SIMULATION MODELING OF THE CRIMINAL JUSTICE SYSTEM AND PROCESS

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ABSTRACT

The purpose of this paper is to provide a primer for criminal justice professionals and a resource for computer scientists on simulation modeling as it has been and can be applied to the criminal justice system and process (CJSAP). Simulation will be defined, as well as classified on analog-digital, abstract-concrete, and deterministic-probabilistic continuums. Ten conditions necessary for the criminal justice professional to seek a simulation modeling solution are spelled out, along with six conditions necessary for the effectiveness of simulation modeling. Some pitfalls of modeling in the CJSAP are discussed along with a caution about four types of criminal justice professionals that simulation scientists might encounter. A brief historical sketch of simulation is presented in a general context and to the CJSAP in particular.

Successful simulation models that have been developed in the areas of overall criminal justice planning, police patrols, court management, juror management, corrections, parole/probation, juvenile deliquency, felony investigations, police communications, prosecution, and offender tracking are identified and described. An extensive list of 126 references is provided. The paper identifies areas within the CJSAP that still have not received attention from simulation modelers or for which there is a paucity of models.

INTRODUCTION

The general methods and concepts of simulation have been with us for a long time. A type of simulation is involved in procedures such as food flavoring, mood setting, wear testing, stress analysis, scale modeling, flight simulation, athletic conditioning, and skill training. In routine interpersonal relationships, imitation of dress, behavior, actions, speech, etc. is usually considered to be a compliment and the highest form of flattery. In man-machine systems such as the CJSAP, the simulation of operations, procedures, routines, products, etc., is often regarded as a saviour and the highest form of analysis when all other methods prove to be inaccessible, inadequate or inaccurate.

WHAT IS SIMULATION?

Webster's dictionary defines simulation as "the act of feigning; pretense; false resemblance as through imitation; or counterfeiting." This definition would be openly accepted by those who either know very little about computer simulation or by those who regard such a procedure as a threat to their executive authority. Remarkably, the same reaction might be evoked from those who do know a great deal about simulation as it applies to large scale, complex urban systems, and in particular to those dealing with the CJSAP. Of course, there are a host of laymen and professionals, between the extremes cited above, who have hailed simulation as the greatest tool and/or method yet to be introduced for the study of the CJSAP. This apparent conflict over the merits of simulation arises, primarily, from a lack of complete understanding about the underlying principles of simulation, an unrealistic expectation about what it can accomplish, and conflicting objectives and viewpoints of its prospective users.

There is no totally acceptable definition of a simulation model, nor is there a complete theory of simulation modeling. A model can be defined as a representation designed to describe, to explain, to control, to predict and to explore, as realistically as possible, the essential aspects of a concept, device, object, process, phenomenon, or system. The model is structured around specified assumptions and definitions, and is governed by accepted rules of inference and operation. The model is designed to be an idealized simplification which is easier to use and understand than the complex reality from which it is derived and patterned. Yet, the model, no matter how seemingly accurate and predictive, must of necessity be incomplete and inconsistent with respect to the original reality. (18) No model is time or data invariant, and as such must be ever ready to be fine tuned in order to restore its relationship with reality. When it fails to respond to such adjustments it must be rejected as the late 19th century Bertillon model of criminal identification was.

Simulation models are characterized by the compression of time in order to provide repeated, cost-effective opportunities to experiment on the reality under study without interfering with normal operations, and also permitting the widest range of input data and relationships among the variables being considered. Digital computer simulation is characterized by its non-destructive nature, speed, massive output, and its ability to absorb large statistical data inputs and to model large numbers of stochastic variables. At the other end of the spectrum its drawbacks are its high cost runs, its difficulty to debug, and its insensitivity to unmeasurable variables, poorly documented facts, and humanistic factors.

THE NATURE AND SCOPE OF SIMULATION

Mathematical simulation can be classified into two broad areas - the analog and the digital. These two classifications approximate the classical partitioning of numbers by the ancient Pythagoreans into the continued (used to study geometry and astronomy), and the discrete (used to study arithmetic and music). Analog simulation involves the use of a continuous yardstick, such as the flow of current in an electrical network, in order to simulate the behavior of a different phenomenon, such as a vibrating mechanical spring. Digital simulation involves the use of a finite generating device, such as Comte de Buffon's method of dropping pins of length d onto a flat, level plane marked off with parallel lines 2d units apart, in order to approximate the value of π as the ratio of total pins dropped divided by the total number of lines touched. Modern simulation methods incorporate the best aspects of the analog and digital methods of simulation into a hybrid form which makes use of modern high speed electronic computers. (17)

Simulation models of the CJSAP are often more probabilistic than deterministic due to the amorphous nature of the subject being modeled. Although data, methods, and models are rarely so clear cut, the four broad solution classifications based on the relationships between data from the real system and models of the real system can be illustrated by the 2 x 2 matrix in Figure 1.

FIGURE 1

Solution Classifications Based On Data Versus Model

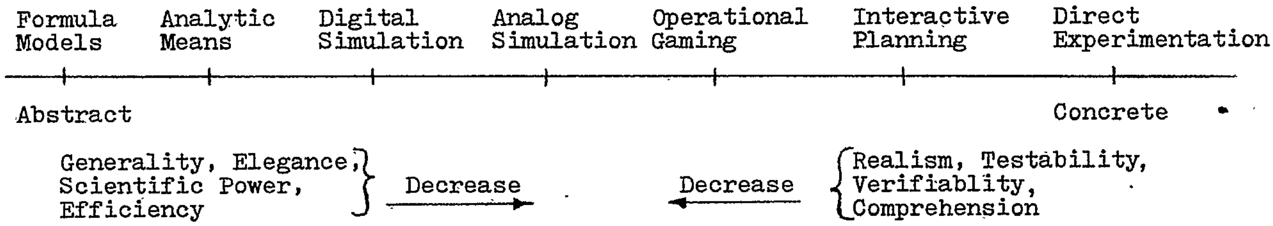
Nature of the Data from the Real System	Type of System Model Employed	
	Deterministic	Probabilistic
Deterministic	Analytical	Iterative
Probabilistic	Statistical	Simulation

Methods of problem solving can be represented on a continuum as in Figure 2 with certain specified points indicated. Lists of criteria are provided at either end of the continuum in their position of maximum effectiveness, and an indication of how their effectiveness decreases is indicated by the arrows.

To many pure mathematicians, any deviation from the methods of strict analysis found in the formula models and analytic methods is tantamount to scientific heresy. Thus, they would regard the methods of digital simulation (and any other of the methods to the right of analytic methods in Figure 2) to be totally unacceptable in the study of the CJSAP and any other system or process for that matter. Such an intransigent position is similar to that of the died-in-the-wool Aristotelians who regarded Galileo's introduction of experimentation as a complete debasement of ancient metaphysical

FIGURE 2

The Continuum of Problem Solving Methods



traditions. Not withstanding this small band of zealots, properly employed, digital simulation is regarded by most professionals as the "wind tunnel" method for the CJSAP.

WHEN IS SIMULATION NEEDED AND EFFECTIVE?

It has been claimed that simulation is the method of last resort ... to be used when all else fails ... the only game in town ... and an act of desperation. However, the necessity for and the effectiveness of simulation are not nearly so capricious. Simulation is necessary and advisable in the analysis of systems and processes, according to Bohigian (17), when one or more of the following conditions apply:

(a) the system is only partially understood or exceedingly complex,
(b) the system is new, proposed, or nonexistent,
(c) the analytical formulation of the problem is unwieldy or unattainable,
(d) there are a large number of poorly defined variables,
(e) there is a great deal of undifferentiable interdependence among the variables.
(f) the objectives are to predict outcomes, to verify projections, to perform experimentation, or to train personnel without interfering with the system's operations,
(g) an operational model of the system is needed,
(h) experimenting on the actual system would be too costly,
(i) manipulating the actual system would be too time consuming, impractical, or counterproductive, and
(j) the system is so unstable or variable that feasible solutions require constant monitoring and reevaluation.

McLeod (88), has observed that "It would seem that the fact that simulation is a useful tool for exploration can be supported almost without reservation." He then procedes to claim that for simulation to be effective in prediction it must meet the following conditions:

(a) all the information upon which the model is based is dependable,
(b) the computer program faithfully reflects the parameters of the components and their interactions,
(c) the mechanization of the program can be completely verified,
(d) the simulation experiment is properly planned to yield results amenable to rigorous analysis, and
(e) all assumptions necessary for the development of the model and the planning and execution of the simulation are tenable and factored into the analysis.

To these five conditions might be added still one more condition:

(f) there must be full and total cooperation between the highest managers of the CJSAP, and those who will plan, develop, run, implement, evaluate, and revise the computer simulation model.

ORIGINS OF COMPUTER SIMULATION

Mathematical simulation methods, especially those requiring electronic computers, are of very recent origin. John von Neumann and Stanislaw Ulam developed simulation, as we know it today, during World War II. Their then secret project, code named "Monte Carlo" was concerned with finding a mathematical representation of atomic chain reactions, energy levels, and depth penetration in nuclear piles caused by bombarding neutrons. Obviously, the potential danger was too great for direct experimentation, so they made use of existing probability and statistical theory to formulate the new and powerful method of digital simulation.(17)

Probably the first application of computer simulation to the CJSAP was the 1965 work by Space General Corporation (112), which developed cost-effective and operating analyses of the California system of criminal justice. Following this there were three studies in 1967. Wallace (122), used computer simulation to evaluate an automatic license plate scanning system used to trace stolen automobiles. Navarro and Taylor (97), simulated the processing of felony defendants through the District of Columbia trial court system. Duffy et al. (39) used a computer simulation to determine the needs of the New York City Police Department's emergency communication system prior to the centralization and installation of the 911 number. In 1968 Casey (25), did a preliminary study of police patrol force requirements using computer simulation. In the same year Navarro and Taylor performed two other computer simulations dealing with the court system (96) and (118). There were four studies in 1969. Hauser, et al.(56) and Drabek (38) dealt with police communication systems. Larson (74) did his pioneering work on examining existing and alternative police dispatch-patrol systems in Boston and New York City. And Merrill and Schrage (91) proposed using simulation for the efficient utilization of jurors. Finally, Heller and Kolde (60) used simulation to model the St. Louis Police Department's real-time motor vehicle inquiry system. Many other works were to follow these early studies as the bibliography clearly indicates.

POTENTIAL PITFALLS OF SIMULATION

Simulation modeling is a subset of operations research modeling; and as such the "15 M criterion" that characterizes studies of the latter type can also be used to identify studies of the former type:

the manipulation of mathematical models so as to measure and give meaning to the optimal management of men, machines, money, methods, materials, and messages in their murky milieu. The complexities of the "murky milieu", along with the unexpected component interactions from so many parts of the CJSAP make simulation studies particularly vulnerable to overlooking key variables, making wrong estimates of component effects, ignoring changes in component behavior, measuring data incorrectly, ignoring dimensional analysis, and drawing unsupportable conclusions.

The most heralded potential pitfall for any simulation study has been that of GIGO (garbage in, garbage out). Yet, as Ida Hoos of the University of California has warned, there is a potential for GIGO to come to mean "garbage in, gospel out." (88) Another potential abuse of GIGO in this regard, particularly among managers within the CJSAP who are unfamiliar with computer simulation or who are under tremendous pressure from "higher-ups" to show results, would be that of "gather it in, grind it out."

Computer scientists are constantly faced with a trade-off relationship that is not restricted to those working in the CJSAP. What balance should be struck between designing a simple, accurate, and usable computer simulation model that of necessity must simplify and leave out data and contingencies, versus building a complex, ponderous simulation model that incorporates "all" data but is therefore too costly, and virtually impossible for CJSAP managers to use or understand. There have been few simulation models developed and implemented which have demonstrated significant improvements over existing heuristic operating practices within the CJSAP. There is also a tendency for the computer scientist to design a new model from scratch rather than modify an existing model (thereby often rediscovering the wheel), or to develop purely theoretical models (a model for a model's sake) which avoid the difficulties of implementation and dealing with CJSAP managers.

Finally, the computer scientist must be aware of the potential pitfalls to be found among the types of managers to be encountered in the CJSAP. The majority of such individuals are eager, willing and grateful to receive help from outside specialists. However, there are a few who still regard any new method as a direct threat. Among this latter group there appears to be at least four broad classifications.

(a) The Doubting Thomas - He has little regard for anything that is not in line with traditional practices within the CJSAP. He has little use for mathematical analyses in general, and a large measure of contempt for computer simulation in particular. No model will be acceptable no matter what its accomplishments have been.

(b) The Miracle Seeker - Just about the antithesis of the Doubting Thomas, he is usually so desparate to improve operational efficiency, increase clearance rates, and modernize procedures that he will try anything once. The more mystical the method seems, the more likely he is to try it. After all, he probably regards a computer simulation model as a scientific voodoo doll with which he hopes to kill off his particular Nemesis - crime rates, court backlogs, manpower shortages, etc.

(c) The Penny Pincher - He more than likely accepts computer simulation modeling, but imposes a key restriction which reflects his lack of understanding of its methods. Usually such a manager provides no direction for the computer scientist, he is not concerned with the model proposal or the final product, and rarely is of help in providing sources for needed data and component relationships. Typically, he will tell the computer scientist that he can make any study he wishes to but that the budget allocation is restricted to some ridiculously low figure.

(d) The Billiard Ball - He is the type who has no opinion one way or the other with respect to any new proposal for improvement within the part of the CJSAP that he manages. He responds exclusively and reflexively to a direct hit from a cue ball in the form of pressure from politicians, the press, or the public. For one who usually has no stomach for simulation models, it is truly amazing to observe the pie-in-the-sky proposals he will entertain once he is under fire.

There are of course other types and many blends of those cited above, but any resemblance to any CJSAP manager alive, under siege, or dead is purely coincidental.

CRIMINAL JUSTICE PLANNING MODELS

The JUSSIM models of Belkin, et al. (12,13) are generally regarded to be the most used and successful simulation models of the overall CJSAP. The works of Cassidy (26) and Cassidy-Johnson (27) are an application of JUSSIM to the Canadian CJSAP. Fey, et al. (41,42) developed a simulation analysis of the Atlanta, Georgia CJSAP. McEachern (86) developed a corresponding prototype for Los Angeles County. Renshaw, et al. (103, 104) developed a PHILJIM model based on data from Philadelphia but with broader implications. Other simulation models and related works in this category are to be found in: (1,6,11,15,16,17,20,28,32,35,47,63,64,78,83, 90,93,121;126), and the previously cited study, (112).

POLICE PATROL MODELS

Adams-Barnard (2) used simulation to demonstrate a dispatching delay reduction using an automated system for the San Jose Police Department (PD). Bohigian (17) gives the anatomy of a digital simulation to show the effects of reducing a PD of three response jurisdictions to a PD with either two or one. Heitzman's study (59) dealt with establishing optimal patrol reserves in each of a four-tiered priority response system in the Van Nuys, California PD. In the classic works of Kolesar-Walker (69,70), calls to the police are traced through every stage until the unit is again available for service. Larson (76) dealt with simulated evaluations of preventive patrol, changes in resources and scheduling, overlapping sectors, and car locator systems. Lipsett-Arnold (80) dealt with simulating operations of a semi-rural PD in Gloucester, Ontario. Nasta-Peck (94,95) used a simulation analysis on the South Bend, Indiana PD. Smith, *et al.* (110,111) developed a program to handle calls to the Aurora, Illinois PD that is applicable to PDs receiving less than 200 calls per day. Urban Sciences, Inc. (119) improves on Larson's work but still makes no provision for time variance, meal breaks, and changes in patrol units. Wolf (125) uses data form the Washington, D. C. PD in developing his simulation model of police patrol. Other simulation studies and related works are to be found in: (3,7,9,24, 29,30,33,34,36,50,61,68,75,79,92,107,113). Previously cited simulation studies in this category are: (25,60,74).

PROSECUTION MODELS

There seems to be only two simulation studies in this area. The work of Sain, *et al.* (105) describes a primarily algebraic technique for simulating felony processing times in two counties of Indiana. The PROMIS model prepared by Peat, Marwick, Mitchell & Co. (117) is specifically designed as a prosecutor's management information system rather than a simulation model. It establishes a priority prosecution case order based on four criteria. Related works in this category can be found in: (14,19,51, 52,53,71,89,114,115,123).

FORENSIC SCIENCE MODELS

Perhaps no area of the CJSAP suffers from such a paucity of simulation literature as does that of forensic science. The only work available is by Krendel, *et al.* (72), which used data from criminalistic laboratories in Pennsylvania and New Jersey to simulate a forensic laboratory as a production facility subject to time constraints.

COURT OPERATION MODELS

Hann (52) and Hann-Salzman (53) developed a CANCOURT simulation model based on the Canadian CJSAP. The model is a complex case by case simulation dealing with case origin, scheduling, court queues, classification systems, bail setting, rescheduling hearings and plea bargaining. Haynes, *et al.* (57,58) developed a non-computerized simulation for the felony courts of the 20th judicial circuit of Florida. Horwitz (62) discussed three computerized models for the study of court resources and delays. The classic works of Jennings (65,66,67), though not exclusively simulation studies, are nevertheless very valuable in the analysis of court operations. The pioneering works of Navarro-Taylor have already been cited (96,97,118). Other simulation models and related works in this category are to be found in: (8,22,40,46,73,81,82,98,100, 101,106,116).

JUROR MANAGEMENT MODELS

Lasdon, *et al.* (77), developed a simulation model of juror utilization in Cleveland, Ohio that reduced the number of juror-days needed by 28%. White (124) proved with simulation that by using four courtrooms, multiple *voir dire* hearings, and trying cases only when all cases on the docket had juries chosen, the overall size of the jury pool could be significantly reduced. The work of Merrill and Schrage (91) has already been cited.

CORRECTIONS, PAROLE AND PROBATION MODELS

Anderson-Brill (5) developed a theoretical simulation model with the prison/parole system represented as a feedback process for criminal offenders. Bateman-Doescher (10) used a digital computer simulation model of incarceration rates and offender characteristics from the Louisiana court system and penitentiary in order to study the needs for developing new correctional institutions. Gottfredson, *et al.* (49), used operational gaming simulation to study parole decision-making. Hann, *et al.* (54, 55) used a simulation model to predict and compare the penal population in Canada from 1942 to 1962. Related work in jail population management is to be found in Burke, *et al.* (23), and in probation decision-making may be found in McEachern-Newman (85).

JUVENILE DELIQUENCY MODELS

It seems that the work of McEachern, *et al.* (84), is the only simulation model of the juvenile justice system, but it was never implemented. Related works in this category are to be found in: (21,112,120).

POLICE COMMUNICATION MODELS

Alliston-Kochhar (4) described the philosophy and problems associated with the development of a computer simulation model of a communication system for the Ontario Provincial Police. Doering (37), developed, implemented and tested a simulated set of situation scenarios used to train new police dispatchers for the Orlando, Florida PD. Rath-Braun (102) used simulation to gather otherwise hard to get data on the police communication center in Chicago, Illinois. Other simulation studies, previously cited, in this category are: (38,39,56,122).

OFFENDER TRACKING MODELS

Apparently, Jago's study (64), is the only simulation study dealing with tracking individual offenders through the CJSAP. Based on data from Ventura County, California, the DOTSIM model filled a void in the JUSSIM model, but fails to account for queueing effects. McCoy's study (83), deals with aggregate flows of individuals simulated through all aspects of the CJSAP of Richmond, Virginia.

AREAS FOR FURTHER STUDY

Despite the fact that 126 references have been compiled for this paper relating to simulation models of the CJSAP, there remain many areas yet to be studied using simulation or which are in need of additional work. Even in those areas which have received a good deal of attention from simulation modelers, there is a need for further verification and/or a refinement of earlier results. It is clear that the bulk of the simulation models have been developed in the areas of criminal justice planning, police patrols and communication systems, and court operations. The areas of juror management, corrections, parole, and probation barely have been addressed. The areas of juvenile deliquency, forensic science, prosecution, and offender flow are virtually virgin areas.

In addition to the areas cited above, the following specific examples are considered to be prime targets for computer simulation:

(a) circulation flow of counterfeit bills,
(b) simulation version of the PROMIS model,
(c) bail conditions versus jumping bail,
(d) judicial sentencing versus recidivism,
(e) analysis of specific felony patterns,
(f) assignment of equal detective work loads,
(g) effects of work load on clearance rates,
(h) effects of white collar crime on society,
(i) relationship between rapid adjudication and crime rates,
(j) ramifications of strict enforcement of laws dealing with gambling, narcotics, prostitution, alcohol, etc.

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