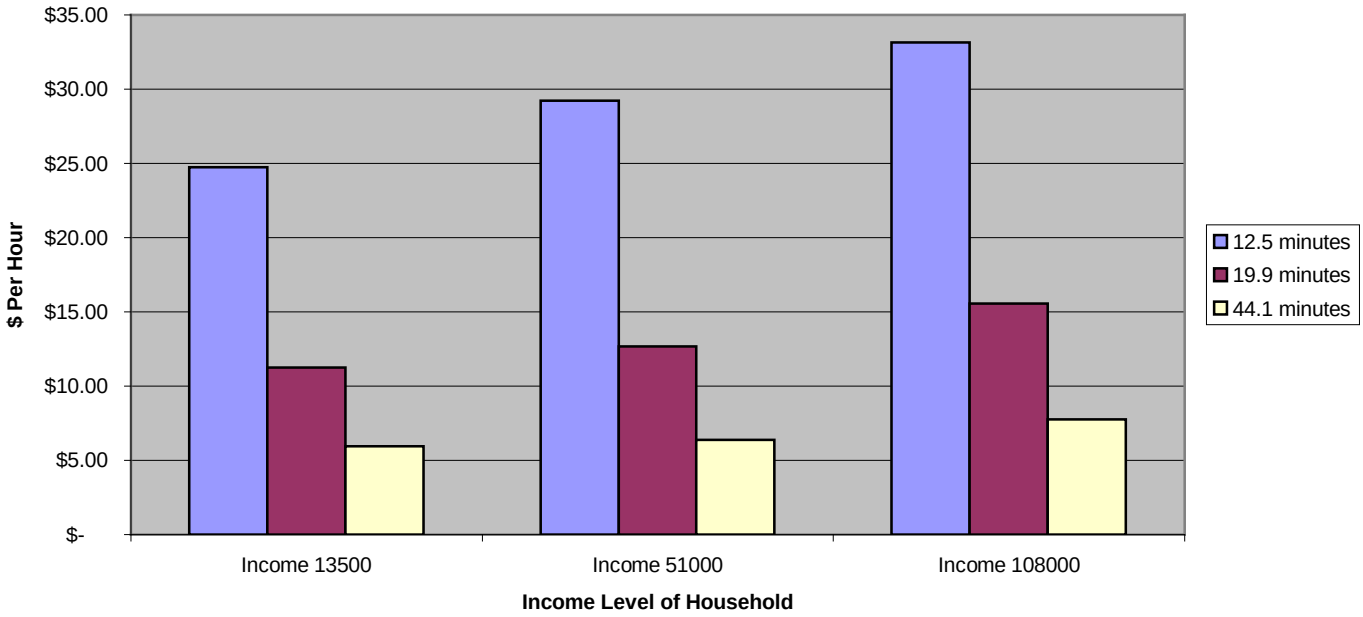
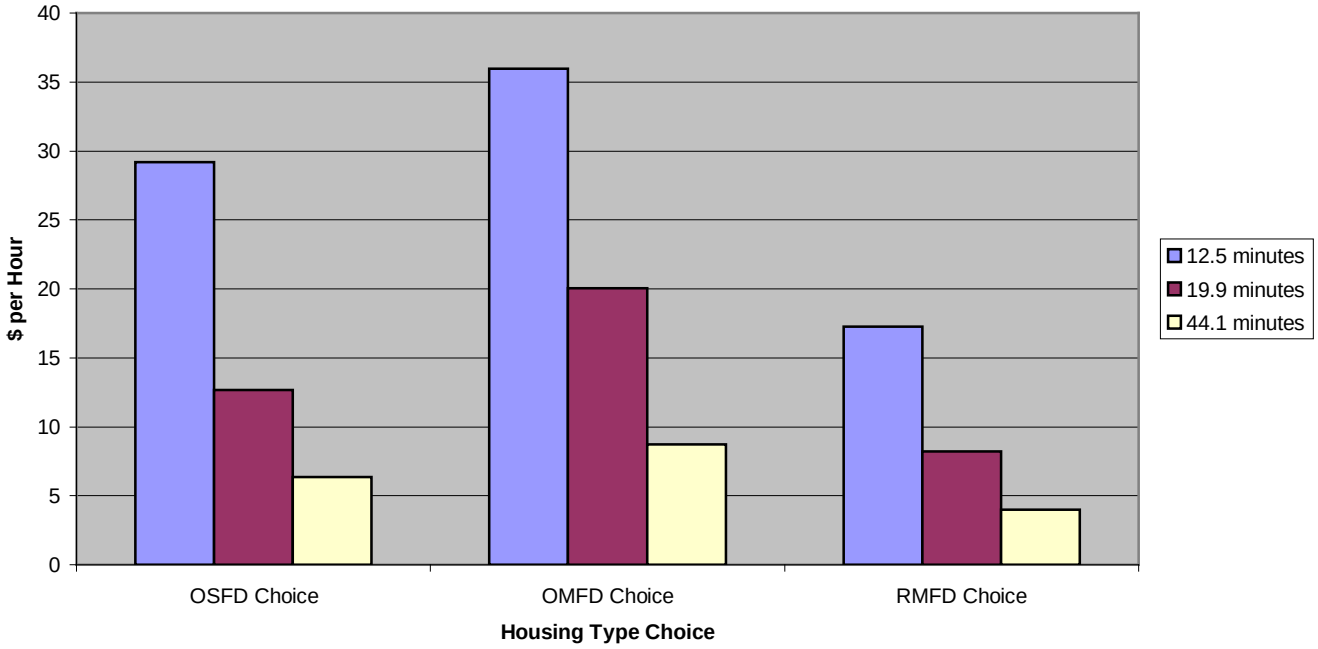


Figure 2 retains the information depicted in Figure 1 and expands it to show how value of time varies by income class as well as location. Hardly surprising is that the value of time increases in all locations as income level increases. Not apparent however is that lower income groups' value of time is a substantially higher percentage of their hourly wage income. From a "social justice" perspective this property of the residential model lends credence to efforts to subsidize low – moderate income housing in high access locations. While the total value of time is not necessarily maximized, consumer surplus benefits are proportionately higher in lower income groups. Later we will return to this subject in our consumer surplus section.

Figure 3 provides yet another dimension to the value of time measurements. Figure 3 shows value of time by housing type choice and location.

Figure 3: Implicit Value of Travel Time - Value of Time by Housing Type Choice and Travel Time - Moderate Income Group



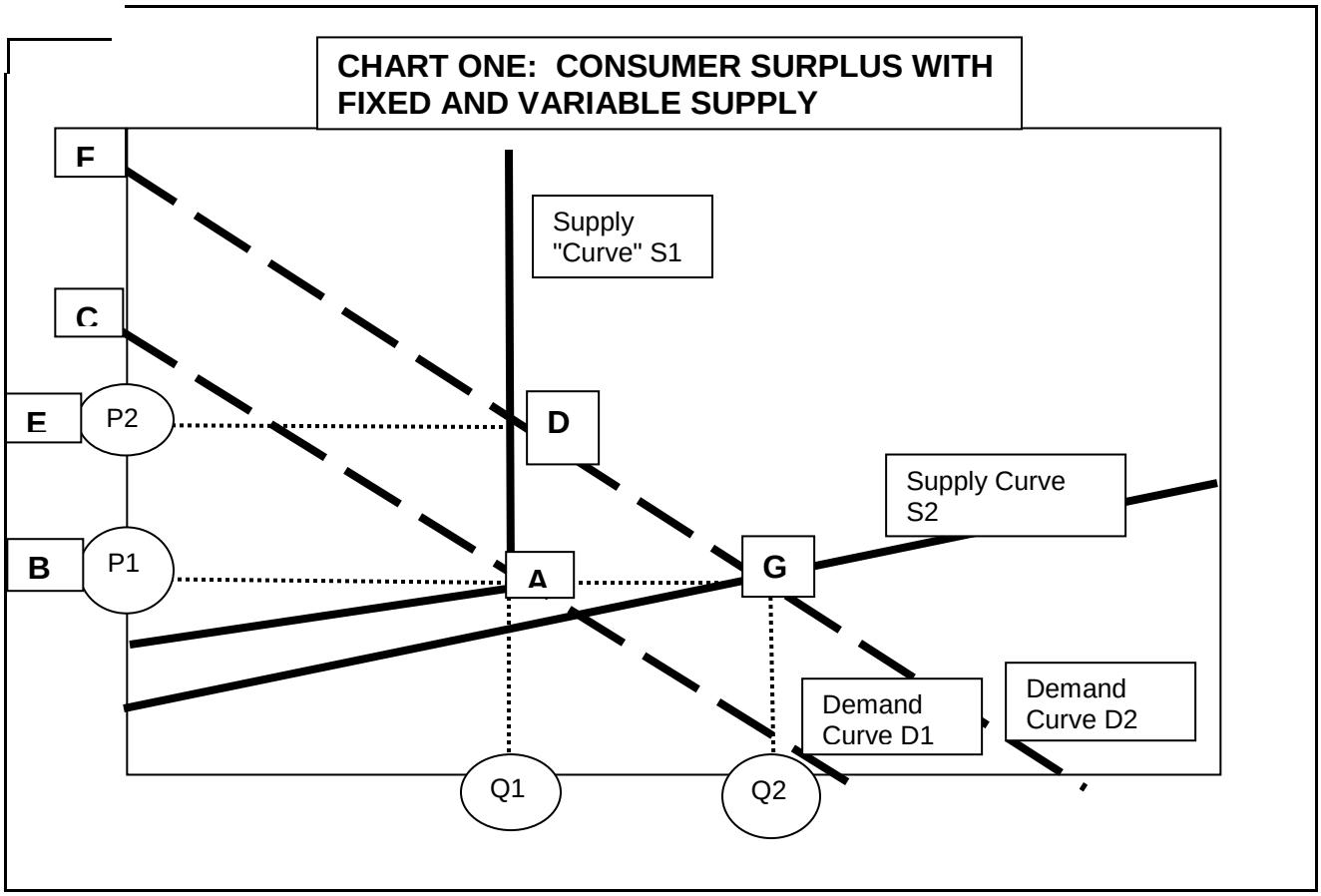
As in Figures 1 and 2, value of time varies by location but in Figure 3 it is shown to vary by housing type as well. Given the strong correlation between income and housing tenure, it is not surprising that owner single family detached (OSFD) has a higher value of time than renter multi-family (RMFD). Most interesting is that owner multi-family (OMFD) choice reflects the highest value of time. While income wise there is little difference between owner occupied single family and multi-family, there are substantial differences in age, household size and presence of children. The much higher value of time for OMFD choosers puts a greater emphasis on providing opportunities for providing this type of supply at close in, high access locations.

Again, it is worthwhile to repeat that the value of time calculations are derived from MetroScope. They remain properties of the model; not observations of real data. We provide them as a means of assisting in interpreting model results. For instance, regardless of income class or housing type choice, as travel times increase; the amount of housing price or rent reduction (necessary to compensate commuters for the increased travel time) proportionately declines. A regulatory regime that relies on increased travel times for urban containment but concurrently has low cost rural housing development; will be relatively ineffective in MetroScope simulations.

Calculations of Consumer Surplus

MetroScope also allows for calculating the consumer surplus that results from implementing a particular policy. For instance, say the region implemented a transportation improvement that resulted in a 10% commuter travel time savings between Ezones 105 and 106 (Central Eastside-Lloyd Center) and Ezone 101 (CBD). We are able to use the residential model in MetroScope to calculate the residential benefits that would accrue to such an improvement. Our measure of benefit is called consumer surplus and it is

based on “willingness to pay”. The calculations are detailed in Exhibit Four but first we illustrate consumer surplus with the following graphic.



Some of you may remember the econ 101 micro economics section with the demand-supply-price-quantity graphs. The point where the supply and demand lines cross determines the price (P on the vertical axis) and the quantity consumed (Q on the horizontal axis). In the example shown in Chart One we have two supply lines, two demand lines, two prices and two quantities consumed. The first demand curve noted by dashed lines (D1) represents demand prior to an improvement that increases the utility of the choice up to the demand curve D2. The first supply line signified by a solid line intersects the demand line at point A. In this case we characterize the supply line (S1) as inelastic after it passes the demand line (D1). Notice that after point A it goes straight up. At point A the small dotted lines extend left to the price level (P1) and downward to the quantity level (Q1). The dotted lines denote the price (P1) and quantity consumed (Q1) when demand just equals supply.

Note that in the chart above that the demand curve extends upward beyond the dotted price line (P1) as it goes to the left of point A. What this means is that all consumers with a demand preference greater than the market price P1 are paying less for the product than they would be willing to pay. This difference between the market price and what they are willing to pay we define as the “consumer surplus” measure. In the example above the area of the triangle formed by the points A, B and C constitutes an estimate of the before improvement consumer surplus in our example.

As stated earlier the demand line D2 represents demand after an improvement has increased the utility of the product. Relative to our MetroScope model this would be an increase in access for a particular location. The demand line D2 intersects both supply lines. It intersects supply line S1 at the point D. The dotted lines extend left to the new price P2 and downward to the previous quantity consumed Q1. The inelastic supply line S1 does not allow for additional production so all of the utility associated with the improvement is capitalized into a price increase from P1 to P2. The amount of consumer surplus resulting from the improvement is the triangle formed by the points D, E and F. The area of this triangle is roughly the same as the triangle (A,B,C). As a consequence little or no net benefit resulted from the improvement with an inelastic supply line S1.

The supply line S2 represents an elastic supply line and it intersects the demand line D2 at the point G. The dotted lines extend left to the original price P1 and downward to the new quantity consumed Q2. In this example the price does not change and all the utility resulting from the travel time improvement results in increased consumption (point Q2). The total consumer surplus is now represented by the large triangle – G, B, F and the net increase in consumer surplus resulting from the improvement is the area of the polygon – G, A, C, F.

Other than to explain graphically the concept of "consumer surplus", Chart One points out that the benefits of improvements depend not only upon the improvement itself but on the ability of the market to convert the improvement into increased usage. Now we can move on to a more realistic example.

Figure 4 depicts the change in "willingness to pay" by consumption class for Owner Occupied Multi-Family in Ezones 105 and 106 (Lloyd District and Central Eastside).

Figure 4: Willingness to Pay for Owner Occupied Multi-Family - Ezones 105 & 106 with 10% Travel Time Decrease

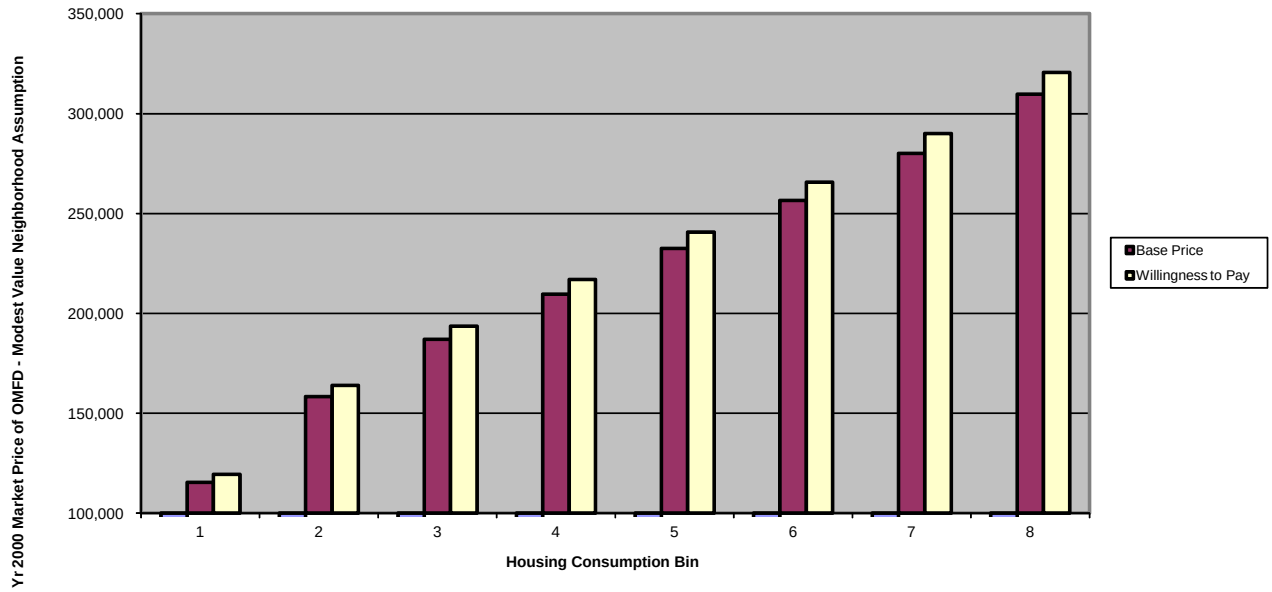
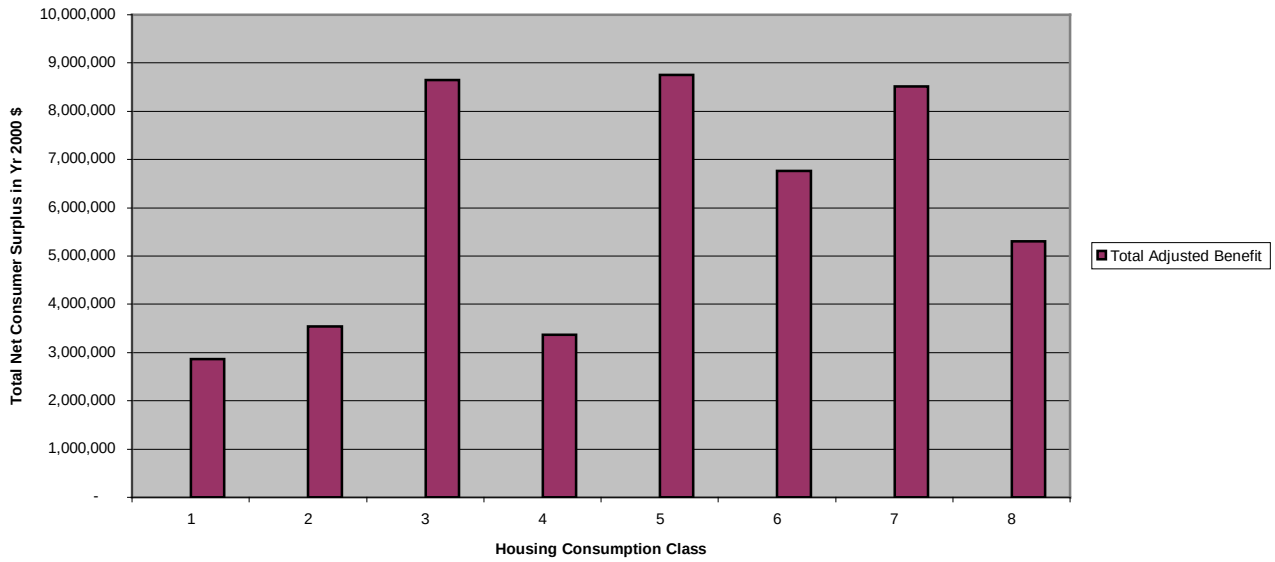


Figure 4 indicates that every consumption group is willing to pay a bit more for their owner occupied multi-family dwellings in Ezones 105 and 106 as the result of the travel time improvement to the CBD (Ezone 101). For instance, consumption class 2 increases their price from $158,000 to $164,000 (Year

2000 $) and consumption class 8 increases their bid price from $310,000 to $321,000. To arrive at these numbers we operated the MetroScope residential model to yield a change in housing price after the improvement that returned the utility in the target Ezone to a level that it had prior to the improvement. This is equivalent to jumping from the demand line D1 to D2 shown in Chart One above.

Figure 5 below shows the total computed consumer surplus in Ezones 105 and 106 resulting from the 10% travel time improvement to Ezone 101. Compared to our example in Chart One above, we have assumed an inelastic supply curve (S1), so the number of dwelling units of OMFD and RMFD (the only units produced in the Ezones) remains the same as before the travel time reduction. Consequently, prices increase somewhat to offset the value of the improvement and act to reduce the net increase in consumer surplus. However, unlike our Chart One example, there is still an increase. These net increases in consumer surplus are depicted in Figure 5.

Figure 5: Total Net Consumer Surplus by Consumption Class for OMFD and RMFD in Ezones 105 & 106 for Travel Time Decrease of 10%



The amounts to not vary consistently across all consumption classes since there are varying numbers of dwelling units in each consumption class. Exhibit Four attached shows the details of the computations for both OMFD and RMFD dwelling types. The total net consumer surplus benefit owing to the 10% travel time saving amounts to $48 million in this example[1]. Keep in mind this is an example and is computed for residential only. Nonresidential uses would also experience a benefit. Also, it is totally conjectural whether a 10% decrease in travel time represents a realistic outcome for any particular transportation improvement. Also, since supply is fixed price increases reduce the net benefits somewhat. Total unadjusted benefits (the polygon A,B,F,D in Chart One) amount to $68 million. If it were possible to provide sufficient land resources and regulatory capacity to have an elastic supply

[1] While a 10% travel time savings between 2 zones appears a modest improvement, achieving such may prove difficult. For example, one may be tempted to associate the provision of a street car line between the CBD, Lloyd Center and Central Eastside as representing a 10% travel time reduction. However, it may well be that reductions in bus service, loss of auto traffic lanes, etc. may have an offsetting impact to the addition of street car service, so the amount of improvement may be less.

curve, then the number of dwelling units would be materially greater and the difference between willingness to pay and market price would be larger. This happenstance would produce even larger net consumer surplus benefits (the triangle G,B,F in Chart One).

Finally, since we can enumerate the benefits by consumption class we are able to make "social justice" type of assessments of the benefit incidence. Figure 6 below shows the incidence of consumer surplus as a percent of annual household income by consumption class.

Figure 6: Consumer Surplus Benefit per Household by Tenure and Consumption Class - Percent of Annual Income

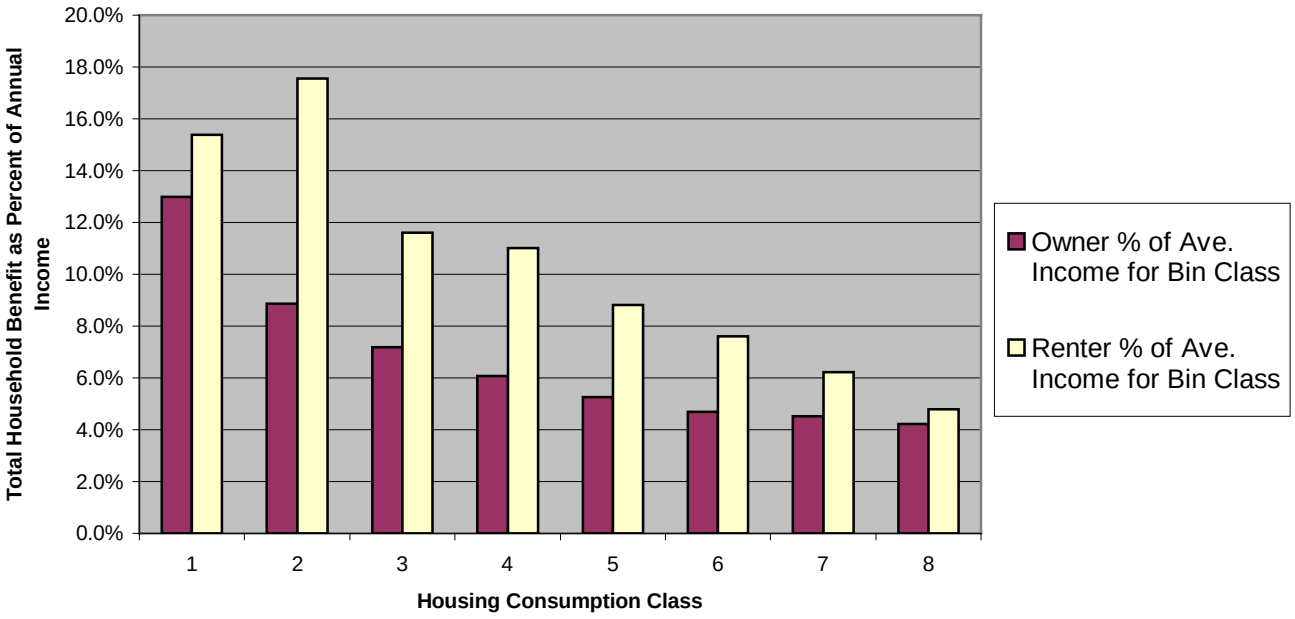


Exhibit Five on which Figure 6 is based, indicates that the absolute amount of net consumer surplus benefit increases as income increases. However, expressed as a percentage of income, the benefit is proportionately higher for low income groups. Also, it is proportionately higher for renters than it is for owners.

Summary

Probably most important to keep in mind is that the above information may or not be factual. At present it stems entirely from the properties of the MetroScope simulation model. As such it represents a derived, *ex ante* model prediction that may be independently validated. For the present it serves as an example of the type of information that may be obtained from the model with some additional model manipulation and interpretation based on neoclassical welfare economics' theory.

EXHIBIT ONE: OWNER SINGLE FAMILY DETACHED

Employment Zone: 101 (CBD)	Residential Zone: 103 (West Hills)					
Consumption Bin:	SFD House Price - Travel Time 12.5 Min. (Base Line)	SFD House Price - Travel Time 18.75 Min.(50% Increase)	SFD House Price - Travel Time 6.25 Min. (50% Decrease)	Implict Hourly Value of Time - Travel Time 12.5 Min. (Base Line)	Implict Hourly Value of Time - Travel Time 18.75 Min. (50% Increase)	Implict Hourly Value of Time - Travel Time 6.25 Min. (50% Decrease)
1(Low Income)	$ 241,543	$ 228,124	$ 260,330	NA	$ 21.78	$ 30.53
4(Moderate Income)	$ 458,767	$ 433,280	$ 494,449	NA	$ 23.67	$ 33.12
8(High Income)	$ 699,148	$ 660,302	$ 753,521	NA	$ 29.71	$ 41.58
Employment Zone: 101 (CBD)	Residential Zone: 120 (Mid County)					
Consumption Bin:	SFD House Price - Travel Time 19.9 Min. (Base Line)	SFD House Price - Travel Time 29.85 Min.(50% Increase)	SFD House Price - Travel Time 9.95 Min. (50% Decrease)	Implict Hourly Value of Time - Travel Time 19.9 Min. (Base Line)	Implict Hourly Value of Time - Travel Time 29.85 Min. (50% Increase)	Implict Hourly Value of Time - Travel Time 9.95 Min. (50% Decrease)
1(Low Income)	$ 158,130	$ 149,584	$ 172,992	NA	$ 8.72	$ 15.17
4(Moderate Income)	$ 300,339	$ 282,951	$ 328,566	NA	$ 10.15	$ 16.47
8(High Income)	$ 457,705	$ 431,206	$ 500,722	NA	$ 12.73	$ 20.66
Employment Zone: 101 (CBD)	Residential Zone: 411 (Battleground)					
Consumption Bin:	SFD House Price - Travel Time 44.1 Min. (Base Line)	SFD House Price - Travel Time 66.15 Min.(50% Increase)	SFD House Price - Travel Time 22.05 Min. (50% Decrease)	Implict Hourly Value of Time - Travel Time 44.1 Min. (Base Line)	Implict Hourly Value of Time - Travel Time 66.15 Min. (50% Increase)	Implict Hourly Value of Time - Travel Time 22.05 Min. (50% Decrease)
1(Low Income)	$ 127,311	$ 117,697	$ 142,021	NA	$ 4.43	$ 6.78
4(Moderate Income)	$ 241,427	$ 223,544	$ 269,743	NA	$ 4.71	$ 7.45
8(High Income)	$ 367,926	$ 340,672	$ 411,078	NA	$ 5.91	$ 9.35

EXHIBIT TWO: OWNER MULTI - FAMILY ATTACHED						
Employment Zone: 101 (CBD)	Residential Zone: 103 (West Hills)					
Consumption Bin:	OMFD House Price - Travel Time 12.5 Min. (Base Line)	OMFD House Price - Travel Time 18.75 Min.(50% Increase)	OMFD House Price - Travel Time 6.25 Min. (50% Decrease)	Implict Hourly Value of Time - Travel Time 12.5 Min. (Base Line)	Implict Hourly Value of Time - Travel Time 18.75 Min. (50% Increase)	Implict Hourly Value of Time - Travel Time 6.25 Min. (50% Decrease)
1(Low Income)	$ 128,163	$ 109,854	$ 162,034	NA	$ 29.75	$ 55.02
4(Moderate Income)	$ 232,644	$ 199,409	$ 294,129	NA	$ 30.86	$ 57.09
8(High Income)	$ 343,785	$ 294,672	$ 434,642	NA	$ 37.56	$ 69.48
Employment Zone: 101 (CBD)	Residential Zone: 120 (Mid County)					
Consumption Bin:	OMFD House Price - Travel Time 19.9 Min. (Base Line)	OMFD House Price - Travel Time 29.85 Min.(50% Increase)	OMFD House Price - Travel Time 9.95 Min. (50% Decrease)	Implict Hourly Value of Time - Travel Time 19.9 Min. (Base Line)	Implict Hourly Value of Time - Travel Time 29.85 Min. (50% Increase)	Implict Hourly Value of Time - Travel Time 9.95 Min. (50% Decrease)
1(Low Income)	$ 91,368	$ 75,899	$ 119,416	NA	$ 15.79	$ 28.63
4(Moderate Income)	$ 165,854	$ 137,774	$ 216,767	NA	$ 16.38	$ 29.71
8(High Income)	$ 245,087	$ 203,593	$ 320,323	NA	$ 19.93	$ 36.14
Employment Zone: 101 (CBD)	Residential Zone: 411 (Battleground)					
Consumption Bin:	OMFD House Price - Travel Time 44.1 Min. (Base Line)	OMFD House Price - Travel Time 66.15 Min.(50% Increase)	OMFD House Price - Travel Time 22.05 Min. (50% Decrease)	Implict Hourly Value of Time - Travel Time 44.1 Min. (Base Line)	Implict Hourly Value of Time - Travel Time 66.15 Min. (50% Increase)	Implict Hourly Value of Time - Travel Time 22.05 Min. (50% Decrease)
1(Low Income)	$ 69,595	$ 55,564	$ 92,045	NA	$ 6.46	$ 10.34
4(Moderate Income)	$ 126,331	$ 100,861	$ 167,083	NA	$ 6.70	$ 10.73
8(High Income)	$ 186,683	$ 149,045	$ 246,903	NA	$ 8.16	$ 13.05

EXHIBIT THREE: RENTER MULTI - FAMILY ATTACHED						
Employment Zone: 101 (CBD)	Residential Zone: 103 (West Hills)					
Consumption Bin:	RMFD House Price - Travel Time 12.5 Min. (Base Line)	RMFD House Price - Travel Time 18.75 Min.(50% Increase)	RMFD House Price - Travel Time 6.25 Min. (50% Decrease)	Implict Hourly Value of Time - Travel Time 12.5 Min. (Base Line)	Implict Hourly Value of Time - Travel Time 18.75 Min. (50% Increase)	Implict Hourly Value of Time - Travel Time 6.25 Min. (50% Decrease)
1(Low Income)	$ 104,420	$ 99,431	$ 113,068	NA	$ 9.98	$ 17.30
4(Moderate Income)	$ 161,380	$ 150,504	$ 179,783	NA	$ 14.14	$ 23.92
8(High Income)	$ 291,848	$ 272,326	$ 325,129	NA	$ 15.86	$ 27.04
Employment Zone: 101 (CBD)	Residential Zone: 120 (Mid County)					
Consumption Bin:	RMFD House Price - Travel Time 19.9 Min. (Base Line)	RMFD House Price - Travel Time 29.85 Min.(50% Increase)	RMFD House Price - Travel Time 9.95 Min. (50% Decrease)	Implict Hourly Value of Time - Travel Time 19.9 Min. (Base Line)	Implict Hourly Value of Time - Travel Time 29.85 Min. (50% Increase)	Implict Hourly Value of Time - Travel Time 9.95 Min. (50% Decrease)
1(Low Income)	$ 61,142	$ 56,479	$ 68,914	NA	$ 5.86	$ 9.77
4(Moderate Income)	$ 97,673	$ 90,068	$ 110,089	NA	$ 6.21	$ 10.14
8(High Income)	$ 176,636	$ 163,164	$ 199,089	NA	$ 6.87	$ 11.46
Employment Zone: 101 (CBD)	Residential Zone: 411 (Battleground)					
Consumption Bin:	RMFD House Price - Travel Time 44.1 Min. (Base Line)	RMFD House Price - Travel Time 66.15 Min.(50% Increase)	RMFD House Price - Travel Time 22.05 Min. (50% Decrease)	Implict Hourly Value of Time - Travel Time 44.1 Min. (Base Line)	Implict Hourly Value of Time - Travel Time 66.15 Min. (50% Increase)	Implict Hourly Value of Time - Travel Time 22.05 Min. (50% Decrease)
1(Low Income)	$ 48,429	$ 43,954	$ 56,062	NA	$ 2.54	$ 4.32
4(Moderate Income)	$ 77,364	$ 70,216	$ 89,557	NA	$ 2.64	$ 4.49
8(High Income)	$ 139,908	$ 126,982	$ 161,959	NA	$ 3.00	$ 5.08

EXHIBIT FOUR: RESIDENTIAL CONSUMER SURPLUS ESTIMATES OF REDUCING CENTRAL CITY TRAVEL TIME 10%

		OWNER OCCUPIED MULTI-FAMILY				
Bin Class	Base Price	Willingness to Pay	Market Price Adjusted	Demand in DU	Total Unadjusted Benefit	Total Adjusted Benefit
1	$ 115,459	$ 119,534	$ 117,836	205	$ 835,375	$ 348,090
2	$ 158,314	$ 163,901	$ 161,573	192	$ 1,072,704	$ 446,976
3	$ 187,068	$ 193,670	$ 190,919	1461	$ 9,645,522	$ 4,019,211
4	$ 209,584	$ 216,981	$ 213,898	135	$ 998,595	$ 416,205
5	$ 232,472	$ 240,677	$ 237,259	833	$ 6,834,765	$ 2,847,194
6	$ 256,531	$ 265,585	$ 261,813	333	$ 3,014,982	$ 1,256,076
7	$ 280,108	$ 289,994	$ 285,875	647	$ 6,396,242	$ 2,664,993
8	$ 309,707	$ 320,638	$ 316,083	92	$ 1,005,652	$ 419,060
Total:				3,898	$29,803,837	$ 12,417,805
NOTE:	Based on e zones 105 and 106 travel time to CBD (ezone 101) and rezone of ezone 106 (Central Eastside) to multi-use central city.					
		RENTER OCCUPIED MULTI-FAMILY				
Bin Class	Base Price	Willingness to Pay	Market Price Adjusted Benefit	Demand in DU	Total Unadjusted Benefit	Total Adjusted Benefit
1	$ 91,151	$ 92,763	$ 91,224	1638	$ 2,640,456	$ 2,520,882
2	$ 109,524	$ 111,461	$ 109,612	1675	$ 3,244,475	$ 3,097,075
3	$ 130,903	$ 133,218	$ 131,008	2096	$ 4,852,240	$ 4,632,160
4	$ 145,361	$ 148,186	$ 145,728	1200	$ 3,390,000	$ 2,949,600
5	$ 164,152	$ 167,340	$ 164,564	2128	$ 6,784,064	$ 5,907,328
6	$ 184,964	$ 188,236	$ 185,113	1763	$ 5,768,536	$ 5,505,849
7	$ 212,440	$ 216,197	$ 212,611	1633	$ 6,135,181	$ 5,855,938
8	$ 263,330	$ 267,987	$ 263,541	1100	$ 5,122,700	$ 4,890,600
Total:				13,233	$37,937,652	$ 35,359,432
Total:	**BENEFIT SUMMARY**					
	Total Unadjusted Benefit	Total Adjusted Benefit				
	$ 3,475,831	$ 2,868,972				
	$ 4,317,179	$ 3,544,051				
	$14,497,762	$ 8,651,371				
	$ 4,388,595	$ 3,365,805				
	$13,618,829	$ 8,754,522				
	$ 8,783,518	$ 6,761,925				
	$12,531,423	$ 8,520,931				
	$ 6,128,352	$ 5,309,660				
	$67,741,489	$47,777,237				

EXHIBIT FIVE: EQUITY DISTRIBUTION OF TRAVEL TIME SAVINGS						
Consumption Bin Class	Owner Income by Bin	Renter Income by Bin	Benefit per Owner DU Bin Class	% of Ave. Income for Bin Class	Benefit per Renter DU Bin Class	% of Ave. Income for Bin Class
1	$ 13,065	$ 10,000	$ 1,698	13.0%	$ 1,539	15.4%
2	$ 26,230	$ 10,526	$ 2,328	8.9%	$ 1,849	17.6%
3	$ 38,315	$ 19,048	$ 2,751	7.2%	$ 2,210	11.6%
4	$ 50,795	$ 22,308	$ 3,083	6.1%	$ 2,458	11.0%
5	$ 65,061	$ 31,534	$ 3,418	5.3%	$ 2,776	8.8%
6	$ 80,523	$ 41,033	$ 3,772	4.7%	$ 3,123	7.6%
7	$ 91,346	$ 57,603	$ 4,119	4.5%	$ 3,586	6.2%
8	$ 107,770	$ 92,593	$ 4,555	4.2%	$ 4,446	4.8%