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COMPUTER MODELING FOR THE LAKE TAHOE BASIN: IMPACTS OF EXTREME LAND-USE POLICIES ON KEY ENVIRONMENTAL VARIABLES

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ABSTRACT

A socio-economic System Dynamics model of population growth and land-use in the Tahoe basin was developed utilizing the best available statistical data and incorporating citizens' hypotheses (perceptions of reality). Citizens and planners participated in two series of modeling workshops.

Computer simulation runs were made of seven extreme land-use policy packages. Each policy package was simulated using three different model versions developed in the modeling workshops.

The projections show that the number of acres developed (and the related lake water clarity reduction) would be greater with upzoning policies, such as density variances, than with outright stimulatory ones, such as new industry promotion. The impacts of the different policies upon population growth (and thus air clarity) vary radically with different sets of citizens hypotheses regarding tourism. The results indicate that consideration of various hypotheses of system behavior is critical in land-use planning.

INTRODUCTION

Lake Tahoe, in the high Sierra Nevada mountains of California and Nevada, contains an immense volume of water of unusual clarity and intense blue color. (The only other high altitude lake in the world which rivals its color and clarity is the much smaller Crater Lake in southern Oregon.) During the last three

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decades, the land surrounding this remarkable lake has sustained a rapidly accelerating population growth [1]. Residents and tourists have been attracted by the area's gambling casinos and ski facilities as well as by its natural scenic beauty. The increased development accompanying this population growth has caused the quality of the water in the lake, particularly around its margins, to deteriorate [2]. The influx of people and cars has threatened the quality of the entire terrestrial, aerial and aquatic environment [3]. In response to his threat:

1. the bistate Tahoe Regional Planning Agency (T.R.P.A.) was created in 1968; and
2. in 1973 the powers of the then relatively inactive California Tahoe Regional Planning Agency (C.T.R.P.A.) were considerably increased.

The policies and actions of these agencies have been intensely debated within the Tahoe community. Local citizens have strong and diverse opinions regarding the future of the area and the role of regional government in that future.

This project was designed to create an instrument which could be used in the area's regional planning process. With the help of regional planners and other interested citizens, we developed a socio-economic computer simulation model of population growth and land-use in the Tahoe basin. The model is designed for use in comparing various policy alternatives, especially land-use policies. By modifying the model's assumptions in different computer runs, citizens and planners can compare the broad long-range social and economic implications of potential governmental policies. The model can be used as a tool for the planners, but more importantly, it can be used to increase citizen contribution to the planning process. Citizens can compare the impacts of different policies and then make formal recommendations to the regional agencies; or citizens and planning staff members can explore various policies in joint workshop sessions.

This article includes a general description of our model's structure and a limited discussion of the use of local citizens in calibrating and implementing the model (as background for the presentation of computer simulation results). A more detailed description of the model structure and of citizen participation in the modeling process can be found in Sloane and Dickinson [4].

MODEL METHODOLOGY

This project uses an adaptation of the System Dynamics methodology developed by Jay Forrester of M.I.T. [5]. All System Dynamics models emphasize "patterns of interrelationships" rather than extensive use of "traditional data analyses." [6] The structure of a System Dynamics model is intended to parallel reality as closely as possible. In fact, most of the variables in System Dynamics models have recognizable real-life equivalents. This type of model is best used for comparing the broad long-range impacts of various policy alternatives.

Despite the fact that Forrester's methodology represents a major breakthrough in computer modeling technique, there has been severe criticism of Forrester's *Urban Dynamics* and *World Dynamics* models [7] and of the Club of Rome's *Limits to Growth* System Dynamics model. These models have been accused of:

1. being simplistic;
2. using too little statistical data; and
3. incorporating too many of the modelers' own biases.

We feel these criticisms have some merit. In contrast, our own approach has been to develop a moderately large model which utilizes the best available statistical data and which incorporates citizens' perceptions of reality rather than those of the modelers alone.

The model contains approximately sixty major variables and a total of approximately 400 equations. This is considerably larger than the models referred to above, but not nearly large enough to commit any of the "Seven Sins of Large Scale Models" (i.e., expensiveness, mechanicalness, grossness, hypercomprehensiveness, wrongheadedness, hungriness and complicatedness) as defined by Douglas Lee [8]. We tried to avoid the excesses of the large land-use models, which contain thousands of equations, while providing sufficient detail (disaggregation) for the results to be of value to planners.

Our model utilizes the best available statistical data in the base-year estimates. Due to the many unusual characteristics of the Tahoe socio-economic system (such as the peculiar combination of gambling and skiing recreational attractions), state and national statistics are of little relevance. Fortunately, there have been two comprehensive socio-economic studies of the Tahoe basin itself. The most reliable source is the T.R.P.A.-C.T.R.P.A. transportation study which was conducted in winter and summer 1974, and involved seven separate surveys with a 10 per cent sampling in each [9]. Additional socio-economic information was available in reports prepared for the T.R.P.A. by Economics Research Associates [1, 10].

Of equal importance is the descriptive data which we were able to obtain from local citizens. Most computer modeling projects have relied almost exclusively upon the theories and perceptions of the academic community [11]. This is one of the few projects which has made a genuine effort to include citizens in the modeling process. The modelers interacted with local citizens and planners in two series of modeling workshops. The first series of six workshops was conducted for a Planning and Research (P and R) Advisory Group. The second series of five workshops was conducted for a Citizens Advisory Group. Members of the P and R Advisory Group also attended the second series of workshops as observers. They participated in the general discussion but not in any specific group recommendations.

MODEL STRUCTURE

The initial model structure was based upon a simpler model of Plumas County, California [7]. Socio-economic models of Lake George, New York [12], the Susquehanna River Basin [13], and Vancouver, B.C. [11] also had a strong effect on the original structure. The Lake George model inspired our use of the primary market area population as the basis for tourist and "second home occupant" sub-population calculations. Our year-round residents age structure calculations (including births, deaths, aging and migration of separate age groups) were derived from the Susquehanna model's demographic sub-routine, and our "market reconciliation" comparisons of housing supply with housing demand were influenced by the Vancouver housing sub-model logic.

The initial model structure was reviewed in detail by the members of the Planning and Research Advisory Group who made many substantial recommendations for revision. The revised model was then presented to the members of the Citizens Advisory Group who suggested a few relatively minor modifications. The advisory groups' recommendations are noted on the listing of sub-models and related major variables (see Table 1).

The most significant interactions among groups of major variables are illustrated on the schematic of the model structure shown in Figure 1. (The basic diagramming technique is an adaptation of that first used by Jay Forrester in *Industrial Dynamics* [5].) Our model consists of two basic networks: population and land. Each of the two networks contains several categories ("levels") which are expressed in common units (people or acres). These units can be thought of as "flowing" between categories in a particular network. People in the "primary market area population" flow to and from Tahoe "residents" and Tahoe "tourists" categories. ("Residents" include year-round and locally employed seasonal residents. "Tourists" include all other people in the basin.) Acres flow from undeveloped land to commercial and residential developed land categories. Although housing and business are expressed only in units of developed land in the diagram, they are expressed in a variety of units (e.g., hotel-motel rooms, square feet of gambling casino floor space, and number of available jobs) within the model itself.

The model elements shown within circles on the diagram are the "auxiliary variables." The curved broken lines connecting network categories to auxiliary variables represent information flows, as opposed to unit flows ("flow rates") which are indicated by solid straight lines. Thus, air quality (miles distance visibility) is calculated from the number of vehicle miles; vehicle miles, in turn, are determined by the peak summer population. The size and composition of the peak summer population also determine the sub-populations' housing demand. Housing demand and housing supply (housing units), both disaggregated by market value groupings, are then compared ("reconciled") in a housing market sub-model.

Lake water quality (clarity) is calculated in computer simulation runs of a

Table 1. Sub-models and Related Major Variables

SPECIAL FACTORS
- Promotional Activity Factor[a]
- Major Crime Factor[b]
- Lake Water Clarity Factor
- Distance Visibility Factor
- Population Density Factor
- Remaining Open Space Factor

TOURIST AMENITIES
- Gambling Casino Floor Space (square feet)[b]
- Gambling Casino Units (rooms)
- Hotel-Motel Units (rooms)
- Campground Units (spaces)
- Trailer Park Units (spaces)

TOURIST VISITOR DAYS
- Peak Summer Tourist Population
- Peak Winter Tourist Population
- Tourist Visitor Days

YEAR-ROUND RESIDENTS' AGE STRUCTURE
- Year-round Residents under 16
- Year-round Residents aged 16 to 20
- Year-round Residents aged 21 to 64[a]
- Year-round Residents over 64

BUSINESS UNITS
- Tourist Accommodations (lodging) Business Units
- Gambling Casino (other than lodging) Business Units
- Construction Industry Units
- Other Business Units

YEAR-ROUND RESIDENTS' EMPLOYMENT STATUS
- (Employed year-round residents are disaggregated by three income groupings)[a]
- Year-round Residents not in Labor Force
- Year-round Residents Employed in Year-round Jobs
- Year-round Residents Employed in both Summer and Winter Seasonal Jobs
- Year-round Residents Employed in Summer Seasonal Jobs only
- Year-round Residents Unemployed

AVAILABLE JOBS
- (All job categories are disaggregated by three salary groupings)[a]
- Year-round Jobs
- Summer Seasonal Jobs
- Winter Seasonal Jobs

LOCALLY EMPLOYED SEASONAL RESIDENTS
- (Employed seasonal residents are disaggregated by three income groupings)[a]
- Summer Employed Seasonal Residents
- Winter Employed Seasonal Residents

HOUSING DEMAND
- (All housing demand is disaggregated by three market value groupings)
- Permanent Resident Housing Demand
- Seasonally Employed Residents' Housing Demand
- Second Home Housing Demand

HOUSING SUPPLY
- Vacant Lots (disaggregated by four residential density zones)
- Dwelling Units (disaggregated by four residential density zones; also by three market value groupings within two structure types)

HOUSING MARKET RECONCILIATION
- Permanent Homes
- Seasonally Employed Residents' Homes
- Second Homes
- Vacant Homes (disaggregated by three market value groupings)

BASIN ACREAGE
- Undeveloped Acres (disaggregated by seven land use zones)
- Vacant Lot Acres (disaggregated by four residential density zones)
- Residential Acres (disaggregated by four residential density zones)
- Tourist Accommodation Acres (Hotel-Motel, Gambling Casino, Trailer Park, and Campground)
- Other Business Acres

[a] Variables and/or disaggregations requested by the Planning and Research Advisory Group.

[b] Modifications recommended by members of the Citizens Advisory Group.

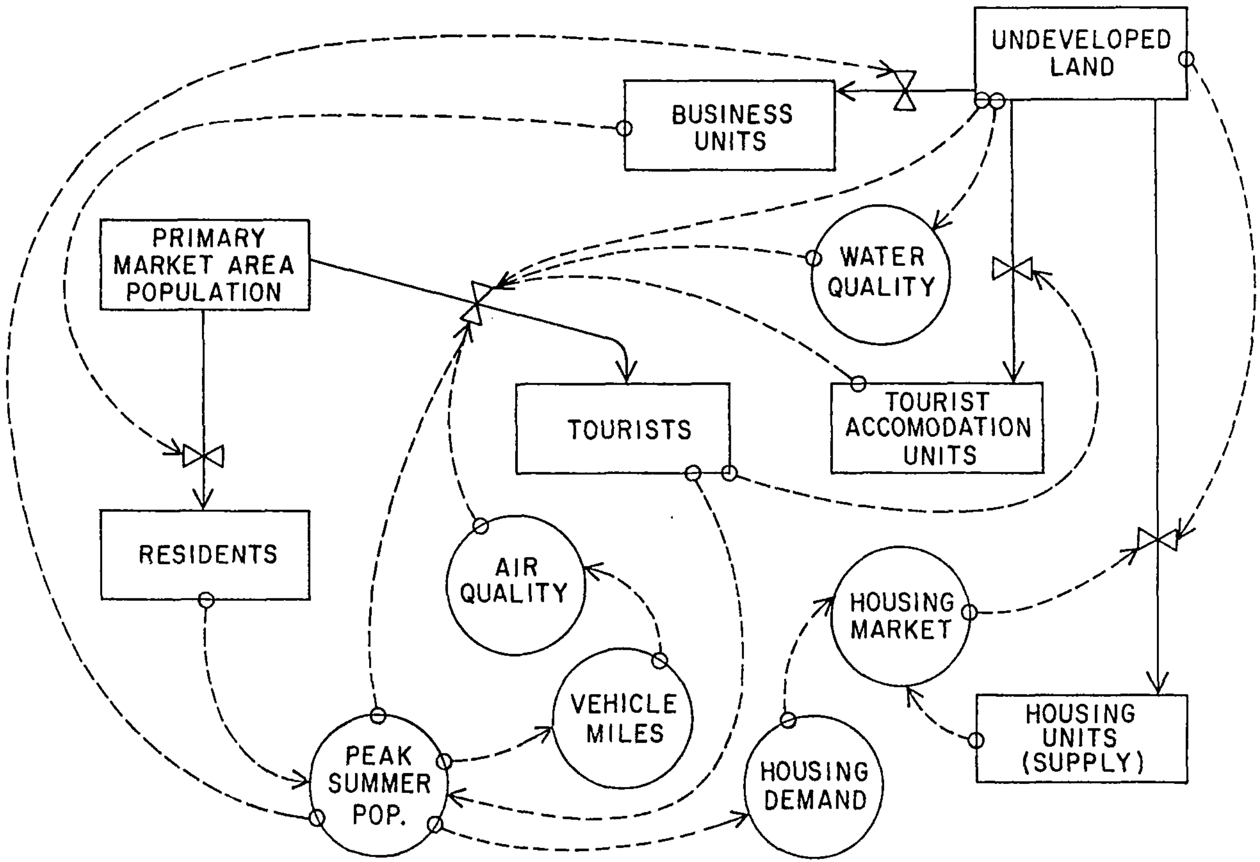

Figure 1. Flow diagram of the most significant interactions among groups of major variables.

separate "mini-model" (as well as in simulation runs of the main model) using developed acreage estimates which have been projected in the main model's simulation runs. A separate model is used for water quality calculations because changes in the lake occur on a longer time scale.

The bow-tie symbols on the diagram denote "decision functions" (valves which regulate the flow of units between two categories in a particular network). The status (numerical value) of a variable which influences a particular unit flow is transmitted via an information flow. Thus, the migration of residents is regulated by the number of available jobs. The number of business units, and therefore the number of available jobs, is in turn determined by the size of the peak summer population. The number of tourists regulates the construction of tourist accommodations, while both the housing market and the amount of developable land affect the number and type of housing units constructed. Construction can also be affected by water supply or sewer capacity limitations. These limitations are not included in the basic model structure, however, primarily because of the current controversy regarding appropriate limits.

The influx of peak summer tourists is increased or decreased by changes in the number of gambling casino facilities and/or changes in environmental attractiveness as determined by the area's peak population, land development, air quality and lake water quality. And although it is not shown on the diagram, promotional activity (a function of the number of service-industry business units) also affects the flow of tourists. In addition, the peak summer overnight tourists are *limited* by the number of available accommodations and the peak day tourists by transportation accessibility to the basin.

MODEL EQUATIONS

The following sample equation describes the population flow from the "primary market area" to one of the "tourists" categories.

$$\text{number of peak summer tourists} = \text{primary market area population} \times \text{ratio of '74 peak summer tourists to '74 primary market area population} \times \text{promotional activity multiplier} \times \text{gambling attraction multiplier} \times \text{environmental attractiveness multiplier}$$

The "ratio of '74 summer tourists to '74 primary market area population" can be thought of as describing the "normal" position of the valve which regulates the population flow. Changes in the promotional activity, gambling attraction, or environmental attractiveness "multiplier functions" would have an inhibitory or a stimulatory effect on the valve. Changes in more than one of these would have a multiplicative effect.

Multiplier functions describe hypotheses about the system's behavior. Because of the potentially controversial nature of these functions, due to the polarized socio-political situation at Lake Tahoe, the members of the P and R Advisory Group recommended that they be specified by the Citizens Advisory Group. However, the only controversial multipliers turned out to be those used in the tourism calculations.

Because previous testing had revealed that the model was very sensitive to assumptions regarding tourism, three separate versions of the model were created to reflect different hypotheses on the subject. The model versions span the spectrum of opinion regarding the impact that increases in population and land development would have on peak summer tourism. The "growth positive" version hypothesizes a positive impact on tourism; "growth negative" a very negative impact. "Group mode" describes moderate impacts.

COMPUTER SIMULATION RUN RESULTS AND DISCUSSION

In order to observe the range of system behavior (patterns of land-use and population growth) which could be projected with the various model versions, the modelers designed six extreme policy packages. The packages include the following policies which were selected because they illustrate some of the major land-use options:

a. CONSTRUCTION AND SUB-DIVISION MORATORIUM
b. HOUSING OCCUPANCY LIMITATION (MAXIMUM OF 5 PEOPLE PER HOUSE)
c. REMOVAL OF MOST CAMPGROUND AND COMMERCIAL ZONE LIMITATIONS
d. INCREASE IN THE NUMBER OF RESIDENTIAL UNITS PER ACRE ALLOWABLE (50 UNITS PER ACRE FOR ALL RESIDENTIAL ZONES)
e. ADDITIONAL ACRES ZONED RESIDENTIAL (APPROXIMATELY 50% INCREASE IN ACREAGE)
f. DOUBLING OF GAMBLING CASINO FACILITIES
g. NEW LIGHT INDUSTRY (10,000 ADDITIONAL YEAR-ROUND JOBS)

These land-use policies were combined into two "very restrictive" packages (policies a and b), two "unrestrictive" packages (policies c, d and e), and two packages which contain both unrestrictive and "stimulatory" policies (policies f and g are stimulatory). In addition, the unmodified base model (basin-wide T.R.P.A. general plan) was included for comparison. Each of these seven policy packages was then simulated using three different model versions (growth positive, group mode, and growth negative as described above) in a total of twenty-one computer simulation runs.

Table 2 provides a description and comparison of the different policy packages. Each package is compared to the one shown immediately preceding it so that the impact of each additional policy can be analyzed. (Projections from the simplest very restrictive and the simplest unrestrictive packages are compared with the base model projections.) Separate comparisons are made for each of the three model versions used. The 30-year projections which we selected are for three of the main population variables and two of the more interesting land-use variables. The population variables are "total summer population" (total population on an average day of the peak summer month), "year-round residents," and "summer tourists" (summer tourists on an average day of the peak month, excluding those staying in housing units). The land-use categories are "homes" (which include houses, apartments, condominiums, etc.) and "tourist accommodations" (which include hotel-motel rooms and trailer park and campground spaces).

The first two policy packages shown in Table 2 are those which we labeled unrestrictive. These policies would not have a sizable impact on the basin's population if either the group mode or the growth negative hypotheses are correct. If the growth positive hypotheses are correct however, the impact on population size, particularly by a removal of commercial zoning limitations, would be enormous. Likewise, the removal of commercial restrictions doesn't have much of an impact upon the 30-year projection of total *dwelling units* except with the growth positive model version. However, with the growth positive hypotheses the impact on dwelling units is considerable indeed, due almost entirely to the increased number of tourist accommodations. The upzoning of residential acreage causes a large increase in the 30-year projections for housing units with all three model versions.

The third and fourth packages, containing both unrestrictive and stimulatory policies, have a sizable impact upon the total population projections no matter which model version is used. (Of course, the impact is by far the greatest with the growth positive hypotheses.) The two packages have about the same relative effect on dwelling unit projections with both the group mode and the growth negative model versions. However, the doubling of gambling facilities has a much larger impact upon the tourist accommodation projection when the growth positive model version is used.

The last two packages shown in Table 2 contain the most restrictive building policies possible, short of a basin-wide demolition program. But despite the predictable effect a construction moratorium has on the 30-year dwelling unit projections, the impact upon total peak summer population projections is rather surprising. Using the growth positive model version, the 30-year peak population projection for the most restrictive package is almost as high as the projection for the most stimulatory package using the group mode version. There are currently enough unoccupied housing units, even during the peak summer months, to accommodate many more people. That fact plus the

Table 2. Comparison of 30-year Projections from "Extreme Policies" Simulation Runs. Separate comparisons are made for each of the three model versions used. Projections are each compared with those of the policy package immediately preceding. (Runs #13, #23, #33 and #11, #21, #31 are compared with the base model projections.)

	Different Hypotheses (Model Versions)		
Policy Package	*Growth Positive*	*Group Mode*	*Growth Negative*
REMOVAL OF MOST CAMPGROUND AND COMMERCIAL LIMITATIONS	Dramatic increases: Projected year-round population is 6 times larger (than base model projection). Summer tourist population projection is 3 times greater. Tourist accommodation projection is 6 times greater. (simulation run #13)	No appreciable impact. (simulation run #23)	No appreciable impact. (simulation run #33)
removal of most campground and commercial limitations + INCREASE IN THE NUMBER OF RESIDENTIAL UNITS PER ACRE ALLOWABLE + 50% INCREASE IN RESIDENTIAL ACREAGE	Housing units projection is 4 times greater than for the above package. Year-round residents projection increased only 24% (compared to projection for the above package). No additional effect on tourism. (simulation run #14)	Housing units projection is twice as large as for the above package. Year-round residents projection increased only 12%. No additional effect on tourism. (simulation run #24)	Housing units projection is twice as large as for the above package. Year-round residents projection increased only 3%. Summer tourists projection *decreased* 9%. (simulation run #34)
removal of most campground and commercial limitations increase in the number of residential units per acre allowable	Year-round residents projection increased 86% (compared to projection for the above package). Summer tourists projection	Year-round residents projection increased 42%. Tourists projection increased only 17%.	Year-round residents projection increased 34%. Summer tourists projection increased only *6%*.

50% increase in residential acreage + DOUBLING OF GAMBLING CASINO FACILITIES	increased 81%. Housing units projection increased only 5%. Tourist accommodations projection increased more than *twofold.* (simulation run #15)	Total dwelling units projection increased 20%. (simulation run #25)	Total dwelling units projection increased 16%. (simulation run #35)
removal of most campground and commercial limitations increase in the number of residential units per acre allowable 50% increase in residential acreage doubling of gambling casino facilities + 10,000 ADDITIONAL YEAR-ROUND JOBS	No additional significant impacts. (simulation run #16)	Year-round residents projection increased 56% (compared to projection for the above package). The total peak summer population projection increased 20%. The number of housing units projection increased 16%. (simulation run #26)	Year-round residents projection increased 53%. Summer tourists projection *decreased* 9%. The number of housing units projection increased 16%. (simulation run #36)
CONSTRUCTION AND SUB-DIVISION MORATORIUM	Total peak summer population projection decreased 24% (from base model projection). Total dwelling units projection decreased 39%. (simulation run #11)	Total peak summer population projection decreased 9% (from base model projection). Total dwelling units projection decreased 31%. (simulation run #21)	Total peak summer population projection *increased* 4%. Total dwelling units projection decreased 27%. (simulation run #31)
construction and sub-division moratorium + HOUSING OCCUPANCY LIMITATION	Total peak summer population projection decreased an additional 4%. (simulation run #10)	No additional appreciable impact. (simulation run #20)	No additional appreciable impact. (simulation run #30)

likelihood that occupants would "double up" in a housing shortage (the average number of people per year-round resident's home is currently only 2.9) could allow more than a doubling of total housing occupants given the current housing supply. Additional housing occupants plus increased numbers of day-use visitors account for most of the population growth projected for the very restrictive policy packages (with all three model versions).

The other surprising population projections for the very restrictive policies involve the growth negative model version. If the growth negative hypotheses are correct, the very restrictive policies would increase the size of the total peak population more than would the unrestrictive policies. Also, the number of summer tourists would be greater than with any of the other policies, including the stimulatory packages. These results are caused by the growth negative hypothesis which states that increases in developed acreage ("urbanization") would have a very negative "environmental attractiveness" effect upon tourism.

Tables 3, 4 and 5 contain the actual 30-Year population and dwelling unit projections from each of the twenty-one computer simulation runs. Table 3 contains the growth positive projections, Table 4 group mode and Table 5 growth negative.

Several of the growth positive projections, shown in Table 3, are noteworthy: With the most restrictive policy package (simulation run #10), the housing occupancy limitation causes a slight decrease in the 30-year projection of the number of peak summer tourists (compared to simulation run #11), even though "summer tourists" do not include people staying in houses in the basin. This is due to the growth positive hypothesis that a decrease in the total peak population would have a negative effect upon tourism. The most stimulatory policy package (simulation run #16) results in such a tremendously large population projection that even the considerable residential "upzoning" included in the package is insufficient to meet the housing demand.

The following growth negative (Table 5) projections should also be noted: Each added unrestrictive or stimulatory policy, with the exception of doubling gambling facilities, causes an additional *decrease* in the 30-year projections of peak summer tourists. However, the number of year-round residents increases with the addition of each such policy. Although fewer tourists mean fewer available service jobs, the increases in housing and business construction jobs more than make up the difference. Of course, in order to maintain a constant number of construction employees, building construction would have to continue indefinitely (an unlikely prospect).

ENVIRONMENTAL IMPACTS

The 30-year projections show that no matter which hypotheses are assumed (growth positive, group mode or growth negative) the land-use policies which would probably cause the greatest number of acres to be developed are those

Table 3. 30-Year Projections from "Extreme Policies" Simulation Runs Using "Growth Positive" Model Version

			30-Year Projections				
			Population			*Dwelling Units*	
Simulation Run	*Land-Use Policies*	*Model Version*	*Total Summer Population*	*Year-Round Residents*	*Summer Tourists*	*Homes*	*Tourist Accommodations*
#10	building & subdivision moratoriums plus limit of 5 people per house	"GROWTH POSITIVE" (extreme positive impact on tourism)	281,000	40,000	173,000	28,000	15,000
#11	building & subdivision moratoriums	–"–	294,000	40,000	175,000	28,000	15,000
#12	base model only	–"–	388,000	54,000	233,000	43,000	26,000
#13	remove campground and commercial limits	–"–	1,195,000	324,000	780,000	46,000	159,000
#14	above plus additional acres zoned residential & expanded units per acre allowable	–"–	1,491,000	401,000	780,000[a]	188,000	165,000
#15	above plus doubled gambling facilities	–"–	2,512,000	746,000	1,508,000	197,000	361,000
#16	above plus new light industry (10,000 additional jobs)	–"–	2,550,000	784,000	1,508,000[a]	197,000	363,000

[a] The 30-year projections of the number of peak summer tourists in simulation runs #13 and #14 are exactly the same, as are the projections in runs #15 and #16, because the upper limits had been reached on the most sensitive of the tourism multiplier functions: the promotional activity multiplier and the peak population environmental attractiveness multiplier.

Table 4. 30-Year Projections from "Extreme Policies" Simulation Runs Using "Group Mode" Model Version

			30-Year Projections				
			Population			Dwelling Units	
Simulation Run	*Land-Use Policies*	*Model Version*	*Total Summer Population*	*Year-Round Residents*	*Summer Tourists*	*Homes*	*Tourist Accommodations*
#20	building & subdivision moratoriums plus limit of 5 people per house	"GROUP MODE"	175,000	39,000	99,000	28,000	15,000
#21	building & subdivision moratoriums	–"–	175,000	39,000	99,000	28,000	15,000
#22	base model only	–"–	193,000	51,000	102,000	41,000	20,000
#23	remove campground and commercial limits	–"–	194,000	51,000	103,000	41,000	21,000
#24	above plus additional acres zoned residential & expanded units per acre allowable	–"–	201,000	57,000	103,000	89,000	21,000
#25	above plus doubled gambling facilities	–"–	255,000	81,000	120,000	107,000	25,000
#26	above plus new light industry (10,000 additional jobs)	–"–	305,000	126,000	123,000	125,000	27,000

Table 5. 30-Year Projections from "Extreme Policies" Simulation Runs Using "Growth Negative" Model Version

			30-Year Projections				
			Population			Dwelling Units	
Simulation Run	*Land-Use Policies*	*Model Version*	*Total Summer Population*	*Year-Round Residents*	*Summer Tourists*	*Homes*	*Tourist Accommodations*
#30	building & subdivision moratoriums plus limit of 5 people per house	"GROWTH NEGATIVE"	175,000	39,000	99,000	28,000	15,000
#31	building & subdivision moratoriums	–"–	175,000	39,000	99,000	28,000	15,000
#32	base model only	–"–	169,000	45,000	88,000	40,000	18,000
#33	remove campground and commercial limits	–"–	169,000	45,000	88,000	40,000	18,000
#34	above plus additional acres zoned residential & expanded units per acre allowable	–"–	160,000	46,000	80,000	82,000	17,000
#35	above plus doubled gambling facilities	–"–	190,000	62,000	85,000	97,000	18,000
#36	above plus new light industry (10,000 additional jobs)	–"–	214,000	95,000	78,000	112,000	18,000

Table 6. Negative Impacts of Various Land-Use Policies Upon Distance Visibility (for a given set of hypotheses regarding tourism)

Hypotheses (Model Versions)	*Air Quality (Degradation) Impact of Extreme Policies*		
	"Very Restrictive"	*"Unrestrictive"*	*"Stimulatory"*
"Growth Positive"	Least	Greatest	Intermediate
"Group Mode"	Least	Intermediate	Greatest
"Growth Negative"	Intermediate	Least	Greatest

which are unrestrictive rather than those which are stimulatory. Stimulatory policies can have little effect upon land development unless they are coupled with prerequisite upzoning (unrestrictive) policies. Unrestrictive policies alone have almost as great an effect upon development as unrestrictive and stimulatory policies combined. Of course, policies which are considerably more stimulatory than those used in these comparisons, for example *quadrupling* of gambling casino facilities, might have the greatest effect of all (if used in conjunction with unrestrictive policies). The number of acres developed would be lowest with very restrictive land-use policies.

Policies affecting land development also affect lake water quality. Changes in the remarkable clarity of Lake Tahoe's water would certainly result from any significant increase in the number of acres disturbed by development (thus adding algal nutrients to the lake) [14].

Changes in Tahoe air quality (distance visibility) result from changes in the total number of passenger miles or from changes in the average number of passengers per vehicle [15]. Assuming that the average number of passengers per vehicle did not vary significantly among the policy packages, the impacts of the different policies upon distance visibility vary radically depending upon which tourism hypotheses are used. For example, of the three policy categories the unrestrictive policies cause the greatest degradation in distance visibility given the growth positive hypotheses. But given the growth negative hypotheses the unrestrictive policies cause the *least* degradation in distance visibility of the three policy categories. Table 6 shows the relative air quality impact of each type of policy for a given model version.

As stated earlier, the model is designed to project the broad long-range social and economic implications of policy alternatives. The actual evaluation of the policies may vary considerably from one individual to another. Each person must weigh the potential tradeoffs according to his or her personal values and social priorities.

Thus, a person concerned primarily about lake water clarity should support very restrictive policies (e.g., a building moratorium) or even stimulatory policies (e.g., new industry promotion) if not combined with unrestrictive ones (such as density upzoning variances). He should certainly not support unrestrictive policies. This advice would apply no matter what his personal hypotheses regarding tourism.

A person primarily concerned about distance visibility would have to consider not only his own perceptions of reality (hypotheses), but also the possible consequences if his perceptions were wrong. For example, as do many environmentalists, he might personally believe that increased urbanization would have a negative "environmental attractiveness" effect upon tourism (growth negative hypothesis) and would therefore feel compelled to support unrestrictive policies for maximum distance visibility in the long run (see Table 6). But if he were wrong and greater urbanization actually had a positive "environmental attractiveness" effect upon tourism, the policies that would cause the least air quality degradation would be the very restrictive ones. Of course, a person *equally* concerned about air and lake water quality would be "safest" if he were to support very restrictive policies. (Supplementary policies, causing an increase in the average number of passengers per vehicle, could offset the negative air quality impacts of any of the three types of policies discussed.)

Intelligent land-use policy making involves the establishment of specific socio-economic (including environmental) priorities and the selection of explicit working hypotheses regarding the behavior of the system. Often people who differ regarding policies are actually in agreement as to priorities, but have different mental models of the system involved. A computer simulation model, such as ours, can help citizens with common goals to determine which policies would best achieve those objectives no matter which perceptions of reality are correct. It can also help citizens with different goals to identify policies which would be an effective compromise.

REFERENCES

1. Economics Research Associates, *Housing Element Update, Lake Tahoe Region,* Tahoe Regional Planning Agency, 157 pp., 1973.
2. C. R. Goldman and E. de Amezaga, Primary Productivity of the Littoral Zone of Lake Tahoe, California-Nevada, *Symp. Biol. Hung., 15,* pp. 49-62, 1975.
3. California Tahoe Regional Planning Agency, *Regional Plan,* C.T.R.P.A., 94 pp., 1975.
4. B. A. Sloane and T. E. Dickinson, *Socio-Economic Comparison of Tahoe Basin Land-Use Policy Alternatives,* Tahoe Research Group, University of California, Davis, 112 pp., 1977.
5. J. W. Forrester, *Industrial Dynamics,* The M.I.T. Press, Cambridge, Massachusetts, 464 pp., 1961.
6. M. Greenberger, M. A. Crenson and B. L. Crissey, *Models in the Policy Process,* Russell Sage Foundation, New York, 355 pp., 1976.

7. T. E. Dickinson and S. I. Schwartz, Socio-Economic Impacts of Rural Land-Use Control: A Simulation Study, *Journal of Environmental Systems*, pp. 279-297, Winter 1974.
8. D. B. Lee, Jr., Requiem for Large-Scale Models, *AIP Journal*, pp. 163-178, May 1973.
9. Tahoe Regional Planning Agency, *Transportation Systems Planning Process Study Design and Unified Work Program for the Tahoe Region*, T.R.P.A., 116 pp., 1973.
10. Economics Research Associates, *Economic Analysis of Projected Growth for the Lake Tahoe Basin*, Tahoe Regional Planning Agency, 367 pp., 1971.
11. M. A. Goldberg, *The Last of the Dinosaurs or the First of the Primates: Yet Another Simulation Study*, University of British Columbia, 32 pp., 1973.
12. H. I. Stern, A Model for Population-Recreational Quality Interactions of a Fresh Water Site, *Socio-Econ. Plan. Sci., 7*, pp. 1-11, 1973.
13. H. R. Hamilton, et al., *Systems Simulation for Regional Analysis: An Application to River-Basin Planning*, The M.I.T. Press, Cambridge, Massachusetts, 407 pp., 1969.
14. C. R. Goldman and T. A. Cahill, Danger Signs for Tahoe's Future: The Continuing Decline in Air and Water Quality, *Cry California, 10:*2, pp. 30-35, 1975.
15. T. A. Cahill, L. L. Ashbaugh, J. B. Barone, and P. J. Feeney, *Spatial Distribution of Primary Automotive Pollutants at Lake Tahoe*, Proceedings of Conference on Sierra Nevada Meteorology, South Lake Tahoe, California, pp. 23-33, June 19-21, 1978.

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