The MetroScope Infrastructure Post Processor – Beginning Discussion on What it Takes to Build a Region

Background

We define Infrastructure as the building of roads, streets, sewers, parks, water mains, schools, jails, etc. necessary to supply the public side of the private-public development partnership that produces urban areas. As long as we have had signs of civilization and urban development, infrastructure has always been with us evidenced in city walls, cisterns and remnants of irrigation systems over 5000 years old. What is fairly new is the interest accorded infrastructure in planning and land location choice criteria. Urban containment, emphasis on increased densities and choice of location are oftentimes cited in planning requirements as justified by the "efficiencies" to be gained from infrastructure cost savings. Though often cited, infrastructure costs are almost never measured in any consistent and commensurable format when evaluating urban planning location choice alternatives. Accordingly, several years ago we exploited the richness of MetroScope output to build a post processor that consistently and completely estimated the full infrastructure costs associated with accommodating future growth for any chosen policy scenario. We are particularly interested in developing data to answer two basic infrastructure questions. These are: one, how much does it cost and two, how does that cost vary with location and density? Below we further define what we are talking about and provide examples of the results we obtain from our MetroScope infrastructure cost post processor.

Basics – Just What is Infrastructure And How Do We Measure It?

Infrastructure costs while often discussed and cited as the reason various land use policies are being pursued, are seldom actually measured. In those instances when infrastructure costs are reported, there is seldom consistency between the capital items being measured nor in the accounting structure used to measure them. [1] In MetroScope we include all capital items in the public domain that are typically required and available in an urban region. These data are tabulated for the United States as a whole annually in the National Income and Product Reports and carried under the generic title: "Fixed Assets of State and Local Government". [2]

Figures One and Two below summarize the data for government and for private fixed assets net of equipment and furnishings.

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[1] For a review of the field see: Parsons, Brinkerhoff and ECONorthwest, **The Full Social Costs of Alternative Land Use Patterns: Theory, Data, Methods and Recommendations,** (US DOT, June 1998), 189 pages.

[2] Tables 4.1, 5.1,7.1B,4.7,5.7 and 7.5B,"Current-Cost Net Stock of Government Fixed Assets, etc." Bureau of Economic Analysis, 2010.

Figure One displays the absolute current value of the fisced assets of State and Local government and the average amount per capita as of the 2004 – 2007 period.

National Fixed Asset Data

Fixed Assets of State and Local Government - Current $

State and Local Structures	Dollar Amount in Billions 09	US Per Capita 2004 - 2007
Residential	$ 226.1	$ 729.4
Office	$ 568.1	$ 1,832.6
Commercial	$ 10.2	$ 32.9
Health care	$ 180.0	$ 580.6
Educational	$ 1,840.7	$ 5,937.7
Public safety	$ 148.3	$ 478.4
Amusement and recreation	$ 172.7	$ 557.1
Transportation	$ 554.8	$ 1,789.7
Power	$ 263.8	$ 851.0
Highways and streets	$ 2,765.9	$ 8,922.3
Sewer systems	$ 586.3	$ 1,891.3
Water systems	$ 428.0	$ 1,380.6
Conservation and development	$ 103.6	$ 334.2
Other structures\5\	$ 17.0	$ 54.8
Totals	$ 7,865.5	$ 25,372.6

Figure 1: In 2009 the value of local and state government capital facilities amounted to 7.9 trillion $.

Figure One displays the current $ value of the fixed assets (real estate) of State and Local Government. This includes government buildings of all types, correctional facilities, hospitals, schools, parks, transit systems, public power utilities, roads, bridges, sewer, water, etc. These values added together amount to over $25,000 per person for the US. This corresponds to roughly $61,000 per household. Current $ values are not adjusted for inflation so the present replacement cost of these facilities is much higher than the current dollar estimate. However, the list gives us a good estimate of the relative value of the various functional components of infrastructure.

We may also ask the question of how does the level of State and Local infrastructure investment compare to the level of private real estate investment?

Figure Two shows the current net value of private real estate investment in the US and the average amount per capita during the 2004 – 2007 period. The private fixed structures data are then compared to the public fixed structures data.

National Fixed Assets – Private Structures Value

Private Value - Current $

Private Fixed Asset Structure Value	Dollar Amount in Billions 09	US Per Capita 2004 - 2007
Residential	$ 17,602	$ 56,781
Nonresidential	$ 10,885	$ 35,112
Totals	$ 28,487	$ 91,893
Total Public and Private Fixed Assets:	$ 36,353	$ 117,266
Public as Percent of Total:	21.6%	

Figure 2: Private residential and nonresidential fixed assets amounted to 28.5 trillion $.

Figure Two provides us perspective on the current value of public and private real estate investment in the United States. In other words, what does the National Bureau of Economic Analysis think all of the nation's roads, bridges, parks, homes, businesses, etc. are worth right now? The answer is 36 .4 trillion dollars – 17.6 trillion in residences, 10.9 trillion in factories and businesses and another 7.9 trillion dollars in the required state and local infrastructure necessary to make that private investment usable. Put in a bit simpler terms for every dollar we invest in real estate and infrastructure 78 cents goes to private real estate and 22 cents goes to the infrastructure necessary to make it work.

Figures One and Two provide us with a working definition of State and Local government infrastructure investments and provide us the insight that on average the value of these assets should be about 20-25% of the value of total private and public fixed assets. Viewed in per capita terms state and local infrastructure amounts to about 25,500 dollars per person in current dollars. Conventionally, we allocate infrastructure cost to both residential and nonresidential fixed assets. Combining the data in Figures One and Two, yields an estimate of current infrastructure value of $ 35,500 per dwelling unit and $22,500 per job.

As noted earlier the values in Figures One and Two are in current dollars meaning that older structures are greatly undervalued in terms of present replacement costs. Figure Three below provides an estimate of the amounts presently being invested in private real estate and public infrastructure.

Figure Three: Current Investment in Fixed Assets Annual Average

Category of Fixed Asset Investment Ave. Ann. 2004 - 2007	$ in Billions
Average Annual Private Residential Investment 2004 - 2007	718.85
Average Annual Private Nonres. Investment 2004 - 2007	403.85
State Local Infrastructure Fixed Investment Ave Ann 2004 - 2007	242.28
Total Average Annual US Fixed Assets 2004 - 2007	1364.98
State - Local Infrastructure as Percent of Total:	17.8%
State - Local Infrastructure $ per House Constructed:	$ 86,384
State - Local Infrastructure $ per Job Created:	$ 34,708

Figure 3: Allocating Capital Costs by Real Estate Values Yields $86,000 per house and $35,000 per job.

Figure Three provides a more up to date picture of US infrastructure and fixed asset investment patterns. In Figure Three we use a 4 year average of annual outlays when the US economy was growing fairly rapidly during the 2004 – 2007 period. In comparison to Figures One and Two we note that State-Local infrastructure spending as a percentage of private fixed asset spending is lower than the stock share noted in Figure Two – 17.8% compared to 21 .6%. This agrees with the widespread observation the government infrastructure outlays continue to lag behind private spending for capital items. Secondly from Figure Three we observe that State – Local infrastructure spending per house constructed amounts to roughly $86,000 compared to $35,500 for the stock accounts that are denominated in current dollars. This is consistent with the observation that the stock accounts substantially understate the cost of replacing existing infrastructure in today's dollars. So we can assume $86,000 per house as a conservative estimate on average of how much State and Local government should be paying for the array of streets, bridges, parks, buildings, transit, water, sewers, etc. necessary to render land suitable for dense urban habitation consistent with present day environmental, public safety and planning standards.

Local, Community and Regional Facilities – Logical Nexus and Why We Underfund Infrastructure.

Besides categories of capital investments, infrastructure also has three spatial levels. These spatial levels are local investments, community investments and regional investments. Beyond spatial extent each of these levels also involve different funding mechanisms, administrative structures and probably most importantly different logical nexus between demand for investment and the supply of investment.

Local

We define the local level to consist of the capital facilities that are located in subdivisions, multi-family areas or within business developments with immediate proximity to the developments that they are serving. Typically, the capital infrastructure items furnished in the public domain at this scale consist of:

1. Water service lines and hookups
2. Sanitary collection lines and hookups
3. Storm water collection and detention
4. Local streets, sidewalks, curbs and street lighting
5. Neighborhood parks, water features, landscaping

With the exception of neighborhood parks and landscaping features most of the local capital investment follows the local street alignment and costs of provision are dominated in lineal feet rather than diameters or volume/capacity or usage. In clearer terms a 30 foot wide neighborhood street can serve 2 housing units per block or it can just as adequately serve 20 units per block.

Administratively, local infrastructure is typically provided by the private sector as part of the subdivision development process with local government enforcing standards and picking up responsibility for maintenance and replacement upon completion. Most local infrastructure is financed[3] by the private developer who recoups costs upon sale of the completed lots or alternatively the completed housing. As a consequence, if local government is adequately enforcing development standards this level of infrastructure is built and paid for as development occurs since development cannot occur without it. Here we note that there is a very tight local nexus between development and infrastructure provision. Also cogent is the observation that local infrastructure costs, most often absolutely necessary for development to occur, are also the most often omitted in "case study" infrastructure costs studies since the cost of provision is seldom routed through government capital budgets; though accounting wise they ultimately show up as assets and liabilities on government fixed asset accounts.

[3] Most US jurisdictions also allow for the LID (Local Improvement District) process wherein a developer or group of majority land owners forms a LID that provides for the issuance of tax exempt G.O. backed bonds to finance the development with reimbursement occurring from assessments against the benefited property payable upon sale of the tax lot and/or home. Since the LID process is slow and beset with high overhead, in times of rapid development private developers generally provide their own financing.

Community

The next level up the spatial hierarchy consists of community level infrastructure. Broadly defined, these investments consist of capital facilities that are not necessarily located at the site of development but can be directly related to a particular development in an intuitive way. Among the capital items we typically list as community level infrastructure are:

1. Major water distribution lines and pump stations
2. Water production, storage and treatment facilities
3. Major sanitary sewer collection, pump stations and treatment facilities
4. Storm water collection and treatment
5. Transportation collector streets, minor arterials, traffic safety, bike and pedestrian ways
6. Community parks and recreation
7. K-12 school facilities

Cost wise community level facilities are much more heterogeneous than local level. Water distribution, sewage and storm water collection lines generally follow the street and road system of urban areas. Up to a point distribution and collection lines and roads exhibit cost profiles that are more driven by lineal feet than capacity. In other words, it does not cost that much more to install a 20" sewer collector than it does a 10" sewer collector though the 20" line has roughly 4 times the capacity. For transportation the cost relationship is more linear as capacity tends to increase only proportional to cost; meaning that a 50% increase in cost buys you roughly a 50% increase in capacity for a collector or an arterial. Community parks and K-12 school facilities are most often defined by community standards for park/school lot size and embellishments so the resultant costs have a fairly wide variance depending on the standards you are assuming.

At the community level service provision, standards enforcement, budgeting and financing are exclusively carried out or contracted for by government. Significant is that demand for community level capital improvements change as a "stepped function" as development occurs. In plain terms what happens is that sewer, water and road improvements once built accommodate considerable growth, oftentimes 10 – 20 years of growth, before their installed capacity is used up. The resultant lag between development and the need to provide necessary infrastructure greatly complicates efficient and timely[4] facility investment. Private utilities providing natural gas, electricity, etc. face the same issues and have long ago adopted utility accounting procedures sufficient to efficiently charge for capacity as it is used and to maintain and replenish the capital plant on a continuous basis. Government budgeting approaches tend to be on an annual "as needed" basis so capital requirements only show up as a big lump of capital outlays tied to the actual facility construction. For most of a facilities' economic life it shows up in government budgeting as a free use facility with little or no relation between service fees and the level of capacity being depleted. In addition capital financing is often times restricted to voter approved property tax based general obligation bonds rather than service charge based revenue bonds as commonly used by private utilities. This means future capital requirements and the need to replenish existing community facilities are poorly anticipated. It is not uncommon to read of "building

[4] The author recognizes efficient implicitly includes timely but I like the rhetorical ring to the phrase.

moratoriums" imposed in rapidly growing areas due to a lack of sewer or water capacity. Considering that the utilities involved have an absolute monopoly on a service everyone needs such outcomes are puzzling .

Moving from traditional public utilities to transportation at the community level we encounter additional difficulties engendered by the "public good" aspect of transportation. This attribute of transportation requires government to establish some means of properly valuing and charging for the service since private market prices do not naturally arise in the market place. This is in contrast to local transportation facilities that are required to produce marketable lots for development. For instance, it is not uncommon in many less completely regulated jurisdictions to have a complete system of well developed residential streets connect into a one lane paved or gravel road that previously served as a county rural road. Secondly, properly planning, funding and building community level transportation facilities is further complicated by the difficulties in allocating costs and benefits. Collector streets and minor arterials serve numerous neighborhoods to some degree; not just the developments that are immediately adjacent to them. Lack of consensus on how these transportation costs should be allocated provides a consistent and strong bias towards underfunding.

Community parks and K-12 education capital facilities are pure public goods with no natural market price, nor any agreement among jurisdictions as to what constitutes an appropriate level of service. Consequently, they require an aggressive government program for funding and building the facilities as development occurs. Suffice to say some jurisdictions are better at it than others.

The loose logical nexus between community level capital facilities and development is most profoundly experienced in terms of funding the required capital expenditures. As noted several times, there is little or no private market incentive to provide these goods[5]. Government in the past has relied on some user charges, State and Federal grants, taxes, utility fees, property tax bond levies, etc. to provide community services. Typically, for water, sewer, transportation, parks and oftentimes education the most uniform government funding mechanism has come to be the system development charge that is explicitly levied against each development unit to recover a proportionate share of the capital cost of community services. Presently, it is not uncommon in many west coast states for the levels of SDC's to exceed $25,000 per housing unit. Also coming into more common use is the street utility district where a monthly or other periodic charge is levied against property on a front foot or related basis to build and maintain a portion of the transportation system situated within the district (usually coterminous with the enacting jurisdiction). The utility district funding approach is the one most like the private utility funding approach.

Regional

Regional facilities we define as the level of capital investments that have benefits (and allocated costs) that extend over the greatest spatial extent. Unlike local and some of the community facilities

[5] A few very large (600 - 1000 plus acres) master planned communities with sufficient scale to substantially capitalize the benefits of community facilities do provide for collector streets, arterial streets, water and sewage and associated improvements as part of the development.

usage drives the need to provide regional level facilities; not space consumed. For our purposes we define regional facilities to be:

1. Transit facilities and equipment of all types
2. Major roads, arterials, highways, freeways, and bridges
3. Marine and air terminals, ferries
4. Public buildings (other than k-12 education) including publically owned recreation/exposition

The bulk of the investment in the above list falls in the area of transportation, particularly the infrastructure devoted to vehicular transportation (see Figure One). Unless otherwise noted we limit the following discussion of regional facilities to vehicular transportation. In the case of regional transportation facilities costs are proportional to usage and in some instances may be increasing relative to the increment of added capacity. Recalling our example from local streets where 20 units per acre may be accommodated for roughly the same cost as 2 units per acre; increasing the throughput of an urban freeway from 2000 vehicles per hour to 4000 vehicles per hour; a 100% increase, may involve a 150% increase in cost. For a variety of environmental, regulatory and just plain physical reasons, the above enumerated facilities display few if any economies of scale and may more often display diseconomies of scale.

Within a broad range regional facilities do not possess a natural and intuitive level of service that would be relatively constant across jurisdictions. Subject to the vagaries of geography (Dallas, Phoenix and Tucson probably do not have much in the way of marine terminal investment) levels of service vary considerably depending on what the community feels their priorities are. Figure Four below shows the variation of in road miles per 1000 population and population density as of 2008 for a combination of 60 US regions, subregions or cities

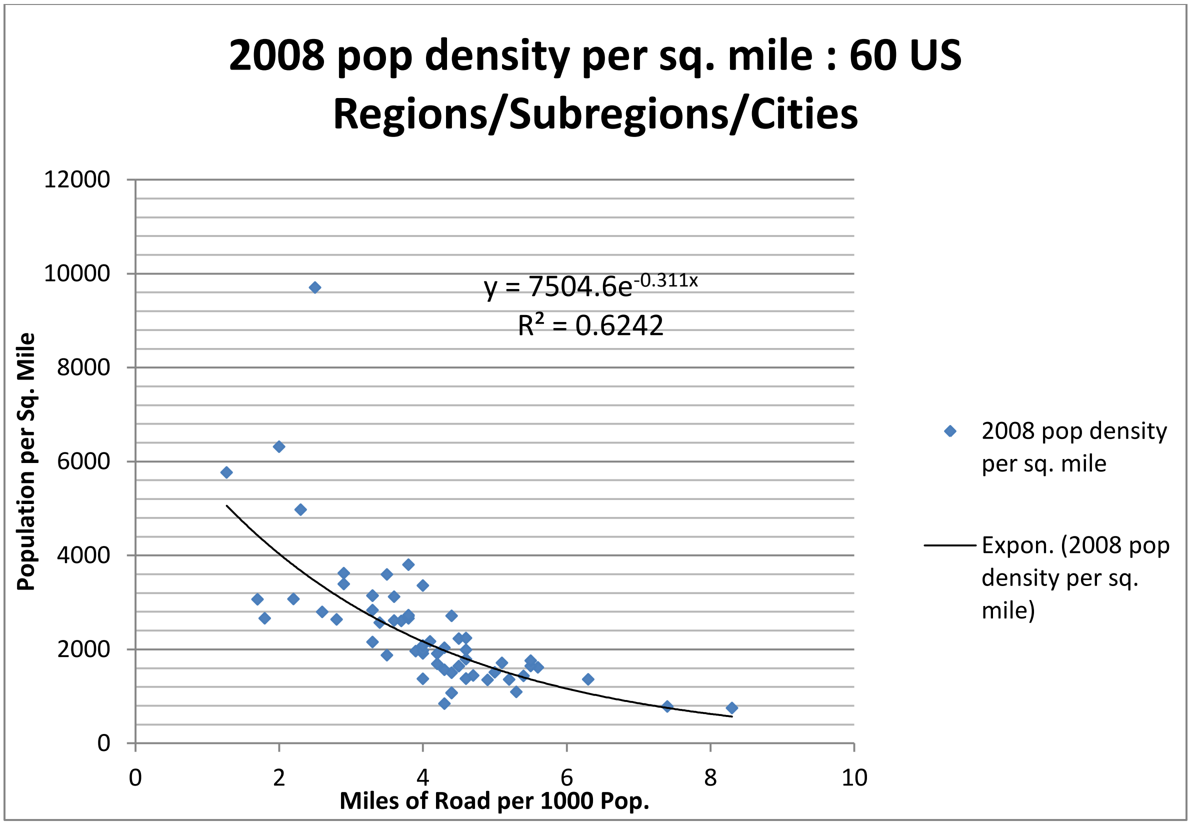

Figure 4: Denser regions require far fewer miles of road per person than do low density regions.

Depending on where you are road investment levels vary dramatically from under 2 miles per 1000 people to over 8. Also noticeable is that road investment correlates well with density; reflecting our earlier observation that a 30 foot local street can serve 2 or 20 housing units per acre equally well. Different development options using different densities produce substantial differences in transportation investment levels.

Only when we reach the level of regional facilities does transportation investment become dominated by usage rather than density per se. Figure Five reflects the relationship between miles of road per 1000 population and per capita vehicle miles traveled.

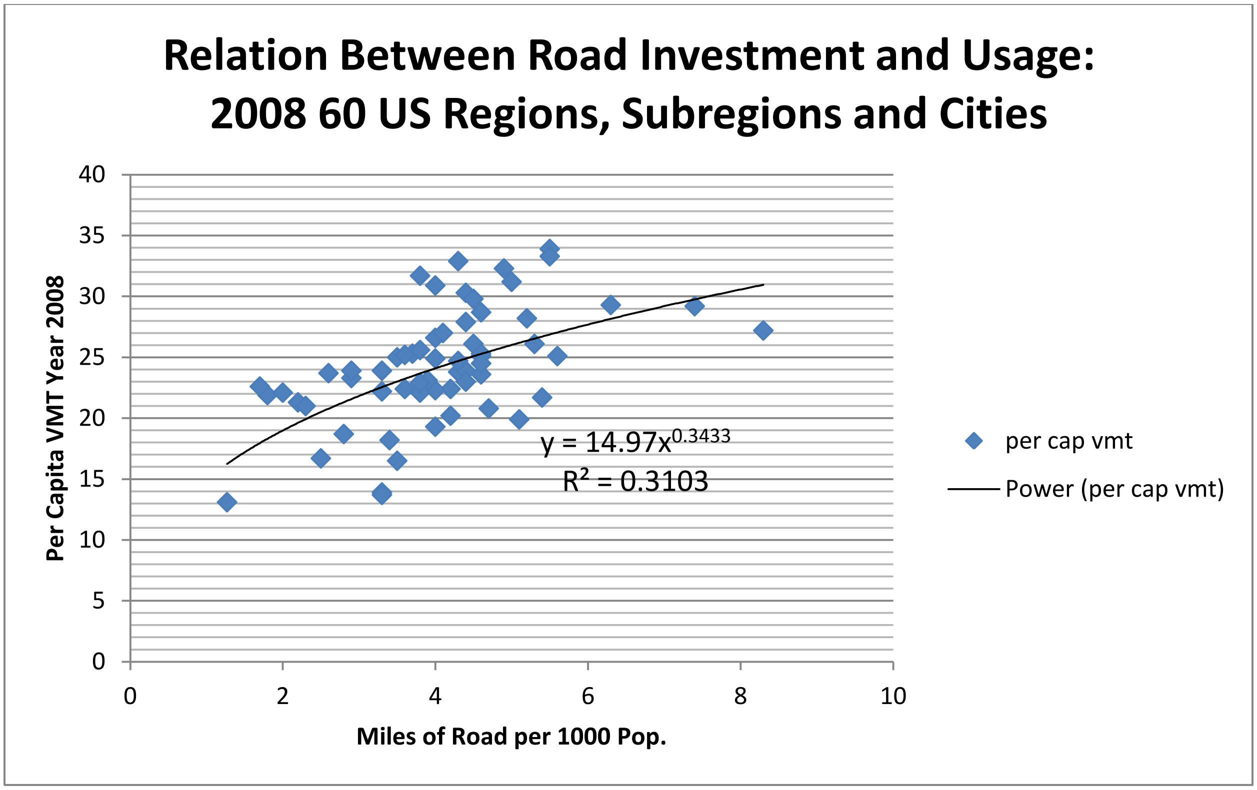

Figure 5: Density, Vehicle Miles Traveled and Road Miles per Person are all interrelated.

In Figure Five we can see that on average increasing the investment in roads by 100% is correlated with an increase in per capita VMT of about 30%. The higher the usage rates, the more likely there will be a need for investment in regional transportation facilities.

It is both intuitive and factual that administratively regional facilities pose the greatest challenges resulting from the total breakdown of the logical nexus between demand and supply. As noted earlier, in present day North America building an urban subdivision necessarily requires the full panoply of local government infrastructure which is funded fairly routinely upon marketing of the subdivision. Community level infrastructure for utilities and in many instances transportation are also provided (not necessarily 100%) and funded as development occurs. Conversely, Regional level infrastructure dominated by transportation has no connection between regional development and the requirement to build new and replace old transportation facilities.

Lack of logical nexus is most acutely felt in funding for Regional level transportation infrastructure and in achieving public consensus about the what, where and how much to pay. Unlike private utilities for electricity and natural gas households and businesses are not charged periodically for the system capacity they are using. Funding originally intended as a reasonable proxy for usage such as the gas tax has not been modernized to be anywhere commensurable with the replacement needs of the system let alone providing new capacity to accommodate growth.

Administratively, regional level capital funding is further complicated by the connected nature of regional transportation facilities. Externalities both positive and negative are not localized to a particular administrative jurisdiction. For example, one hardly notices transportation improvements several hundred miles from one's front door. However, the existence of these improvements ultimately affects the value of the street outside your front door. Being adjacent to a street that did not go anywhere clearly provides no value. The value of your street depends on what it is connected to. Unfortunately, governments in administering regional transportation facilities focus almost exclusively on the improvements located within their jurisdiction. A classic example of this funding myopia was the refusal of Clackamas County voters to contribute a small ($5) annual fee toward the rebuilding of the Sellwood Bridge located within Multnomah County even though the percentage of bridge use from Clackamas County equaled Multnomah County users. This problem exists as well between transportation modes. Transit improvements in particular are beset with funding problems because voters not directly using the system do not perceive how others using the transit system may relieve congestion on the roads they use.

Allocating Infrastructure Capital by Usage and Density

To this point we have provided definitions and denominated the various categories of infrastructure capital by averages based on national investment patterns. So – if someone were to ask how much public investment would be required to build a brand new region of 1 million households and 1.3 million jobs? Our answer would be 1 million times $86,384 plus 1.3 million times $34,708 which equals: 131.5 billion dollars; payable sooner, not later. However, infrastructure has other numeric attributes beyond the type, level and total cost of provision. Certainly from a regional planning perspective the most important set of attributes involves the unit cost of various types and levels of infrastructure as a function of urban form. Specifically does our above answer to the capital cost question change much if our region occupied 200 square miles or if it occupied 400 square miles? Also, to be a bit more realistic what are the infrastructure cost consequences of accommodating all of a region's growth at the regional edge (or beyond) at 2 units per acre versus accommodating 50% of the growth at the region's center at 20 units per acre? It is extremely helpful to know what providing a full range of all levels of governmental infrastructure costs on average. However, we still need to know how this average cost varies with urban form.

Validating the General Functional Form of Density and Usage Relationships

Figures Four and Five shown in the previous section, while limited to regional level road transportation facilities, do a good job of depicting the shape of most capital infrastructure costs with respect to density and usage.[6] We may exploit those relationships particularly for regional level transportation facilities and express unit costs in terms of densities. Figure Six provides a tabular example of regional level transportation costs expressed as a function of density. This table is based on the 2008 national Highway Statistics data for urban regions that are displayed in Figures Four and Five.

[6] A major exception is transit which actually displays the opposite relationship with respect to density; when density increases per capita usage more than proportionately increases. Consequently, unit costs of transit with respect to density are increasing.

ROAD CAPITAL COSTS AND DENSITY

Density Class	Density HH per Acre	Population per Square Mile (1)	Road Miles per 1000 Persons	Urban Road Cost per 1000 Persons
Rural Residential	0.33	202	13.58	$ 89,984,196
SFR1	1	605	7.56	$ 50,075,929
SFR2	2	1,210	5.22	$ 34,608,281
SFR3	3	1,816	4.21	$ 27,881,966
SFR4	4	2,421	3.61	$ 23,918,340
SFR5	5	3,026	3.21	$ 21,236,259
SFR6	6	3,631	2.91	$ 19,269,675
SFR7	7	4,236	2.68	$ 17,749,730
SFR8	8	4,841	2.50	$ 16,530,350
SFR9	9	5,447	2.34	$ 15,524,505
MUR1	10	6,052	2.22	$ 14,676,720
MUR2	20	12,104	1.53	$ 10,143,318
MUR3	30	18,156	1.23	$ 8,171,906
MUR4	40	24,207	1.06	$ 7,010,210
MUR5	50	30,259	0.94	$ 6,224,121
MUR6	60	36,311	0.85	$ 5,647,736
MUR7	70	42,363	0.79	$ 5,202,256
MUR8	80	48,415	0.73	$ 4,844,869
MUR9	90	54,467	0.69	$ 4,550,067
US Urban Region Average	4			$ 26,499,410

Notes: Derived from FHWA, 2008 Urban Highway Statistics for all US regions > 900K population

(1) Population per square mile adjusted downward for other uses to 39.4%.

Figure 6: Urban Road Costs decrease as density increases.

The tabular data of Figure Six exploit the relationship noted at the regional level between road facilities per 1000 population and population density per square mile. As already noted local, community and regional levels of capital facilities may be expressed as either a function of density or a function of usage. As figures Four and Five in the previous section attest, they are not independent. In general as density increases overall usage increases but not proportionally. Figure Six above derived from the national relationship between miles of road per 1000 population and population density per square mile (Figure Four). Using national data on road construction costs per lineal foot for an urban 4 – 5 lane arterial with traffic controls and safety we are able to derive the cost per 1000 population as a function of zoned residential density (column on the far left). Note that the density/cost relation in Figure Six is not linear but reflects the nonlinear relationship of Figure Four. A 270 fold reduction in population density per square mile increases the road cost per 1000 population about 20 times.

Figure Seven provides a graph of the relationship between dwelling units constructed at various density levels and the road costs per dwelling unit. What we provide is a comparison to comparable costs per DU as calculated from the MetroScope infrastructure cost post processor.

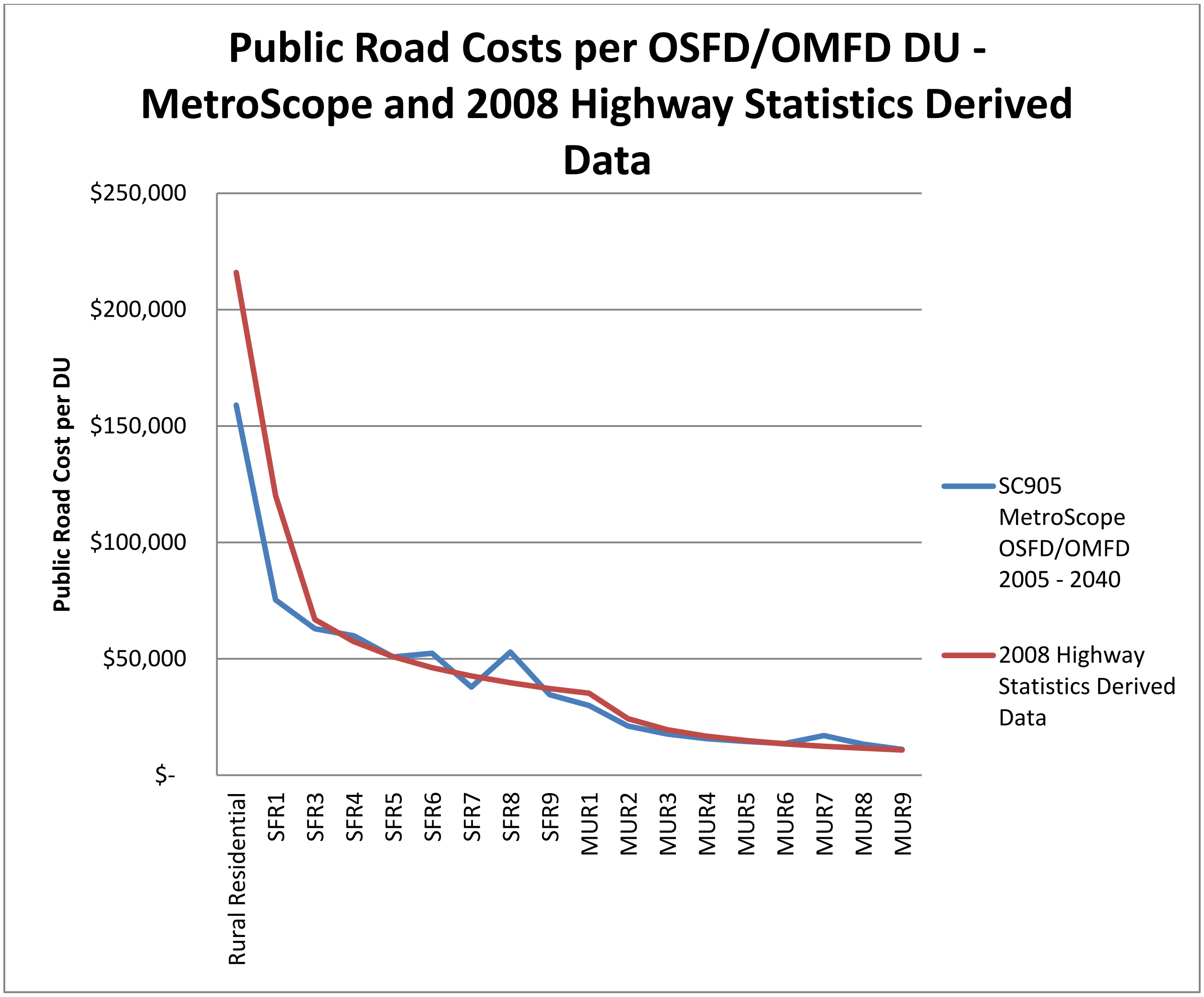

Figure 7: MetroScope zoning/density classes closely match the road cost curve.

Though as documented below the MetroScope post processor for transportation uses density for local streets and usage for community and regional roads, the relationship between density and usage allows us to compare road costs to road costs derived from 2008 national highway statistics. For purposes of comparison, we have included the unit costs of all roads and streets – local, community and regional but excluded bridges/major interchanges and marine and air terminals. We note that in Figure Seven the relationship between the two independently derived series is quite close. There are some differences owing mostly to MetroScope also varying unit costs by housing type, income and location within the region as well as usage and density.

Present Specifics of Allocating Infrastructure Costs per DU as Function of Density or Usage

Though the specifics of each infrastructure type vary widely in terms of average amount and usage, there are some generalities that all infrastructure types and levels share. Below we illustrate the general features with a set of examples taken from the MetroScope post processor. First in Figure Eight we display the general relationship for a set of infrastructure costs per dwelling unit that decrease as density increases.

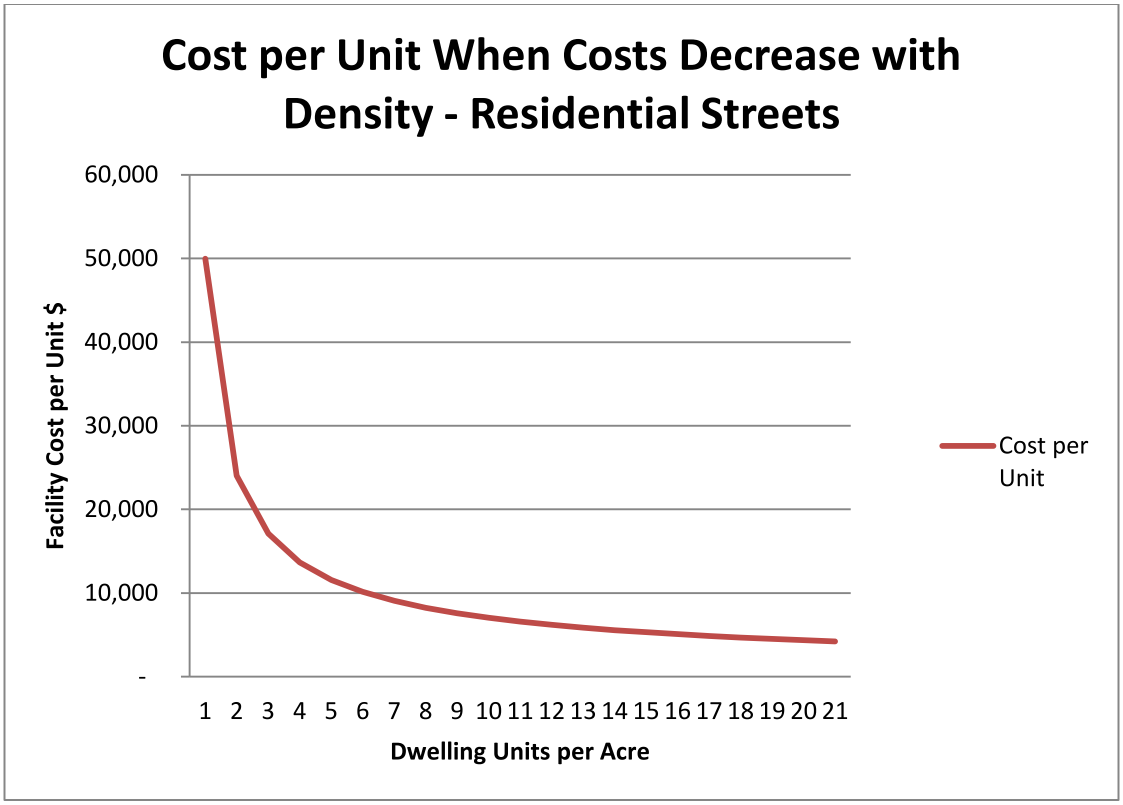

Figure 8: Local level unit costs fall dramatically with density then level off.

In Figure Eight we use the example of residential streets to show how unit costs decrease with density. Graphically one can imagine a 200' x 200' street grid with one house per block. That gives you about $50,000 per unit. However, you can put 15 units on the same street system per block for not much more total cost. Doing this yields about $ 6,000 per unit.

Of course we have types and levels of infrastructure where costs per dwelling unit are constant or increasing with density. The most significant of these are transit which we treat exclusively as a regional level service. Measured in terms of usage transit costs are assigned to the densest areas usually disproportionately populated with low, moderate income and multi-family housing.[7] Figure Nine displays the general shape of the relationship.

In Figure Nine we note that units costs increase with density; but not proportionately. Increasing density by a factor of 15, increases unit costs roughly 4.5 times. Considering the level of usage increases by a factor or 20 to 50; means the cost per user is sharply declining. Figure Nine also illustrates another aspect of the lack of logical nexus for regional facilities. Expensive per user transit in

[7] It is fair to point out that assignment of costs by area (as opposed to usage) produces declining costs with density for transit (though not nearly as steep as for residential streets). While transit service to low density suburban areas is very limited, measured in terms of dwelling units served it is very expensive. However, for a regional service we assume benefit accrues to each user from the entire system; hence total system cost divided by total number of users equals benefit per user. Since most usage comes from low to moderate income households in medium to high density areas, most of the cost is assigned there.

the suburbs has a mirror image with expensive per DU transit service in the inner city. The existence of the one confers benefits to the other in terms of system completeness and providing multi-modal

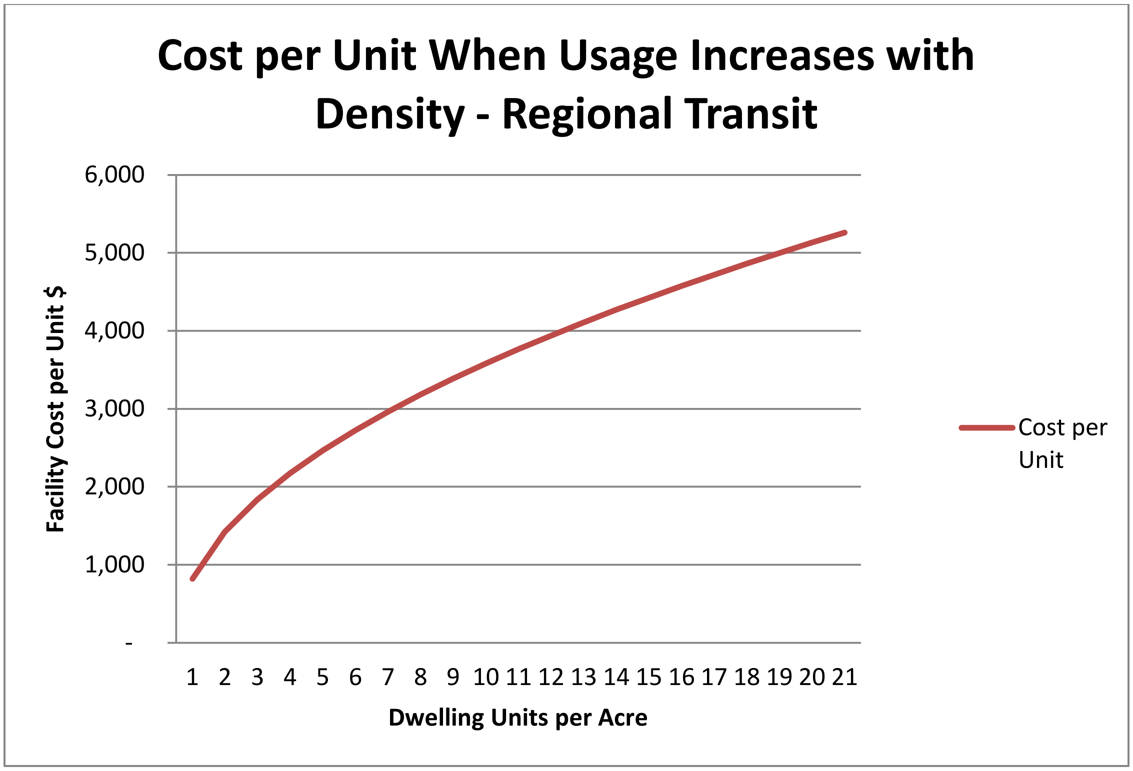

Figure 9: Transit is an example of capital requirements where unit costs increase with density.

congestion relief in both locations. However, residents of the inner city are not able to perceive the benefit of suburban transit which they almost never use; nor do suburban residents value transit connectivity that enables them to drive to work with minimum roadway congestion. More familiar to urban dwellers are the examples of large subsidies per vehicle mile traveled that go to rural roads when compared to heavily traveled urban roads. However, not paying the subsidy would eliminate those road links from the connectivity of the system resulting in the eventual loss of benefit for urban road users as well.

Figure Ten based on MetroScope postprocessor estimates of costs for regional vehicular transportation and bridges as a function of vehicle miles per DU provides another view of regional facility unit costs as a function of usage. Here the unit costs are assumed to be almost linear with usage. Basically an eight fold increase in usage brings about a seven fold increase in unit costs. One may also make the argument that unit costs for urban road transportation are increasing rather than decreasing with usage. In other words, an eight fold increase in usage may engender a 10 – 12 fold increase in unit costs.[8] For the present we are assuming a slightly less than linear relationship between usage and unit cost.

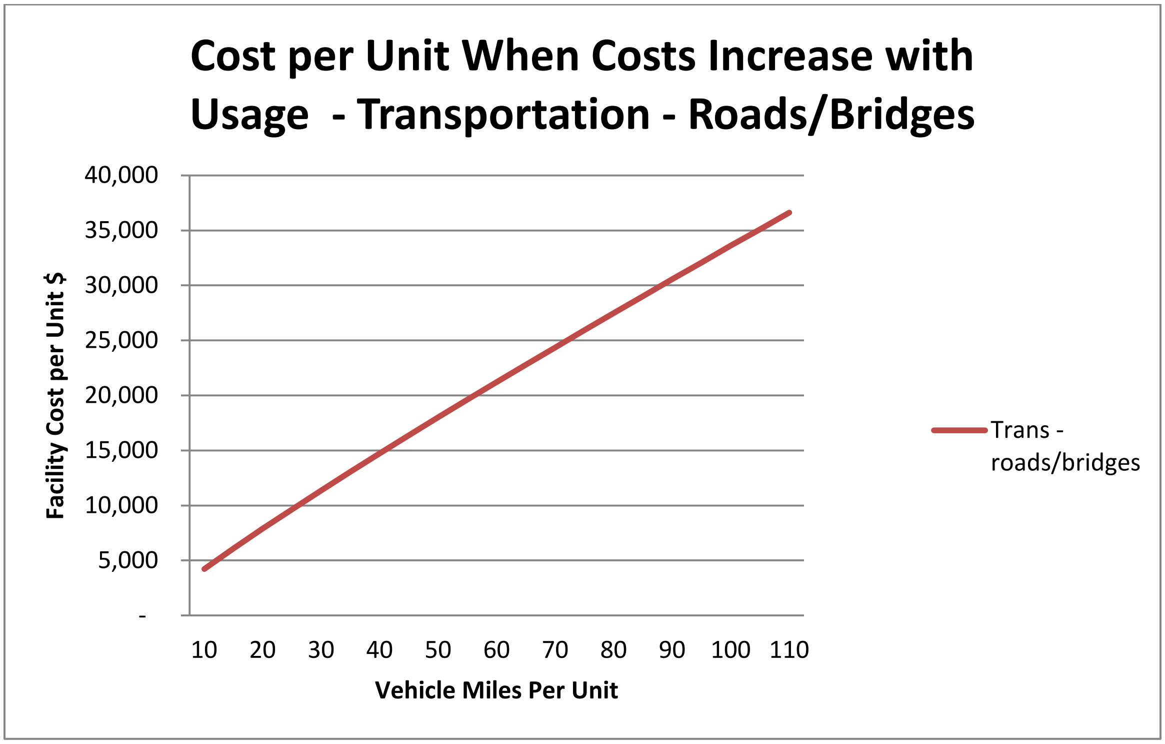

Figure 10: Roads and Bridges are examples of facilities where unit costs per DU increase with usage.

Since MetroScope allocates household demand by income, age, etc. to different housing types and locations that in turn drive the infrastructure postprocessor, we can backtrack and express infrastructure unit costs by income and location among other variables of interest. Figure Eleven below displays examples of infrastructure costs by income and location.

[8] Substantively, we are talking about the increase in capacity of moving from a 4 lane to an 8 lane urban freeway with off ramps, interchanges, etc. Does doubling the number of lanes double capacity? If effective capacity only goes up 50%, then unit costs are increasing with usage; rather than mildly decreasing as we have assumed here.

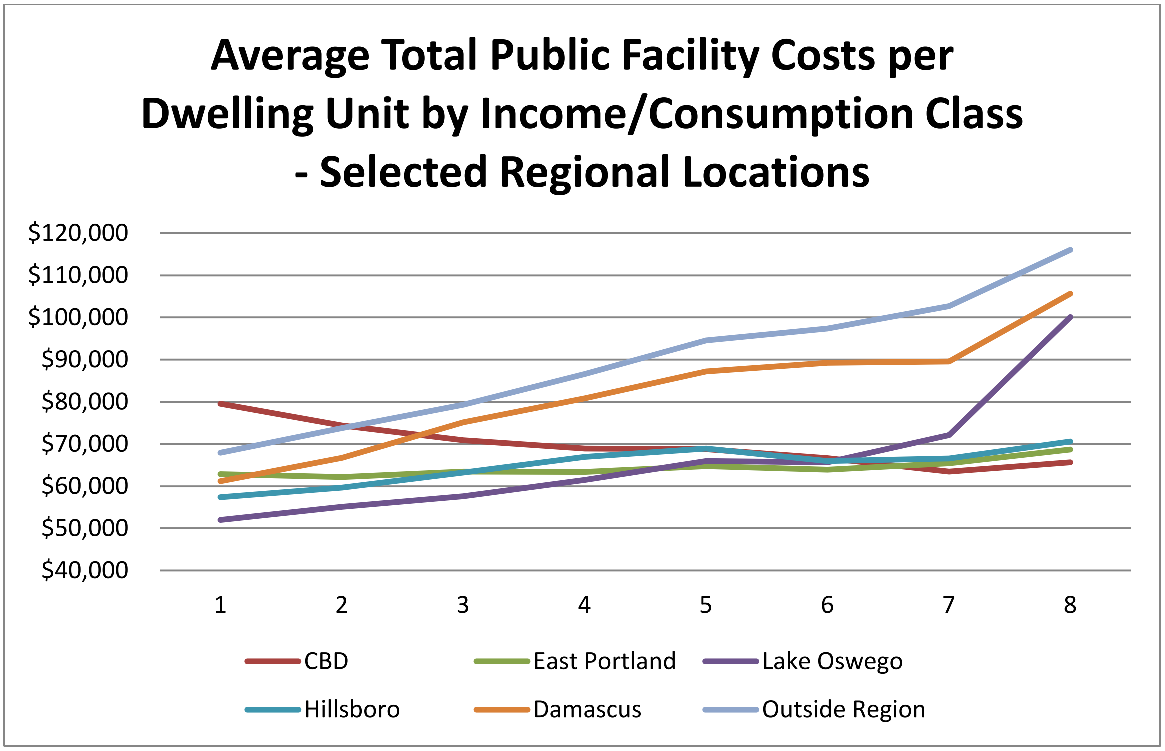

Figure 11: Public facility costs vary by income level and location in different ways.

In Figure Eleven total public facility costs per dwelling unit (vertical axis) are compared to each of eight income/consumption bins (horizontal axis) with one being the lowest income and smallest household size and eight being the highest income and largest household size. Though we have the same data for all 425 census tracts, 4 housing types and 400 HIA's, we have selected only 6 locations and compressed the 400 HIA's into 8 income consumption bins.

Notable from Figure Eleven is that the census tracts representing the CBD are the only ones displaying a pattern different than the rest. For the CBD the highest infrastructure costs occur for the lowest income/consumption groups with the higher groups being lower. This reflects the fact that lower income groups are major transit users; in the CBD higher income groups are dominated by condo owners in very dense developments who have very short trips and relatively low VMT.

Hillsboro and East Portland form another group of census tracts with similar patterns; being relatively low per DU and staying that way across all income/consumption classes. Lake Oswego has much the same pattern except for the top 2 income/consumption classes dominated by large household sizes and very high incomes that produce a large amount of per household vehicle miles traveled.

Damascus and census tracts outside the Metro region reflect low densities of development and a peripheral location that necessitate very high levels of vehicle miles traveled per household. In these census tracts densities decrease and travel markedly increases as income increases; resulting in facility costs that increase steadily with income.

Figure Eleven underscores several points of commonality in regard to infrastructure costs. First, lower income households (with the exception of transit) require lower levels of capital inputs for urban development. Second, from the perspective of urban form, development in the urban center requires considerably less investment, then development on the urban periphery. However, development in jobs rich suburban areas with mixed use such as the Hillsboro area displays development costs no larger than those of central Portland.

Estimating by Census Tract and Income/Consumption Level Infrastructure Costs

Finally, we move from the more general observations to the computational details of the three levels of infrastructure costs associated with development. In setting up the system of allocating capital costs by rzone and income/consumption bin by the previously defined 16 capital facility classes, we provide for maximum flexibility to accommodate different estimates of the average amount for each class and for different viewpoints on how that cost should be allocated. Accordingly, we developed our allocation method using the same allocation formula that provides for easy substitution of starting values and distribution parameters. Graphically, we have already previewed the results of the methods used in the previous section highlighting capital facilities that increased/decreased with density and or usage. Consequently, we shall not dwell on it here other than to emphasize the post processor allows for easy changes in base amounts and distribution parameters.

Below we review each of our 16 capital facility items, the base amounts we are presently assuming and the distribution curves that we use to assign costs by rzone and income/consumption class.

Local Level Capital Costs

Capital Item	Base (Average) Cost per Unit	Unit Cost Distribution	Basis of Average Cost per Unit
Water distribution – Local – OSFD	$5500	Density – slightly decreasing per unit	SDC's, hookup fees, literature search
Sanitary sewer collection – Local- OSFD	$5000	Density – slightly decreasing per unit	SDC's, hookup fees, literature search
Storm drainage – Local – OSFD	$2000	Density – slightly increasing per unit	Literature search, impermeable surface coverage; assumes on site retention
Local streets – OSFD	$10000	Density – moderately decreasing per unit	SDC's, literature search, subdivision development costs
Neighborhood parks – OSFD	$1000	Density – moderately increasing per unit	SDC's, Park standards per 1000 pop; literature search
Total Local Services	$23500	NA	NA

Figure 12: Local level capital facilities we expect to total to $23,500 per DU on average.

Figure Twelve above summarizes the basic assumptions used to estimate local capital costs for these items. We should note that costs were constrained to add up to more reliable average values for the totals of local, community and regional facilities. Here we take for granted that costs will vary dramatically at small scales. It is always the case that idiosyncrasies of geography, past investment levels, accounting practice and community standards generate a very wide variance in per unit public facility cost estimates. The intent here is to produce consistent and complete capital facility costs that capture the systemic variation in these costs.

Figures Thirteen and Fourteen provide the same data for community and regional costs.

Community Level Capital Costs

Capital Item	Base (Average) Cost per Unit	Unit Cost Distribution	Basis of Average Cost per Unit
Community water distribution, trunk lines, pump stations - OSFD	$1500	Density – slightly decreasing per unit	SDC's, hookup fees, literature search
Community water storage and treatment – OSFD	$2000	Density – very slightly decreasing per unit	SDC's, hookup fees, literature search
Community sanitary sewer trunk and treatment - OSFD	$3000	Density – very slightly decreasing per unit	SDC's, hookup fees, literature search
Community storm water collection and treatment – OSFD	$1000	Density – slightly increasing per unit	Literature search, impermeable surface coverage; assumes on site retention
Community transportation – collectors, minor arterials, traffic safety – OSFD	$7500	Usage in per household VMT – costs increasing almost linearly per unit with usage	Literature search
Community parks and recreation - OSFD	$500	Constant	Arbitrary amount – Level of service highly variable from community to community
Schools - OSFD	$4500	Density – very slightly decreasing per unit	SDC's, household size and student demand studies, RSMeans
Total Community Costs	$20000	NA	NA

Figure 13: Community level capital facilities amount to $20,000 per unit on average.

Regional Level Capital Costs

Capital Item	Base (Average) Cost per Unit	Unit Cost Distribution	Basis of Average Cost per Unit
Regional transportation- transit – OSFD	$2750	Usage but using density as a surrogate – moderately increasing with density	Unit cost adjusted to approximate a 4.5 billion $ outlay over 35 years
Regional transportation – roads, bridges, freeways, etc.	$20000	Usage increasing almost linearly with income and household size	Highway usage statistics, costs adjusted to NIPA fixed asset accounts
Regional transportation – air and marine terminals	$1500	Constant per unit	Approximation to NIPA accounts – highly variable across regions
Regional public facilities – admin, jails, courts, stadiums, offices, etc.	$5500	Usage, very slightly decreasing with density	NIPA accounts – low end of the estimate range
Total Regional Level	$29750	NA	NA

Figure 14: Regional level capital facilities amount to $30,000 per DU.

The total average per dwelling unit cost of all three levels of capital facilities adds up to $73250 per unit. This compares to our NIPA based estimate of current $ of new investment of $86400 per dwelling unit. Part of this difference is that we have omitted the fixed asset value of public utilities and quasi-private enterprises that more communally minded governments offer such as power facilities and hospitals.

Results of Applying the Infrastructure Post Processor or How Much Does it Cost to Provide for 580,000 Households over the next 35 Years?

As the preceding narrative highlights, we do not lack for estimation details for the three levels of public infrastructure necessary to build a modern urban region. The 16 different types of capital outlays may be displayed by location, density, usage and income/consumption class. From a policy perspective we are particularly interested in how costs vary by location, density and income. Not parenthetically, we are also interested in funding adequacy, unit costs and the lack of logical nexus between regional transportation costs and the location and density of urban development.

Figure Fifteen displays the summary totals for one of the MetroScope forecasts conducted as part of Metro's urban form policy analysis leading to the Metro Chief Operating Officer's 2009 "Strategies for a Prosperous and Sustainable Region". In the particular scenario being modeled we anticipate accommodating 585,000 new households between 2005 and 2040. UGB expansion, transportation investment, urban renewal subsidies and land regulation in this scenario are set to best replicate existing policies into the future to constitute the "base case". We should point out that here we are looking at only the infrastructure cost per dwelling unit. 38% of the total infrastructure cost accrues by assumption to nonresidential growth that is denominated in employment.[9] In the Figure below we can see that average unit costs for future growth are fairly close to our baseline assumptions documented in Figures Twelve through Fourteen. They are a bit higher because the baseline growth pattern has slightly lower densities and incorporates continued real income growth that drives greater private and public consumption.

Infrastructure Costs by Class 2005 - 2040

Infrastructure Costs 2005 - 2040 by Capital Type

Infrastructure Item	**Amount**		**Cost per Unit**	
Dwelling Units Added		585,860		NA
Water Distribution - Local	$	3,126,427,547	$	5,336
Sanitary Sewer Collection - Local	$	2,842,206,861	$	4,851
Storm Water Runoff - Collection - Local	$	1,409,365,789	$	2,406
Streets, Sidewalks, Curbs, Street Lights - Local	$	7,848,258,807	$	13,396
Neighborhood Parks - Greenspaces - Local	$	996,384,524	$	1,701
Water Distribution - Trunk Lines - Pump Stations - Community	$	852,662,058	$	1,455
Water Production, Treatment and Storage - Community	$	1,140,755,746	$	1,947
Sanitary Sewer Collection and Treatment - Community	$	1,711,133,619	$	2,921
Storm Water Runoff - Collection and Disposal - Community	$	704,682,894	$	1,203
Transportation - collectors, minor arterials, traffic safety, local bike lanes - Community	$	4,152,671,451	$	7,088
Parks, trails and recreation - Community	$	292,910,478	$	500
Schools - Community	$	2,557,986,175	$	4,366
Transportation - Transit- Regional	$	4,442,740,645	$	7,583
Transportation - Roads/Bridges - Regional	$	11,073,790,536	$	18,902
Transportation- Marine/Air - Regional	$	878,731,435	$	1,500
Other Public Facilities and Buildings - Regional	$	3,126,427,547	$	5,336
Total Local Infrastructure	$	16,222,643,527	$	27,690
Total Community Infrastructure	$	11,412,802,422	$	19,480
Total Regional Infrastructure	$	19,521,690,163	$	33,321
Total Infrastructure	$	47,157,136,113	$	80,492

Figure 15: The residential infrastructure bill for adding 586,000 DU amounts to about $47 billion. Though not itemized here, accommodating nonresidential growth adds another $20 billion to the bill.

Looking at just the residential side we note that total spending in this “base case” 35 year scenario amounts to over 47 billion dollars. In return the private residential market makes a 190 billion dollar investment in 2003 dollars.

Based on our previous discussion we may now assess the expenditure requirements enumerated in Figure Fifteen from the revenue perspective. Recall that for the category of local

[9] As noted in Figure 3 we split infrastructure costs between residential and nonresidential on the basis of real estate value. Roughly 38% of US private structures are nonresidential.

infrastructure, in this case totaling 16.2 billion $, our existing systems provide for full collection provided that the responsible governments enforce existing development standards. Essentially, on average every lot developed in the region is expected to include roughly $28,000 in local infrastructure provided for the most part by private developers and turned over to local government for operations, maintenance and eventual replacement. Very roughly converted to physical units, local governments will be expected to increase their inventories of local infrastructure by the equivalent of over 12,000 lineal miles with an annual operating and maintenance cost in excess of 100 million $. This to emphasize once again, is for local level capital facilities; a capital item that seldom or never even shows up in local government budget accounts.

Moving to community level capital facilities, we note that Oregon Statutes prohibit collecting SDC's or impact fees in support of education capital facilities. Secondly, past practice and difficulty in establishing cost responsibility for transportation and recreation related capital expenses combine to limit revenue recovery for community level infrastructure to about 50%. This means substantial amounts of these community requirements go unfunded or are funded from a combination of various state and local taxes, federal grants, exactions, etc. Most of the community level short falls occur as expected in the transportation categories as sewer and water systems by definition must be complete in order to work. Like local level facilities community facilities end up in the public domain and require operating, maintenance and eventual replacement. Measured in lineal feet they amount to roughly ¼ to 1/6 the spatial extent of local facilities but their unit costs are 3 – 5 times that of local services.[10]

Finally we comment on the regional facilities bill. We expect this bill to accommodate residential development to amount to 19.5 billion $. As noted earlier, there is no logical nexus between development and the need to supply this level of facilities. Consequently, neither consistent fixed asset accounting, nor funding and dedicated resources exist. Demand for capital outlays occur on an "as needed" basis and may be funded from grants, general obligation or revenue bonds, operating revenues, toll revenues or most often simply deferred. Ready examples exist in our region with both the 2.2 – 4.5 billion Columbia River Crossing Bridge replacement and the 250 – 325 million Sellwood Bridge replacement facing planning and financing crisis and delays. While only now constituting a federal, state and local government crisis, the facilities have been in use and wearing out for up to 100 years while the region has grown by a factor of 4 – 5 times with no attention paid to their eventual replacement.

Figure Sixteen below takes the same data and reconfigures it by housing type and summarizes it for the entire 7 County economic region. What is most discernable from Figure Sixteen is that capital facility costs vary by a factor of about 40 – 50% by housing type. Single family averages over $90,000 per unit while multi-family averages about $65,000. This reflects the underlying sizes, densities and locations where these units are predominately built. Notable also is that about 65% of SFD expenses occur in the regional category while but 40 – 45% of MFD expenses occur in that category. Keep in mind that regional facilities constitute the most difficult to fund and replace level of capital facilities. SFD locations are necessarily in lower density, more remote locations of the region which result in

[10] For instance a 30 foot collector street is not wider than a 30 foot residential street but it may have 5000 vehicles per day versus 50 for a residential street; not to mention bike lanes, major traffic control and safety devices, etc.

substantially higher VMT per household. This happenstance results in two challenges for regional growth management; units costs are higher and the likelihood of efficient cost recovery is very low. MFD development (both owner and renter occupied) by contrast has lower unit costs with a greater share concentrated at the local and community level where cost recovery is more directly related to development as it occurs.

Scenario 905 Capital Cost Estimates 2005 - 2040

Infrastructure Costs by Housing Type and Scale Class

Dwelling Unit Type	Units Produced	Local Costs	Community Costs	Regional Costs	Total Costs	Cost Per Unit
Owner Occupied Single Family	333,119	$ 11,458,764,785	$ 7,511,075,467	$ 11,381,653,910	$ 30,351,494,163	$ 91,113
Owner Occupied Multi-Family	119,442	$ 2,076,007,070	$ 1,696,415,257	$ 3,952,442,476	$ 7,724,864,803	$ 64,675
Renter Occupied Single Family	15,136	$ 539,270,642	$ 316,695,543	$ 448,633,553	$ 1,304,599,738	$ 86,193
Renter Occupied Multi-Family	118,163	$ 2,148,601,030	$ 1,888,616,155	$ 3,738,960,224	$ 7,776,177,409	$ 65,809
Totals	585,860	$ 16,222,643,527	$11,412,802,422	$ 19,521,690,163	$ 47,157,136,113	$ 80,492

Figure 16: Lower density single family dwellings are the most expensive to provide for.

Figure Seventeen below displays the same data by a Metro major geography called HNA (Housing Needs Area).   Besides geographic resolution we have also focused on transportation costs; displaying all three levels of transportation costs and grouping all other costs regardless of level under the category of other. Though the geography is at a high level of aggregation, we can still discern substantial patterns and differences between areas.   First, looking at total costs per unit we observe a range of 56 to 96K $ per dwelling unit. Higher income single family dominated developments at the urban edge comprise the higher costs while low, moderate income multi-family dominated developments within built up urban areas comprise the lower cost locations.

Examining the next to last column in Figure Seventeen reveals that almost none of the spatial variation in infrastructure unit costs owes to the category of “other costs”. The range per unit goes from

31 to 37K $. The means most all of the variation at this fairly large scale of spatial resolution owes to the three levels of transportation costs.

In Figure Seventeen we have itemized transportation costs by level: local, community and regional to evaluate how these costs change with geography. A cursory examination of the data indicates that all 3 levels of transportation costs exhibit considerable spatial variation. For instance, the CBD very heavily served by transit with high levels of transit ridership costs 28,000 $ in transit investment for each DU developed. By way of contrast, Damascus with low levels of service and even lower levels of ridership costs 2000 $ per DU. When we examine the roads and bridges column the relationship reverses with the CBD costing 7,000 $ per DU and Damascus 24,000 $. Local transportation costs repeat the road/bridges pattern. Due to very high densities CBD local transportation costs per DU amount to 1400 $. Damascus local transportation costs amount to about $16,000 per DU.

Infrastructure Costs by HNA Area

Regional Residential Costs Per Unit - 2005 - 2040

HNA Area	Units Built	Local Transportation Costs per DU	Community Transportation Costs per DU	Regional Transit per DU	Regional Roads/Bridges per DU	Total Other Costs per DU	Total Costs per DU
Portland CBD	37,569	$ 1,401	$ 2,646	$ 28,194	$ 7,057	$ 30,794	$ 70,092
Northeast Portland	12,249	$ 3,682	$ 3,286	$ 17,976	$ 8,764	$ 31,057	$ 64,766
Gresham-Wood Village-Fairview-Troutdale	22,003	$ 7,494	$ 5,734	$ 6,807	$ 15,291	$ 31,816	$ 67,143
East Portland	21,288	$ 3,725	$ 3,999	$ 14,217	$ 10,665	$ 30,785	$ 63,391
Southeast Portland	14,289	$ 4,317	$ 3,445	$ 14,578	$ 9,187	$ 31,101	$ 62,627
West Portland	34,616	$ 6,206	$ 3,934	$ 18,370	$ 10,490	$ 31,909	$ 70,909
North Portland	11,406	$ 3,469	$ 3,337	$ 18,377	$ 8,900	$ 30,867	$ 64,950
Lake Oswego	3,569	$ 16,368	$ 5,845	$ 3,177	$ 15,588	$ 34,293	$ 75,271
Gladstone - Clackamas	3,629	$ 7,183	$ 4,486	$ 5,339	$ 11,962	$ 31,801	$ 60,770
Milwaukie	3,872	$ 5,479	$ 3,507	$ 6,368	$ 9,353	$ 31,116	$ 55,823
Happy Valley	8,386	$ 12,297	$ 5,973	$ 4,134	$ 15,927	$ 33,437	$ 71,767
Damascus	33,685	$ 15,628	$ 8,985	$ 2,087	$ 23,960	$ 34,724	$ 85,383
Oregon City	27,158	$ 11,350	$ 7,035	$ 7,266	$ 18,760	$ 33,345	$ 77,757
West Linn	11,890	$ 17,509	$ 8,434	$ 1,614	$ 22,492	$ 35,408	$ 85,457
Wilsonville	5,032	$ 24,776	$ 8,829	$ 2,193	$ 23,545	$ 36,681	$ 96,023
North Hillsboro	9,829	$ 4,265	$ 4,866	$ 9,959	$ 12,976	$ 30,702	$ 62,768
East Washington County	24,034	$ 5,764	$ 4,231	$ 9,233	$ 11,284	$ 31,282	$ 61,794
South Beaverton	5,233	$ 6,259	$ 3,758	$ 7,737	$ 10,021	$ 31,451	$ 59,226
Tigard - King City	9,890	$ 7,818	$ 4,692	$ 7,370	$ 12,512	$ 32,137	$ 64,530
Tualatin	8,281	$ 12,532	$ 8,877	$ 2,538	$ 23,673	$ 33,832	$ 81,453
Sherwood - Scholls	3,120	$ 10,445	$ 7,431	$ 4,320	$ 19,816	$ 32,773	$ 74,784
SW Beaverton	8,049	$ 9,191	$ 5,839	$ 4,223	$ 15,570	$ 32,564	$ 67,387
South Hillsboro	6,181	$ 5,406	$ 5,184	$ 7,107	$ 13,824	$ 31,130	$ 62,651
Forest Grove - Cornelius	3,786	$ 7,412	$ 8,083	$ 4,845	$ 21,554	$ 31,888	$ 73,781
Remainder of Region	256,816	$ 20,449	$ 9,412	$ 2,746	$ 25,098	$ 35,172	$ 92,876
Region Overall	585,860	$ 13,396	$ 7,088	$ 7,583	$ 18,902	$ 33,523	$ 80,492

Figure 17: Transportation cost variation produces most of the variance in costs by location.

To summarize this section the data point to overall higher costs and less logical nexus with development as we move from dense central city locations to low density peripheral locations. Ironically, even with transit accounted for, the higher subsidies appear consistently correlated medium to high income households locating in low density SFD at the urban edge.

So What Problem Have We Corrected Anyway?

In the Introduction we noted that cost of infrastructure and the need for investment efficiency are frequently talked about but seldom actually measured. Unfortunately, given the few times such costs are actually measured; the results are so various as to preclude any further helpful discussion of infrastructure costs associated with development. Cost estimates vary dramatically for substantive reasons such as average costing for an entire region or marginal costs for a subdivision located on a hill, separated by a ravine. Most often the large differences owe to mundane mistakes and inconsistencies such as not defining what costs are included (local facilities since they tend to be self-funded are often times omitted as are major regional facilities that have no local ownership). Failure of local governments to adequately inventory, track and account for fixed assets adds another layer of confusion to the discussion. Consequently, we never move to the first condition for a helpful discussion of what to do about timely and adequate provision of public capital; namely consistent measurement and agreement of responsibility and funding principles.[11]

The above discussion and cost estimates we intend to provide as a substantive starting place for defining what we are measuring, discussing the attributes of the capital facilities and their funding nexus. Moreover, in calculating and distributing these costs we establish reasonable unit costs backed by national asset accounting and provide a verifiable methodology for distributing these costs by development density and usage. We should also emphasize that these costs are directly calculated as a post processor from the output of Metro's integrated land use and transportation model: MetroScope.

[11] The popular general principle of "let development pay for itself" actually amounts to a recipe for underfunding, lack of sufficient investment and within a multi-jurisdiction region substantial location and development distortion. If appropriate utility accounting were used and complete logical nexus between all levels of capital requirements enforced, we would pay for facilities over their useful life spans and strongly encourage using excess capacity (but paid for as it is used) first.

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