An Analytical Tool for Economic, Land Use, and Social Impact Analyses of Major Infrastructure Projects

A Report to:

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Executive Summary

California has more money to spend on infrastructure projects today than at any time in the recent past. Given this increased level of infrastructure investment, infrastructure agencies – especially Caltrans – have struggled in recent years with methods to identify and mitigate the impacts of those infrastructure investments.

The goal of this project is to outline a new statistical model that will more accurately assess the social and economic impacts of infrastructure projects by canvassing existing technologies and data, building upon techniques pioneered by the principal investigators, thus improving the "state of the art."

The basic analytical approach will be to examine land use, economic, and demographic changes before and after the construction of major infrastructure projects that were built in the past two decades, and to use quasi-experimental research techniques to understand what would have happened to land use, economic, and demographic changes had the infrastructure not been built.

When using quasi-experimental techniques, the researcher chooses an "experimental" group, affected by the project, and a "control" group, not affected by the project. Comparing impacts across those two groups mimics the research design of controlled experiments, allowing the possibility of easy-to-understand inferences about the impact of the program. The use of a quasi-experimental approach will allow the impact of the infrastructure project on census tracts to be estimated in a way that is both technically sound and easily communicated to stakeholder groups. The model would use a wide variety of data on demographics, economics, building and property values, and transportation.

There are four steps in applying a quasi-experimental approach to the study of urban growth and infrastructure:

1. Choose the geographic areas that will constitute the "experimental" or "treatment" group.

2. Choose the superset of geographic areas from which a control group will be selected.

3. Implement a matching method to select a matched-pair control geographic area for each experimental area.

4. Test whether the outcome variable differs across control and experimental groups.

It is our view that the best case study project to test this methodology will be a highway project. Highway projects have obvious impacts on the surrounding communities and can be readily correlated with surrounding physical and economic impacts. Also, most literature has been conducted on highway projects.

For example, this methodology could have been used to help rank the many projects competing for Proposition 1B money earmarked for improvements to Highway 99. The funding decision was made on the basis of safety and congestion measures, the latter of importance because of congestion's degrading impact on air quality. Had the model been available, the list of criteria could have been expanded to include growth-inducing impacts as well.

Similarly, the model could be used to compare dramatically different *types* of proposed infrastructure projects that could be used to deal with the same infrastructure problem. For example, the state is now moving forward – after a 40-year delay – with the "gap closure" for the 710 Freeway in South Pasadena. Several alternatives have been proposed, including a tunnel and a "multi-modal low-build" alternative that would improve a variety of transportation components without building a freeway. Currently, studies are underway on the financial and technical feasibility of these alternatives, but the application of this methodology could assess the social and economic impact as well.

The next step would be to apply this methodology to an actual infrastructure project proposal as a kind of a "beta test". Once the methodology has been beta-tested, the Keston Institute should work collaboratively with infrastructure agencies, especially Caltrans and the U.S. Department of Transportation, to introduce the methodology into decision-making processes and environmental review processes throughout California.

Introduction

California has more money to spend on infrastructure projects today than at any time in the recent past. Voters approved close to $40 billion in infrastructure bonds in the November 2006 election, with the vast majority of the money slated for transportation and flood control improvements – classic public infrastructure projects that have the potential to provide great public benefit but also considerable disruption to existing communities. Given this increased level of infrastructure investment, infrastructure agencies – especially Caltrans – have struggled in recent years with methods to identify and mitigate the impacts of those infrastructure investments.

In 2006 alone, Caltrans concluded two efforts seeking to provide more clarity in analyzing the impact of transportation projects:

- On behalf of Caltrans, UC Davis's Information Center for the Environment conducted a study of new integrated land use/economics/transportation models, concluding that integrated models dealing with land use, transportation, and economic data together will provide more effective analysis for new projects. (http://www.ice.ucdavis.edu/um/Portals/0/06.22.06%20Updated%20Report.pdf)

- In a joint effort with the Federal Highway Administration, Caltrans also produced a new Guidance document for Growth-related and Indirect Impact Analysis under the California Environmental Quality Act and the National Environmental Policy Act. (http://www.dot.ca.gov/ser/Growth-related_IndirectImpactAnalysis/gri_guidance.htm)

The goal of this project is to outline a new statistical model that will more accurately assess the social and economic impacts of infrastructure projects by canvassing existing technologies and data, building upon techniques pioneered by the principal investigators, thus improving the "state of the art."

When fully developed, this model will provide policymakers with a new tool to ensure that such projects have maximum economic benefit and minimum social disruption, one with which to analyze whether new infrastructure, especially on the urban fringe, causes new growth; and what growth patterns (and resulting impacts) will occur if no infrastructure project is built.

These questions have policy and legal ramifications. It is possible that, in the future Environmental Impact Statements, under the National Environmental Policy Act, will require more refined understanding of how growth patterns differ depending on whether or not a major infrastructure system is built. More broadly, the debate about urban sprawl, Smart Growth, and related topics reflects our imperfect understanding of the determinants of metropolitan growth, and resulting disagreements complicate the analysis and forecasts for virtually all major urban infrastructure projects.

Recent improvements in data availability and research approaches create the prospect – for the first time ever – of building an analytical tool that can apportion growth to infrastructure projects and predict growth induced by new infrastructure. The key developments are:

- The advent of GIS technology and the resulting increase in the availability of spatially detailed data for a large number of metropolitan areas. Population, employment, sociodemographic characteristics, and land prices or proxies for land prices are now available for small geographic areas.

- Recently successful applications of statistical techniques developed by the principal investigators to model growth-inducing impacts of infrastructure. (Boarnet and Chalermpong, 2002)

- Recent applications of quasi-experimental designs that provide insight into the growth-inducing effect of infrastructure. These research designs can provide information on causality in addition to simple associations. (Chalermpong, 2002)

Using these advances, we will describe in detail a prototype model that can predict the social and economic impact of a major infrastructure project. The result will illustrate the potential for substantial improvements in analyzing and forecasting the environmental, economic, land use, and growth impacts of major infrastructure projects.

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Chalermpong, Saksith. *Economic Spillovers of Highway Investment: A Case Study of the Employment Impacts of Interstate 105 in Los Angeles County*. Ph.D. Dissertation, University of California, Irvine, 2002. (Advised by Marlon Boarnet)

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2. Methodology

The basic analytical approach will be to examine land use, economic, and demographic changes before and after the construction of major infrastructure projects that were built in the past two decades, and to use quasi-experimental research techniques to understand what would have happened to land use, economic, and demographic changes had the infrastructure not been built.

Quasi-experimental techniques have become popular in program evaluation. When using quasi-experimental techniques, the researcher chooses an "experimental" group, affected by the project, and a "control" group, not affected by the project. Comparing impacts across those two groups mimics the research design of controlled experiments, allowing the possibility of easy-to-understand inferences about the impact of the program.[1]

An example of a recent application to transportation projects is research by Chalermpong (2004), who used this "case-control" method, and tests before and after infrastructure construction, to show that the opening of the Century Freeway in Los Angeles County in the 1990s was associated with more rapid employment growth within a mile of the freeway corridor and reduced employment growth more distant from the freeway corridor, compared to what would have been expected had the freeway not been built. One of the principal investigators (Boarnet) is currently advising the World Bank on adopting similar methods to understand the impact of infrastructure projects in developing countries.

Quasi-experimental techniques can be used to ensure that a set of geographic locations – "experimental" and "control" groups – are chosen that are as similar as possible based on key characteristics.[2] The use of a quasi-experimental approach will allow the impact of the infrastructure project on census tracts to be estimated in a way that is both technically sound and easily communicated to stakeholder groups.

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[1] For discussions and applications of quasi-experimental techniques, see Chalermpong, Saksith. 2004. Empirical Study of the Economic Spillovers of Interstate 105 in Los Angeles County. *Transportation Research Record 1864*, Transportation Research Board, pp. 94-102, Cook TD, Campbell DT. *Quasi-Experimentation: Design and Analysis Issues for Field Settings*. Boston: Houghton-Mifflin, 1979, Dehejia, Rajeev H. and Sadek Wahba. 1999. Causal Effects in Nonexperimental Studies: Reevaluating the Evaluation of Training Programs. *Journal of the American Statistical Association* 94, 448: 1053-1062, Dehejia, Rajeev H. and Sadek Wahba. 2002. Propensity Score Matching Methods for Nonexperimental Causal Studies. *Review of Economics and Statistics* 84,1: 151-161, Holzer, Harry J., John M. Quigley, and Steven Raphael. 2003. "Public Transit and the Spatial Distribution of Minority Employment: Evidence from a Natural Experiment." *Journal of Policy Analysis and Management* 22,3: 415-441, Rosenbaum, Paul R. and Donald B. Rubin. 1983. The Central Role of the Propensity Score in Observational Studies for Causal Effects. *Biometrika* 70: 41-55, Smith, Jeffrey A. and Petra E. Todd. 2005. Does Matching Overcome LaLonde's Critique of Nonexperimental Estimators? *Journal of Econometrics* 125: 305-353.

[2] For a discussion of the technique and applications to highway impacts, see Terance Rephann and Andrew Isserman. 1994. "New Highways as Economic Development Tools: An Evaluation Using Quasi-Experimental Matching Methods," *Regional Science and Urban Economics*, 24, 723-751. Saksith Chalermpong. 2002. "Economic Spillovers of Highway Investment: A Case Study of the Employment Impacts of Interstate 105 in Los Angeles County," unpublished Ph.D. dissertation, University of California, Irvine.

As example, estimates of census tract employment growth in both the “build” and “no-build” scenarios for infrastructure project projects could be mapped, allowing a visual presentation. A common approach is to combine regression analysis with quasi-experimental methods to further control for possibly confounding factors. Quasi-experimental analyses, for different categories of infrastructure projects, can allow forecasting of land use, growth, economic, and by extension social impacts of major projects.

3. Literature Review

Highway and Road Infrastructure

The overall picture of roadway improvements and regional development and growth is unclear. What is apparent, however, is that highway investments are more likely to shape overall growth rather than create it

Chandra and Thompson (2000) analyze the impacts of interstate highway construction on county-level economic activity for the United States. Their study finds that counties with new interstate highways had significantly higher levels of earnings than counties that did not have such projects. Furthermore, they find that earnings in counties adjacent to interstate counties actually fell. They conclude that the overall net effect of interstate highway construction, including both types of areas, is near zero.

Bollinger and Ihlanfeldt (2003) study the impact of government interventions on the spatial distribution of employment at the census tract level in the Atlanta metropolitan region. Controlling for other exogenous factors, the authors find that highway improvements are associated with increases in census tract employment levels. These findings confirm those of Luce (1994) showing that job growth within Philadelphia metropolitan area cities is dependent upon local access to interstate highways or railway lines.

Conversely, Bruinsma, Rienstra, and Rietveld (1997) find no significant increases in employment as a result of new highway construction. Using sector-level employment data, the authors analyze aggregate employment growth in regions with and without major highway projects. Though regions with new highways did exhibit growth in the transport and communications sector, the effect was not significantly different from other control regions that did not have new highway construction.

Using a quasi-experimental approach, Rephann and Isserman (1994) use matching methods to examine the effects of interstate highway expansion on economic growth of U.S. counties during the 1963-1975 time period. They find that proximity to existing urbanized areas is a necessary precondition for growth in counties with new federal highways. The study shows that rural or off-interstate counties showed little or no growth when compared to their urban counterparts.

Cervero (2003) provides a study that looks at the effects of highway improvements and construction on traffic patterns in 24 California freeway projects over a 15-year period. Utilizing a path model approach and panel data, he finds that both induced demand, from decreases in travel times, and induced investment, resulting from new development along the freeway, account for increases in traffic counts in the study areas. Thus, investments in new highway infrastructure in California have historically led to decreases in travel times and increases in the amount of developed land within areas in close proximity to the project.

In a study designed to analyze the effects of transport related infrastructure on regional economic growth, Button, Leitham, McQuaid, and Nelson (1995) use multivariate analysis to examine infrastructure provision in the Strathclyde region in Scotland. The empirical results show that road improvements have differential effects depending on country of origin of the investing firms. For example, firms from outside the region invest more into the study area than locally based establishments. The authors conclude that improvements in road networks largely support linkages between outsider establishments, local markets, and other corporate branches and headquarters. This implies that regional expansion of road and highways may increase foreign investment into an area but may not enhance the productivity of local firms.

An empirical study conducted by Baum-Snow (2006) is one of the only analyses to directly estimate the direct effects of the interstate highway system on suburbanization in central and suburban cities. The study utilizes decennial data on the population of central and suburban cities from 1950-1990. He notes that although metropolitan population grew by 72 percent during this time period, central city population declined by approximately 17 percent. The empirical evidence suggests that one new stretch of interstate construction within a central city was associated with a population reduction of 18 percent.

The author further estimates that had the interstate highways not been built, central city population would have grown by about 8 percent. This suggests that although decentralization would have likely occurred without new highway construction, improved access to central cities via the interstate system significantly decreased the population of central areas.

Water and Sewage Infrastructure

Studies analyzing the effects of water and sewage infrastructure on urban growth and development are not as abundant. Existing empirical literature rarely focuses upon the impacts of specific water and sewage projects, but rather accounts for them in context of other growth-inducing factors. No clear pattern of the water/sewer infrastructure impacts emerges from the existing empirical evidence

For instance, Burge and Ihlanfeldt (2006) examine the effects of impact fees on housing construction in Florida counties. They find that impact fees levied within counties tend to expand the stock of multifamily housing. However, impact fees that are specifically used for water and sewer infrastructure are found to reduce multifamily unit construction throughout all metropolitan areas. This result, though, may be due to local governments using excessively high water/sewer impact fees for multifamily units in hopes of discouraging land uses that are costly in public services.

In a longitudinal analysis of lot sizes and residential densities in Texas, Maryland, and Virginia, Peiser (1989) finds that leapfrog-style growth patterns are actually associated with higher developed densities of the parcels that were initially skipped over. Within his study, he also finds that extending sewer and water lines greater than a mile from existing infrastructure are usually not economically feasible from the standpoint of local government finance. Thus, viewing the expansion of water/sewer lines as a growth-inducing catalyst may be incorrect; urban growth and development will occur in areas where sewer lines exist only if other exogenous demand characteristics are present.

Carruthers and Vias (2005) use regional adjustment models to examine growth patterns in the Rocky Mountain West. In their analysis, a variety of public expenditure measures are hypothesized to increase or decrease changes in population and employment densities. They find that although spending on roads is associated with a decrease in population density, spending on water and sewerage is correlated with an increase in both population and employment densities over a 15-year time period in the Rocky Mountain West.

In an explicit study of wastewater treatment and urban growth, Hopkins, Xu, and Knaap (2004) examine economies of scale of waste treatment plants and costs of development in the Chicago Metropolitan area. While the study focuses primarily on the importance of timing plant consolidation, the authors do conclude that large treatment facilities are only needed to support the most dense and rapidly growing developments. In most instances though, moderate to low rates of metropolitan growth and density can be adequately serviced by smaller, more numerous wastewater treatment facilities. This may imply that only small investments in water and sewer infrastructure are needed to facilitate moderate intensity development over the short-run.

In sum, studies on the direct effects of sewer and water infrastructure expansion are rare. Rather, most papers analyze the impacts of water and sewer expenditures in a public expenditure framework. Most empirical evidence on local government water/sewer expenditures is mixed. For instance, Carruthers and Vias (2005) find that expenditures in the Rocky Mountain west are associated with an increase in both population and employment densities, while Burge and Ihlanfeldt (2006) conclude that water/sewer impact fees levied by local governments in Florida are correlated with a reduction in multi-family residential unit construction. Similar to the impacts of highways, Peiser (1989) finds that extending sewer lines greater than one mile from existing development will only allow growth to occur if sufficient demand (in the form of large scale residential developments) exists. However, Hopkins, Xu, and Knaap (2004) find that only small scale water/sewage treatment plants are needed to support even moderate regional growth.

Communication Infrastructure

Scholarly literature that empirically examines the role of communication infrastructure in the urban growth process is scarce. One of the first studies of modern communication and urban growth is that of Moss (1987). This paper considers the effects of telecommunication infrastructure on the patterns of development in world cities. The effects appear to vary depending on the intrametropolitan location of telecommunication infrastructure. For example, the author finds that telecommunications projects within central world cities lead to the centralization of business services in the urban core while dispersing information based industries to the periphery of the metropolitan region. Here, the urban development effects of communication infrastructure are primarily dependent upon the types of firms that utilize the good as opposed to the level of overall infrastructure investment.

Another study on the effects of telecommunications infrastructure on regional economic growth is that of Yilmaz, Haynes, and Dinc (2002). The authors attempt to test for possible spillover effects of improvements in telecommunications between U.S. states. Using panel data for the lower 48 states from 1970-1997, the empirical evidence suggests that there are significant negative spillover effects from state improvements in telecommunications infrastructure. The authors find that improvements increase output in the respective state, but reduce output in adjacent states. Furthermore, the authors find that this effect increases with proximity to the host state. Policy implications include using telecommunications projects for facilitating regional development efforts within states. However, the negative externalities associated with these improvements could lead to non-optimal levels of infrastructure provision as states compete with one another to provide high levels of telecommunications access. The authors estimate that the cumulative effects of such excess provision could lead to an overall reduction of output by 0.0009 percent.

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4. Categories of Infrastructure Projects

Public infrastructure is commonly defined as the basic physical systems that support the daily activities of a community or a region. The Keston Institute's mission statement focuses on transportation, water, power, environment, and related municipal public works projects.

Because the literature on infrastructure impacts is so mixed, it was difficult to create a system of categories that groups projects together based on similar expected impacts. Similarly, it was difficult to categories infrastructure projects based on size, simply because the range of infrastructure projects is so great.

Therefore, we sorted infrastructure projects in two different ways. The most obvious way to sort the infrastructure projects is *by type of infrastructure* – highways, transit, water and sewer, etc. But a second way to sort the infrastructure projects is *by characteristic* – whether the project is new or an upgrade; what the purpose of the project is; and in some areas what medium is involved. Tables 1 and 2 show these different sorts.

Table 1. Infrastructure Projects Sorted by Type

Roads and highways	Transit	Water and Sewer	Telecommunications	Energy
Bridges	Heavy rail	Reservoirs	Land Lines	Hydroelectric Plants
Tunnels	Light rail	Canals	Towers and wireless systems	Transmission Lines
Highways	BRT	Sewer Trunk Lines	Undergrounding of existing lines	Power Plants
	Intercity rail	Water Treatment Plants		Transfer Stations
	Transfer Centers	Flood control levees and retaining walls		Undergrounding of existing lines
		Stormwater Runoff Projects		Wind turbines
				Geothermal
				Offshore facilities
				Pipelines

Table 2. Infrastructure Projects Sorted by Characteristic

New?	Setting	Media	Purpose
New Construction	Urban	Oil & Gas	Transport
Expansion	Suburban	Electricity	Storage
Retrofit	Rural	Fiberoptic	Transfer
Upgrade	Intercity		Generate/Produce

Obviously, infrastructure projects in each type category could also be broken down by characteristic, though not all characteristics would apply to all kinds of infrastructure projects. For example, highway projects – which we believe to be the most likely type of project on which to test this methodology – might fall into a range of "new?" and "setting" categories. But the medium and purpose is always the same – vehicles and transport.

Indeed, it might be possible to create a much more fine-grained typology within each of the "characteristic" categories. With the category of highway expansion, for example, a wide range of projects might be included, such as:

- Additional lanes
- Additional ramps and transition lanes
- Addition of HOV lanes
- Gap closures
- Bypasses
- Grade Separations

Each of these types of projects could be expected to have a different type of impact.

One possible categorization method that we have not included in this analysis is the type of financing used for the project. We did not include this because our general view is that the type of financing does not alter the nature of an infrastructure project and therefore should not affect its impact. However, this is a question worth exploring further. A project's financing might affect both its nature and its use.

As the literature review suggested, there is some evidence that the use of impact fees for a highway project might affect the nature of the land use patterns around it. In addition, toll financing could affect how a highway project is used and therefore its impact.

5. Data Availability for Impact Analyses of Major Infrastructure Projects

Here is a brief discussion of and a table listing the various data available for use in assessing the growth impacts of major infrastructure projects.

Demographic Data

While the U.S. Census is only conducted once every ten years, state and regional agencies generally produce annual estimates. The level at which data are available varies from agency to agency, and depending on the location of the infrastructure project being studied, small area data (e.g. census tract, block group, and bloc data) may not be available free of charge from public agencies.

In addition to the public agencies, private companies maintain proprietary databases and provide various products for a fee. Claritas is one such company that sells annually updated demographic estimates. These may be purchased alone or bundled with other types of information.

Economic Data

Data on economic activity are available from the several public databases, but the size of the reported areas varies. The Economic Census is conducted once every five years; the smallest data unit available is ZIP Code. Annual surveys include County Business Patterns (data available by County and Metropolitan Area), Survey of Manufactures (data available only by State), and Non-Employer Statistics (data available State, County and Metropolitan Area). Data coded by address is available from private sources such as Claritas and ESRI. These private databases include data on type of business (SIC or NAICS codes), number of employees and annual sales. Claritas updates their business database monthly.

In addition to data based on census divisions or ZIP codes, Claritas offers data based on service areas for gas, electric and telecoms service boundaries. For these areas, information on rates, revenue and number of residential and industrial consumers is available along with demographic and business data.

A problem with respect to data available from private companies like Claritas is that they are not available retrospectively. This is because the data collection and reporting methods are frequently changed, compromising period-to-period comparability. Data currently available from Claritas is for 2006, but the company also provides Census 2000 benchmark data.

Property Valuation and Building Statistics

Census data provide information on occupancy, tenure, age of housing stock and house price. Current site specific information on property valuation, structure type, structure size and building class is generally available from county assessors' offices, though not usually for free. While the data are available on a site-specific basis, they are generally gathered on a ZIP code or city boundary basis. Depending on the agency involved, building permit statistics may be available on a small area basis or by address. As with assessors' data, a charge is usually made to cover data processing.

Current property information is also available from private companies (e.g. Claritas and DataQuick). Depending on the reporting format, historic information may be embedded in the report (e.g. original value, changes in size and value due to remodeling).

Transportation Data

Data on annual average daily traffic are available for state-maintained roads through state departments of transportation by route number and postmile. Similar information is available from municipal roads departments for local thoroughfares, generally by street name and intersection. Data for state roads is frequently available on-line (AADT and truck counts from 1992 to the latest survey are easily downloadable in spreadsheet form on the Caltrans website). Data for recent years may also be available on-line from counties, cities, or metropolitan planning organizations either in spreadsheet or PDF formats. Archived data may have to be purchased.

Table 3 summarizes data availability.

Table 3: Data Sources and Availability

Data Type	Agency	Source	Data Level
Population	U.S. Census Bureau	Decennial censuses	Tract, block group, block
	State agencies (e.g. CA Dept. of Finance) Metro planning orgs Regional planning orgs	Annual population estimates (based on latest national census)	Depending on agency, data available at various levels: C-tract, subregional area, ZIP code, community planning areas, etc.
Demographic – Race, Age, Education, Self-reported income	U.S. Census Bureau	Decennial censuses	Tract, block group, block
Demographic – population, Income producing assets	Claritas	Projections based on decennial censuses	Tract, block group, block
Economic – Businesses	U.S. Census Bureau	Economic Censuses 1992, 1997, 2002 County Business Patterns	County, Metropolitan Area, ZIP Code
Economic – Employment	U.S. Census Bureau, state agencies (e.g. CA EDD)	Economic Censuses	County, Metropolitan Area, ZIP Code
Economic – Businesses	Claritas, ESRI	Private databases	ZIP Code
Property valuation: Occupancy, tenure, year built, parcel value, structure value	U.S. Census Bureau	Public database	Tract, block group, block
Property valuation: parcel value, structure value	County assessors DataQuick	Public database Private database	Parcel specific; generally gathered by ZIP Code
Building statistics: Building permits, zoning, square footage, type, class	Planning agencies	Public databases	Municipal boundaries, may be available on small area- or site-specific basis
Non-residential building occupancy: # employees, annual sales, SIC and NAICS codes	Claritas	Private database updated monthly	Address specific
Transportation – AADT state roads	State Departments of Transportation	Public database	Route number and postmile.
Transportation – AADT local roads	County and municipal roads departments	Public database	Segment or intersection
Gas, electric and telecoms – small area demography, business characteristics, rates, # residential consumers, # industrial consumers, revenue	Claritas	Private database	Service boundary areas to block group level

6. Possible Case-Study Highway Projects

It is our view that the best case study project to test this methodology will be a highway project. Highway projects have obvious impacts on the surrounding communities and can be readily correlated with surrounding physical and economic impacts. Also, most literature has been conducted on highway projects. Furthermore, in the context of California today, few brand-new highway projects are constructed. The most probable projects to analyze are expansion or improvement projects.

In addition, our view is that the best subject of analysis would be a project completed shortly after a decennial Census, thus allowing us to compare Census data before and after the project is completed.

Based on these criteria we have compiled a list of highway projects that could be good subjects of analysis. We have focused on California highway projects completed in the early 1990s so that 1990 and 2000 Census data can be used for comparison.

I-10 – Harbor Freeway Transitway (Completed 1996)

I-105—HOV lanes between I-405 and SR-605 (1993)

I-405—HOV lanes between SR110 and 120th St. 1993)

I-405—HOV lanes between Bellflower and SR-605 (1993)

I-880—Reconstruction after Loma Prieta earthquake (1997)

SR55 – Orange County, widened between SR-22 and McFadden Avenue, with a direct carpool lane connector between Interstate 5 and SR-55. (1995)

SR 85 – West Valley Freeway (1994)

SR99 – Merced River bridge widening (1997)

SR99—Livingston Bypass (1997)

I-105 – Los Angeles County (Completed 1993)

Orange County Toll Road Network (Completed 1999)

7. Feasibility of the Quasi-Experimental Method

In this section we describe a quasi-experimental method that could be used for studying the impact of infrastructure on growth and development. To illustrate the feasibility of the approach, we will choose a small number of experimental and control census tracts for the case of a new toll road in Orange County, California.

There are four steps in applying a quasi-experimental approach to the study of urban growth and infrastructure:

1. Choose the geographic areas that will constitute the “experimental” or “treatment” group.

2. Choose the superset of geographic areas from which a control group will be selected.

3. Implement a matching method to select a matched-pair control geographic area for each experimental area. The number of control areas can be varied – for example, more than one control can be matched to each experimental group, although here we will discuss a balanced test with each experimental geographic area matched to one control group.

4. Test whether the outcome variable differs across control and experimental groups.

As an example, if we wanted to study the growth-inducing impacts of highways, a typical approach would be to examine population and employment changes in census tracts. The experimental census tracts would be in a suitably chosen corridor close to the highway project, and a more distant area would be chosen from which to draw control group census tracts. The matching technique would be implemented using data from before the construction of the highway project, in order to choose control census tracts that are similar to experimental census tracts on key characteristics other than access to the highway improvement.

Once the experimental and control groups are chosen, simple comparisons of changes in tract population and employment during a “before construction” and “after construction” time period would be the cornerstone of the empirical test. As an example, if the experimental and control tracts showed no difference in population and employment growth rates before the construction of the highway project – but contained statistically significant differences after construction of the highway project -- that would be evidence that the highway project altered growth patterns. The magnitude of the difference between those two groups would give an estimate of the magnitude of any growth-inducing effect from the highway. The researcher could pursue more sophisticated matching techniques, including matching on several variables and varying tolerances for accepting a match, to address questions of the quality of match quality.

Each of the first three steps above is discussed in more detail below.

1. Choose experimental group. A common method is to select geographic areas, such as census tracts, within a specific distance from an infrastructure project. The distance would be chosen to reflect the expected physical range of the impact. For example, noise contours from highways have been shown to affect house prices within distances that are typically less than a mile from the highway (Langley, 1981). House price premiums resulting from improved highway access have been measured within two miles of toll road improvements (Boarnet and Chalermpong, 2001). Chalermpong (2004) chose an experimental corridor that extended for one-mile on either side of the new highway in his study of growth impacts from the construction of Interstate 105 in Los Angeles County. Other types of infrastructure might have impacts that are realized over different distances.

2. Choose the superset of geographic areas from which the experimental group will be chosen. Typically, the researcher would choose control-group geographic areas from a region that is similar to the experimental group, but distant enough from the infrastructure improvement so that one would expect a substantially lower magnitude of infrastructure impacts among the control group candidates as compared with the experimental group. Chalermpong (2004), for example, chose control group census tracts from the same broad neighborhood as the I-105 corridor, but he required that control group tracts be at least two miles from the I-105, while his experimental group was a mile or less from the new highway.

3. Implement a matching method. The purpose of the matching technique is to choose control areas that are as similar as possible to experimental areas. To ground the discussion, consider the problem of studying how highway access influences census tract population and employment growth. Control group census tracts should be chosen based on similarity to the experimental group census tracts, using variables that measure criteria that are important for the outcome variables – in this example, population and employment growth. As an example, the table below shows variables that have been shown to be associated with census tract population and employment growth.

Table 4: Matching Variables for Census Tract (or other small area) Population and Employment Change

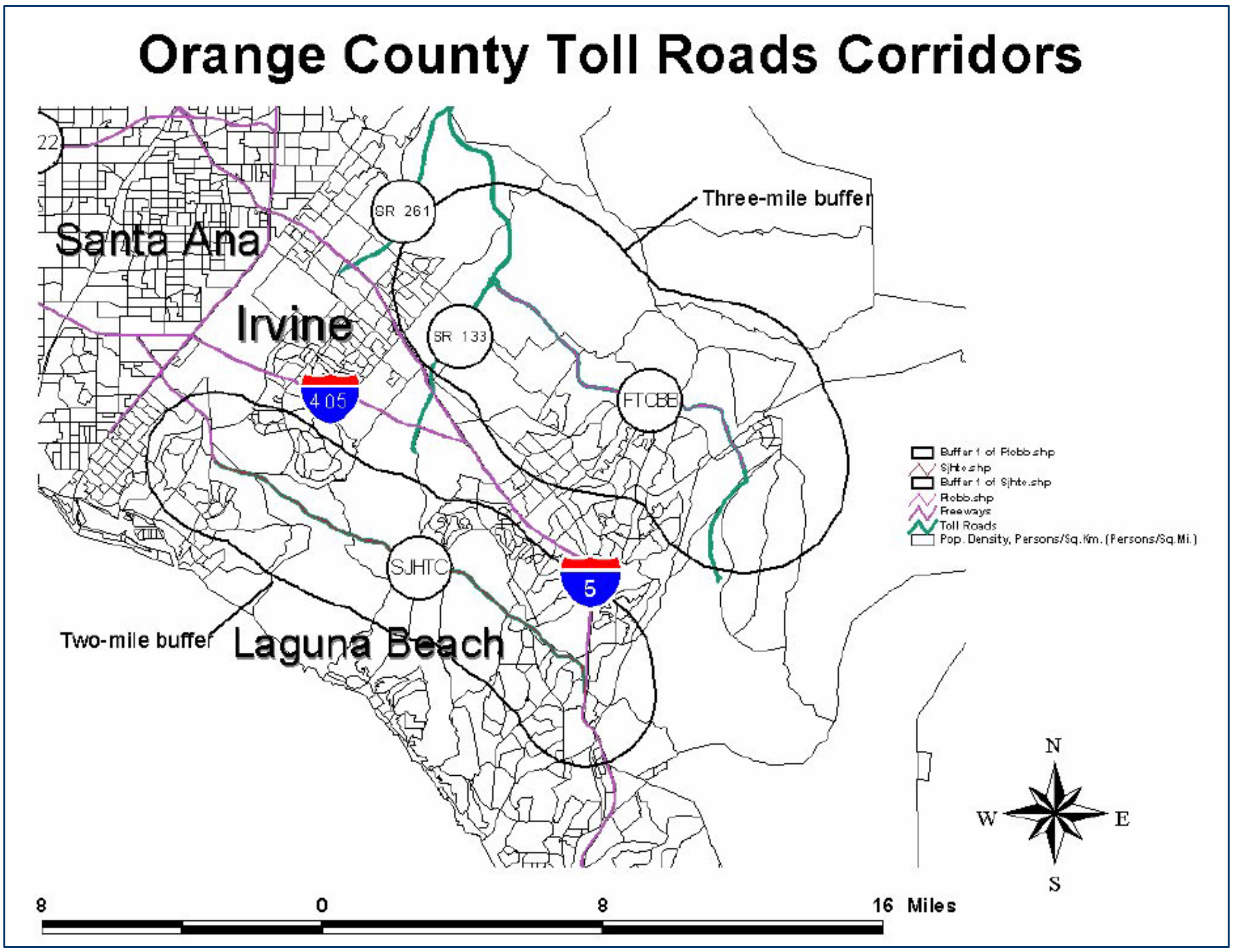
Impact or Outcome Variable	Matching Variables, drawn from characteristics associated with changes in the outcome variable
Census Tract Population Growth	Access to employment opportunities (e.g. gravity variables that measure access to employment) Access to shopping opportunities (e.g. gravity variables that measure access to retail employment) School quality Local taxes and public expenditures Crime rates Demographic composition of the census tract Income levels/poverty rates for the census tract Housing stock age (to proxy a range of infrastructure and amenity characteristics) Access to residential amenities
Census Tract Employment Growth	Access to labor force or output markets (e.g. gravity variables that measure access to surrounding population) Industry Structure Measures of access to agglomeration benefits, such as concentration of firms in similar or different industries Access to infrastructure, other than the infrastructure project being studied Local taxes and public expenditures Crime rates Income levels/poverty rates for the census tract

Conceptually, one would pair the experimental tract that is closest to the control tract on the several characteristics, using multiple variables. This would involve minimizing a sum of squared difference for several variables, or more formally using a matrix minimization technique, as in Isserman and Rephann (1993) or Chalermpong (2004).

A simpler, and more common, approach is to use a propensity score. To implement a propensity score approach, the researcher first runs a discrete choice regression with the dependent variable indicating membership in either the experimental group or the control group superset. Both to illustrate this approach and to examine its feasibility, we have developed a propensity score match for ten census tracts near the earliest opening portions of the toll road network in Orange County, California.

As background, the Transportation Corridor Agencies in Orange County constructed fifty-one new centerline miles of tolled highway during the 1990s. The San Joaquin Hills, Eastern, and Foothill corridors are portions of California State Routes 73, 241, 261, and 133. The earliest parts of that toll road network opened in the early- to mid-1990s, and are shown below.

Map 1: Orange County Toll Road Network – Initial Phases



We use a propensity score matching technique to choose matching control census tracts for ten "experimental" census tracts. The experimental, or treatment, group comprises the census tracts that contained an on-ramp to the earliest opening phases of the San Joaquin and Foothill corridors. Those tracts are within the two- or three-mile buffers shown in Figure 1, but the experimental tracts do not exhaust the two- or three-mile buffers shown in Figure 1. The ten experimental census tracts, using 1980 tract definitions, are tract numbers 52503, 52510, 52405, 32007, 62614, 52406, 42303, 42309, 32010, and 52407.[3] Those tracts were designated by a "toll road" dummy variable equal to one. The toll road dummy variable equals zero for all other tracts in Orange County.

We then run a discrete choice regression to predict the toll road dummy variable. (This is equivalent to predicting membership in the experimental group, based on observable characteristics.) The probit regression is shown below, with estimated coefficients and diagnostic statistics.

$$\text{Toll Road Dummy} = \underset{(-4.31)}{-1.64} - \underset{(-3.55)}{3.74\times10^{-4}}\text{Pop80} + \underset{(5.22)}{2.08\times10^{-4}}\text{Pop90} - \underset{(-0.77)}{5.63\times10^{-5}}\text{Emp90}$$

Psuedo R-squared = 0.4083	Log-Likelihood = -29.873378
Number of obs = 404	LR chi2(3) = 41.23
	Prob > chi2 = 0.0000

Where Pop80 = census tract population in 1980
Pop90 = census tract population in 1990
Emp90 = census tract employment in 1990
z-statistics are in parentheses below the coefficients

The independent variables in the above regression are chosen for illustrative purposes. If we were using this matching technique as part of a test of the impact of the toll road on census tract population or employment growth, a more complete set of independent variables chosen from among those in Table 4 should be used. Similarly, in a more complete analysis, one would more carefully tailor the control group superset to the problem, as opposed to using all remaining census tracts in Orange County, as was done in this analysis.

The propensity score technique is implemented by using the probit regression coefficients shown above to give a predicted value of the dependent variable for every census tract. The predicted value can be interpreted as the probability that a tract with given characteristics has a value of one for the toll road dummy variable. More importantly, for the propensity score technique, tracts with closer predicted values have closer values of the three independent variables. The predicted value from the regression is called a propensity score. Census tracts with very similar predicted values from the above regression have similar values of the three independent variables. The propensity score

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[3] These are not all of the census tracts that contain on-ramps onto the toll roads. We chose ten tracts to illustrate the matching technique.

thus allows an analyst to mimic multivariate matrix minimization techniques across several variables.

For each census tract in the experimental group, we chose the control group census tract with the closest propensity score. In this way, a matching control group tract is chosen for each experimental tract. The result is summarized in Table 5, below, with experimental tracts shown in green and the matching control tracts shown in yellow.

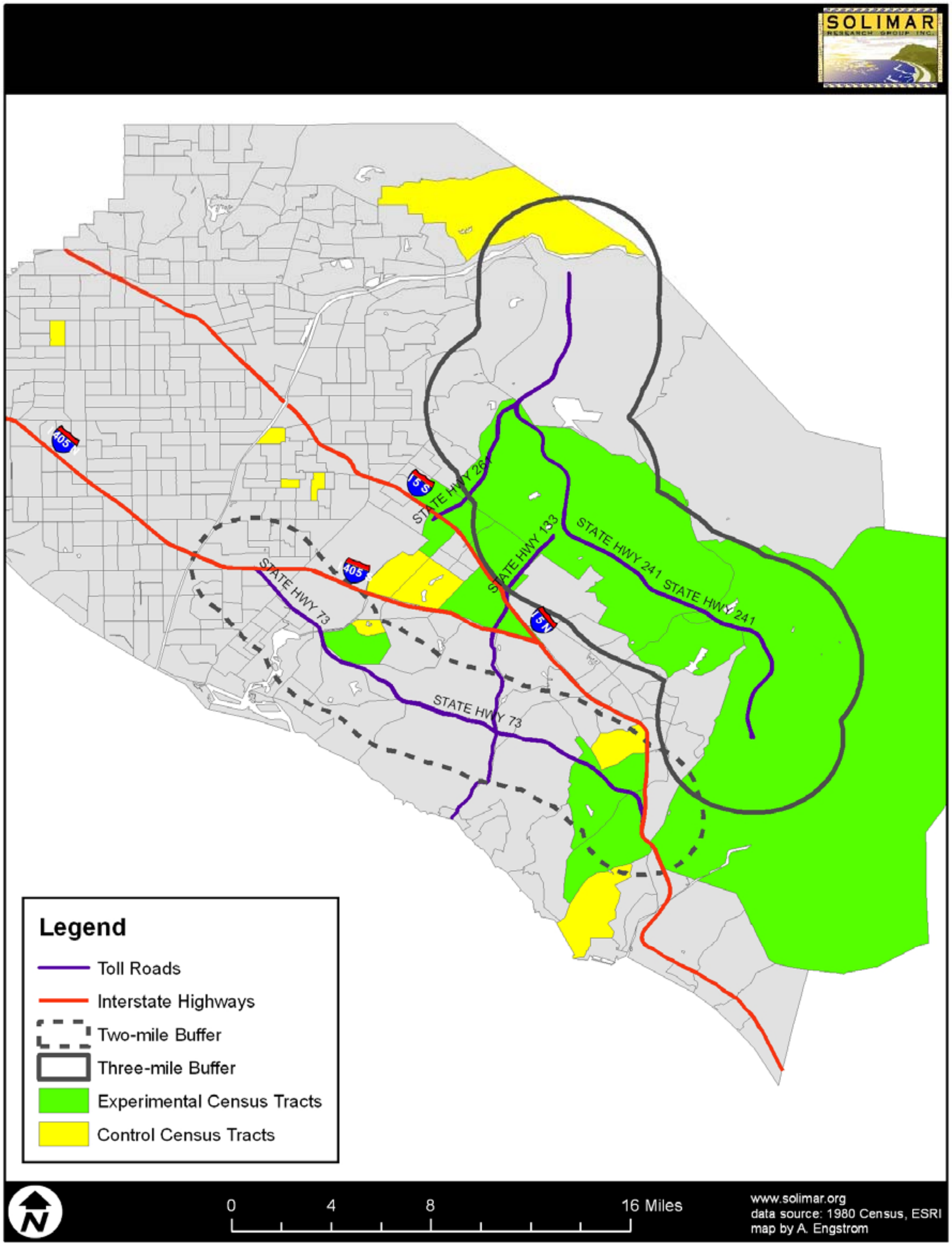
Table 5: Experimental and Control Census Tracts

Tract Number	*Pop80*	*Pop90*	*Emp90*	*Propensity Score*	
52503	4943	6340	1291	0.012486	
110202	4469	5422	993	0.0125828	
	474	918	298		Experimental minus Control
52510	1086	2102	5735	0.0266397	
75302	2529	3407	929	0.0268252	
	-1443	-1305	4806		Experimental minus Control
52405	4546	8806	4083	0.0410744	
74902	4159	6961	207	0.0392852	
	387	1845	3876		Experimental minus Control
32007	13966	26398	2826	0.0631378	
74602	4480	8677	590	0.0613112	
	9486	17721	2236		Experimental minus Control
62614	2998	6083	60	0.0668405	
42308	3112	7953	5530	0.0719155	
	-114	-1870	-5470		Experimental minus Control
52406	3180	11879	2723	0.3039127	
62615	2	5128	3092	0.226537	
	3178	6751	-369		Experimental minus Control
42303	6607	20754	3288	0.5078855	
52508	8562	23867	8400	0.3627686	
	-1955	-3113	-5112		Experimental minus Control
42309	2534	18580	8810	0.7816625	
52509	1712	9953	1517	0.3830742	
	822	8627	7293		Experimental minus Control
52407	5655	26012	2491	0.9348252	
42314	5590	17303	1905	0.4052443	
	65	8709	586		Experimental minus Control
32010	3468	26403	1823	0.9928201	
21808	7807	29374	4939	0.8979642	
	-4339	-2971	-3116		Experimental minus Control

As one can see, for some matched pairs, the values of the regression independent variables (Pop80, Pop90, Emp90) are close. In many cases in the above table, though, one or more of the Pop80, Pop90, or Emp90 variables is considerably different across the experimental and control tract. The quality of the matching process is a crucial feature of quasi-experimental techniques, and in a more complete analysis one would refine the match by using a more complete set of variables in the probit regression, imposing tolerance limits for acceptable matches, and (as appropriate) more carefully choosing the superset of census tracts from which the control group would be chosen. For example, when applying the propensity score technique, one can discard paired matches if the difference between propensity scores is beyond a particular tolerance, which narrows the focus to pairs that are judged to be better matches.

Map 2 shows the geographical distribution of the experimental (in green) and control (in yellow) Census tracts.

Map 2: Experimental and Control Census Tracts



In terms of feasibility, we conclude that the propensity score method warrants further examination. The data to implement a propensity score match are available for many projects, and the matching technique is relatively straightforward. With a broader set of independent variables in the propensity score (probit) regression, this technique can be applied to the problem of choosing a control group.

Once experimental and control groups have been chosen, examining differences across those groups in the level or change of key outcome variables completes that analysis. That remains as a future step, following a more complete implementation of the matching technique.

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8. Controlling for Covariates: The Role of Regression Analysis in Quasi-Experimental Research

In classical research design, the goal of a quasi-experimental approach is to mimic the control and experimental groups of randomly assigned trials, in which case a simple comparison of mean values across control and experimental groups can give an average "treatment" effect. A simple comparison of means across experimental and control groups would be possible if the matching technique sufficiently controls for other factors that might explain the variables of interest, for example population and employment growth in the example above. Yet the question remains of what to do if the matching technique is not perfect, as might often be the case. (Recall that in the previous section, the control and experimental tracts sometimes differed substantially across some variables.)

A common solution to this problem is to combine regression analysis with quasi-experimental techniques. For an outcome variable, *Y*, the general approach is shown below.

$$Y = a_0 + \mathbf{X_1}a_1 + \mathbf{X_2}a_2 + a_3 I' + u \qquad (1)$$

$$I = b0 + \mathbf{X_1}b_1 + \mathbf{Z}b_2 + v \qquad (2)$$

Where *Y* is the outcome variable

I is an indicator variable, = 1 if the observation is in the experimental group, 0 if the observation is in the superset for the control group

I' is a dummy variable, = 1 for observations in the experimental group and 0 for observations in the matched control group based on the propensity score analysis

X1, X2, and Z are vectors of variables, with X1 being the variables that are associated both with group membership (I) and the outcome variable (Y)

a0, a1, a2, a3, b0, b1, and b2 are coefficient vectors or scalars

u and v are error terms.

Adapting the above general model to the case of highways and population or employment growth in census tracts, the *Y* variable would be population or employment change in census tracts, and *I'* would be a dummy variable indicating whether the tract is in the experimental or control group. The impact of the infrastructure project, the highway, can be measured by the coefficient on *I'*, a_3.

In a quasi-experimental approach, equation (2) is the discrete choice regression used to develop the propensity score. In the example from the previous section, *I* was a toll road dummy variable. Once control tracts are matched to experimental tracts based on a propensity score criterion, the variable *I'* can be constructed to reflect membership in either the control or experimental group for the tracts chosen by the propensity score method. To illustrate the method, if the vectors $\mathbf{X_1}$ and $\mathbf{X_2}$ are excluded from the regression in equation (1), a test for the significance of a_3 is simply a differences in means test across the two groups – control and experimental observations.

Including covariates in a regression framework is most common when there are variables that affect the outcome, *Y*, but that do not affect group membership, *I*. The quasi-experimental research approach has been most commonly applied to examine the effect of specific programs – for example welfare or job training programs for individuals or enterprise zone programs for geographic areas.[4] In those cases, equation (2) in the framework above models program participation.

Consider the example of enterprise zone programs. Particular areas are typically chosen for enterprise zones based on observable characteristics, and equation (2) would model the enterprise zone selection process. If a researcher were studying the impact of enterprise zone status on employment growth, equation (1) would then model employment growth in a set of enterprise zone communities and a control group chosen based on equation (2).[5] In cases where the propensity score regression models a real program selection process, it is often possible to identify variables that influence the outcome variable but that do not influence program selection, and so an approach like equations (1) and (2) is possible. The analog for infrastructure programs presents some difficulties.

Using the example of the impact of a highway on census tract population and employment growth, the selection regression in equation (2) does not predict the highway's location. Instead, the role of the selection regression is simply to choose similar control and experimental census tracts from among tracts that are near the highway (an experimental group) and more distant from the highway (the superset for choosing the control group.) Equation (2) is an attempt to control for factors other than distance from the highway that might influence population and employment growth. For that reason, all variables that might affect population and employment growth, other than highway access, could be on the right-hand side of equation (2), in which case there would be no **Z** variables – variables in equation (2) but excluded from equation (1). The extent to which this is a complication remains to be seen, but it is a possibility.

A full research program that combines quasi-experimental design with regression controls to examine the impact of infrastructure would have to examine this question. One possibility is that there are, indeed, variables that are important for growth patterns but that would not be used in the selection regression in equation (2). It is also possible that the independent variables in equations (1) and (2) are the same. Even in that case, it might be appropriate to use a regression technique to control for co-variates. Consider the following simplified example.

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4 For an example of the quasi-experimental approach applied to a job training program, see Dehejia, Rajeev H. and Sadek Wahba, "Causal Effects in Nonexperimental Studies: Reevaluating the Evaluation of Training Programs," *Journal of the American Statistical Association*, 1999, vol. 94, no. 448, pp. 1053-1062. For an example of a quasi-experimental approach applied to an enterprise zone program, see O'Keefe, Suzanne, "Job Creation in California's Enterprise Zones: A Comparison Using a Propensity Score Matching Model," *Journal of Urban Economics*, January 2004, Vol. 55, No. 1, pp. 131-150.

5 For an example, see O'Keefe, Suzanne, "Job Creation in California's Enterprise Zones: A Comparison Using a Propensity Score Matching Model," *Journal of Urban Economics*, January 2004, Vol. 55, No. 1, pp. 131-150.

$$Emp_i = a_0 + a_1 Pop_i + I'_i + u \qquad (3)$$

$$I_i = b_0 + b_1 Pop_i + v \qquad (4)$$

The indicator variable, *I'*, is constructed based on matched pairs from the propensity score regression in equation (4), and the propensity score is based on finding pairs of census tracts that are close in population. Many propensity score matches will result in non-linearities – some matched control-experimental pairs will be close in population, others will be further apart. Including population (the variable Pop_i) in the regression in equation (3) provides additional control for this non-linearity. This illustrates one justification for adding regression control techniques even if the independent variables in the propensity score and outcome regressions do not differ. More generally, some experimentation is needed to examine the most appropriate combination of regression and quasi-experimental selection techniques.

We anticipate that a combination of regression and quasi-experimental techniques will be similar to the system of equations in (1) and (2), with the possibility that there are no independent variables that appear in only one equation. In such a circumstance, the choice of variables for equation (1) will be the variables shown in Table 4. In such cases, the analysis should be alert to possible co-linearity between the independent variables in an outcome regression and a control-experimental indicator variable based on the same set of variables. Yet non-linear responses are one reason why such co-linearities might not be a major issue, and why a full regression analysis, combined with quasi-experimental techniques, would be preferred.

9. Using This Analytical Tool to Provide More Certainty in Infrastructure Planning

As stated at the outset, such analysis is becoming more important as California undertakes a new round of infrastructure projects, especially in the transportation arena. Caltrans in particular will be under pressure to maximize every project's benefit to a community while simultaneously minimizing its impact, and also delivery projects in a more timely fashion. Californians will want "bang for the buck" on new transportation projects, and they will want that "bang" now.

As Caltrans' recent Guidance on growth-inducing and indirect impacts suggests, the agency must devise standardized methodologies that can assess the economic and social impact of projects in an accurate and timely manner. The purpose of this report has been to assist in this effort by outlining a new statistical model that will more accurately assess the social and economic impacts of infrastructure projects.

This model can provide better information at the infrastructure planning stage – helping to maximize an infrastructure projects' economic value. Because it will be an "off-the-shelf" model, the model can be run on specific infrastructure projects relatively quickly and cheaply. And because the model can assess the impacts of alternative scenarios, it can easily be plugged into a CEQA or NEPA analysis.

Operation of this model would require – as a CEQA or NEPA analysis does – the construction of several alternative scenarios. The scenarios could include a "no-project" alternative (retaining the status quo); different versions of the proposed project; and alternative locations for the project. This last possibility also creates the opportunity for Caltrans and the California Transportation Commission to model the potential benefit and impact of different projects.

Highway 99 Projects

For example, Proposition 1B set aside $1 billion for projects to improve Highway 99 in the Central Valley. In December 2006, the California Transportation Commission approved guidelines for distribution of these bond proceeds. (http://www.catc.ca.gov/SR99_Bond_Guidelines_adopted_12-13-06.pdf.) These guidelines had very broad requirements, including a geographical split (95% of the funds for the San Joaquin Valley and 15% for the Sacramento Valley) and, in the case of the San Joaquin Valley, adherence to the Route 99 Business Plan, a stakeholder plan. The Route 99 Business Plan gave priority to upgrading four-lane stretches of the road to freeway status, as opposed to, for example, capacity expansion projects.

In March of 2007, the CTC allocated all $1 billion in Proposition 99, selecting six projects in the Sacramento Valley ($147 million) and eight projects in the San Joaquin Valley ($828 million). In making the San Joaquin Valley the San Joaquin Valley selections, the CTC chose several projects from Tulare up to Merced counties that widened the highway from four to six lanes and declined to fund a proposal from Kern County to expand a stretch of the highway in Bakersfield from six to eight lanes.

In the case of the various Highway 99 projects seeking funding from the Proposition 1B proceeds, the model could have be used to expand the criteria list used to determine the distribution of funds. The funding decision was made on the basis of safety and congestion measures, the latter of importance because of congestion's degrading impact on air quality. Had the model been available, the list of criteria could have been expanded to include growth-inducing impacts as well. Various configurations (e.g. different distances between access points included in the conversion of an expressway stretch to freeway status) might have been compared to each other and to comparable historic situations along the same highway.

The Merced County portions slated for upgrade to freeway status run through exclusively agricultural areas. The closest urban development is nearly 1.5 miles from the northern terminus at McHenry Road. Similarly, the stretch from Goshen to Kingsburg, which straddles the Fresno and Tulare County line and is proposed to be expanded from four to six lanes, runs through an area which is strictly agricultural except for the rural community of Traver, which had fewer than 1,000 residents in 2000. In each instance, comparisons could be made to control areas and to other stretches of Highway 99 in the San Joaquin Valley which abutted largely rural lands prior to construction of the same kinds of improvements but where land use has since converted to urban uses. The purpose would be to determine:

1. Whether the proposed improvements could be expected to induce farmland conversion to urban development,

2. What pattern any induced development would be expected to take, and

3. How quickly the conversion from rural to urban uses might be expected to proceed.

The output from this model might be combined with a transportation model to assess how travel demand would be affected under various scenarios, an air quality model to determine how each scenario would be expected to affect air quality, with a watershed model to determine how demand for water might be affected. It could also be used in input-output or other econometric models to determine how the structure of the regional economy might be expected to change.

710 Freeway Alternatives

Similarly, the model could be used to compare dramatically different *types* of proposed infrastructure projects that could be used to deal with the same infrastructure problem. For example, the state is now moving forward – after a 40-year delay – with the “gap closure” for the 710 Freeway in South Pasadena. Because this gap closure would require demolition of many buildings in an historic neighborhood in South Pasadena, several alternatives have been proposed, including a tunnel and a “multi-modal low-build” alternative that would improve a variety of transportation components without building a freeway.

Both these alternatives are being examined for their technical feasibility, their cost, and their impact on transportation. However, this model could be used to assess the social and economic impact of such alternatives. As gap closures and freeway expansions in congested urban areas become more prevalent, such analysis will become far more important.

Next Steps

This paper has laid out the methodology for a model that can effectively assess the social and economic impact of a proposed infrastructure project. This methodology can be used for many different purposes, including generating information for the CEQA/NEPA analysis, ranking different infrastructure projects, and comparing the impacts of different alternatives to deal with the same infrastructure problem. The methodology responds to an urgent need, especially in infrastructure planning, by creating a relatively simple analytical tool that can be used quickly and easily.

The next step would be to apply this methodology to an actual infrastructure project proposal as a kind of a “beta test”. This methodology could be applied to any infrastructure project but it is probably best suited to a highway project. Given the large amount of funding available for highway projects in California currently, the Keston Institute should undertake a “beta test” of the methodology on a pending infrastructure project proposal, or else partner with Caltrans or another transportation infrastructure agency to undertake the task.

Once the methodology has been beta-tested, the Keston Institute should work collaboratively with infrastructure agencies, especially Caltrans and the U.S. Department of Transportation, to introduce the methodology into decision-making processes and environmental review processes throughout California.