Staff Paper Series

Staff Paper P75-17 August 15, 1975

USE OF SIMULATION IN PLANNING

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Paper prepared for Conference on Alternative Methods for Public Policy Research in Rural America North Central Regional Center for Rural Development, Ames, Iowa, April 22 - 23, 1975.

Use of Simulation in Planning[1]

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SIMULATION is a technique for representing the workings of a complex system such as the governmental activities of a large city or the total economy of a multi-county region. Three types of simulation are identified in this presentation -- computer simulation, games and gaming simulation.

Computer simulation is based on the manipulative capabilities of modern computers to explore complex, mathematical models of urban and regional systems. In games, on the other hand, the behavior of decision makers is simulated by condensing their roles into a few representative forms and by applying rules that closely depict their real life constraints. In gaming simulation, however, the computer provides both an environment for the game and a laboratory for experimentation. Operational gaming, finally, includes both games and gaming simulations and, hence, involves the playing of games with or without use of a computer.

Our intent is to relate the three types of simulations to planning. We are trying to attain a better understanding, not only of _what_ happens (which, for a complex system is already a difficult task) but, also, _how_ and _why_ these happenings occur. Our intent, therefore, is to identify practical uses of simulation in coping with and understanding problems of local and regional change and development.

Our presentation is in two parts. Computer simulation models are presented, first, starting with the Chicago Area Transportation Study (CATS) Model as a prototype of the special-purpose planning model [14, 69]. Computer model characteristics are described further with reference to the recently implemented Minnesota Regional Economic System Simulation Laboratory (SIMLAB). User and operator manuals for SIMLAB, (graded by learning proficiency level grades 11 to 14, 15 to 17 and 18 and over) are being developed in collaboration with computer and educational systems specialists [8].

Operational gaming models start with Community Land Use Game (CLUG) and Metropolis as precursors of the operational gaming models [22, 28] The City Model, which is being used for teaching planning courses at the University of Minnesota and Mankato State College, is one of the most recent versions of computer-based games [5]. Another version is the River Basin Model, which is used in watershed research at North Dakota State University, the University of Oklahoma, and, also, the urban and regional studies program at Mankato State College.

Planning applications of simulation models will vary with the style of planning [9, 17, 18, 19, 30, 35, 40, 47, 52, 54, 65, 74, 78, 79, 85, 87, 95, 99, 100, 102, 111, 112, 121, 122]. Three planning styles are presented here as options to highly centralized command planning [34, 62]. For the latter, simulation models provide scenarios and projections of what is likely to happen.

In policy planning limiting factors in local and regional change are identified and alternative approaches for moving away from an unsatisfactory social or economic situation are devised and tested [97]. Knowledge of relationships between policy incentives and their outcomes (which is essential in knowing when and how to manage policy changes) is acquired by technical analysis, controlled experiments, projective techniques, and economic and social indicators. Uses for both computer simulation and operational gaming are found in policy planning.

Corporate planning, in contrast, is identified as a structured variation on politics-as-usual; it involves negotiation among representatives of major interest groups -- a process which is readily simulated in a variant of operational gaming. The aim of the corporate style of planning is a temporary "mutual adjustment" of interests in which government planners perform the role of brokers among a small number of competing interests [33].

Participant planning refers to community forms of decision-making which can involve neighborhoods, cooperatives or voluntary organizations. Spatial contiguity of individuals in the participant style of planning is an important, though not necessarily essential, requirement [81]. Again, a simulation approach may be used to help professional as well as participant planners in learning about the problems they are facing and the available methods for dealing with them, and in providing relevant information about the external environment.

The three planning options are incorporated in what Kalba calls competitive planning in which motivation for public sector participation occurs because of its reliance upon private compliance [62]. The private and public sectors try to expand the scope of decision-making in return for a reduction of uncertainty concerning the decision-making environment.

Again, computer simulation approaches may be used to show citizen and special interest groups how to reduce the adverse local impacts, for example, of a large suburban commercial or rural industrial development program. Simulation also may be used to show the local impacts of alternative income redistribution, service delivery and public financing strategies.

COMPUTER SIMULATION

Use of computer simulation in planning is colored currently by the widely-held view that large-scale models are unmanageable because of their excessive comprehensiveness and data requirements, coupled with grossness of spatial detail [61, 72]. For our purposes, however, computer simulation is viewed as an increasingly efficient and accessible means for understanding the processes and directions of local and regional change.

We identify a representative series of computer simulation models and assess their strengths and weaknesses in helping both professional and participant (citizen) planner to develop values, knowledge, abilities and skills for the different styles of planning which occur in the public sector (Fig. 1). Indeed, we recognize a shift away from authoritarian and hierarchical planning to varieties of participant planning for which computer simulations can provide alternative scenarios of the external environment. The simulations can show, also, the economic constraints on equality of access to jobs, income and services in the regional community. Likewise, they reveal the dynamic interrelationships between the private and public sectors.

(Figure 1 here)

Transportation

Computer simulations of regional transportation development are cited first because of their early occurrence [60]. They also illustrate the limitations of large-scale models which are goal-oriented, optimizing models rather than role-oriented, simulation models.

The Chicago Area Transportation Study (CATS) model is the precursor of the Pittsburgh, Detroit and other large-scale transportation models [13, 14, 69, 92]. Land use is based on a probabilistic allocation of activities to land parcels. Projections of population and growth in open space and transportation, commercial, residential, and industrial activities are data inputs for the transportation forecasts.

Most recent efforts in transportation systems modeling deal with state and multi-county regions in the national economy [21, 98]. The U.S. input-output model provides the national economic constraints in the programming of least-cost interregional commodity shipments in one study [93, 120]. A shift-share model is used in allocating national employment levels among urban regions in another study [41].

Population and Employment

Subarea changes in residential population and employment as a function of migration and areawide growth are simulated in a large-scale model of EMPIRIC, which is a linear programming simulation of five "located" variables (i.e., types of population and employment) in 29 subareas, for which constraints are imposed by 14 to 22 "locator" variables (i.e., types of social and private overhead capital) [46, 47].

State-level simulations of population and employment are provided in a non-optimizing system model of the Iowa economy [79]. Here, an input-output submodel is used primarily as an accounting framework for achieving internal consistency in the projection series. A related set of multi-variable equations are used recursively to make the model dynamic and to provide for public (or "outside") interventions in regional development activities.

Residential and Housing

Again, a micro-system approach is used in the residential and housing models of which the Penn-Jersey Transportation Model is a prototype [45, 106]. Market demand for land is determined for the highly disaggregated residential sector by linear programming solutions which yield optimal location patterns for housing by maximizing "rent-paying-ability", i.e., the difference between the available household budget for housing and transportation, and the market costs, if sites were free.

Later variants include models of land use succession and housing renewal [13, 74]. Construction, deterioration and modification of housing in urban districts and conversion of rural to urban land are simulated by these models.

Total Systems Approach

Interdependence of transportation development and land use changes was recognized in the large-scale modeling efforts of the 1960's, particularly in the urban development models [60, 61, 75, 90]. The earliest models were theoretical and not empirical. However, the Pittsburgh Urban Simulation

Model was empirical and descriptive in its representation of several of 39 computer subroutines; a variant of this model was incorporated into METRO (which is discussed in the next section). Later, the Iowa, the Susquehanna Basin, the West Virginia, the Urban Dynamics and, also, the rural urban and resource development models were developed to simulate the regional impacts of urban-industrial change [2, 4, 6, 15, 25, 31, 32, 40, 57, 58, 59, 66, 68, 70, 76, 80, 86, 88, 89, 94, 101].

Recent efforts in modeling a total regional system include SIMLAB -- the Minnesota regional system model -- and the input-output based models used in state energy and economic development planning [30, 32, 38, 79, 82]. Also relevant here is the reconciliation of large-scale system orientation with local perspectives on the incidence of state and regional development impacts [53, 57, 84].

We present SIMLAB now to illustrate the use of a computer-interactive approach in regional systems modeling and evaluation. A series of interdependent subsystems are identified in the basic model as follows:

(1) Markets -- export and local -- and respective roles in private sector planning;

(2) Investment -- output-expansion, pollution abatement, and regional infrastructure, including energy and transportation facilities;

(3) Demand -- household, business and government -- and role in "driving" production,

(4) Production -- both goods and services, private and public, current and capital;

(5) Value added -- household and business income and its distribution and deployment in the economy;

(6) Employment and labor force -- in terms of production requirements and existing labor force of given skills distribution;

(7) Population and households -- growth dynamics and dependency on jobs and overall role in "driving" demand;

(8) Fiscal and ecologic -- public revenues and waste emissions and their relation to the production system.

Each submodel is linked to the preceding and succeeding submodels by a feedback loop. A series of nine parameters are presented initially for review and adjustment in a particular sequence by the model operator. Each variable, however, is determined endogeneously, except for the starting input variables. Eventually, the input and output variables will be linked to a regional development game (which is patterned after the City Model cited earlier).

In addition, a series of submodels are being developed which are linked to the preceding system model. The submodels are treated as separate modules in an expanded system model.

The additional computer simulation modules are identified, therefore, as follows:

(1) Transportation and land use -- their interdependence and interaction with markets, production and population and with the ongoing activities in the economic, governmental and social sectors of the local community and/or regional community;

(2) Energy allocation, conservation and development -- their interaction with demand and production and with economic, governmental and social sectors in the community;

(3) Economic development -- alternate strategies for economic base expansion to support essential environmental and human services;

(4) Housing and environmental services -- impacts of providing, using and financing of residential units and related public infrastructure on economic, governmental and social sectors;

(5) Human services delivery -- impacts of providing, using and financing essential social services on economic, governmental and social sectors in the community.

Each module thus will provide data which can be used in the community and regional development games, and will receive data from each of the three community sectors. Initially, however, the computer modules will be linked only to the basic system model.

Proposed, therefore, is a modularized computer capability for simulating the local and regional incidence of economic development impacts. Such a capability is being developed in the use and extension of SIMLAB as a laboratory setting for experimentation with a regional system model. For example, a majority of high schools and all institutions of higher education in Minnesota are linked already to the central computer facility which holds the SIMLAB programs. Actual data for selected areas in Minnesota are available also for use in the computer simulations. The next step is to introduce the planning student and practitioner to SIMLAB and its potential capabilities for regional economic systems experimentation.

OPERATIONAL GAMING

Current operational gaming models for use in planning have evolved from the two models cited earlier, i.e., CLUG and Metropolis (Fig. 2). Weaknesses and strengths of these models are presented in terms of our current experience with the City Model in college classrooms and planning workshops.

(Figure 2 here)

A primary distinction occurs between the early games and the more recent gaming-simulation models, i.e., use of the computer in decision simulation [26]. The manual games differ further in the use of a grid playing board to represent a geographical area. CLUG, for example, is played on a grid board while METROPOLIS is not. CLUG is more systematic while METROPOLIS is more role playing. The two approaches are incorporated in the several versions of the CITY MODEL.

Manual Games

CLUG [28, 29], LUGS [107, 109] and NEW TOWN [71] illustrate the manual grid board games. The designer's objective in each game was education. Because these games are played in planning courses in North America and Europe, they are presented here [78]. METROPOLIS [22, 23] is not played on a grid board, but it, also, is a manual game.

Each of the manual games is differentiated according to three characteristics, namely, the player objectives, the amount of economic growth, and the locational pattern. Planning uses for the manual games evolve from the three characteristics.

Player Objectives

In CLUG (Cornell, and later Community, Land Use Game), the player objectives are to build, operate and maintain the community and to make money. The players make all employment and commercial decisions. Profits depend upon location with respect to other businesses, and households and utilities. Government decisions are made by majority vote and include setting the local tax rate and expanding utility services. Sale of heavy industry output to national markets brings money into the local system. Money leakages occur out of the local system for government expenses, construction costs, land purchases from the bank, transportation charges, and purchases of goods and services from outside the community.

LUGS (Land Use Gaming Simulation) is a modified version of CLUG but certain distinct differences occur in the two games. Making a business profit and providing adequate government services are important player objectives. Private decision makers develop heavy industry, commercial business serving households, and housing while government decision makers develop municipal services, parks, terminals and communication links. Income in the private sector is totally a function of employees hired and distance to a terminal. Owners of housing units are penalized by lower income if the residences are not located within a certain distance of commercial businesses, municipal services and parks.

NEW TOWN is still another adaptation of CLUG. Four versions of the game are available. Version I provides for a specified objective, namely, to achieve the highest ratio of total revenue to total land cost. Players roll dice to decide the type and density of development units they may place on owned or rented land. Bonuses in the form of increased incomes are provided for retail agglomerations, retail neighborhoods, industrial sites adjacent to the rail and/or the river and resident sites adjacent to the lake. In Version II, money is introduced as a medium of exchange. Bidding of retail and industrial units, taxation and redevelopment of property occurs to maximize rate of return. Additional bonuses are awarded to the teams (up to four in total) with the largest amount of industrial income and with homogeneous land uses on a parcel. The public sector is introduced in a Version III. Here the planners objective is set by the system or self-established in such a way as to serve or shape future development. Bonuses are affected by the placement of utilities, parks and schools. Finally, Version IV expands the range of government activity. Economic bonuses now reflect sociological and aesthetic benefits. New public land uses include fire stations, health clinics, town halls, sewage plants, institutions, civic centers, refuse disposal plant, and an airport.

In METROPOLIS a real metropolitan area is used in simulation. The gaming activity focuses on the Capital Improvement Program for the single political jurisdiction which is represented. The players, in their various roles, are forced to choose between alternative courses of action on three capital improvements per round at the same time they are trying to achieve personal objectives. In each round, the administration prepares the capital improvement program, the politicians decide the annual budget, and the land speculators try to influence the formation of the capital programs so that increased profits accrue to them.

Growth and Location

Community growth in CLUG and LUGS is determined by the players and limited by cash balances. In NEW TOWN, however, growth is determined by dice roll. Before parcels can be developed, they must be served by utilities that emanate from the utility plant and run along the edge of the parcels.

In METROPOLIS growth depends upon the resolution of community issues in each round. The gaming focus here, of course, is the capital improvement program.

Natural features, such as a lake or river, influence the locational pattern of CLUG and LUGS. Three zones are delineated on the board in NEW TOWN; these represent the downtown, the transitional area and the suburbs and they are determined by dice role. Precise location of development within each zone, however, is based upon ownership and location relative to other units and natural features. Locational features are not important in METROPOLIS.

Use of the grid board is essential in achieving a locational perspective in a community development game. For this reason, particularly, CLUG has been most widely modified and extended for land use and environmental teaching and planning purposes.

Computer-Based Games

METRO [24, 62], CITY I [26, 31], APEX [15] and CITY MODEL [26, 50, 51] illustrate the computer based games. The two city games, unlike METRO and APEX, make use of a grid board, but they were not started with real data. Both METRO and APEX deal with the real data base of Lansing, Michigan. Again, the three criteria cited earlier are used in illustrating the content and use of the computer-based games.

Player Objectives

In METRO players are assigned as members of two types of teams, a functional team, a politician, planner, school board, land developer, and a locational team of central city, suburbs, or urbanizing township in which each player has a role and a jurisdiction to represent. Household, industrial and commercial behavior is simulated by the computer, which also serves as a data bank and processes the inputs and generates outputs. The computer also controls the simulated population which elects politicians to office. Politicians are in charge of the budget for their jurisdictions, some public land purchases, zoning, and carrying out specific capital improvement projects. Land developers attempt to relate to the politicians in attempting to make successful land purchases and building decisions for the growth that is generated each round by the simulated land users, i.e., industry, commerce and households. School decision makers try to improve schools, and get re-elected; they set school tax rates, purchase land, allocate a budget and make capital improvements. Finally, planners work one year ahead of the politicians and try to plan future programs; their task is essentially one of trying to pursuade the community to accept their suggestion.

APEX is an extensively modified version of METRO. The Lansing data base is still employed, but the number of analysis areas (which are not located on a game board by coordinate) has been reduced from 44 to 29. Players no longer make school decisions, but the six local industrialists and a county air pollution control officer (APCO) assume air-control roles. The county APCO is the only player concerned exclusively with air pollution conditions of the simulated area. The other players are concerned with air pollution only insofar as the costs of controlling pollution affect them. The impact of regulations affect them or the simulated electorate become vocal in their opposition to undesirable pollution levels. Players who are land developers buy, sell and develop land in response to a simulated market. Simulated developers take up any remaining demand which the gaming developers do not need. Success of the county APCO depends on his ability to pursuade other local decision makers of the worth of his programs.

CITY I is an extension of CLUG and METROPOLIS; hence, a decision-making environment is provided in which the interrelatedness of decisions across the urban system and over time can be experienced and observed. Nine teams of from one to five members per team are the decision makers who effect land use and urban development on a 25 x 25 grid on which the game is played. Nine types of private land use are developed, i.e., heavy industry, light industry, business goods, business services, personal goods, personal services, high-income residences, middle-income residences, and low-income residences. Each of the nine teams is elected or appointed by elected officials to assume the duties of one of nine governmental functions which are performed simultaneously with the entrepreneurial functions common to all teams. Teams set their own objectives for both the public and private actions they undertake.

CITY MODEL is an extensive evolution beyond the CITY I model. The social sector is added to the system which provides for multiple jurisdictions; also, the transportation component is expanded to include commuter bus and rapid-rail travel. Economic teams begin play with some developed property and certain amounts of cash and undeveloped property. To develop new parcels of land, however, zoning, and utilities and highway access must be secured from the government sector. Social decision makers provide for the population units in the area. Time allocation and boycotting decisions are made for the three major socio-economic classes of residences in the community. Governmental decision makers are elected by the social players or are appointed by the already elected officials to assume the duties of one of the governmental functions which are performed simultaneously with economic and social functions. They make service delivery, policy and capital improvement decisions. Players set their own objectives for both the public and private actions which they undertake.

Growth and Location

Community or area growth depends on the resolution of the decision making processes among the several sectors in each of the four illustrated games. Rules and regulations established and maintained by the governmental sector have a decisive impact influence on growth.

Locational questions are handled by game players in the two-city games in a variety of decisions which have their outcomes represented on the gaming board. Capital improvement decisions on the other hand, are not place specific. Neither are the air pollution controls place specific within the larger metropolitan area.

PLANNING APPLICATIONS

Computer simulation and operational gaming models are viewed, finally, in the context of planning and planning education. The elected models are compared and evaluated according to certain planning-related criteria cited earlier. These criteria relate to both the issues and the tools involved in urban and regional development planning in the United States. Their usage offers considerable potential to develop values, knowledge, abilities and skills of professionals and participants in the planning process.

The uses of knowledge and the flexibility of system designs are noted in the review of evaluation techniques and processes by Hudson, Wachs and Shafer [53, p. 260]. The simulation approaches are viewed as part of an evaluation process which allows for the use of both technical knowledge and personal knowledge in formulating alternative approaches to regional development which are sensitive to local values and concerns (Table 1). Unlike the conventional economic approaches (e.g., cost-benefit and cost-effectiveness analysis), both personal and technical knowledge and system design features can be handled in the computer simulation and operational gaming approaches.

(Table 1 here)

Regional systems design solutions may be sought by use of one or more of several complementary evaluative techniques, such as benefit-cost and cost-effectiveness analysis [12]. Computer-based interactive programs also (e.g., INTUVAL) are available for local proponents or opponents of change to determine the local impacts of regional development alternatives and to develop a set of inputed weights for each criterion used in evaluation process [46]. SIMLAB is being developed as a computer-interactive programming technique which provides for facilities and related instructional resources.

Finally, "dialectical scanning" has been suggested as a viable structure for citizen participation in planning [53, p. 262]. In this approach agreement is sought on whether conflicts exist and whether the counter disagreements are properly assigned with their opposites. Differences thus determined are to be reconciled in the second stage of dialectical scanning [67]. Operational gaming approaches are included with the dialectical scanning approach suggested by Hudson, Wachs and Shafer.

Because of the multiplicity of goals and interest groups in state and regional planning, the several simulation approaches, thus, are viewed as being useful in identifying critical decision constraints and variables. The intent is not to prescribe certain development alternatives, but to explore the implications of each alternative for the relevant interest groups (which may approve or oppose these alternatives, depending upon their respective goals and values). Sought here is a composite technical-and-organizational capability for facilitating dialogue and interaction between planners and interest groups involved in formulation of policies on state and regional development.

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TABLE 1: Comparison of Selected Evaluation Techniques and Processes in the Use of Technical and Regional Knowledge and System Design Features[1/]

	Conventional Benefit Cost Analysis	Modified Cost/Effectiveness Approach	Computer Interactive Programming and Simulation	Dialectical Scanning and Operational Gaming
1. Aggregate monetary impacts	M	U	U	U
2. Scaled measures of non-monetary impacts	0	M	U	U
3. Spatial disaggregation of impacts	V	V	M	U
4. Subjective weighting of various impact criteria	0	U	U	U
5. Intangibles (non-quantified impacts)	0	V	V	U
6. Contextual specificity (inclusion of unique local phenomenon as planning referents)	0	V	V	M
7. Easily incorporates new performance criteria	0	0	0	M
8. Encourages generation of new program alternatives	0	0	U	U
9. Provides rapid assessment of options by multiple criteria	0	0	M	M

1/ Listing of items and evaluation techniques are adapted from 53,p.260 . Symbols used in body of table denote importance of knowledge or design attributed as follows: M - major strength of method, U - usual characteristic, V - variants of method might incorporate the one characteristic, 0 - lack of characteristic.

FIGURE 1. A GENEALOGY OF COMPUTER SIMULATION MODELS

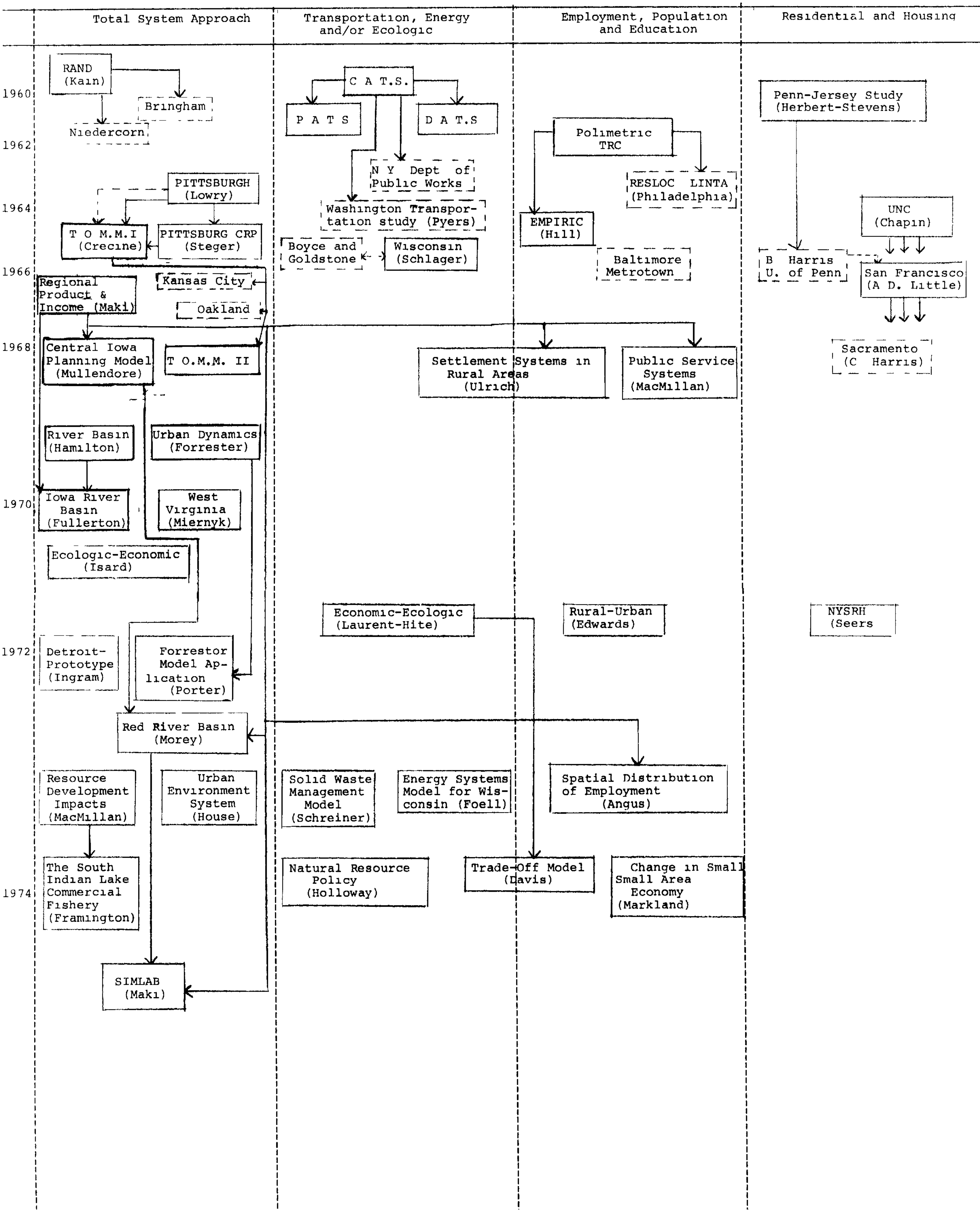

FIGURE 2. A GENEALOGY OF OPERATIONAL GAMING MODELS