USING I-O ANALYSIS AND CGE MODELING
TO ESTIMATE INFRASTRUCTURE DEMAND IN HAWAII

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Karl Kim, Ph.D.
Professor of Urban & Regional Planning

Denise Eby Konan, Ph.D.
Professor of Economics

University of Hawaii at Manoa
2424 Maile Way, Honolulu, HI. 96822
U.S.A.

The purpose of this paper is demonstrate how input-output data and techniques of regional analysis can be used to estimate direct and indirect demand for urban infrastructure (water, wastewater, electricity, propane, solid waste, etc.). Using a CGE model, alternative scenarios for population growth and visitor spending in Hawaii are evaluated in terms of the impact on infrastructure services. The focus of the analysis is on the quantification of infrastructure demand as a proxy for stress on the environment induced by changes in population and economic structure. The methods and tools not only demonstrate the compatibility and versatility of input-output analysis and CGE models, but also the paper serves to illustrate the interrelationships between the economy and the environment, important elements of the debate on "sustainable development." The potential contributions of this research are in terms of both better understanding of the data and methods as well as helping to frame important policy choices involving growth, development, and tourism.

INTRODUCTION

While Hawaii conjures images of white sandy beaches and swaying palm trees, it is also a place well suited for the development and testing of economic models. Due in part to its geographic isolation, its centralized system of government consisting entirely of one state and four counties, and the availability of comprehensive economic data, Hawaii provides an interesting location for the application of the methods of regional analysis. After describing the data and methods, four different scenarios involving different levels of population growth and visitor spending over a thirty year period are developed as way of comparing baseline (existing) conditions to possible alternative futures. In order to better understand the nature and level of infrastructure demand, input-output methods are used to characterize both industrial use of infrastructure services as well as total demand for infrastructure services by visitors and residents. Then, using a CGE model, the estimated levels of infrastructure demand for each of the four scenarios are estimated. Using a comparison against baseline levels, critical points in time at which infrastructure demand exceeds current levels demanded are identified. These "trigger points" signal the need for more planning, financing, and delivery of crucial environmental services. In a concluding section, the results are summarized and the implications for policy are described.

Hawaii is known not just for tourism, but also for the natural and cultural assets which are attractive to visitors. Yet it is tourism and the growth of the visitor industry as well as the economic activity and development associated with it that is perceived to threaten the quality of the environment. Table 1, Overview of the Economy, demonstrates the extent to which tourism dominates the economy. With a population of approximately 1.2 million, the labor force amounts to just over 594,700 persons. The job count, including part time and self-employed positions amounts to 742,200 jobs. Visitor expenditures amount to over $10.9 billion, annually. Notably, household spending ($24.96 billion), exceeds visitor spending by more than two times. Wage and salary income amounts to $21.6 billion, while proprietors' income is just over $2 billion, annually. Visitor spending amounts to approximately 28% of the total gross state product which amounted to $38.5 billion (excluding inter-industry demand and imports).

More details are presented in Table 2, Structure of Hawaii's Economy. This represents a 13 sector aggregation of economic activity. A more disaggregated view of economic activity will be presented later in the paper. In terms of total output, Hawaii's economy is dominated by three sectors – services (25.8%), accommodations (21.2%), and government (14.6%). Services include finance, insurance, health care, education, and other business activities. The accommodation sector includes not just hotels, but also time share, condominium, and apartment rentals. Government activity includes not just local, state, and federal government, but also military spending which is significant in Hawaii. Several other sectors emerge as significant components of the economy. Retail and wholesale trade combined amounts to 10.7% of total output, while construction spending totals to approximately 6%. Restaurants account for 3.9% of total output in Hawaii. Combined manufacturing activities (primarily food, agricultural products, clothing, and others) amounts to 5.8% of output. Transportation (6%), particularly air transport (3.5%), are also sizeable components of the economy as are utilities (2.9%). Agriculture, which once dominated the state's economy, today amounts to only 1.4% of output. Entertainment and golf comprise about 1.8% of total output.

The preceding discussion on Hawaii's economy serves to frame some of the key policy choices and concerns facing the state. It is clear that the state's economy is dominated by the visitor industry, which along side federal government spending represent the major sources of external income. Much of Hawaii's economy is also built around the provision of goods and services to residents, who comprise the bulk of the workforce. Wage and salary income provides the lion's share (86.6%) of household spending. While visitor spending is a key component to the state's economic vitality, there are questions regarding the impact of additional growth on the quality of life, the quality of the visitor experience, and the quality of the environment. One approach to ascertaining quality of the environment involves the examination and measurement of the demand for infrastructure services – water, wastewater, energy, solid waste, and fossil fuel use. Increases in the level of demand suggest both additional pressures on the environment as well as a need for added capital investment in infrastructure services. While other measurements and perceptions of environmental quality are important, and, while various approaches such as surveying the attitudes of residents and tourists have been undertaken both in Hawaii and elsewhere, the principal thrust of this paper is centered on the measurement and quantification of the demand for infrastructure as it relates to changes in the structure of economy and population base. Three general policy questions, to which this analysis is focused on, arise:

1) How is the demand for infrastructure services related to the structure of Hawaii's economy?
2) How is future demand for infrastructure services related to changes in the population and economy?
3) What are the policy implications arising out of alternative scenarios of population growth and visitor spending in Hawaii?

DATA AND METHODS

The principal source of data used in this paper comes from Hawaii's Input-Output (I-O) Table (1). The I-O Table provides information on the interactions between industries and final users (households, visitors, government, and exports). Largely based on the Census of Business which is conducted every 5 years, the full I-O table has detailed information on 131 different sectors and includes data on the compensation of employees, proprietors' income, indirect business taxes, and other capital costs. Final demand sectors include not just households and visitors, but also government. The 1997 data includes an updated system of industrial classification codes. Previously, SIC (Standard Industrial Classification) codes were used. The new classification system, the North American Industry Classification (NAICS), allows for the analysis of additional industries such as sightseeing. It also groups related industries – those that share the same production processes or functions together.

The I-O Table used in this analysis has been aggregated to 40 sectors. It includes key sectors related to tourism, such as hotels, restaurants, amusements, museums, transportation, trade, auto rental, as well as sectors which generate stress on the environment, including agriculture, construction, manufacturing, as well as those sectors providing electrical, sewer, water, natural gas, and other services. In addition to using economic data contained in the I-O Table, information on quantities demanded for key infrastructure services was collected or derived from additional sources. Water and sewerage use by sector was collected from the county water departments. Information on water from private wells was also collected from the State Department of Land and Natural Resources. Similar information on quantities of energy and fossil fuel use by various economic sectors were obtained from other published reports and studies done by the Energy Resources and Technology Division of the Department of Business, Economic Development, and Tourism. (2) Solid waste quantities were derived based on estimates that were developed by the California Integrated Waste Management Board, then adjusted based on information received from the Hawaii Department of Health, Office of Solid Waste Management. The estimated quantities for the various infrastructure services were then allocated to each of the sectors based on levels of spending as reported in the I-O Table.

Standard techniques were used to estimate the infrastructure demand by various industries and by households and visitors (final demanders). More detailed explanation of these methods can be found in standard texts (3, 4). The total estimated infrastructure demand (D_i) can be expressed as follows:

$$D_i = \sum_{k=1}^{n} d_{ik} + \sum_{y} d_{iy} \qquad (1)$$

where

i = type of infrastructure
d_{ik} = demand for infrastructure type i by the k^{th} industry sector
d_{iy} = demand for infrastructure type i by the final demand sector, y = residents, visitors, government etc.
n = number of industry sectors

A three step process is used to estimate the infrastructure demand. First, the direct infrastructure demand for each industry sector (ρ_{ik}), equivalent to the amount of a particular type of infrastructure required by each industry sector to deliver one dollar's worth of its output is estimated:

$$\rho_{ik} = \frac{d_{ik}}{x_k} \qquad (2)$$

where

x_k = total output of industry sector k.

Second, the "total requirements matrix" or the Leontief inverse $(I\text{-}A)^{-1}{}_{kj}$, a derivation of the 1997 I-O table, is estimated. Each column in the total requirements matrix represents the direct and indirect impact on the row industry sectors of a $1 change in the column sector's final demand. With 131 industrial sectors, this comprises a 131 × 131 matrix. Multiplying the direct infrastructure intensity and the total requirements matrix produces the "total infrastructure requirements" for each industry sector (t_{ij}), which shows the total amount of infrastructure required *directly and indirectly* by each industry sector to deliver one dollar's worth of its output. The total infrastructure needed for each industry sector t_{ij} can therefore be calculated as:

$$t_{ij} = \rho_{ik} (I - A)^{-1}{}_{kj} \qquad (3)$$

where $(I\text{-}A)^{-1}{}_{kj}$ = total requirements matrix or Leontief inverse, which represents the direct and indirect impacts on sector k by $1 change in final demand of sector j.

The third component needed to estimate infrastructure demand are the expenditures by households and the expenditures by visitors. By multiplying the total infrastructure requirements with households and visitor expenditures, the indirect infrastructure requirements by residents and visitors, respectively, are estimated. Indirect infrastructure requirements by residents or visitors (p_i) can be calculated as:

$$p_i = \rho_{ik}(I - A)^{-1}{}_{kj}\, y_j \qquad (4)$$

where y_j = household or visitor expenditures in sector j. The sum of the indirect infrastructure requirements by all the final demand sectors is equal to the total direct infrastructure requirements by all the industry sectors.

Based on this method, estimates for water, sewer, electricity, propane, and solid waste disposal are derived. This approach allows for both the estimate of overall aggregate levels of demand for infrastructure as well as estimates of per capita, per day levels. While this is useful in terms of examining the interrelationships between industrial structure and infrastructure demand, it is necessary to apply more sophisticated modeling techniques to assess the long range interactions between population growth, industrial structure, visitor spending, and infrastructure demand.

Using the same I-O data, a Computable General Equilibrium CGE Model is developed. The approach assumes that standard equilibrium conditions are satisfied such as supply equals demand for all goods and services and that while profits can accrue in each industry, expenditures by each agent must equal income and the economy, overall, is in balance. Final output (Y_i) in sector i is produced according to a Leontief function (zero elasticity of substitution) using intermediate inputs (Z_{ji}, where $j = 1, .., n$) and real value added (V_i). Sectors i include each of the infrastructure sectors (water, electricity, solid waste, propane, etc.) as well as the key sectors in the economy (agriculture, construction, manufacturing, hotels, restaurants, trade services, utilities, trade, etc.).

$$Y_i = \min\left[Z_{1i}/a_{1i}, Z_{2i}/a_{2i}, Z_{3i}/a_{3i}, \ldots Z_{ni}/a_{ni}, V_i/a_{Vi}\right] \quad (5)$$

A sub-production function specifies the substitutability between labor (L_i), capital (K_i), proprietor income (R_i), intermediate imports (M_{Yi}), and other value added (OV_i) in producing real value added (V_i) in each sector i, where σ_i is the constant elasticity of substitution (CES) among value added variables.

$$V_i = \left[a_{Li}L_i^{(\sigma_i-1)/\sigma_i} + a_{Ki}K_i^{(\sigma_i-1)/\sigma_i} + a_{Ri}R_i^{(\sigma_i-1)/\sigma_i} + a_{Mi}M_{Yi}^{(\sigma_i-1)/\sigma_i} + a_{OVi}OV_i^{(\sigma_i-1)/\sigma_i}\right]^{\sigma_i(\sigma_i-1)} \quad (6)$$

Constant returns to scale and perfect competition ensure that the producer price (p_i) equals the marginal cost of output in each sector. Total output equals producer costs, where $p_L, p_K, p_R, p_{MY},$ and p_{OV} equal the market price of labor, capital, proprietor income, intermediate imports, and other value added, respectively.

$$p_iY_i = \sum_j p_jZ_{ij} + p_LL_i + p_KK_i + p_RR_i + p_{MY}M_{Yi} + p_{OV}OV_i \qquad (7)$$

Factors are assumed to be mobile across sectors, but fixed in total supply, with endowments $\overline{L}$, $\overline{K}$, $\overline{R}$, $\overline{M}$, $\overline{OV}$. Given the competitive nature of the model, all factors will be fully employed in equilibrium. The following market clearing conditions hold in the factors markets:

$$\overline{L} = \sum_i L_i,\ \ \overline{K} = \sum_i K_i,\ \ \overline{R} = \sum_i R_i,\ \ \overline{M} = \sum_i M_{Yi},\ \ \overline{OV} = \sum_i OV_i. \quad (8)$$

Expenditures are assumed to be equal to income as investment decisions are held fixed. Residents receive income from primary factors as well as inflows from non-resident expenditures. The expenditures of non-residents such as visitors, federal government and exports) are assumed to be exogenously determined. Each agent is modeled as a representative consumer who maximizes utility (U_h) subject to a budget constraint. Income elasticities are set at unity as given by a Cobb-Douglas utility function. A constant share of income is spent on each commodity, where $C_{h,i}$ is the consumption of commodity k by household h.

$$U_h = \prod_i C_{h,k}{}^{bk},\ \sum_k b_k = 1 \qquad (9)$$

The visitor industry is treated similarly, with expenditures being derived by a Cobb-Douglas utility function. If visitor spending were to increase, the demand for tourism related goods and services would increase, putting upward pressure on prices in those sectors especially favored by visitors. Given the fixed supply of factors, the expansion of tourism-related services will lead to fall in the output of other sectors. The prices of factors which are relatively intensive in the industries that expand will increase on average, reflecting the increase in demand for their services. The model represents a classic Walrasian system. Changes in parameters of the system induce an optimal response on the part of producers and consumers resulting in a new set of market-clearing equilibrium prices. The model is estimated using GAMS (General Algebraic Modeling Systems) software and the MPSGE sub-system (5, 6).

The approach entails comparing baseline macroeconomic conditions as well as prices and quantities demanded for key infrastructure services under alternative scenarios of population growth and visitor spending. Using the CGE Model, the future demand for key infrastructure services is also simulated.

POPULATION GROWTH AND VISITOR SPENDING SCENARIOS

In order to model the effects of alternative levels of population growth and visitor spending, four different scenarios were formulated:

1) VLPL = low visitor spending, low population growth;
2) VLPH = low visitor spending, high population growth;
3) VHPL = high visitor spending, low population growth;
4) VHPH = high visitor spending, high population growth.

In the first two scenarios (VLPL and VLPH), visitor spending is kept low, but population varies between assumptions of either low or high growth. In the third and fourth scenarios (VHPL and VHPH), high levels of visitor spending occur along with both low and high levels of population growth. In order to base these scenarios on realistic levels of population growth and visitor spending independent projections of population, tourism, and economic growth were developed (7). A sequential process was used to derive visitor spending levels. Visitor arrivals were first estimated on the basis of variables such as the GDP of the origin country, the relative cost of a Hawaii vacation, exchange rates, and supply constraint factors such as the occupancy rate. The length of stay was then determined based on ARIMA models that assumed that deviations from recent average length of stay are transitory. Visitor spending was based on the application of per person per day level of spending, broken into two categories - lodging and all other expenditures. Population and labor force projections were made using a methodology that linked demographic changes to Hawaii's economic performance relative to the U.S. as a whole. The model employed a variation of the standard cohort-component technique in which the size of each cohort declines due to mortality and either increases or decreases due to net migration. The technique used base year populations and forecast values of age-specific fertility rates, survival rates, and migration rates.

Using a 30 year time horizon, and assuming constant rates of labor force participation, the labor force is projected to grow from the current (baseline) levels of 594.7 thousand to 690.4 thousand (under the low growth scenario) and to 743.9 thousand (under the high growth scenario). Under the low projection, the labor force is estimated to grow to 690,424 persons by 2030, while under the high projection, the labor force is projected to grow to 743,888 persons. It should be noted that the projections for growth in Hawaii are somewhat restrained. The difference between the low and high projection for the labor force in 2030 is only 53,464 persons. Even under the highest growth scenarios, the total labor force will remain below 750,000 persons and the state's total population will remain below 1.5 million persons in 2030. This relatively low level of overall growth matches expectations and seems to be consistent with state and county development plans. The potential variance in visitor spending projections, however, is much larger. Annual visitor spending is estimated to grow from the baseline level of $10.9 billion to $23.9 billion under the low growth scenario and to $34.5 billion under high growth scenario.

BASELINE CONDITIONS

In this section, the estimated levels of infrastructure demand by the key industrial sectors and also by households and tourists are analyzed using traditional input-output techniques. Understanding infrastructure demand by industries is important for two different reasons. First, industries need basic infrastructure services in order to produce their various goods and services. Second, in order to account for the demand for infrastructure among certain final demanders, such as visitors, it is necessary to consider both direct and indirect demand. Table 3, Output and Infrastructure Demand by Sector, contains a summary of output and expenditures by households and visitors on 40 sectors. The table also summarizes estimates of the demand for water, sewer, electricity, propane, solid waste disposal, and fossil fuel for these 40 industrial sectors in Hawaii. The largest users of water on an annual basis include hotels (4.4 billion gallons), real estate rental (4.2 billion gallons), restaurants (3.1 billion gallons), electric companies (3.6 billion gallons), and of course, agriculture - crops (12.8 billion gallons). Notably, industries consume approximately 40.2 billion gallons of water per year. Of this, approximately 21.9 billion gallons ends up as wastewater. The key sectors in terms of wastewater generation include hotels, real estate rental, restaurants, and other large water users.

The largest sectors in terms of direct electricity use include retail trade (1,136 GWh), hotels (897 GWh), petroleum manufacturing (422.6 GWh), real estate rental (378.1 GWh), restarents (340.1 GWh), food processing (331.1 GWh), other services (320 GWh), and water/sewer services (302.6 GWh). Retail trade accounts for more than one-fifth of total electrical demand by industries in the state. Propane has a distinctly different distribution. The bulk of propane gas use is concentrated in two sectors, hotels and restaurants. Other large users include health services, retail trade, and government. The industries which generate the most solid waste in Hawaii include restaurants, construction, professional services, health services, and retail trade. A total of 1.49 billion pounds or more than 744,000 tons of solid waste is generated each year by industries in Hawaii. The significant sectors in terms of fossil fuel use (limited in this analysis to highway gasoline and diesel fuel), include sightseeing transportation (10.9 million gallons), trade (12.8 million gallons), construction and mining (4.5 million gallons), rental car companies (5.4 million gallons), trucking (3.9 million gallons), and other ground transportation (4.2 million gallons).

Demand for Infrastructure: Residents and Visitors

One of the most powerful uses of input-output techniques is for the estimation of direct and indirect demand by final demanders. This is particularly useful for comparing the environmental impacts of tourists and others who may be purchasing infrastructure services indirectly. Table 4, Direct and Indirect Infrastructure Demand contains the baseline estimates of direct and indirect demand for water, sewer, electricity, propane, and solid waste disposal services by both residents and visitors. In all categories of infrastructure service, with the exception of propane gas, the direct demand by residents far surpasses the total indirect demand for these services by visitors. As noted earlier, residents directly consume these infrastructure services while visitors consume them indirectly through the purchase of other goods and services, such as hotel rooms or restaurant meals. Residents purchase approximately 43.3 billion gallons of water directly compared to only 11.9 billion gallons purchased indirectly by visitors. If the indirect demand for water by residents is added to their direct demand, the total demand for water is approximately 61.4 billion gallons per year. In aggregate, residents use approximately 5.2 times more water per year than visitors. Similarly, residents generate an estimated 33.6 billion gallons of wastewater compared to 8 billion gallons by visitors, more than a four fold difference. While the direct use of electricity by residents is about 2,665 gigawatts, compared to 1,944 gigawatts (indirectly) consumed by visitors, the total use by residents, including indirect demand is 5,253 gigawatts. In other words, residents consume 2.7 times the total amount of electricity consumed by visitors. Visitors, however, consume, in the aggregate, more propane than residents (1,521,257 mmBtu versus 1,287,940 mmBtu). Yet in terms of solid waste disposal, resident generate far more (2,423,229,185 lbs) than visitors (421,326,645 lbs). According to these estimates, residents generate 5.75 times more waste annually than do the visitors coming to Hawaii. Similarly, the level of direct demand for highway fuel by residents, on an annual basis, amount to more than 322.7 million gallons compared to 21.6 million gallons, annually, for tourists. Residents directly consume almost 15 times the amount of highway fuel than that consumed by tourists. While tourist purchases on a per capita, per day basis are much higher than residents, so the indirect demand for fuel by tourists is higher, the overall aggregate annual demand (direct and indirect) is much higher for residents than tourists.

Another way of examining the demand for infrastructure services is estimate the per day levels, accounting for both the population size and the number of visitors (see Table 5, Per Capita Infrastructure Demand, 1997). On a per day basis, residents use approximately 138.9 gallons (accounting for both direct and indirect demand). Visitors, however, use much more water, approximately 206.7 gallons per day (based on indirect demand only). Similarly, the amounts of waste water generated on a per capita, per day basis are much higher for visitors (139.8 gallons) than for residents (75.9 gallons). Electricity use by visitors is also much higher than for residents (33.9 KWh versus 11.9KWh). Visitors, however, use on a daily basis about nine times the amount of propane that residents use. The table also contains data on per capita solid waste generation. Visitors generate 7.3 pounds of solid waste per day compared to residents who generate 5.5 pounds per day. Residents consume more fuel per capita than tourists. The per capita, per day use of highway fuel by residents amounts to .73 gallons, compared to .38 gallons per day by tourists. But because their spending is higher, the total per capita, per day fuel consumption by tourists is higher than for residents (.91 versus .80 gallons per day).

FUTURE DEMAND FOR INFRASTRUCTURE

One of the advantages of CGE modeling is the ability to specify not just prices responses, but also to simulate the demand for various goods and services in terms of quantities. In this section, the quantities demanded for key infrastructure services (water, electricity, utility gas, solid waste disposal, and petroleum) are estimated according to the four different scenarios.

Table 6, Infrastructure Demand in Quantities has been prepared to summarize the key results of the simulations. The table contains quantities for 1997 (baseline) and for 2010, 2020, and 2030. There are two approaches to analyzing these results. First, it is instructive to look at each scenario and compare the simulated changes in demand over time to the baseline conditions. Second it is useful to compare each of the four scenarios in terms of the differences in infrastructure demand over time.

Low Visitor Spending, Low Population Growth. The baseline (1997) demand for water is approximately 100.3 billion gallons. This grows to 104.7 billion gallons in 2010, 141.8 billion gallons in 2020, and 268.5 billion gallons in 2030. The demand for electricity shows a similar pattern of increase, growing from 10,009 GWh in 1997 to 26,772 GWh in 2030. Propane increases from 3,706,735 mBtu to 7,155,616 mmBtu in 2030. The increase in solid waste generation grows from 3,198 million pounds in 1997 to over 4,656 pounds in 2030. The demand for petroleum increases from 2.0 billion gallons in 1997 to 5.4 billion gallons in 2030.

Low Visitor Spending, High Population Growth. With higher levels of population growth, the demand for infrastructure is notably higher. The demand for water grows from 100.4 billion gallons in 1997 (baseline) to 117.6 billion gallons in 2010, to 227.8 billion gallons in 2020, to 663.8 billion gallons in 2030. The increase in demand for electricity is also more significant, growing from 10,009 GWh in 1997 to 62,526 GWh in 2030. Propane demand increases to 10,192,741 mmBtu in 2030, while solid waste generation grows to 6,501 million pounds in 2030. The demand for petroleum also climbs to 11,931.9 million gallons.

High Visitor Spending, Low Population Growth. In this scenario, the increase in the demand for infrastructure is characterized by less of an increase than the high population growth scenario. Demand for water grows to 285 billion gallons in 2030. Electricity demand is at 30,540 GWh in 2030. In 2030, propane demand is at 7,318,191 mmBtu, while solid waste generation is at 4,677.5 million pounds. Petroleum demand in 2030 grows to 7.3 billion gallons per year.

High Visitor Spending, High Population Growth. This scenario produces the greatest demand for infrastructure services. Demand for water grows to 669 billion gallons in 2030. Electricity demand rises to 63,815 GWh and propane use jumps to 10,817,440 mmBtu in 2030. Solid waste generation grows to 6,594 million pounds per year in 2030. In that year, petroleum demand is expected to rise to 12.5 billion gallons per year.

In examining these four scenarios, low visitor spending combined with low population growth generates the least demand for new infrastructure, while the high visitor spending combined with high population growth generates the highest demands for infrastructure. The impact of population growth is much more significant than visitor spending as the low visitor spending, high population growth scenario generates much more demand across all forms of infrastructure than the high visitor spending, low population growth scenario.

Another way of using the information generated by the CGE model is to conduct an analysis of key points in time when the demand for infrastructure increases. These points in time may trigger the need for additional planning, investment and implementation of new infrastructure services. This type of "demand based" analysis can help to identify when levels of demand reach "critical" levels. The advantage of the CGE model is that in addition to generating annual projections of infrastructure demand, the effects of the difference scenarios with respect to visitor spending and population growth can be modeled. Using the CGE model, estimates of annual quantities for infrastructure services have been developed. They are expressed both in terms of quantities demanded as well as the in terms of the percentage change in quantities over the baseline year (Table 7). Then, three types of "trigger points" were devised. The first trigger point represents an indication of recovery from the recession and the recent downturns in Hawaii's economy. This point is identified by the year in which the demand changes from negative to positive levels. For illustrative purposes this trigger has been coded as a "yellow" condition. A second trigger involves identifying the point in time, when the level of demand increases to 25% over the baseline (1997) levels. Based on other studies which assessed infrastructure capacity, it can be assumed that none of the infrastructure services – water, electricity, solid waste disposal, currently have surplus capacities in excess of 25%. Therefore, this condition, that is when the demand exceeds 25% of the baseline has been designated as a "amber" condition. The "red" condition occurs when infrastructure demand reaches 50% of the total baseline condition. This would represent a particularly serious condition. The appendix contains the complete year to year analysis for the four different scenarios.

Low Visitor Spending, Low Population Growth. This scenario will produce "yellow" conditions for water and solid waste in 2007, and "yellow" conditions for electricity, propane, and petroleum in 2004. The "amber" condition is reached first by petroleum in 2013, followed by electricity in 2017. Water reaches "amber in 2019, while the "amber" trigger point is reached for propane in 2021. The "amber" condition is reached for solid waste in 2027. The "red" trigger point (50% increase over the baseline) is reached for petroleum demand in 2025, while electricity reaches the "red" condition in 2026. Water demand reaches this critical "red" trigger at 2027. Notably, under this scenario, the increase in propane and solid waste demand never grows to more than 50% of the baseline condition.

Low Visitor Spending, High Population Growth. With this scenario, the "yellow" conditions (change from negative to positive demand) occurs much sooner than in the first scenario. Water reaches this level in 2005, while electricity and solid waste reach this 2004, and propane and petroleum demand reaches the "yellow" condition as early as 2003. The "amber" condition is reached in 2012 for petroleum demand, in 2013 for both water and electricity. The "amber" condition for propane occurs in 2014 and then in 2019 for solid waste disposal services. The "red" trigger is increased in 2019 for water and electricity services. Petroleum reaches the red condition in 2020, while this trigger is reached for propane in 2024 and 2030 for solid waste. With this scenario, the trigger points are reached much sooner than in the low population growth scenario.

High Visitor Spending, Low Population Growth. In this scenario, water demand reaches the "yellow" trigger in 2006. The "yellow" condition occurs for electricity and propane in 2004, while solid waste reaches this condition in 2008. The "yellow" trigger occurs in 2003 for petroleum demand. The "amber" condition is reached first by petroleum demand in 2008. This condition is reached by electricity in 2014, by water demand in 2017, by propane demand in 2022, and solid waste disposal demand in 2027. The "red" trigger is not reached for either propane or solid waste disposal services, but it is reached for petroleum (2016), electricity (2024), and water (2026).

High Visitor Spending, High Population Growth. Under this scenario, the demand for infrastructure services reaches the "trigger" points much earlier in time than in any of the other scenarios. The "yellow" condition has been reached for electricity, propane, and petroleum in 2003, while it is reached for water and solid waste in 2004. "Amber" conditions occur in 2009 for petroleum demand, 2011 for electricity demand, 2013 for water demand, 2014 for propane, and 2019 for solid waste disposal. The "red" trigger is reached in 2018 for electricity and petroleum, 2019 for water demand, 2023 for propane, and 2030 for solid waste disposal service.

A consistent pattern that has been reported earlier emerges. Population growth rather than visitor spending is the key determinant for both demand and when the critical "triggers" will occur. The low population growth, low visitor spending scenario delays the occurrence of triggers while the high population, high visitor spending scenario accelerates their occurrence. Demand for petroleum, electricity, water tends to reach critical levels first, while the demand for propane and solid waste services reaches critical levels further out in time. Under the high growth scenarios, there are pressing needs ("amber" level) for petroleum, water, electricity within the next decade. Under the low growth scenarios, the demand for these services reach the "amber" level in 15 to 20 years.

Some of the services (water, electricity, and solid waste) involve local or statewide resources produced in Hawaii. While other types of demand (propane and petroleum) will be met by imports. Each of the services is quite different in terms of its production requirements. Both water and solid waste services require natural resources, while electricity involves importing fossil fuels.

POLICY IMPLICATIONS

One way of assessing the implications of these four different is by examining macroeconomic indicators associated with the four alternative scenarios. These are summarized in Table 8. Included are baseline conditions and macroeconomic indices for each of the four scenarios estimated for 2030.

The first two rows in the table contain both baseline and inputted levels of population growth and visitor spending according to the combinations of high and low levels used to define the four scenarios.

Gross state product both in terms of actual and real dollars is the greatest for the high population scenarios, reaching $368.5 billion for the high visitors spending, high population scenario and $354.1 billion for the low visitor spending, high population scenario.

The consumer price index is a measure of inflation for both residents and visitors. Notably, under high visitor expenditure, low population growth scenario, the consumer price index is the highest (174.7), but with high visitor spending and high population growth, the index drops to 142.7. The lowest consumer price index occurs with low visitor spending and low population growth (118.0). This would indicate that the worst case for Hawaii consumers is to have low population growth, but high visitor spending. On the other hand, if examining the welfare of visitors, the value for tourist occurs with low population growth and low visitor spending, when the projected visitor price index is 127.8. The worst case for visitors would occur with high visitor spending and low population growth.

It is interesting to note, that under all scenarios, household spending far outpaces that of visitor spending. The highest level of visitor spending occurs in 2030, approximately $34.5 billion. Household expenditures range between a low of $82.5 billion in (low visitor spending, low population growth) to a high of $213.6 billion (high visitor spending, high population growth). This shows the dominance of resident spending as a key component of Hawaii's economy. Even under the most optimistic scenario in terms of visitor spending, it is far below the level of economic impact associated with households in Hawaii.

Table 8 also shows the changes in wages and salary income according to the four different scenarios. Under the low visitor spending, low population growth scenario, wage and salary incomes grows from $21.6 billion in the baseline to $58.2 billion under the low visitor spending, low population growth scenario. Under the high visitor spending, high growth scenario, wage and salary incomes grow to $144.6 billion. The per capita wages figures show that the increases are the greatest under the scenarios of high visitor spending and high population growth. Low population growth appears to have the effect of keeping wages down, especially with low visitor spending. Proprietors fare best in terms of conditions of high population growth and high visitor spending. In 2030, they earn more than $17.2 billion in income with high visitor spending and high population growth.

It is apparent that the strongest economic driver is population growth. While visitor spending is an important component of the economy, the difference between the high and low visitor spending with low population growth in terms of real gross state product is much smaller than the effects on gross state product of high versus low population growth. While the highest levels of economic growth occur with both increased population and increased visitor spending, more of this is due to population growth than due to visitor spending.

One of the overarching findings in this study is that in actuality, the economic activity and the resulting environmental consequences generated by residents is far greater than that of visitors. While many sectors are important to tourism, many of business activities in the state are really oriented towards providing goods and services to the resident population. While a sizeable share is directly employed in visitor-related businesses, the economy that it is needed to house, feed, educate, and care for a resident population in excess of one million persons is far greater and more complex than the economy needed to sustain the 100,000 or so visitors present in Hawaii on any given day.

While the per day, per person spending levels for residents is lower than that of visitors, the economic and environmental impacts of residents far outweighs that of visitors.

The share of imports purchased by visitors, moreover, is lower than the share of imports purchased by residents. Many of the goods and services purchased by visitors are "non-tradable." This means that are both produced and consumed within the state. Examples are hotel services, restaurant meals, automobile rental, sightseeing, entertainment and other visitor activities. Residents, on the other hand, make purchase of many goods produced outside the state, such as automobiles, clothing, appliances, and other "tradable" goods which are imported into the state.

Measures of welfare for different groups in society were estimated for the four different scenarios. A mixed bag of findings results. While low population growth with high levels of visitor spending creates high levels of inflation for residents, it also generates high levels of growth in wage and salary income. It also reduces welfare to visitors as the level and quality of service without growth in the labor force declines. Because so much of the economy is dependent not just on visitors spending money in the economy, there are also income benefits associated with high levels of population growth. Real per capita incomes are the highest with combined high visitor spending and high population growth. Gross state product is more a function of high population growth than visitor spending, especially in the long term. In the short term, an infusion of visitor spending does appear to promote higher levels of wage and salary income and per capita salaries and wages, but by 2030, it is the dynamics of population growth rather than visitor spending that matter most.

The analysis also demonstrates the extent to which the responses over time vary by industry. When visitor spending increases, there are certain obvious beneficiaries, such as hotels, air transportation, entertainment, etc. Yet, the growth in population benefits other industries – agriculture, rental housing, manufacturing, trade, and services. Given that so much of the state's economy is based on services to residents, there is a general pattern in which the high population growth scenarios produce similar levels of output for both high and low visitor spending levels in many industries.

There is value to the combination of input-output techniques and CGE modeling. On the one hand, the use of methods of regional analysis to examine direct and indirect demand magnifies the relationships between industrial structure and infrastructure demand and also brings into sharper focus the stresses on the environment generated by workers and residents as opposed to tourists and those directly involved in the visitor industry. This is an important starting point from which to begin the analysis of alternative scenarios of growth and development. CGE modeling, using the same database, provides a powerful tool for not just estimating new equilibriums but also prices and quantities associated with alternative scenarios. Examining the demand for critical infrastructure services over time can also be conveniently carried out with this methodology. These "triggers" can help to identify key points in time to initiate the planning, financing, and delivery of important public services. The ability to benchmark measures of economic welfare of these alternative scenarios against baseline conditions is also an added benefit of this approach.

While the deployment of both I-O techniques and CGE modeling was instructive, this exercise has also heightened the need for additional refinement, integration, model development, and calibration. While our published work to date has focused on more narrow research topics such as modeling the impact of changes in visitor spending on the transportation industry (8) and examining the relationship between fuel use and environmental quality (9), it is evident that these tools and methods are particularly valuable in the modeling of interactions between the economy, environment, and community. This analysis has shown that while visitors spend more and generate greater environmental impacts on a per capita, per day basis, it is the economic activity of residents in Hawaii that generates far more economic and environmental impact, both in the short and long term. The looming question remains unaddressed – if not tourism, then what will be Hawaii's source of external income? Future research will focus more closely on the relationships between the visitor industry and the workforce as well as more attention to managing the environmental, social, and cultural impacts of consumption.

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TABLES

Table 1. Overview of Economy

Population (thousands)	1,211.6
Labor Force (thousands)	594.7
Job Count (full-time & part-time & self-employed) (thousands)	742.2
Visitor Expenditures ($ million)	**10,931.0**
Household Expenditures ($ million)	**24,962.0**
Wage & Salary Income ($ million)	21,626.2
Proprietor's Income ($ million)	2,088.0
Gross State Product ($ million)	*38,537.0

Table 2. Structure of Economy

Industry	**Output ($m)**	**Output (%)**
Agriculture	823	1.4%
Construction	3,524	6.0%
Manufacturing	3,416	5.8%
Air Transportation	2,044	3.5%
Transportation	1,465	2.5%
Entertainment	844	1.4%
Golf	230	0.4%
Accommodations	12,496	21.2%
Restaurants	2,275	3.9%
Trade	6,312	10.7%
Services	15,181	25.8%
Utilities	1,691	2.9%
Government	8,566	14.6%
Total	58,868	100.0%

Table 3: Economic Activities and Infrastructure Demand in Hawaii, 1997

Industry	Output ($million)	Household expenditures ($million)	Visitor's expenditures ($million)	Water (1000 gallons)
Hotels	3,456.4	170.0	3,247.4	4,392,570
Real estate rental	9,019.3	5,211.4	239.7	4,220,882
Restaurants	2,274.7	1,017.1	1,126.2	3,102,155
Wholesale trade	1,939.0	686.6	190.3	517,582
Retail trade	4,179.5	2,311.7	1,087.7	-
Performing arts	155.6	62.2	31.1	206,573
Amusement	157.1	27.6	129.5	68,670
Recreation	150.7	63.7	84.7	155,794
Museums historical	77.2	38.5	38.6	83,844
Sightseeing transport	303.7	15.2	285.5	-
Golf courses	229.8	88.5	141.3	1,138,964
Air transportation	2,044.1	337.9	1,555.2	229,530
Trucking	279.0	98.0	18.3	86,716
Water transportation	522.8	133.1	116.2	44,838
Ground transportation	128.9	34.6	76.2	110,274
Automobile rental	393.3	32.5	314.8	571,348
Parking lots	109.4	77.2	10.4	149,095
Transit	110.0	30.9	0.4	-
Crops	393.9	56.2	15.8	12,834,240
Animal	212.0	41.8	1.3	1,357,286
Commercial fishing	69.7	24.0	1.4	20,806
Landscaping services	147.8			89,726
Construction	3,524.3			179,057
Food processing	1,054.5	419.5	52.3	511,660
Clothing	209.4	39.8	18.8	36,012
Chemical	73.9			32,839
Petroleum	1,419.3	187.8	208.4	1,312,188
Other manufacturing	659.4	35.9	16.6	138,806
Information	1,940.3	776.9	33.4	644,908
Professional services	6,578.0	2,047.2	72.3	942,443
Travel reservations	456.8	148.8	191.2	34,094
Education private	477.5	307.9	7.0	473,329
Health services	3,859.3	3,642.6	83.3	1,243,976
Laundry	97.7	60.0	12.7	160,881
Other services	1,771.5	848.7	39.9	858,924
Electricity	1,169.1	394.6		3,659,714
Waste management	190.4	5.7		156,405
Water sewer	280.3	182.2		76,365
Propane gas	51.2	12.8		859
Other government	8,565.8	264.9	45.6	401,106
Total	58,732.5	19,934.2	9,493.4	40,244,458

Industry	Output ($million)	Water (1000 gallons)	Sewer (1000 gallons)	Electricity (GWh)	Utility Gas (mmBtu)	Solid Waste Disposal (lbs)	Petroleum Products (gallons)
Hotels	3,456.4	4,392,570	3,514,056	897.0	1,149,900	76,755,614	20,256,411
Real estate rental	9,019.3	4,220,882	3,376,705	378.1	41,395	17,448,355	6,485,178
Restaurants	2,274.7	3,102,155	2,481,724	340.1	704,600	313,157,141	15,174,935
Wholesale trade	1,939.0	517,582	414,066	97.4	-	41,662,660	6,110,586
Retail trade	4,179.5	-	-	1,136.4	153,300	148,040,690	6,902,328
Performing arts	155.6	206,573	165,258	4.5	-	11,314,336	59,036
Amusement	157.1	68,670	54,936	30.2	-	4,559,176	216,423
Recreation	150.7	155,794	124,635	44.0	11,770	7,626,528	617,172
Museums historical	77.2	83,844	67,075	14.1	-	3,493,800	101,146
Sightseeing transport	303.7	-	-	8.6	3,874	12,994,737	11,038,970
Golf courses	229.8	1,138,964	911,171	67.4	-	6,432,468	303,438
Air transport	2,044.1	229,530	83,624	37.4	4,775	20,655,454	341,467,938
Trucking	279.0	86,716	69,373	15.7	3,198	11,932,766	4,005,986
Water transport	522.8	44,838	35,870	19.1	4,616	3,600,255	5,655,571
Ground transport	128.9	110,274	88,219	3.3	-	10,217,105	4,159,761
Automobile rental	393.3	571,348	457,078	7.0	-	1,593,937	5,368,765
Parking lots	109.4	149,095	119,276	14.8	-	2,759,326	253,367
Transit	110.0	-	-	3.3	-	3,819,400	3,746,232
Crops	393.9	12,834,240	-	35.7	-	17,402,579	3,355,449
Animal	212.0	1,357,286	1,085,829	36.3	-	,319,363	508,331
Commercial fishing	69.7	20,806	16,645	-	-	3,868,200	9,936,990
Landscaping services	147.8	89,726	71,781	0.4	-	8,563,307	72,340
Construction	3,524.3	179,057	43,246	50.8	-	199,200,245	21,326,053
Food processing	1,054.5	511,660	409,328	331.1	-	22,462,543	8,497,659
Clothing	209.4	36,012	28,810	12.7	-	6,547,007	192,643
Chemical	73.9	32,839	26,271	3.8	-	776,951	255,721
Petroleum	1,419.3	1,312,188	1,049,750	422.6	-	1,119,600	13,052,681
Other manufacturing	659.4	138,806	111,045	38.9	-	18,558,577	1,112,837
Information	1,940.3	644,908	515,927	38.7	-	37,706,260	3,785,018
Professional services	6,578.0	942,443	753,954	141.9	-	184,041,571	11,451,622
Travel reservations	456.8	34,094	27,275	20.2	-	24,037,723	2,626,668
Education private	477.5	473,329	378,664	28.4	-	22,993,012	1,844,186
Health services	3,859.3	1,243,976	995,181	267.3	191,900	157,420,335	13,043,881
Laundry	97.7	160,881	128,705	12.4	9,205	4,277,472	1,823,295
Other services	1,771.5	858,924	687,139	320.0	2,086	59,083,187	14,448,844
Electricity	1,169.1	3,659,714	2,927,771	6.8	-	1,466,728	542,713,054
Waste management	190.4	156,405	125,124	0.5	-	4,169,993	3,646,850
Water sewer	280.3	76,365	61,092	302.6	-	1,182,600	2,199,573
Natural gas	51.2	859	687	2.8	-	191,993	37,043,058
Other government	8,565.8	401,106	320,885	144.5	75,119	6,817,913	2,706,608
Total	58,732.5	40,244,458	21,928,174	5,337.0	2,355,737	1,488,270,906	1,127,566,601

Table 4: Direct and Indirect Infrastructure Demand, 1997

	Water (1000 gallons)	Sewer (1000 gallons)	Electricity (GWh)	Propane Gas (mmBtu)	Solid Waste Disposal (lbs)	Highway Gasoline & Diesel (Mgals)
Direct Use by Residents	43,299,259	22,953,795	2,665	559,900	1,709,974,458	322.7
Direct Use by Visitors	-	-	-	-		21.6
Indirect Use by Residents	18,130,692	10,633,929	2,588	728,040	713,254,728	31.0
Indirect Use by Visitors	11,856,771	8,022,264	1,944	1,521,257	421,326,645	30.4
Total Use by Residents	61,429,951	33,587,723	5,253	1,287,940	2,423,229,185	353.7
Total Use by Visitors	11,856,771	8,022,264	1,944	1,521,257	421,326,645	52.1

Table 5 : Per Capita Infrastructure Demand, 1997

	Water (gallons)	Sewer (gallons)	Electricity (KWh)	Propane Gas (mmBtu)	Solid Waste Disposal (lbs)	Highway Gasoline & Diesel (gal)
Direct Use per Resident Day	97.9	51.9	6.0	0.001	3.9	.73
Direct Use per Visitor Day	-	-	-	-	-	.38
Indirect Use per Resident Day	41.0	24.0	5.9	0.002	1.6	0.07
Indirect Use per Visitor Day	206.7	139.8	33.9	0.027	7.3	0.053
Total Use per Resident Day	138.9	75.9	11.9	0.003	5.5	0.8
Total Use per Visitor Day	206.7	139.8	33.9	0.027	7.3	0.91

Table 6 Infrastructure Demand in Quantities

visitor low pop low	1997	2010	2020	2030
Water (gal mil)	100368.6	104667.8	141815.1	268501.2
Electricity (GWh)	10009.0	11176.0	15152.8	26771.9
Utility gas (mmBtu)	3706734.7	3954147.4	4818859.9	7155616.6
Solid Waste(lb mil)	3198.2	3244.6	3617.3	4656.3
Petro (gal mil)	2030.9	2512.2	3494.1	5388.5

Visitor low pop high	1997.0	2010.0	2020.0	2030.0
Water (gal mil)	100368.6	117556.0	227833.1	663820.9
Electricity (GWh)	10009.0	12085.0	22070.2	62525.6
Utility gas (mmBtu)	3706734.7	4358937.4	6426680.7	10192741.2
Solid Waste(lb mil)	3198.2	3482.5	4442.7	6501.1
Petro (gal mil)	2030.9	2509.7	4250.3	11930.9

Visitor high pop low	1997.0	2010.0	2020.0	2030.0
Water (gal mil)	100368.6	110260.9	150224.3	285010.4
Electricity (GWh)	10009.0	12116.0	16822.4	30539.5
Utility gas (mmBtu)	3706734.7	3949267.1	4795140.6	7318190.9
Solid Waste(lb mil)	3198.2	3228.7	3596.6	4677.5
Petro (gal mil)	2030.9	3137.9	4835.2	7270.1

visitor high pop high	1997.0	2010.0	2020.0	2030.0
Water (gal mil)	100368.6	120873.5	233899.2	668543.9
Electricity (GWh)	10009.0	12841.9	23619.2	63815.4
Utility gas (mmBtu)	3706734.7	4426553.6	6751384.3	10817439.5
Solid Waste(lb mil)	3198.2	3476.0	4489.1	6593.9
Petro (gal mil)	2030.9	2866.7	4829.0	12489.5

Table 7. Trigger Point Analysis

	Yellow	Amber	Red
visitor low pop low			
Water (gal mil)	2007	2019	2027
Electricity (GWh)	2004	2017	2026
Utility gas (mmBtu)	2004	2021	
Solid Waste(lb mil)	2007	2027	
Petro (gal mil)	2004	2013	2025
visitor low pop high			
Water (gal mil)	2005	2013	2019
Electricity (GWh)	2004	2013	2019
Utility gas (mmBtu)	2003	2014	2024
Solid Waste(lb mil)	2004	2019	2030
Petro (gal mil)	2003	2012	2020
visitor high pop low			
Water (gal mil)	2006	2017	2026
Electricity (GWh)	2004	2014	2024
Utility gas (mmBtu)	2004	2022	
Solid Waste(lb mil)	2008	2027	
Petro (gal mil)	2003	2008	2016
visitor high pop high			
Water (gal mil)	2004	2013	2019
Electricity (GWh)	2003	2011	2018
Utility gas (mmBtu)	2003	2014	2023
Solid Waste(lb mil)	2004	2019	2030
Petro (gal mil)	2003	2009	2018

Table 8: Macroeconomic Indicators

	Baseline	VLPL	VLPH	VHPL	VHPH
Labor Force (thousands)	594.7	690.4	743.9	690.4	743.9
Visitor Expenditures (million dollars)	10,931.0	23,890.8	23,890.8	34482.5	34482.5
Real Visitor Expenditures ($1997 million)	10,931.0	18,623.0	15,224.6	17897.9	21105.5
Hawaii Consumer Price Index (1997 = 100)	100.0	118.0	136.4	174.7	142.1
Hawaii Visitor Price Index (1997 = 100)	100.0	127.8	156.0	189.7	162.0
Household Expenditures (million dollars)	24,962.0	82,850.7	203,037.9	145466.9	213647.7
Real Household Expenditures ($1997 million)	24,962.0	73,617.6	177,614.0	90509.9	179561.1
Wage & Salary Income (million dollars)	21,626.2	58,210.4	135,462.0	100091.1	144633.9
Real Labor Income ($1997 million)	21,626.2	49,348.6	99,323.8	57293.5	101800.3
Real Per Capita Labor Income ($1997 million)	35.1	69.1	129.0	80.2	132.2
Proprietor's Income (million dollars)	2,088.0	6,275.6	16,638.5	10764.4	17241.2
Real Proprietor's Income ($1997 million)	2,088.0	5,320.2	12,199.8	6161.7	12135.2
Real Per Capita Proprietor's Income ($1997 million)	16.5	36.2	77.0	41.9	76.6
Gross State Product (million dollars)	58,732.5	149,629.4	354,144.5	243144.6	368591.0
Real Gross State Product ($1997 million)	58,732.5	126,850.1	259,666.7	139179.2	259432.1