Kern COG Cube Land Pilot Study

Contents

About this Document

This document describes a pilot study performed using Cube Land with Cube Voyager in Bakersfield, California. Topics include:

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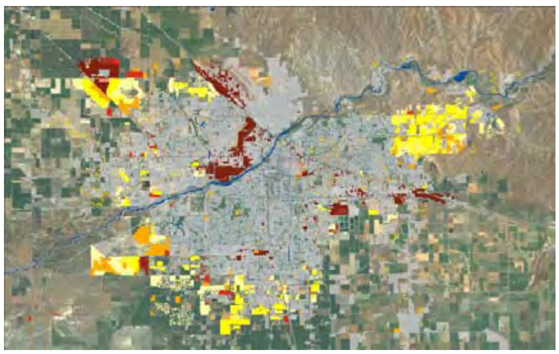
Study Background

California has long been at the forefront of integrated land use and transportation modeling, and the Kern Council of Governments in Bakersfield is no exception. Like other metropolitan planning organizations in the San Joaquin Valley, Kern COG previously used UPlan, a rule-based land use allocation model implemented in ArcGIS, to generate scenarios for evaluation with its Cube travel demand forecasting model. This work initially began with research conducted at the University of California in Davis, spread throughout the state via the award-winning Regional Blueprints program, and has since continued at Kern COG as part of the MPO's ongoing long-range forecasting activities.



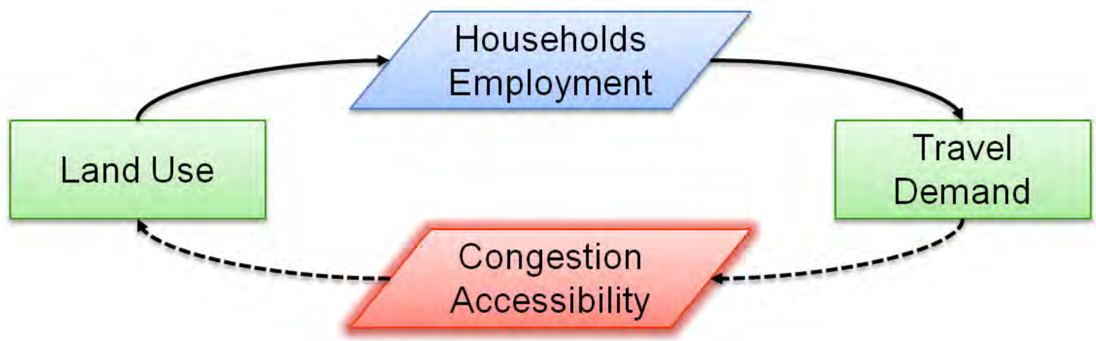
Recent state legislation and regulations (specifically Senate Bill 375 and AB 32) have built upon the success of the Regional Blueprints program in recognizing the important role integrated land use and transportation planning should play in addressing air quality and climate change issues. The Sustainable Community Strategies to be developed for SB 375 demand a fundamentally different approach to forecasting than has been practiced in the past, with better integration between land use and transportation models and a clearer understanding of how the benefits and costs of alternative policies are distributed among system users.

Despite several enhancements, the KernCOG UPlan model was not able to supply the economic detail desired to support SB 375 planning, nor could it be run in "full feedback" with the Kern COG travel demand model to produce equilibrium forecasts. Although other research efforts were underway to integrate land use and transportation models within the state, these projects would not be completed in time to help Kern COG planners meet the current legislative requirements.

Therefore, KernCOG asked Citilabs to examine the possibility of quickly building a new integrated land-use/transportation forecasting model by using Cube Land with available data. Following KernCOG's purchase of the Cube Land software, Citilabs obtained the latest version of the Kern COG Cube and UPlan models and developed a Cube Land pilot study model for further testing and evaluation.

Modeling Methodology

Cube Land is a socio-economic land use forecasting model designed for easy integration with Cube Voyager and ArcGIS. The model developer estimates "bid functions" that describe how households and businesses value transportation accessibility and attractiveness relative to other attributes of the land uses in each zone, along with regional control totals giving the total number of households and jobs of various types. Cube Land then allocates the households and firms to land uses in each zone according to basic principles of economic behavior. The land use patterns output by Cube Land reflect a unique equilibrium between supply and demand in real estate markets, suitable for land use policy scenario comparison. When run in feedback with a four-step travel demand model, Cube Land can also take into account complex interactions between land use and traffic congestion, transit mode choice, and competing travel destinations.



Feedback and Equilibrium

Kern COG's existing rule-based UPlan model is run as a pre-processor to Cube Land. Using assumptions and GIS layers input by the user, UPlan performs a deterministic allocation of land use to grid cells that mimics developer behavior, while not truly representing an economic equilibrium. The UPlan ArcGIS Desktop extension includes an export function to produce the socio-economic data table needed by the Cube travel demand model. The UPlan model is not sensitive to traffic congestion or travel choices such as mode shift.

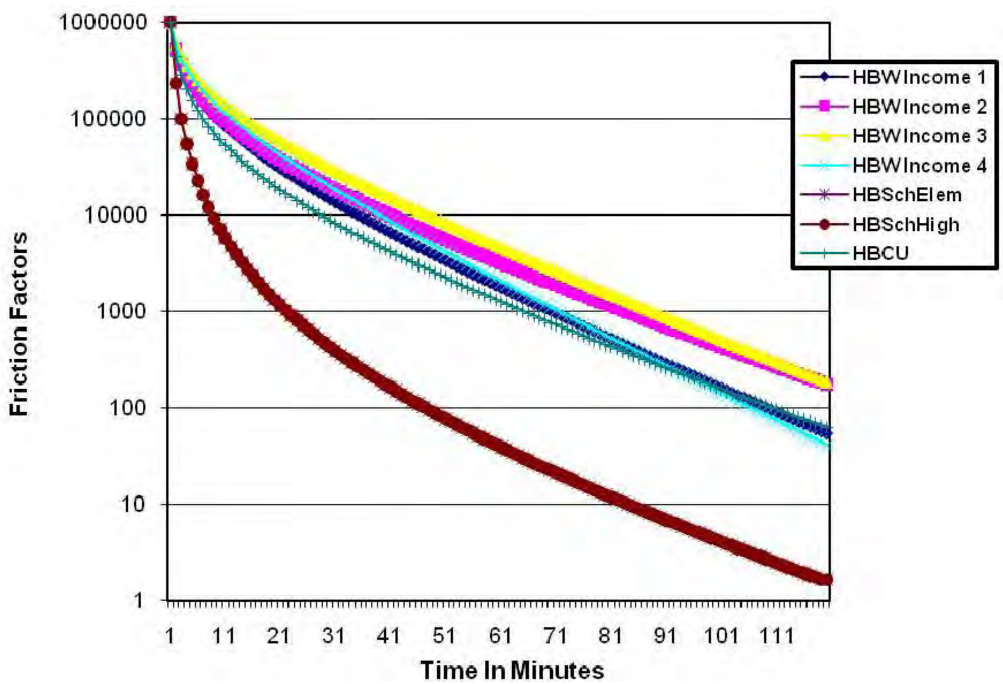
For this pilot study Cube Land was added to the existing feedback loop in the KernCOG travel demand model. For any given forecast year, the land use allocation and travel demand models are run iteratively until a combined land-use/transportation equilibrium is achieved. The land use allocation produced by Cube Land is sensitive to forecasted traffic congestion, mode shift, and competing travel destinations. The fact that the model outputs represent a unique equilibrium solution enables planners to confidently compare performance measures such as CO_2 emissions between alternative scenarios, a key requirement of the SB 375 process.

Integration with Travel Demand Components

Kern COG had previously developed a Cube travel demand forecasting model including a sub-process which takes into account land use variables based on smart growth principles (the so-called "D's"). Citilabs upgraded this model to the latest version of Cube Voyager, including integrated process flow charting and scenario management. Baseline runs were performed to ensure comparability with previous versions of the model.

The KernCOG trip generation model stratifies households by income and size, and a matching classification scheme was used to define household types and control totals in Cube Land. Using County Business Patterns data from the U.S. Census, Citilabs was able to expand the employment classification scheme from six categories to a full set of 20 two-digit NAICS categories.

The KernCOG trip distribution model used a gravity-based formulation, with different "friction factor" curves representing sensitivity to travel impedance by income group and trip purpose, as shown below.

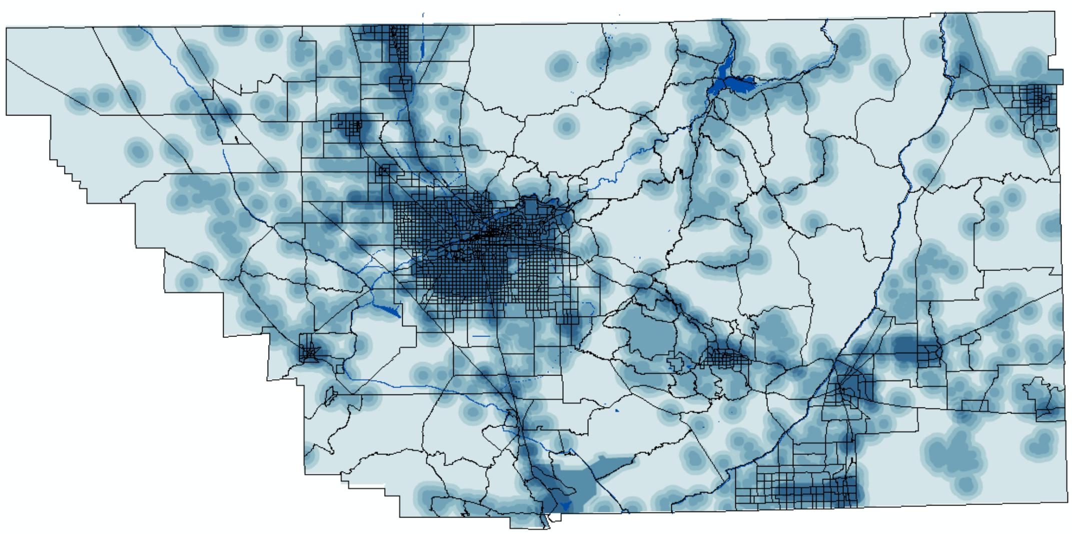


From *2006 Regional Travel Demand Model* report prepared for Kern COG by Parsons, August 2009

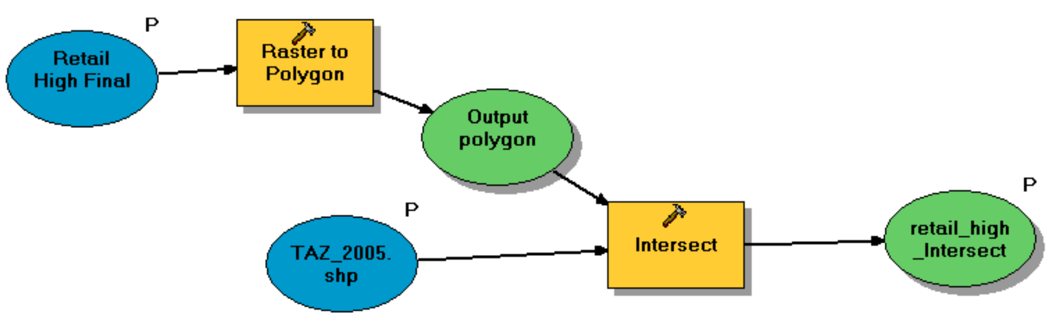
Using Cube Voyager scripts, these friction factor values were translated into accessibility and attractiveness measures by zone and income level. Bid functions were estimated for the area using Census PUMS and LEHD micro-data records, and for both residential and non-residential agents the coefficients of the congested transportation accessibility and attractiveness measures derived from the travel model were significant, suggesting that traffic congestion indeed affects location choices and preferences.

Integration with UPlan

Kern COG had put a substantial amount of investment into improving and enhancing its UPlan model to make it as realistic as possible. Rather than discarding that effort completely, Citilabs developed an approach for this pilot study that integrates the two models using GIS. First, land use types for the Cube Land model were chosen to correspond with the classification scheme used in the Kern COG UPlan model. Second, key indices of development attractiveness generated as an intermediate output by UPlan were incorporated directly into the Cube Land model specification, so that the two models would have a similar representation of developer logic and incentives. Because UPlan uses raster grids as its unit of analysis, whereas Cube Land uses transportation analysis zones, ArcGIS geoprocessing was used to convert the attraction rasters to vector format and summarize the average development attractiveness of each land use type in each zone.



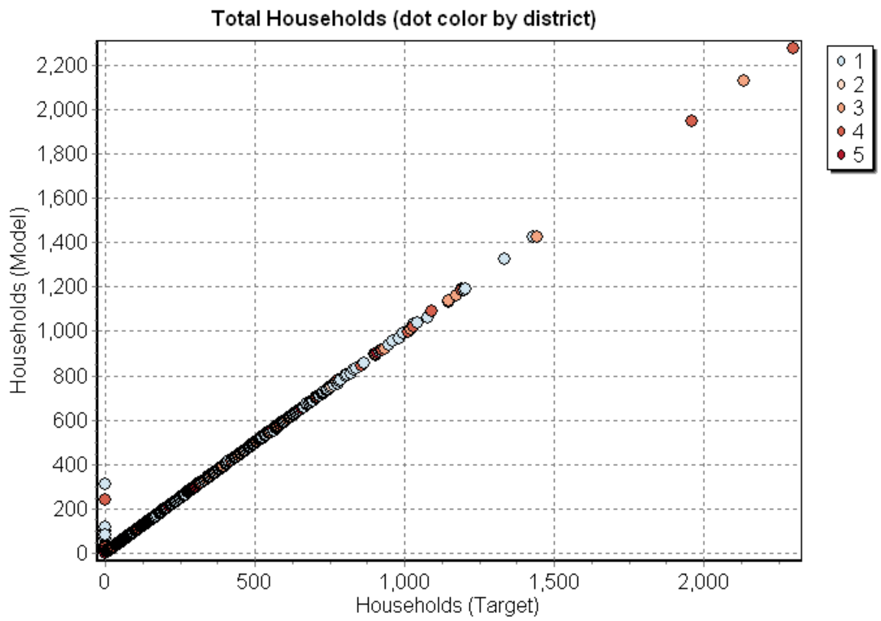
An overlay map comparing TAZ boundaries with a UPlan attraction raster.

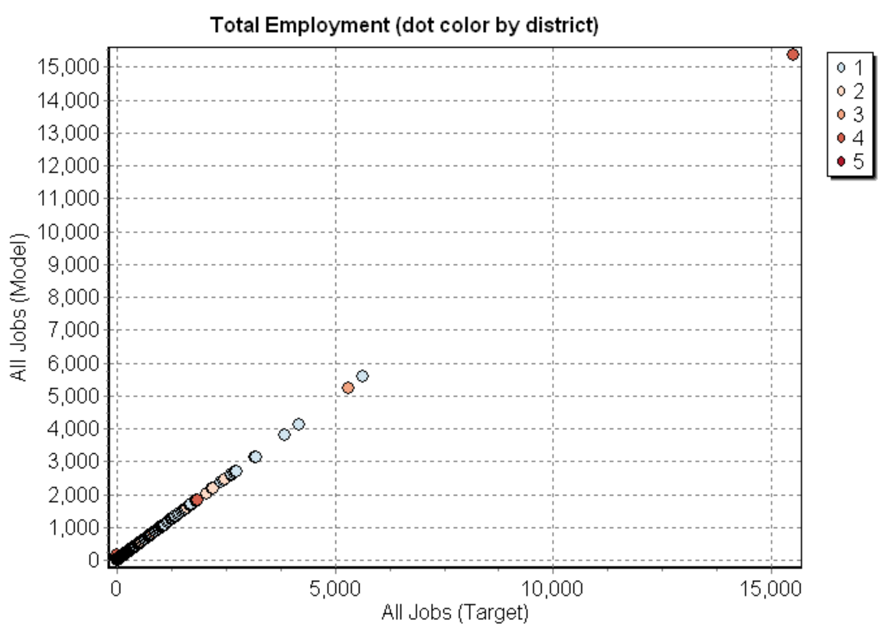


A ModelBuilder diagram illustrating the geoprocessing used to summarize UPlan grids by TAZ.

Findings and Next steps

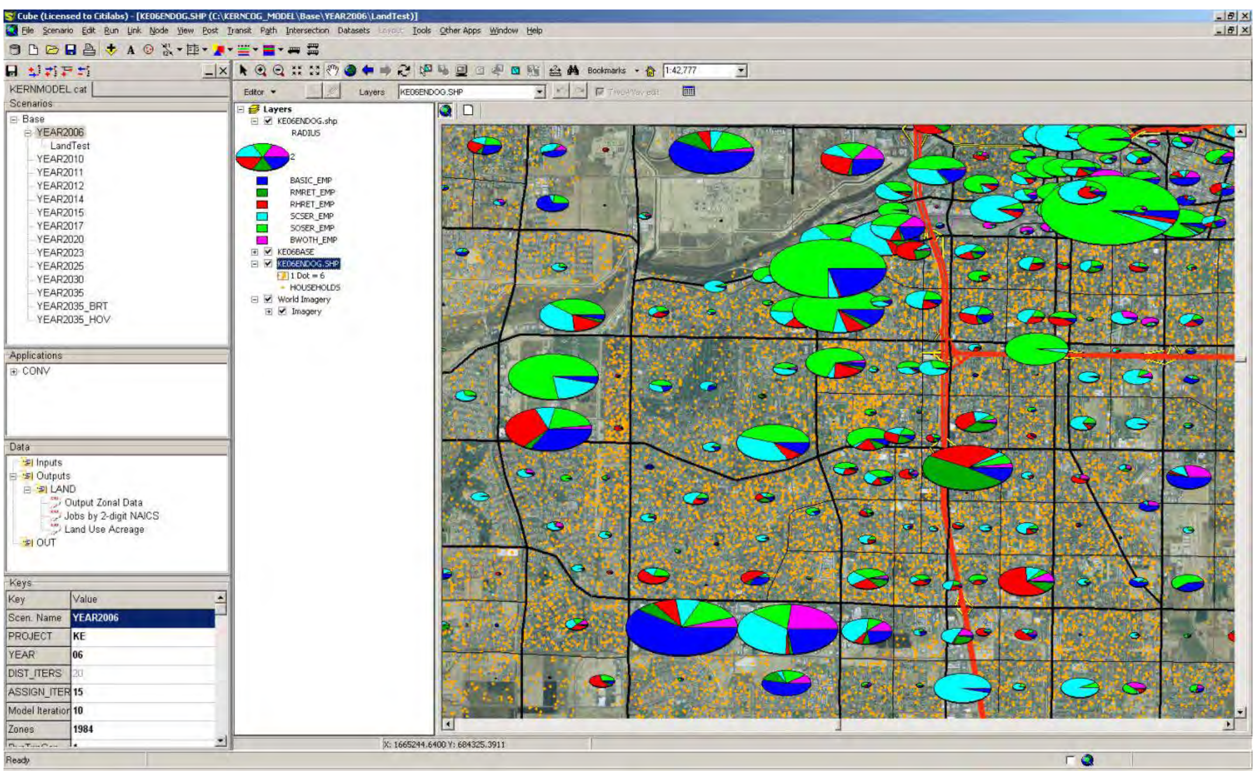
By leveraging the available data it was possible to develop and calibrate a prototype Cube Land model very quickly: including data collection, the overall project schedule was less than three months. Initial calibration results for key metrics, specifically 2006 modeled versus target households and employment by TAZ, are shown below.





The project team recognizes, however, that the model produced by this pilot study might require further enhancement. Therefore, Citilabs provided Kern COG with a semi-automated estimation and calibration application to completely document the model development process and provide a starting point for future model updates. With more data, such as a validated regional digital parcel layer, a household interview survey, and/or more detailed business location information, it may be possible to estimate improved model parameters including a more robust real estate supply model that does not depend upon UPlan to summarize relative development attractiveness.

The Cube Land pilot study model generates a wealth of new information regarding forecasted land use, demographics, and employment in transportation analysis zones, all of which can easily be visualized using the integrated mapping functions in Cube or ArcGIS. While the travel demand forecasting component of the pilot study model is essentially unchanged, the additional detail provided by Cube Land may open up possibilities for a number of desired near-term travel model improvements as well.



An example of a map showing Cube Land outputs overlaid on travel network links and imagery

Citilabs sincerely hopes that this pilot study may serve as an example and road map for similar agencies, illustrating that with Cube Land it is possible to move from rule-based land use modeling in GIS to the economically based equilibrium integrated land-use/transportation forecasting demanded by today's planning regulations.

Appendix A: Data Dictionary

This section describes the tables developed for the Cube Land portion of the model completed in this pilot study. No changes were made to existing travel demand model data structures or processes.

Socio-Economic Agent Type Definitions and Regional Control Totals

Cube Land allocates County-wide control totals for 36 different types of households and jobs to transportation analysis zones within Kern. These comprise 20 NAICS sectors for employment plus 16 household types representing cross-classification by household income and size group (1 person, 2 people, 3 people, 4 or more people). Each type of employment or households used in Cube Land has a corresponding category in the current Kern COG socio-economic classification system: basic production (BASIC), basic warehousing (BWOTH), retail high (RHRET), retail medium (RMRET), service commercial (SCSER), service/office (SOSER), and total households (HOUSEHOLDS). A key to the Kern COG Cube Land socio-economic classification system is shown on the next page.

Base 2006 year regional (Kern County) control totals for these 36 socio-economic types were calculated separately for employment and households. In the case of employment, totals for each NAICS sector were obtained from U. S. Census County Business Patterns data (available at link). Some adjustment to the raw data was necessary to make the total for Cube Land type number 18 (Accommodation and Food Services) equate to the previously estimated Kern total for high-density retail (RHRET). In the case of households, the HOUSEHOLDS field was summarized over all zones in the KE06SOCIO.dbf file included with the travel model to obtain a regional control total for all household types. These totals were then apportioned to each of the 16 household size and income groups based upon the percentages listed on page 23 of the Kern COG 2006 Regional Travel Demand Model documentation (Table 5-1: Proportion of Households by Income Group and Household Size from 2000 PUMS Data).

For future year control total forecasts, Citilabs recommends using interregional demographic and economic models to estimate employment growth and change by economic sector as well as population growth and migration activity by household type. Several commercial as well as public/free sources of such data and forecasts are available. Whenever necessary it should be possible to control the sum of all sectors or household types to match “official” public forecasts (e.g. of population growth). Until such models are available, utility script called “mkTotals.s” is included with the pilot study model to calculate future year Cube Land control totals by totaling jobs and households from traditional zonal data input files and apportioning these totals to the 36 types using base year shares.

Cube Land Socio-Economic Agent Types And Corresponding Kern COG Category

Agent ID	Cube Land Socio-Economic Agent Type Description	Kern COG Category
1	Forestry, Fishing, Hunting, and Agriculture Support Jobs	BASIC
2	Mining Jobs	BASIC
3	Utilities Jobs	BWOTH
4	Construction Jobs	SCSER
5	Manufacturing Jobs	BASIC
6	Wholesale Trade Jobs	SCSER
7	Retail Trade Jobs	RMRET
8	Transportation and Warehousing Jobs	BWOTH
9	Information Jobs	SOSER
10	Finance and Insurance Jobs	SOSER
11	Real Estate and Rental and Leasing Jobs	SOSER
12	Professional, Scientific, and Technical Services Jobs	SOSER
13	Management of Companies and Enterprises Jobs	SOSER
14	Administrative and Support and Waste Management… Services Jobs	SCSER
15	Educational Services Jobs	SOSER
16	Health Care and Social Assistance Jobs	SOSER
17	Arts, Entertainment, and Recreation Jobs	SCSER
18	Accommodation and Food Services Jobs	RHRET
19	Other Services (except Public Administration) Jobs	SCSER
20	Unclassified Employment	BWOTH
21	Households, size=1, income = $0-$24,999	HOUSEHOLDS
22	Households, size=1, income = $25,000-$49,999	HOUSEHOLDS
23	Households, size=1, income = $50,000-$74,999	HOUSEHOLDS
24	Households, size=1, income >= $75,000	HOUSEHOLDS
25	Households, size=2, income = $0-$24,999	HOUSEHOLDS
26	Households, size=2, income = $25,000-$49,999	HOUSEHOLDS
27	Households, size=2, income = $50,000-$74,999	HOUSEHOLDS
28	Households, size=2, income >= $75,000	HOUSEHOLDS
29	Households, size=3, income = $0-$24,999	HOUSEHOLDS
30	Households, size=3, income = $25,000-$49,999	HOUSEHOLDS
31	Households, size=3, income = $50,000-$74,999	HOUSEHOLDS
32	Households, size=3, income >= $75,000	HOUSEHOLDS
33	Households, size>=4, income = $0-$24,999	HOUSEHOLDS
34	Households, size>=4, income = $25,000-$49,999	HOUSEHOLDS
35	Households, size>=4, income = $50,000-$74,999	HOUSEHOLDS
36	Households, size>=4, income >= $75,000	HOUSEHOLDS

Socio-Economic Agent Attributes

The file "f_agents.dbf" (in the Land subdirectory) provides information about the aggregate characteristics or attributes of each socio-economic agent type, such as:

- BASIC, BWOTH, RHRET, RMRET, SCSER, SOSER, HHOLDS: binary (0-1) variables indicating whether an agent type is a household (types 21-36) or a member of a Kern COG employment group (types 1-20). A value between 0 and 1 may be entered to split a Cube Land employment type between two Kern COG groups. This advanced feature could be used, for example, in order to reconcile the NAICS definition of type 18 (Accommodation and Food Services) with the "Retail High (RHRET)" Kern COG employment group definition.

- INCOME: the average annual earnings per worker (for employment types 1-20) or per household (for household types 21-36). For the 2006 base year, U. S. Census County Business Patterns data were used to calculate the value in this field for the 20 NAICS sectors. The year 2006 average income for each group was calculated from U. S. Census data for Ken County as well. Given the average household income values for the highest income group assumed in the pilot model, no TAZ will be forecasted to have a higher average household income than $100,000/year.

- AVGSIZE: the average number of persons per employer or household for each type of employment or household. U. S. Census County Business Patterns data were used to calculate these values for the 20 NAICS sectors included in the model. The definition of average persons per household for the largest household size group (4 or more persons) was calibrated to 4.55 in order to ensure that the region-wide total population in households implied by the Cube Land control totals file matched that implied by the KE06SOCIO.dbf file.

By default, these socio-economic agent attributes are held constant for future year forecasts. However, if desired it is possible to modify or vary these attributes for future years scenario-building purposes; for example to test the effects of changes in average earnings by industry or average household sizes by income group in the future.

Output Zonal Data

For each scenario, the Cube Land application sub-group produces an output shapefile in the scenario directory called "{PROJECT}{YEAR}ENDOG.SHP", where {PROJECT} is the project code defined during scenario setup and {YEAR} is the last two digits of the scenario year; in the base case this becomes "KE06ENDOG.SHP". The shapefile represents a polygon layer corresponding to the transportation analysis zones (TAZs) for the region and the attribute table fields for the shapefile represent the elements of the traditional spreadsheet-based zonal data file that are endogenously modeled by Cube Land.

Output Jobs by 2-Digit NAICS

For each scenario, the Cube Land application sub-group also produces an output shapefile in the scenario directory called "{PROJECT}{YEAR}NAICS.shp", where {PROJECT} is the project code defined during scenario setup and {YEAR} is the last two digits of the scenario year; in the base case this becomes "KE06NAICS.SHP". The shapefile represents a polygon layer corresponding to the transportation analysis zones (TAZs) for the region. The attribute table fields for the shapefile contain forecasted jobs by TAZ for each of the 20 employment types included in the Cube Land model, corresponding to the 20 two-digit NAICS classification groups. The field names used are based upon the industry codes used in the U. S. Census County and ZIP Code Business Patterns files, as follows:

- N11: Forestry, Fishing, Hunting, and Agriculture Support
- N21: Mining
- N22: Utilities
- N23: Construction
- N31: Manufacturing
- N42: Wholesale Trade
- N44: Retail Trade
- N48: Transportation and Warehousing
- N51: Information
- N52: Finance and Insurance
- N53: Real Estate and Rental and Leasing
- N54: Professional, Scientific, and Technical Services
- N55: Management of Companies and Enterprises
- N56: Administrative and Support and Waste Management… Services
- N61: Educational Services
- N62: Health Care and Social Assistance
- N71: Arts, Entertainment, and Recreation
- N72: Accommodation and Food Services
- N81: Other Services (except Public Administration)
- N99: Unclassified

Output Land Use Acreage

For each scenario, the Cube Land application sub-group produces an output shapefile in the scenario directory called "{PROJECT}{YEAR}STOCK.SHP", where {PROJECT} is the project code defined during scenario setup and {YEAR} is the last two digits of the scenario year; in the base case this becomes "KE06STOCK.SHP". The shapefile represents a polygon layer corresponding to the transportation analysis zones (TAZs) for the region and the attribute table fields for the shapefile represent estimates of total acreage consumed for each of the following real estate types, corresponding to the land use types used in the Kern COG UPlan model:

- RES_HI: High-density residential development
- RES_MED: Medium-density residential development
- RES_LOW: Low-density residential development
- RES_VL: Very low density residential development
- BASIC_P: Land used for basic production
- RET_HI: High-density retail development
- RET_MED: Medium-density retail development
- RET_SER: Land used for retail/service economic activity
- SER_WAR: Land used for warehouse-related service activity
- SER_OTH: Land used for other service economic activity

The acreage consumption totals are based upon the number of units of each real estate type in each zone forecasted by Cube Land times the appropriate value (in acres) of the AVGLOTSIZE field in the scenario-specific table F_RESTATE.DBF, which is in turn based upon assumptions extracted from UPlan. Therefore, if the average lot size or average square feet per housing unit and floor-area-ratio assumptions are changed in the UPlan run used as reference for an integrated Cube model run, the land use acreage estimates produced will change correspondingly. Note that, in the pilot study model, forecasted land use totals are not constrained by the total amount of developable land in each zone. However, this option could be changed for a future version of the Kern COG Cube Land model, since location and supply restrictions are an included feature of the software.