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AN EVALUATION OF CJS MODELS:
SIMULATION APPROACHES AND RECOMMENDATIONS

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ABSTRACT

Several analytical and simulation models which have been used for evaluating the Criminal Justice System are examined. The shortcomings of each simulation model is discussed with respect to the simulation language or simulator employed. The Generalized Network Simulator (GNS) is examined as a means of eliminating these shortcomings.

INTRODUCTION

Modeling the performance of the Criminal Justice System is the mainstay of many ongoing studies of crime. The CJS models currently being used for evaluative purposes are either analytical or simular in character. The analytical models have been used chiefly to predict the recidivism rate of career criminals, whereas digital simulation models have been used variously for forecasting resource requirements, for reducing court delays, and for predicting CJS operating costs and recidivism rates. However, many of the models which have been used in the past, or which are in use today, have been limited either in their scope by the assumptions necessary to achieve workable models, or by the state of the art in modeling technology. It is the purpose of this paper to examine several of these models of the Criminal Justice System and to suggest areas in which new models may provide insights into the problem of crime control. The Generalized Network Simulator (GNS) is seen as a vehicle by which such efforts may achieve their modeling objectives.

ANALYTICAL MODELS

The analytical model form first appeared in the 1967 Presidential Commission's Task Force Report: Science and Technology (11). Christensen developed several simple but illuminating models. One model forecasted the number of first offenders who are arrested per year, while other models approximated the number of convictions that could be expected during any recidivists criminal career. Although his models were simplistic, they did spark the imagination of other model builders who have developed not only descriptive models but also models which are policy oriented as well. The analytical models that have appeared in the Criminal Justice literature are aggregate in nature. Because of the need to obtain mathematical solutions to such complex phenomena, these models generally limit the analyst to addressing policy scenarios which are specific and which assume little interaction among the policy variables. In general, these models can be characterized by: a high level of aggregation, an assumed homogeneous criminal population (i.e., no differentiation of offenders), an assumption of steady-state, time invariant parameters, the exclusion of CJS costs and resource usage.

Although Christensen's models were highly simplified empirical models, most other models which have appeared in the literature possess more of the structure of the CJS than did his. One important example of this is the work of Belkin, Blumstein and Glass (2), some of Christensen's earliest successors in applying analytical techniques to the control of crime. They developed a feedback model of the CJS. Although their model contained only two components of the CJS, a combined police and judicial component and a corrections component, their objective was to model the entire criminal career. Thus, the feedback in the model is the flow of recidivists back into the police subsystem. Offenders released from the police-court component are re-arrested with probability α_1 following τ_1 elapsed years while offenders who are released from corrections are re-arrested after τ_2 years with probability α_2. The delays τ_1 and τ_2 were both assumed to be the expected values of exponential distributions. (Stollmack and Harris (14) later demonstrated that this assumption is acceptable.) The model's input was the number of first-offense arrests at time t.

Belkin, Blumstein and Glass used their model of the CJS to analyze the recidivism process assuming $\alpha_1 = \alpha_2 = \alpha$ (i.e., no rehabilitative and special deterrence effects). By varying these parameters, they fit the total number of arrests predicted by the model to the FBI's statistics for the decade beginning in 1960. This parametric analysis resulted in the estimates $\alpha = .86$ and $\tau_1 = 1.2$ years. Further analysis showed that the number of offenses by first offenders had increased while recidivism has declined. (They assumed $\tau_2 = 1$.)

To be sure, Belkin, Blumstein and Glass's model reached a much greater level of sophistication than those of Christensen. They demonstrated that recidivism can be modeled and they later showed that reducing the rate of recidivism is a much more effective method of reducing the total level of crime than is reducing the virgin arrest rate. Unfortunately, this model does not tell the CJS planner how to reduce recidivism, nor does it give any hint as to the alternatives which are the least costly. These important performance measures, it will be seen, are lacking in each of the analytical models surveyed. It is not until the simulation models that such issues are addressed.

The first model to possess recognizable policy variables was developed by Avi-Itzhak and Shinnar (1) and later refined by Shinnar and Shinnar (13). These authors modeled the criminal career of an offender and incorporated the incapacitation effect of the CJS into the model formulation. Two policy variables were included, the length of incarceration and the effectiveness of the police and the prosecution. The processes being modeled were assumed to be in steady state. They further assumed that an offender commits λ offenses per year according to a Poisson distribution. Thus, if the CJS does not affect the behavior of the offender through deterrence, incapacitation or rehabilitation, the expected number of crimes committed by an offender is $E(x) = \lambda T$, where T is the length of a criminal career. However, by assuming an incapacitative effect,

$$E(x) = \frac{\lambda T}{1 + \lambda qJS},$$

where q and S are the policy variables representing the joint probability that an offender is both arrested and convicted and the actual time served in prison, respectively, and J is the conditional probability that an offender is incarcerated following conviction.

The Avi-Itzhak and Shinnar model is a powerful tool because of its ability to relate the expected number of offenses per offender, E(x), to the policy variables q and S. As with other models of this type, the model is highly aggregate and it does not differentiate between the treatment of classes of offenders. The parameters q, J, and S must be estimated separately for each offender category in order to examine differential treatment; however, this approach complicates the analysis of dynamic behavior like the crime switching phenomena observed by Blumstein and Larson (4). Thus, the high level of aggrgation reduces the utility of this model for policy evaluation studies, and the lack of cost and resource considerations excludes the criterion of an incremental crime reduction per incremental cost.

Another policy model, based in part on Avi-Itzhak and Shinnar's work, was formulated by Blumstein and Nagin. Their model, which examines the deterrent and incapacitative effects of incapacitation on the crime rate, is a nonlinear program which minimizes the level of crime, given a capacity constraint on the number of offenders who can be imprisoned at any one time. Although such a constraint appears to hold nationally, local or regional capacity may not be so static. Blumstein and Nagin's expression for the aggregate crime rate is $C = \lambda \eta P$, where P is the fraction of the population that is criminal, η is the proportion of an offender's criminal career that he is active (not incarcerated), and the product $\lambda\eta$ is the effective crime rate per offender. Both P and η were described as functions of J and S: $\eta = 1/(1+\lambda qJS)$ and P is a logistic function of the disutility of imprisonment. The average number of persons incarcerated, I = qJCS, must be less than the prison capacity constraint U. Since both C and I are nonlinear, use of this model requires searching over the acceptable ranges of both Q and S, so that C is minimized when $I \leq U$.

A problem which is particularly evident with this model is its inability to determine an optimal policy over a planning horizon, and none of the analytical models faciltiate the exploration of transient behavior between two policies. A dynamic model would be especially desirable since the delays become extremely important when trying to optimize around a fixed capacity. The possibility of an infeasible level of incarceration as the result of a policy change makes the examination of the dynamic response a critical shortcoming of this and the other analytical models.

SIMULATION OF CJS OPERATIONS

Unlike their analytical counterparts, the simulation models have emphasized the operations of the CJS as opposed to the characteristics of the offender population. Thus, they deal directly with the issues of CJS policy-making. Whereas the performance measures of the analytical models have been the crime rate (first offenders and recidivists), the performance measures of the simulation models are varied, using one or more of the following criteria: annual CJS operating cost, total CJS cost attributable to the average criminal career, CJS resource availability, delays in processing offenders, and recidivism.

The first serious attempt to model the operations of the CJS was by Navarro, Taylor and Cohen (11). Their model, called COURTSIM, makes use of the General Purpose System Simulation (GPSS) language to trace on a day-to-day basis the paths along which offenders progress through the Washington, D.C. judicial system. Processing begins at the moment of an offender's arrest, but continues only until the presiding magistrate delivers his sentence. A limited number of case-specific attributes, such as the date of the indictment and the offender's bail status, accompany each simulated case. The COURTSIM study is particularly noteworthy for its treatment of court delays. Besides including the unavoidable delays associated with processing the offender, capacity and resource scheduling constraints were also introduced for each processing unit. More recent court models, e.g., Holeman (9), are essentially applications of this methodology. Several of these models are discussed by Chaiken, et al.(6).

COURTSIM is an open loop model since only the epoch during which an offender is under the direct purview of the CJS is portrayed. Another important open loop model was first published in 1969 by Blumstein and Larson (4). The so-called JUSSIM I model was used to forecast system costs, workloads, and resource requirements. Unlike the COURTSIM model, JUSSIM does not deal with individual offenders; consequently, queueing phenomena cannot be examined. Following their arrest, offenders are routed through the model by branching ratios that specify the proportion who will follow a specific arc at each decision point in the system. The identifier used to differentiate between offender categories in JUSSIM's first application was the most serious crime for which the offender was charged; however, any set of descriptors could be used. The JUSSIM model is driven by a forecasting function of the total arrest rate. By following the flow of offenders through the model, administrators can predict the workload on each component of the CJS. Possessing this information it is a simple matter to compute the resources required for a given workload, the cost per resource unit following directly.

The beauty of JUSSIM I lies in its ability to capture the essential characteristics of the CJS and to estimate the cost of alternate system loads. Of course, this model invokes several assumptions, but most of these can be dealt with with additional effort; all costs are assumed to be variable (i.e., none are fixed), delays in processing offenders are non-existent, and branching ratios are assumed to be insensitive to changes in system load.

Blumstein and Larson (4) also introduced an extension to the JUSSIM concept which has extraordinary potential for criminal justice planning. The model, called JUSSIM II, is a feedback model wherein offenders are tracked from the point of their first arrest to the point where they finally leave the Criminal Justice System for the last time. JUSSIM II of necessity includes measures of criminal recidivism (the feedback process) in order to determine if and when offenders are re-arrested. The input to this model, the number of first offenders, is added to the number of recidivists to give the total number of arrestees. The input may be either an age-specific cohort or the entire first offender population. If an offender is incarcerated, JUSSIM II determines the delay until the inmate is to be released. Following their release, the model computes the number of arrestees who are re-arrested; this probability is assumed to be a function of an offender's age, while the delay until re-arrest is assumed to be exponential. When an offender is re-arrested, JUSSIM II determines the most serious crime for which he is charged by invoking the Markovian assumption: the current offense depends solely upon the type of the immediately preceding crime. (Wolfgang, Figlio and Sellin (16) tested this assumption with their male birth cohort and found this model to be an acceptable representation of crime switching behavior.)

Since the JUSSIM II analysis of career criminal cost is dependent upon the cost estimates derived using JUSSIM I, many of the limitations of the open loop model also apply to the feedback model. However, this model is one of the more popular planning tools; several implementations now exist (6) (7).

Another feedback model of CJS operations was developed by Pittman (13) to evaluate alternatives in corrections policy. His model is a Markov chain representation similar to the model of crime switching behavior used in JUSSIM II. Unlike the crime switch model whose states correspond to the seven index crimes, Pittman's offenders may be in any of the following four states: in prison because of conviction, in prison because of a technical violation of parole, on parole, and not under CJS supervision.

Possessing the transition matrix P and the cost matrix C, Pittman was able to estimate future system loads and the crime mix given the number of first offenders who are arrested and convicted. In addition, the expected number of times the offender is re-arrested, the average sentence length, the expected criminal profile, and the expected career criminal cost of an offender were all computed analytically under steady-state conditions.

Although Pittman's model is obviously more analytical than simular, his emphasis is on the issues which actually change the flow of offenders within the corrections subsystem. Unlike the models of Belkin et al. (2), Avi-Itzhak and Shinnar (1), and Blumstein and Nagin (5), Pittman's model analyzes the effects on the offender profile of changes in the transition probabilities. In addition, by examining the transitions costs, this model can also be used to develop a least cost solution for reducing crime and thereby overcome one of the major deficiencies with the previous analytical works. Of course, the criticisms of Blumstein and Larson's model apply here as well. The invariance of the transition probabilities could be a problem in forecasting system load, while aggregating the costs can also create problems if the future cost distribution changes. In addition, to further expand the scope of the model to include the police and court subsystems expands the data requirements and complicates the computation of the performance measures. Thus, to resolve the limitations of Pittman's model, would require considerably more data and model analysis in order to draw conclusions about the performance of the entire CJS.

In 1972, a queuing model of the entire CJS was designed which incorporates a model of offender recidivism similar to that demonstrated by Blumstein and Larson. The model is called DOTSIM, an acronym for Dynamic Offender Tracking Simulation (6). DOTSIM, like COURTSIM, follows each simulated offender through the Criminal Justice System; however, like JUSSIM II the input to the DOTSIM model is the number of first offense arrests by crime type. DOTSIM has the capability of delaying the processing of offenders whenever the demand for a particular resource exceeds its supply. This competition over scarce resources makes DOTSIM a keen tool for CJS analysis since a particular policy alternative may arise which could cause resource shortages to delay offenders longer than expected. The random processing of offenders through the CJS itself lends greater resolution to the intricacies of offender-specific policy formulation. The effects of each policy scenario can be determined by measuring the change in the crime rate, resource requirements and system costs relative to a baseline policy. The costs embedded in the model include those which are directly attributable to an offender, based upon his consumption of resources. The indirect costs of equipment and facilities were also apportioned to the offenders.

The DOTSIM model also has its limitations, however. First the increased cost of operating the model and of collecting the necessary empirical data restricts its usefulness as a research tool. This, according to Chaiken et al. (6), is the reason that it has never been implemented. The model was also formulated in such a way as to prevent the testing of scenarios which examine differential recidivism tendencies of alternate correctional programs. A final criticism of this model is its inability to determine career criminal-related statistics.

AREAS FOR FURTHER RESEARCH

It seems that simulation models have provided a great deal more flexibility than their analytical counterparts. However, it can also be said that any future work in modeling the Criminal Justice System must combine the attributes of both model forms. In Table I is listed a brief summary of those performance measures and model characteristics which have been included in the foregoing models and which it seems should also be included in any future endeavors. To fully appreciate the effects of current or proposed policy on CJS performance, each of the performance measures listed in Table I should be included in any evaluation study or model. Although it is clear that each measure separately may produce different optimum policies, some means for combining them should be sought.

As for the characteristics of the models to be developed, as many of the attributes listed in Table I as is possible should be incorporated. The DOTSIM model came closest to achieving this objective, although it did have several important deficiencies - notably in the recidivism and performance measure areas. Any future studies should attempt to correct the deficiencies in these earlier models before real progress is made in this area. In addition, since it is doubtful that the analytical models can reasonably be expected to possess each of these attributes, the simulation model form should be relied upon for such a synthesis.

Because the simulation approach provides the needed flexibility, the Generalized Network Simulator (GNS) is one suggested vehicle for future CJS analysis. GNS is the most recent improvement to the GERTS III series of simulators which combines the resource allocation, queueing and costing features necessary for any discrete event simulation (15). Its capabilities have already been demonstrated in a court simulation (8). Because GNS can be easily modified (it is written in FORTRAN), simulating the CJS can be accomplished using any priority service discipline or routing rules which are needed. A successful implementation of a GNS model of the entire CJS is described in (12) where the authors have attempted to accomplish many of the objectives outlined in this paper.

Although the operating cost of a next event simulator would be greater than for a continuous flow model like JUSSSIM II, the ability to model individual offenders, to examine queueing-related phenomena, and to analyze the effects of comprehensive policy scenarios should justify the extra cost. Otherwise, the delay structure and the expected length of sentences which are a result of different pleas, for example, are lost to the analyst when the individual offender orientation is not assumed. If the level of detail recommended here is successfully implemented in such a model, scenarios related to plea bargaining, deterrence, differential sentencing or juvenile dispositions (to name a few) are all approachable research areas.

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