LANDMARK DEVELOPMENTS

A Gaming Simulation Framework for Planning

by

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ABSTRACT

Planners have generally failed to prevent the urban strife (including civil disorders, housing shortages, visual blight and rising pollution which characterizes so many North American cities. While they cannot necessarily be blamed for these occurrences, they cannot entirely be exonerated. Planning techniques for guiding and controlling urban development have not kept pace with the rapid growth of our modern cities.

Certain techniques have been borrowed from other fields, notably simulation modelling, but their use has frequently been hampered by a lack of data and by the high cost of implementation. Furthermore, these techniques have generally failed to filter down to the Profession at large, with the result that they have largely remained the preserve of the technical expert who may not be in the mainstream of broader planning principles. The sophisticated nature of these techniques has promoted their isolation from the day-to-day planning processes.
One alternative to a rigorous computer simulation is to employ a gaming simulation. The latter may permit a considerable simplification of the model by allowing the players (in this case, planners) to become 'simulation actors' who emulate the behavior of various interest groups or institutions in response to carefully selected rewards. This format has the advantage of precipitating the direct involvement of planners in the model and of facilitating their understanding of problems through the process of abstracting from reality. Such an abstraction is often conducive to the achieving of an overview; this may permit planners to be less distracted by the routine problems of planning administration, which are short term in nature, and to redirect their focus to longer term considerations.

The purpose of this Study is to develop a gaming simulation framework for the analysis of planning problems which are not readily amenable to many quantitative techniques and for the evaluation of alternative planning strategies. This framework or tool is capable of incorporating a series of very simple interrelationships into a recursive process
which will ultimately generate the implications of various decision alternatives and which will permit planners to identify optimum strategies.

The framework incorporates the simulative features of a 'gaming simulation' and the strategy evaluating features of 'game theory'. The former have generally constituted abstractions from reality which were merely assertions in mathematical form but which were not particularly useful for either rigorous analysis or accurate forecasting. The lack of mathematical rigour in their structures has tended to inhibit their use for any but educational purposes, notably prediction and research. The latter have been confined to the identification of optimum strategies in only the most simple exchanges, which cannot generally be related to the complexities of the real world.

This Study represents a step towards combining these two approaches. The gaming simulation framework, when 'primed' with appropriate data, will generate optimum strategies which may be followed by the participants. Its mathematical structure constitutes an amalgam of Markov processes, network
analysis and Bayesian decision analysis.

This technique is primarily designed to be used in the day-to-day planning process in large cities rather than in the cloistered research context, although it may later prove to have even wider applications.

The null hypothesis is presented in the Study which states that the framework is not capable of generating an optimal solution. It was then refuted using probability theory to demonstrate that an optimal solution was attainable.

The use of the framework in the planning context was then illustrated by applying it to the specific public/private negotiations preceding major urban landmark developments in Canada.
# TABLE OF CONTENTS

## Chapter

### I. SIMULATION GAMING - ITS PROBLEMS AND OPPORTUNITIES

1. Statement of the Problem
2. Importance of the Problem
3. Purpose of the Study
4. Importance of the Study
5. Scope of the Study
6. Null Hypothesis
7. Methodology
8. Definitions
9. Organization

### II. THE MATHEMATICAL FRAMEWORK BEHIND THE MODEL

- Introduction to the Framework
- Markov Processes in the Model
- Network Analysis in the Model
- Bayesian Decision Analysis in the Model
- Application of the Technique by Planning Officials
- The Systematic Use of Expertise in Decision Making

### III. THE FUNCTIONING OF THE MODEL

1. Refutation of the Null Hypothesis
2. Some Assumptions of the Model

### IV. CONCLUSIONS

1. Advantages and Disadvantages of the Framework Areas for Further Research

## APPENDIX

1. APPENDIX I
2. APPENDIX II
3. BIBLIOGRAPHY
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>61</td>
</tr>
</tbody>
</table>

Expected payoffs generated by the gaming simulation framework

LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Illustration</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Markov processes and voting patterns</td>
<td>24</td>
</tr>
<tr>
<td>II. Markov processes and traffic accidents</td>
<td>25</td>
</tr>
<tr>
<td>III. Markov processes and fatal traffic accidents</td>
<td>26</td>
</tr>
<tr>
<td>IV. Markov processes and public/private interactions</td>
<td>30</td>
</tr>
<tr>
<td>V. Network analysis in the model</td>
<td>32</td>
</tr>
<tr>
<td>VI. Decision stage I in the model</td>
<td>62</td>
</tr>
<tr>
<td>VII. Decision stage II in the model</td>
<td>62</td>
</tr>
<tr>
<td>VIII. Decision stage III in the model</td>
<td>62</td>
</tr>
</tbody>
</table>
CHAPTER I

SIMULATION GAMING - ITS PROBLEMS AND OPPORTUNITIES

Statement of the Problem

In spite of the fact that planners have developed a body of tools and expertise to make their own contribution to human welfare, they have failed to prevent the urban strife which presently characterises so many of our North American cities. While they cannot necessarily be blamed because the causes may be too deeply rooted to be within the planners' domain, they cannot be entirely exonerated. Planning techniques for guiding and controlling development have not kept pace with the rapid growth of our modern cities.

The immediate pressures upon planning result from a recognition that traditional measures -- principally civic design, the control of land use, and the allocation of subsidies -- do not cure the ills for which they were prescribed.

The success of these techniques has been further hampered by the lack of adequate data with the result that many existing quantitative techniques have been difficult or expensive to apply. Simulation in particular has been costly in this respect.

Importance of the Problem

The exigencies of routine administration are often permitted to inhibit the planning process -- i.e. to
shift the focus of planning from the long to short-term. Planners run the risk, along with their fellow professionals, of falling victim to what might be termed 'Gresham's Law of Administration:

In the absence of concerted effort to the contrary, routine matters tend to steal the attention from major policy problems, and short-range planning tends to push out long-range.

If planners are to achieve and maintain a long range perspective, they must devise techniques which will enable them to acquire an overview which will complement their shorter range skills.

In this respect, one of the most promising techniques has been the 'simulation' model which requires a degree of abstraction from reality which is conducive to achieving this overview. These most typically employ the computer to accommodate the enormous complexity of urban phenomena. However, while the computer represents a potentially powerful planning tool in itself, it will only realize this potential if the experimental model building is linked with the day-to-day planning processes.

While other fields are rapidly adapting to quantitative techniques, planning still largely relies on intuitive processes. While some new techniques have been borrowed, they have not spread to the
Profession at large and have remained the preserve of technical experts who may not be in the mainstream of broader planning principles. Unfortunately, many senior planners today are ill-equipped to appreciate the benefits or understand the problems with such tools as these powerful new computer simulation techniques. "During the 1960's, at least, none of the chief planners or their office heads is likely to have had an opportunity to study simulation techniques at a University and very few have had practical experience with simulation". Furthermore, their use has been hampered by the inadequacy and high cost of data and by the difficulty of relating the outputs of the more cumbersome models to everyday planning problems.

One alternative to a rigorous computer simulation is to employ a gaming simulation. This may allow a considerable simplification of the model by allowing the players to become 'simulation actors' who emulate the behaviour of various interest groups or institutions in response to carefully selected rewards.

A game simplifies the interaction of institutions, allowing a single person to comprehend the strategies open to social units. Therefore, instead of a computer, the model is played out in a human group with the players constrained
by a series of "rules of the game" which conform to the laws of nature, to rulings of the courts, and to expectations based upon custom and tradition. This kind of reductionism is one that is easily understood because people do view organizations as actors within a social setting.18

Purpose of the Study

The purpose of the Study is to develop a gaming simulation framework for the analysis of planning problems which are not readily amenable to many quantitative techniques and for the evaluation of alternative planning strategies. This framework or tool will be capable of incorporating a series of very simple interrelationships into a recursive process which will ultimately generate implications of various decision alternatives and which will permit planners to identify optimum strategies.

Importance of the Study

The importance of the Study lies in the fact that the framework developed attempts to bridge the gap between that body of mathematics called 'theory of games' and 'simulation gaming' techniques which have been derived from such games of skill or chance as chess and military games. The distinction has traditionally been made as follows:

Game theory is concerned with situations - games of 'strategy' in contrast to games of skill or games of chance21 - in which the best course of action for each participant depends on what he expects the other participants to do.22
Unfortunately, 'game theory' has been confined to the identification of optimum strategies in only the most simple exchanges (such as in parlour games) which cannot generally be related to the complexities of the real world. Simulation games, on the other hand, have constituted abstractions from reality which were merely assertions in mathematical form but which were thus not particularly useful for either rigorous analysis or accurate forecasting. This lack of mathematical rigour in their structures has inhibited their use for anything but educational purposes, notably prediction and research:

Operational games are highly effective teaching and communication devices but their utility for prediction and replication tends to be low... it does not seem likely that their utility as predictive devices will be increased until they are linked with highly detailed and sophisticated mathematical models.23

This study represents a step towards remedying this problem. The gaming simulation framework, when 'primed' with appropriate data, will generate optimum strategies which may be followed by the participants. Its mathematical structure constitutes an amalgam of Markov processes, network analysis and Bayesian decision analysis. The design criteria for the model might be summed up as follows:
For economic and social problems the games fulfill - or should fulfill - the same function which various geometricomathematical models have successfully performed in the physical sciences. Such models are theoretical constructs with a precise, exhaustive and not too complicated definition; and they must be similar to reality in those respects which are essential in the investigation at hand. The definition must be precise and exhaustive in order to make mathematical treatment possible. The construct must not be unduly complicated, so that the mathematical treatment can be brought beyond the mere formalism to the point where it yields complete numerical results. Similarity to reality is needed to make the operation significant. And this similarity must usually be restricted to a few traits deemed 'essential' pro tempore - since otherwise the above requirements would conflict with each other. 

Scope of the Study

The Study will develop a gaming simulation framework and will demonstrate how it generates the optimal (and sub-optimal) solutions. Furthermore, its use in planning will be illustrated by applying it to the specific public and private negotiations preceding major urban landmark developments in Canada.

This technique is primarily designed to be used in the day-to-day planning process in large cities rather than in the cloistered research context, although it may later prove to have even wider applications.

Null Hypothesis

The null hypothesis is that the gaming simulation framework devised in this Study is not capable of
generating an optimum solution.

The importance of this approach is that an assertion can be made about the capability of the model to produce an 'optimum solution'. While the latter is subject to all the inadequacies of the model and its assumptions, it may subsequently be improved which will, of course, improve the quality of the solutions.

Instead of formulating hypotheses and predictions directly about the real world, it is possible instead to do the same thing about the model. Any results obtained from an analysis of the model, to the extent that it truly simulates the real world, can then later be translated back into the corresponding statements about the latter. This injection of a model has the advantage that it admits of what may be called pseudo-experimentation.

**Methodology**

The null hypothesis will be refuted using probability theory to demonstrate that an optional solution is attainable from the framework.
Definitions

Definitions will be given for the following terms; a model, a simulation, a game, a major urban landmark development, public/private interaction, a framework and a recursive process.

I. Model

"A model is a representation - actual or theoretical - of the structure or dynamics of a thing in process."

More specifically, "a 'model' in an artificial representation of a system, process, organism, or environment designed to incorporate certain features of that system, process, organism, or environment according to the purposes which it is intended to serve."

II. Simulation

Literally, "a simulation is an operating imitation of a real process".

More specifically, "simulation', as a general field of activity, has to do with the design, building, manipulation, and study of models. A 'simulation' or 'a simulation exercise' is an experiment performed upon a model.

A more rigorous definition has been developed in operations research which refers to 'simulation'
as involving "the development of a descriptive model of an organizational system which is used to try out various decision alternatives without interfering with the real system. The major advantage of this approach is that new policies and procedures can be tested without disrupting the operations of an organization, which would often be extremely costly and difficult, if not impossible to do. One of the most advanced planning applications of simulation was performed in the San Francisco Bay area."

'Simulation' is thus intrinsically connected with model building and manipulation:

The objective of much model-building is simulation. Literally this word means imitation, and most simulations are imitations of real world processes either through a mechanical analogue or through the operation of a computer process. Strictly speaking, the term simulation can be very broadly applied.

III. Game

"A game is any contest played according to rules and decided by skill, strength [and] or apparent luck." The term 'game' is perhaps unfortunate because it connotes 'entertainment' especially of an 'unproductive' nature.
IV. Major Urban Landmark Development

A major urban landmark development is a building or complex of buildings which have the following characteristics:

1. They are located in or near the central business district (i.e., they would not include the suburban shopping centre type of development);

2. They are large scale projects which may have profound impacts upon urban growth and development;

3. They are multi-use in character;

4. They are comprehensively planned;

5. They typically involve the consolidation of scattered land holdings under the administration, control and ownership of one organization or a collectivity of organizations;

6. They generally provide a 'focus' for downtown development and activity.

V. Public/Private Interaction

Public/private interactions consist of the reciprocal overtures, negotiations, proposals, agreements and/or contracts between private firms and public bodies.

VI. Framework

A framework is a conceptual structure which is designed to accommodate various types of data; it is a model without data.
VII. Recursion

Recursion means the solution to a problem in steps where the completion of one step becomes the starting point for the next step. "Unlike iteration, recursion has a substantive content; a recursive projection ordinarily will yield different results from a one-step projection because intervening changes in conditions influence the final outcome.

Recursive or stepwise models...tend to answer the question of how development will actually take place, considering that private decision-makers take a relatively short view and are apt to inspect closely only conditions which exist at the time of their decisions. This...type of model is of greater utility (than a 'one-shot' model) in making realistic decisions about the impact of policy and the feasibility of plans developed on a one-shot basis.

VIII. Solution

"The immediate concept of a solution is plausibly a set of rules for each participant which tell him how to behave in every situation which may conceivably arise."
Organization

The Study will be organized as follows:

Chapter I - the outline of the Study.

Chapter II - an analysis of the mathematical structure behind the gaming simulation framework.

Chapter III - the refutation of the null hypothesis.

Chapter IV - a discussion of the merits of the model and areas for future research.

Appendix I - a discussion of the various types of games; an analysis of the historical roots of gaming simulations and their relevance to the planning context today.

Appendix II - Major Urban Landmark Developments - a gaming simulation developed for planners.
Footnotes - Chapter I

1 Zoning and subdivision control are two of the most common techniques.


3 If a review of these uses were made, it would have to cover the many uses of statistical analyses in urban and regional planning, the techniques ranging from regression techniques to more sophisticated factor analyses, component factor analyses, and cluster analyses. In addition, generalized statistical programs have been written for the ultimate reduction of statistical tools to more readily available and usable forms. Other important aspects would be the relation to economic structure, market analysis, demographic projections, and analyses of governmental resources and requirements. Still another important grouping of research is that of land use model-building activity. Furthermore, during the same time that innovation was taking place with regard to substantive knowledge of land use forecasting problems, a technological breakthrough was being made in the use of simulation. Some of the models dealt with aspects of national, regional, and urban development. Other simulations, while dealing with spatial dimension in part, were concerned with general problems of simulation methodology.


4 For example, the current simulation study of Vancouver being performed jointly by the City of Vancouver, the Greater Vancouver Regional District and the University of British Columbia will cost an estimated three quarters of a million dollars.

Dr. Holling, private interview held at U.B.C. in March 1970.
5 This is, of course, a parody of Gresham's famous law in economics which states that gold will tend to be hoarded and paper money of the same face value circulated since the former has the higher intrinsic value.


6 Increasing complexity presses a profession toward simultaneous development in two directions: one, specialization of technique and subject matter into slightly overlapping cells of sufficient simplicity for individual decision making; and two, the elaboration of new models and devices for achieving an overview. Richard L. Meier, and Richard D. Duke, "Gaming Simulation for Urban Planning," p.3.

7 Experimentation via simulation is essentially a technique for managing, separating, and observing related segments of the seamless web of phenomenal complexity.


8 Britton Harris stresses the complexity of the interrelationships between urban phenomena as being one of the two most important loci for metropolitan planning problems:

"Most of the problems of comprehensive metropolitan planning involve in the first instance very large amounts of detailed information regarding land, buildings, public services and activities... Even more serious is the second characteristic of the working problem. In any realistic and total view of a large city or metropolis, the number of interrelationships among activities and between these activities and the space which they occupy becomes astronomical."

Some of the pros and cons of using a computer in gaming are:

1. Speed and complexity: manual games are limited in complexity because of a long calculation time needed to generate information for decision making.
2. Accuracy: errors in manual computation may result in a loss of faith in the game administrator.
3. Cost: manual games are far less costly both to set up and to run.
4. Flexibility: manual games can more easily be changed if some aspect of the game needs modifying.
5. Comprehensiveness: the computer permits far more comprehensive and detailed information to be generated for decision-making.
6. Ease of experimentation: the game can be tested played more quickly on a computer.
7. Glamour: computer simulations are 'in vogue'.


"The receptivity of the model is most important - both in terms of the level of the detail and in the ultimate reality of the consequences to the harnessed imagination of the planner. While the model-builder is frequently clever in his use of parametric variation to reflect, for example, intended urban renewal changes, it is important - if the model is to become part of the overall planning process - that the planner learns how to utilize the potentially enormous power of computer models to examine highly diverse alternatives thoroughly."

"Although the key decisions are imbedded in the planning standards and the professional predictions, only rarely are their origins or rationals made explicit."


However: "They [i.e. new techniques] were refined in the more unitary settings of the private corporation, the engineering firm, and the single-function governmental agency; and they have proved most useful in designing and constructing machines, buildings, and similar physical objects. Because of their success with very complicated weapon and missile systems and with production processes, some systems analysts and operations researchers are now seeking to apply their sophisticated methods in municipal governments. They are finding, however, that their planning strategies are not easily transferred, since they call for a measure of goal consensus, for a quality, a hierarchy of command, and a degree of control that do not exist in the normal context of public affairs."

Ibid., p. 650-51.

"As it now stands, the urban milieu is fast approaching the limit of the existing planning bag of tricks; it would be a human tragedy if the hard data computer specialist - often inadequately trained in such yet - quantifiable fuzzy fields (social 'well-being,' communication, mental health, community, aesthetics, etc.) - were to dominate planning decision making and skew our urban society in the direction of cost accounting and acreage by input-output analysis measured in the Philistine, if basic metric of dollars, tons, unit things and unit people. Specifically simulation models in
computer language measure too few things too specifically - they are truncated/slanted and convincing at the same time and must be delicately handled in this their initial stage by responsible public and private officials, if we would upgrade our urban civilization."


14 "There is little question but that two-way interaction, planner to model-builder and vice versa, is needed. One important consideration is the active role of the planning department or agency involved and the presence on the staff of such an agency of individuals who are working in a daily relationship, training and being trained by the model-builder. The model exercises discussed above vary in this quality, ranging from relatively complete involvement to very little. In no case to-date has there been, however, a truly daily working relationship yet established where urban renewal planners and decision makers are testing out new alternatives through the use of computer models built for them."

Wilbur A. Steger, "Review of Analytic Techniques for the CRP, p.643.


16 Ibid, p.9.

17 See footnote #20, Appendix I


19 "The 'hand-played' crisis game [Giffen's term for a manually played simulation game] provides, in fact, no more than an additional qualitative tool for the examination of essentially qualitative questions. Aspects of such questions that can be
quantified or computerised are not the important ones. This is unfortunate, for analysis along non-quantitative lines is often less than satisfying in that it is not subject to clear proof. But it has to be accomplished nevertheless, in connection with problems that are frequently of greater import in human affairs. p. 180.


20 "Reflecting the early literature of urban geography and human ecology, city planning has traditionally perceived the city as a discrete physical entity whose signal traits are size, shape and density. This perception has encouraged much the same sorts of morphological measurements and classifications that typified early biology. It's only in recent years that serious attention has been directed to the interaction among city dwellers. The new studies are now leading us to a different conception of the city and of the policy issues associated with urbanization... Unfortunately it is still very poorly understood. Despite all the recent work in urbanism, we still do not have even an inadequate description of the urban system's structure. In search of some organizing principles that might give some coherence to these new findings and conceptions, students of urbanism are turning their attention from considerations of form to considerations of process."


21 The elements of gaming consist of:

1. Chance (stochastic elements)
2. Skill (deterministic elements)
3. Known parameters in the game (structural elements), and
4. Fantasy (a component of activities which are not really games in the strict sense e.g. dancing and skiing) - These activities may be stimulating but are low in cognitive content.


25 Large-scale developments of this type represent a new scale in the urban growth process which poses a great challenge to today's planners and which can be expected to become increasingly prevalent in the future.

"In the metropolitan stage of growth, the typical item of development is big: a regional shopping centre, a hotel-and-office complex, a compound of theatres, a new freeway or university, an industrial or research 'park' or a town-full of housing. From recent experience, we may assume that development proposals on this scale will emerge more and more often in the major cities of Canada. Most of the planning legislation and processes we have date from a very different situation, twenty or more years ago... These large scale projects were never contemplated by the draftsmen of the present planning system, which emphasizes procedure for layout of small tracts of bungalows or assumes that most schemes will be for a simple, single purpose, in a location where the planning board had already anticipated that use and density.

"There are two results of this gap between the familiar public planning system and the way modern metropolitan development tends to be done. First, it becomes more troublesome to the developer to gain approval for an imaginative and varied
scheme (although we know that almost all the urban design we admire was achieved by large landowners seeking a broad blend of uses and activities). Second, consent for work of this kind not being a purpose of the existing public planning system, it tends to be settled by negotiation in camera between developers and officials, by-passing the statutory process and, when the results finally come into public view, often causing upsets or acrimony or dis-enchatement all round."


The variables in the model will be based on:

Dr. Robert Collier, Public/Private Inter-actions in Major Urban Landmark Developments, sponsored by the Canadian Council on Urban and Regional Research, 1970.


There are four types of models:

1. Pictorial - these are essentially descriptive and static. They must usually be supplemented by a verbal explanation.

2. Verbal - these are word pictures which describe or analyse phenomena.

3. Mathematical - these consist of equations which symbolically represent behavior (of humans, animals or things) and which are so structured that the unit relationships among the units and variables involved produce consequences isomorphic to the reality they portray.
4. **Simulational** - these consist of techniques of performing sampling experiments on a model of a system.


The experimentation with models must be contrasted with experimentation using natural phenomena:

"The natural experiment has the advantage of providing data from the empirical system itself. Here the researcher can observe the operation not of the model but of the actual system; validity is assured. Natural experiments, however, have two serious drawbacks from the point of view of the requirements of a scientific methodology:

1. An experimental situation cannot always be found in nature which definitively confirms or unconfirms hypotheses; and

2. When natural experiments are found, it is unlikely that they will be found in sufficient to provide statistically useful samples; reliability becomes a problem."

Ibid., p. 195.

A model attempts to represent as many details of the phenomena as possible although it should discriminate in favour of the deterministic variables:

"A model is a scientific tool. If a model is to be useful for description, explanation, or prediction, there must be some manner of correspondence between the model and the reality it represents. Developing a model involves abstracting from reality those components and relationships which are hypothesized to be crucial to what is being modelled. Important detail is included in the model with the exclusion of redundant and distracting detail. The better the theory, the more knowledge we have about the conditions under which neglected variables do or do not make a difference."

Ibid., p. 191.
One of the most fundamental types of models in planning is the zoning map which represents certain topographical and man-made features of a city.


"In one sense, the idea of reproducing phenomena without using the original can be described as a sampling procedure. Of all the aspects or properties of something 'out there' only selected ones are used. Such is the case even for 'complete' replications (e.g. a mock-up of a weapon that may be different in size). Thus different simulations can be conceived of as falling on a continuum of samples, the point along which represents proportion of characteristics actually employed to the total sample space. The closer the sample comes to exhausting the total number of attributes, the more 'realistic' is the particular form of the simulation."

H. Guetzkow, et al., Simulation in International Relations, p.4.


The Center for Real Estate and Urban Economics, Jobs, People and Land (Institute of Urban and Regional Development, University of California, Berkeley, 1968).


There are many ways to classify games which may be based on:

1. Orientation - role playing vs. 'pure' simulation (i.e. the roles are built into the game).

2. Degree of interaction - in an 'interactive' game, decisions made by one player or team has a mathematically determinable effect upon the results achieved by another player or team.

3. Basis for success - e.g. computer vs. manual games. The former are capable of being considerably more complex (and in some cases more simulational) than the latter.

4. Participation structure - e.g., team play vs. individual play and competitive vs. non-competitive games.

Paul S. Greenlaw, et al., *Simulation In Industrial and University Education*, p.23.

These include the following:

1. Developers,
2. Financial institutions,
3. Architects,
4. Consulting planners and engineers, and
5. Other private organizations.

These include the following:

1. Federal, provincial, regional and municipal governments;
2. Public boards and utilities,
3. Crown corporations, and
4. Other public agencies.


Ibid., p. 623.

CHAPTER II

THE MATHEMATICAL FRAMEWORK BEHIND THE MODEL

Introduction to the Framework

The mathematical framework behind gaming simulation provides a further understanding of this approach to planning problems. The former is the backbone of the simulation and must stand on its own merits. Its basis is founded in statistical theory while the latter is rooted in the social sciences (motivation of players, ramifications of role playing, etc.).

The framework might best be described as a combination of existing techniques: Markov processes, network analysis and Bayesian decision analysis. Each of these is designed to serve a different purpose in the model, but together, they combine to produce a tool which may provide a link between 'gaming simulations' and 'game theory'.

Markov Processes in the Model

The Markov process has been widely used to simulate certain social processes in urban interaction. It is primarily concerned with inter-relationships between social phenomena and the
impact on their probability distributions. It generally represents the effect of the occurrence of one activity upon the recurrence of that same activity. For example, if a man voted Democrat in 1960, he might well be more likely to vote Democrat in the 1964 election. The diagram below indicates, by means of a hypothetical example, that voting for a particular party will increase the probability of voting for the same party in the next:

Figure I

If the voting probabilities in 1964 depend solely on the voting behavior in 1960, the model is called a 'Markov Chain'. If, however, these probabilities depend on voting behavior in earlier elections as well, then it is a 'Markov Process'.

The framework presented in this paper functions in much the same manner, except that the outcome of one activity is permitted to influence
the outcome of a second and related activity. Let us take the following general example before embarking on a discussion of the planning implications of the framework: it is generally recognized that drinking will increase the likelihood of an individual's having an automobile accident while driving. However, it is always possible to have an accident without drinking, but the probability will be lower. Let us assume that if an individual goes to a party, he has an 80% chance of both being offered and accepting a drink.

Let us further assume that the 'odds' are that he will have an accident anyway are .05, but that this figure would be increased to .15 if he has been drinking. The various outcomes would be as follows:

Figure II

- Drink (.80)
  - Acc. (.15)
  - No Acc. (.85)
- Abstain (.20)
  - Acc. (.05)
  - No Acc. (.95)

Further, we might say that an involvement in a traffic accident increases the likelihood of the death of an individual in a given year (i.e. through a fatal accident). Assume that the probability of
dying at the age of thirty is 0.10 and that this would be increased to 0.30 if the individual has been in an automobile accident. The various possibilities would be as follows:

Figure III

Drunk (.80)

Abstain (.20)

Acc. (.15)

No Acc. (.85)

Death (.30)

Life (.70)

Death (.10)

Life (.90)

Death (.30)

Life (.70)

Death (.10)

Life (.90)

In this case, the probabilities at the third stage depend only on the outcomes of the second stage. This situation is analogous to the 'Markov Chain'. If, however, they were also dependent on the outcomes of the first stage (i.e. a drunken person might be better able to survive the impact, once hit, because of more relaxed muscles), then the illustration would be more similar to the 'Markov Process'.

The probabilities of two or more of these events occurring (i.e. conditional probabilities)
are obtained by multiplying the various probabilities together. For example, the probability of drinking and having a fatal accident would be \( 0.036 \) (\( = 0.80 \times 0.15 \times 0.30 \)).

This model, however, differs from the 'Markov Chain' where the occurrence and recurrence of a particular event is of primary concern. For example, the probability of drinking once might increase the desire (and hence probability) of drinking a second time, and so on. Such a process is called 'iterative'.

The framework outlined above, however, is a 'recursive' process, or one that proceeds step-by-step. It distinguishes itself from an 'iterative' process by the fact that each step is not merely a recurrence of the decision made at the last step (e.g. as in successive elections). In a recursive process, new variables or information are introduced at each stage, and the very nature of the event itself may be entirely different from the previous one. For example, the consumption of an alcoholic beverage followed by a traffic accident are separate although related actions. This is not
the case with successive elections which refer to the recurring of a particular action.

In the Planning context the influence of one event upon the occurrence of another is a well known phenomenon. For example, the building of a major office tower might increase the likelihood of a public outcry against traffic congestion. However, the real world is a good deal more complex than these simple relationships, and while one event may induce another, a third may operate to either mitigate or counteract this effect. For example, the traffic problem mentioned above might be mitigated or even eliminated by the installation of a rapid transit system. The degree to which the latter was effective would depend on the various factors involved and how these interacted.

The gaming simulation framework developed in this study is designed to permit this interaction to take place after having assigned mathematical weights to and certain interrelationships between the factors. Let us consider a hypothetical example based on the following assumptions:
1. A large office tower complex in the C.B.D. has an 80% chance of being completed.

2. The current probability of having serious traffic congestion (as defined by some criteria) on a given day is 50%, but this will be increased to 70% if the complex is built.

3. The present traffic congestion has a 40% chance of triggering a strong public outcry, but this will increase to 60% if the complex is built.

4. The current probability of a subway being constructed is 20%, but this will be increased to 35% if there is a strong public concern about traffic.

The various outcomes can be illustrated using a decision tree as follows:
Figure IV

Bldg. (.80)
No Bldg. (.20)

Cong. (.70)
No Cong. (.30)

Outcry (.60)
No Out. (.40)

Sub. (.35)
No Sub. (.65)

Sub. (.20)
No Sub. (.80)

Outcry (.40)
No Out. (.60)

Sub. (.35)
No Sub. (.65)

Sub. (.20)
No Sub. (.80)

Bldg. (.80)
No Bldg. (.20)

Cong. (.50)
No Cong. (.50)

Outcry (.60)
No Out. (.40)

Sub. (.35)
No Sub. (.65)

Sub. (.20)
No Sub. (.80)

Outcry (.40)
No Out. (.60)

Sub. (.35)
No Sub. (.65)

Sub. (.20)
No Sub. (.80)
As can be seen, even a simple example rapidly becomes complex. Since a particular event can occur or not occur, the total number of outcomes is two raised to the power of the number of stages (in this case, $2^4$). Furthermore, the real world can be expected to be infinitely more complex, involving feedback from later stages to earlier ones, etc. (e.g. a subway might reduce traffic congestion, and hence the public outcry).

This traffic example is conceptually similar to the 'drink-don't-drive' example mentioned earlier and forms the basis for the framework for 'Major Urban Landmark Developments'.

Appendix II presents the details of a gaming simulation model designed to be used by planners with respect to such developments.
Network Analysis in the Model

Network analysis is concerned with the costs of various decision alternatives and the provision for their minimization. Generally, a problem is set up in a series of decision stages. The researcher then starts from the last one and works systematically back to the first, calculating the least cost combination for the remaining ones at any given stage. This procedure in effect maps out a decision path of minimum cost.

For example, if one wanted to travel from A to B to C to D at the lowest possible cost, and the modes of transportation available were air, rail and ship, the various alternatives might be indicated as follows:

Values would be assigned to the various paths representing the cost of each decision alternative. Network analysis then starts at the last decision stage C - D and works backwards.
to A, selecting at each stage the optimal combination of modes for the remaining stages.

The framework uses this approach but concentrates not only on minimizing costs ('investments' in the game) but also on maximizing rewards ('payoffs') associated with various courses of action. These costs and payoffs, however, are not expressed in absolute units (as has traditionally been the case when the technique was employed) but are stated in terms of expected payoffs net of investments. The application of this approach in the model will be discussed in the next Chapter.
Bayesian Decision Analysis in the Model

Bayesian decision analysis essentially involves starting with a probability distribution based on past experience (called the 'prior distribution') and modifying it on the basis of current information (called the 'posterior distribution'). In this framework, updating is not carried out by experimentation or gathering fresh information but is performed by the Markov process operation in the model, which continuously adjusts the 'prior' probabilities to reflect new conditions as generated in the game. This aspect will be further explored in the next Chapter.
Application of the Technique by Planning Officials

The gaming simulation framework may be used by planning departments upon the application of a developer to build one of these major projects. While there are some cases where the developer wishes to build within all the by-laws and zoning ordinances, frequently some special consideration is required (such as re-zoning). In these cases, the planning department may exert considerable influence over the project. The gaming simulation framework may then be used to test alternative strategies in order to achieve a more desirable development.

The framework is designed to encourage the planners to be explicit in formulating their approach to the problem instead of merely relying on intuitive judgement, which has all too frequently been the case in the past. The methodology involved in testing these strategies is as follows:

1. The planners decide what type of development they envisage as being not only more desirable (than the one proposed by the developer) but also attainable.
2. Both the initial proposal and the desired proposal are translated into 'profiles' in terms of variables which
represent their principal characteristics (vis à vis land uses, financing structure, amenity, etc. - see Appendix I). These are called 'Project' variables. Appendix II includes a profile of Place Ville Marie.

3. The critical public/private interactions are identified (both on the basis of past experience and on expected conditions) and these become 'Event' variables in the model. (see Appendix II). Some of these will be easy to predict (such as legally required public hearings) while others will be less obvious (e.g. the strong opposition of the ratepayers).

4. Probabilistic weights should be assigned to the variables, and again, past experience may be a guide; however, a word of caution is in order. Statistical techniques are based on a large number of transactions and are, therefore, more directly applicable to such developments as apartment buildings. These are sufficiently common to warrant greater
reliance on past experience (except in extenuating circumstances). Major urban landmark developments are considerably more rare. Furthermore, they may often require re-zoning, or other special considerations which will tend to make them unique.

5. The Game is played using a computer (which will accommodate a greater number of variables, interrelationships and game trials, than a manual game). Various policy strategies may be employed by the planners to achieve a more attractive development from the one initially being proposed by the developer. The Game will produce as outputs the optimum strategies, the public/private interactions that can be expected to occur and the final profile of the development.

6. The Game may then be replayed with altered variables, probabilistic weights or interrelationships to test the consequences of alternate assumptions. In this process, it may be discovered that:

a. the original assumptions produced a result incompatible with reality;
b. the alternate assumptions produced a result incompatible with reality; or

c. certain assumptions may be varied within a wide range without significantly affecting the results. This might indicate which variables planners should concentrate on in the public/private negotiations which actually ensue.

The above suggests that the Game will call for the extensive use of 'expertise' in the selection of variables and the postulation of probabilities and interrelationships. Enormous strides are currently being made in this area, notably in the use of 'free form management' techniques and the 'Delphi' method of soliciting group consensus. The use of expertise will be discussed below.
The Systematic Use of Expertise in Decision Making

The use of 'expertise' in decision making predates the use of sophisticated analytical tools, but recently, many of our modern techniques demand that intuitive judgement be explicitly set out so that it can be incorporated into mathematical models. Dr. Olaf Helmer has articulated the need for the systematic use of expertise in what he calls the 'inexact sciences' in two pamphlets published by the Rand Corporation. He argues that future events are, to a large extent, determined by personal expectations by individuals who may exert their influence on these events, rather than by theoretical considerations.

The use of 'expertise' is needed in some situations where 'relative frequency' will not give an accurate indication of what can be expected in the future. This use of past instances as a basis for probability assignments is common but, in some cases, may be unwarranted in the light of background knowledge.

An everyday example of the use of background knowledge occurs when a doctor is analyzing the symptoms of a patient who may have one of two
diseases. Although one may have a higher relative frequency, the doctor might chose the other in the light of background knowledge about the patient's medical history. Furthermore, we have criteria to evaluate the performance of the doctor (which is his ability to correctly diagnose cases over a long period of time).

In this particular case, the doctor is applying a 'personal probability' to the patient's having one or other disease. "Personal probability is a measure of a person's confidence in, or subjective conviction of, the truth of some hypothesis".

Helmer suggests that one of the most effective ways of systematically utilizing expertise is through the medium of a gaming simulation model:

Epistemologically speaking, the use of an expert as an objective indicator ... amounts to considering the expert's predictive pronouncement as an integral, intrinsic part of the subject matter, and treating his reliability as a part of the theory about the subject matter. Our information about the expert is conjoined to other knowledge about the field, and we proceed with the application of precisely the same inductive methods which we would apply in cases where no uses of expertise is made.
A particularly effective way of encouraging interaction among experts is to place them in a laboratory situation where they are required to participate in a simulation exercise. In a simulation model a kind of conceptual transference takes place. Instead of describing a situation directly, each of its elements is simulated by substituting a mathematical or physical object for the real one and simulative relations for those that really exist. For example, a policy planning operation can be simulated by a set of make-believe decision makers who, playing roles in a laboratory 'game', might go through the decision making motions that their real-life counterparts would be expected to carry out in actuality.20

In operational gaming, the simulated environment is particularly effective in reminding the expert, in his role as a player, to take all the factors into account in making his predictions that are potentially relevant; for if he does not, and chooses a tactic or strategy which overlooks an essential factor, an astute 'opponent' will soon enough teach him not to make such an omission again.21

This discussion begs the question: 'What constitutes expertise?' This is not an easy matter to resolve but Helmer offers the following suggestion:

"The first and most obvious criterion of expertise is of course knowledge... However, the expert's knowledge is not enough; he must be able to bring it to
bear effectively on the predictive problem at hand, and this not every expert is able to do. It becomes necessary also to place some check upon his predictive efficacy and to take a critical look at his past record of predictive performance." 22

The systematic use of expertise in the social sciences opens up an exciting new field for progress. Until recently, however, this development has not been forthcoming:

This prospect constitutes a method whose potential for social-science research has hitherto virtually gone wholly unexplored, and it is our hope that this neglect will soon be remedied." 23
Footnotes - Chapter II

1 It should be noted, however, that gaming may exist in the complete absence of simulation (e.g. shooting dice).

2 For an extensive review of Markov Chains and Markov Processes see:

3 It has been used to simulate voting patterns in successive elections and also social mobility patterns.
   Ibid., Chapter VIII.

4 It is thus not a converging process which will tend towards a certain result if repeated an infinite number of times.

5 Conditional probabilities are discussed in:

6 Conversely, if one were violently ill the first time, then subsequent probability might be lessened.

7 A definition of recursion is presented in Section VII of Chapter I.


9 Major urban landmark developments in Canada have mostly been handled in an 'ad hoc' basis by the various planning departments.
   Ibid.

10 Many phenomena in nature can be closely represented on a 'normal curve'. For a review of probability theory, see:
Almost by definition, a 'landmark' cannot be 'common'.

"Now instead of formulating a hypothesis and prediction directly about the real world, it is possible instead to do the same thing about the model. Any results obtained from an analysis of the model, to the extent that it truly simulates the real world, can then later be translated back into the corresponding statements about the latter. This injection of a model has the advantage that it admits of what may be called pseudo-experimentation."


Free form management is a type of corporate organization, usually in entrepreneurially oriented companies, where rigid job designations and responsibilities are not assigned to upper management. Rather, groups are asked to take on a multi-faceted task (such as the setting up and operation of a new division); it is assumed that the participants will tend to gravitate to those decisions involving their own field of expertise, but will also acquire an interest in other decisions as well. Companies which have successfully used this approach include Xerox and Litton Industries.

The Delphi Technique is one which eliminates: "committee activity altogether, thus further reducing the influence of certain psychological factors, such as spurious persuasion, the unwillingness to abandon publicly expressed opinions, and the bandwagon effect of majority opinion. This technique replaces direct debate by a carefully designed program of sequential individual interrogations (best conducted by question-airs) interspersed with information and opinion feedback derived by computed consensus from the earlier parts of the program. Some of the questions directed
to the respondents may, for instance, inquire into the 'reasons' for previously expressed opinions, and a collection of such reasons may then be presented to each respondent in the group, together with an invitation to reconsider and possibly revise his earlier estimates. Both the inquiry into the reasons and the subsequent feedback of the reasons adduced by others may serve to stimulate the experts into taking into due account considerations they might through inadvertence have neglected, and to give due weight to factors they were inclined to dismiss as unimportant on first thought."

Ibid., p. 47.

14 Dr. Helmer was also the developer of:
Kaiser Aluminum and Chemical Corporation,
Simulating the Future ( Unpublished game developed as a corporate planning tool ).

15 These two works are:


ii. Epistemology of the Inexact Sciences, op. cit.

16 Olaf Helmer, Analysis of the Future, p.4. 
"projections into the future, on which public policy decisions must rely, are largely based on the personal expectations of individuals rather than on predictions derived from well-established theory. Even when we have a formal mathematical model available... the input assumptions, the range of applicability of the model, and the interpretation of the output all are subject to intuitive intervention by an individual who can bring the appropriate expertise to bear on the application of the model."

17 Olaf Helmer, and Nicholas Rescher, Epistemology of the Inexact Sciences, pp. 30-31.
For example, if Smith, who has always paid a 15 ¢ bus fare, is required one morning to pay 20 ¢, past experience would give a falacious indication of future rates; background information would indicate that when rates go up, they stay up:

a knowledge about past instances or about statistical samples—while indeed providing valuable information—is not the sole and sometimes not even the main form of evidence in support of rational assignments of probability values. In fact the evidential use of such *prima facie* evidence must be tempered by reference to background information, which frequently may be intuitive in character and have the form of a vague recognition of underlying regularities, such as analogies, correlations, and other conformities whose formal rendering would require the use of predicates of a logical level higher than the first.

The consideration of such underlying regularities is of special importance for the inexact sciences, particularly the social sciences (but not exclusively) because in this sphere we are constantly faced with situations in which statistical information matters less than knowledge of regularities in the behavior of people, such as traditions and customary practices, fashions and mores, national attitudes and climates of opinion, institutional rules and regulations, group aspirations, and so on.

This non-explicitness of background knowledge, which nonetheless may be significant or even predominantly important, is typical of the inexact sciences, as is the uncertainty as to the evidential weight to be accorded various pieces of *prima facie* information.
in view of indirect evidence provided by underlying regularities. Hence the great importance which must be attached to experts and to expertise in these fields. For the expert has at his ready disposal a large store of (mostly inarticulated) background knowledge and refined sensitivity to its relevance, through the intuitive application of which he is often able to produce trustworthy personal probabilities regarding hypotheses in his area of expertise."

18 Ibid., p. 25.
19 Ibid., p. 41.
20 Ibid., pp. 5-6.
21 Ibid., p. 54.
22 Ibid., p. 42.
23 Ibid., p. 58.
CHAPTER III

THE FUNCTIONING OF THE MODEL

Refutation of the Null Hypothesis

The null hypothesis has been refuted using a hypothetical example to demonstrate how the optimum strategy can be identified. The case was oversimplified to illustrate the point since the complexity of the model increased exponentially with an increase in the number of variables. However, the methodology still pertains to other applications of the model.

Basically, a three variable case was considered where one was a 'Project' variable and two were 'Event' variables. The 'Project' variable corresponded to an element in the profile of a 'landmark development' which the planning department might be particularly anxious to see materialize. The 'Event' variables represented two public/private interactions which were related, in the manner indicated below, to the above particular feature of the development (i.e. the 'Project' variable). The object of
the game was to induce the latter to occur through the strategic investment of resources for which a payoff of 8 chips might be received.

It should be noted that the players do not receive any direct reward for the occurrence of variables 'A' and 'B', but they may increase their expected payoff on 'C' by investing in either of these first two variables. In a sense, 'A' and 'B' represent one means to an end, 'C'.

The players play as a team rather than against one another. The scores attained at the end of each game have no intrinsic importance except as they relate to scores achieved in subsequent replays. This corresponds to reality where a planning department will act as a team (which need not imply unanimity) in order to achieve a particular goal. Its success cannot be measured in terms of one individual project, whose fate may depend on factors beyond its control, but in its success relative to other projects and to other planning departments.

A planning department has certain resources at its disposal which may include money, technical skills, political expertise and time to allocate to planning problems. Any or all of these may be
brought to bear on a problem in order to arrive at a specific goal and which constitute 'investments' in the success of a project.

"... the ultimate criteria in decision-making for a city in the era that is upon us must be the quality of the urban environment produced in that city as a consequence of that decision. Therefore enhanced quality must also be the aim of the game."  

These resources are, to some extent, substitutable for one another and so the planning department must decide on the most effective mix. In the game, however, these investments are represented in a stylistic fashion by spending chips which are limited in supply (as are most resources.) The reward for achieving the particular goal is an expected payoff which corresponds to the notion of utility in economics. This particular aspect of the model will be discussed later in this chapter.

The various roles involved in the public/private interactions are not assumed by the players, who would thus have to play against each other, but are embodied in the game structure itself. That is, the 'environment' responds to the actions
of one particular interest group, which in this case is the planning department. This facilitates the achieving of an overview which would be inhibited if the players were divided into factions.

The case represented below is a three decision model in which the order of decision making is 'A', 'B' and 'C'. The probabilities for each variable presented in the table are starting probabilities before any investments are made and these can be altered in the manner prescribed by the rules. The 'relationships' specified indicate that the occurrence of one variable will increase the chances of the related variable's occurring (indicated by the direction of the arrow). The rewards constitute the direct payoff received if a particular variable occurs. The rules are as follows:

1. Players may raise or lower the probability of the variable being played by 20% by investing 1 chip (positively or negatively). However, in no case may the probability be bid up to 100% or down to 0%. If the planning department allocates
some of its resources to achieve 'C', the original probability is likely to increase, in this case by 20%.

2. Players may also invest 1 chip as above in a related issue and in no other. This reflects the fact that the most direct route (investing only in 'C') may not yield the highest payoff.

3. If the issue 'occurs', related probabilities will move up 20%, and vice versa if it does 'not occur'. An example of this type of relationship in reality is that between density and traffic congestion: if a development is going to consist of a number of sky-scrapers, the project can be expected to increase the likelihood of having a serious traffic problem.

4. In addition, if a player has invested in a related event (either positively or negatively), its probability will go up or down by 40%. If, however, the event does not occur, the probability will be treated as in # 3 above. The 40% increment reflects the fact that while one variable may influence another without any intervention, planners may exploit a particular linkage (i.e. a relationship between variables) in order to receive a higher payoff.
These rules are only used to demonstrate the functioning of the model and to illustrate the manner in which optimum solutions are generated. The specific rules may be modified to meet the requirements of a particular situation without prejudicing the basic mathematical framework.

Each variable is assigned a 'starting probability' but these may soon be modified in the progress of the game. The model essentially performs the updating of these probabilities after the investment decisions at any given stage have been made. This constitutes a modification of the Bayesian approach where the 'prior distribution' based on historical data is updated on the basis of further information gathered by experimentation. This initial distribution thus becomes transformed into the 'posterior distribution' (the equivalent of the 'final probabilities' in the game). However, in the game, the latter distribution is 'resolved' (i.e. goes to 0% or 100%) by the computer which, in effect, roles a dice to see whether or not the event occurs. The occurrence or non-occurrence of this event will constitute a revision of the probability
distributions for later events (i.e. for those that are related) in the manner described in the rules.

It should be emphasized that at each decision stage, what has happened in the past is irrelevant (except to the extent that it bears on the future). Only the future costs and expected payoffs should be taken into account. The decision at any point should be made to maximize the expected payoffs minus the investments made to obtain these payoffs (i.e. to maximize 'net expected payoffs').

Thus the problem at any stage $i$ in the model is to maximize:

$$\left( E_i - I_i \right)$$

Where:

- Number of stages $= n$.
- Expected payoffs at stage $i = E_i$.
- Investment made at stage $i = I_i$.

This is achieved by using the network analysis approach of starting with the last decision and systematically working backwards. The net expected payoffs are calculated for the last stage and the optimal one(s) is (are) indicated.
This procedure is relatively simple for the last stage \((n)\) where an actual payoff of 8 chips is made. The expected payoff is merely this actual payoff multiplied by the probability of its attainment, or:

\[
(p_n) (e_n)
\]

where:

- The final probability of occurring at stage \(n\) = \(p_n\).
- The actual payoff made at stage \(n\) = \(e_n\).

The procedure for the penultimate decision stage is less straightforward, however, and involves conditional probabilities. The situation is complicated by the fact that there is no actual payoff at the stage \((n-1)\) but only at stage \((n)\). Thus the payoff at \((n-1)\) is the expected payoff at \(n\) multiplied by the probability of its attainment at \((n-1)\), or:

\[
E_{n-1} = (p_{n-1}) (E_n)
\]

A small digression here may serve to illustrate the point. If three men were to draw straws for $100, the expected payoff for each would be:

\[
E_n = (1/3) (\$100)
\]

\[
= \$33.33
\]
However, if each contestant has first to flip a coin that landed heads to qualify for the drawing, the expected payoff at the penultimate stage would be the conditional probability of receiving the final reward, or:

$$E_{n-1} = (\frac{1}{2}) (\$33.33)$$

$$= (\frac{1}{2}) (\frac{1}{3}) (\$100)$$

$$= \$16.67$$

In other words, the expected payoff at stage \((n-1)\) is:

$$E_{n-1} = (p_{n-1}) (E_n)$$

This treatment of the conditional probability (known as the 'multiplication rule' for independent trials) is the same for all \(i\), or:

$$E_i = (p_i)(E_{i+1})$$

This process for calculating the net expected payoffs is continued for all stages, culminating in the first, and the optimum decisions at any stage are indicated.

Now returning to the hypothetical planning example, one further comment is warranted. It should be noted that there are expected payoffs both if the event occurs or it does not, but the latter is smaller. The non-occurrence of the event
simply means that the probability of the next event's occurring is lowered. Thus the players may choose to invest to increase their 'chances' of obtaining the payoff. The purpose of the gaming simulation framework is to indicate to them whether or not they should invest. Thus the objective becomes the maximization of:

\[ \sum_{i=1}^{n} (E_i - I_i) = \sum_{i=1}^{n} (p_i) (E_{i+1}) + (p_i') (E_{i+1}) - I_i. \]

where:

- Expected Payoff at stage \( i \): \( E_i \ldots E_i \ldots E_n \) (occurs).
- Expected Payoff at stage \( i \): \( E'_i \ldots E'_i \ldots E'_n \) (does not occur).
- Investment: \( I_i \ldots I_i \ldots I_n \).
- Final Probability at stage \( i \): \( p_i \ldots p_i \ldots p_n \) (occurs)*
- Final Probability at stage \( i \): \( p'_i \ldots p'_i \ldots p'_n \) (does not occur)*
- Direct payoffs at stage: \( e_i \ldots e_i \ldots e_n \) (occurs)
- Direct payoffs at stage: \( e'_i \ldots e'_i \ldots e'_n \) (does not occur)

* \( p_i + p'_i = 1 \) (by definition).
The methodology is as follows:

1. Starting at the last stage - the expected payoffs were calculated. These consisted of the direct payoff (8 chips) multiplied by the probabilities of its occurrence. This can be represented by:

\[ \text{Max.} \ (p_3) \ (e_3) \times (p_3) \ (e_3) - I_3 = E_3 \]

or

\[ \text{Max.} \ (p_3) \ (e_3)^* = E_3 \]

*since \((p_3) \ (e_3) = 0.\)

2. At stage 2, the same procedure was followed, except that there is an expected payoff both if the variable occurred or if it did not. These payoffs were only indirect, however, that is to the extent that the probability of 'C's' occurring was influenced (no direct reward being given for 'B's' occurring).

Thus the decision problem is to:

\[ \text{Max.} \ (p_2) \ (E_3) \times (p_2) \ (E_3') = E_2 \]

3. Step #2 is repeated for each variable in the model using the formula:

\[ \text{Max.} \ (p_i) \ (E_{i+1}) \times (p_i) \ (E_{i+1}) - I_i = E_i \]

4. Now that the expected payoffs are determined, the decision makers start at the first stage and work systematically towards the last. As each decision is resolved, the group should follow that path that would maximize their payoffs from that point on.
Table I constitutes an inventory of the decision alternatives and their expected payoffs both before and after investments. As mentioned earlier, this is a three variable case where each variable has a starting probability as indicated below. Payoffs, if any, are only made if the last (Project) variable occurs. Relationships between the variables (e.g. the occurrence of 'A' will increase the likelihood of the occurrence of 'B') are expressed by arrows below:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type</th>
<th>Probability</th>
<th>Relationships</th>
<th>Reward</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Event</td>
<td>(.40)</td>
<td>A ——— B</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>&quot;</td>
<td>(.20)</td>
<td>B ——— C</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>Project</td>
<td>(.60)</td>
<td>C ——— A</td>
<td>8 chips</td>
</tr>
</tbody>
</table>

Figures VI, VII & VIII which follow Table I indicate the final decision probabilities at each stage which are summarized in the Table I. These diagrams indicate that all possible final probabilities for the variables are:

- C: .40, .80
- B: .20, .40, .60
- C: .40

It would be appropriate at this point to review what is meant by a solution:
We described...what we expect a solution - i.e., a characterization of 'rational behavior' - to consist of. This amounted to a complete set of rules of behavior in all conceivable situations. This holds equivalently for a social economy and for games. The entire result in the above sense is thus a combinatorial catalogue - which we expect from a solution - permits a very brief and significant summarization: the statement of how much the participant under consideration can get if he 'behaves rationally'.

Table I is followed by three decision tree diagrams (Figures VI, VII & VIII) which illustrate all possible decision alternatives at any given stage - i.e., These are not combined into a single diagram in order to reduce the complexity of the graphics.
Scanning the 'net payoff' ($E_1 - I_1$) column, the optimal decision at any given stage is indicated by a 'max'. It should be noted, however that each decision is made on its own and that the next one cannot generally be made until the previous one is 'resolved' (i.e. the model does not map out
Figure VI

[p(A) + .20]

l → p(B) = (.60) if p(A) = 100%
   " = (.20) if " = 0

0 → p(B) = (.40) if p(A) = 100%
   " = (.20) if " = 0

p(A)

Figure VII

[p(B) + .20]

l → p(C) = (.80) if p(B) = 100%
   " = (.40) " " = 0

0 → p(C) = (.80) if p(B) = 100%
   " = (.40) " " = 0

p(B)

Figure VIII

[p(C) + .20]

l → p = (.30) if p(B) = 100%
   " = (.40) " " = 0

0 → p(C) = (.30) if p(B) = 100%
   " = (.40) " " = 0

p(C)

1, 0, -1 \rightarrow Invest 1, 0, -1
a single decision path to be followed in all instances. Table I is an inventory of all possible situations which may arise and it indicates what to do in each).

Thus, in this particular case, it would be best not to invest at all until the last stage (if a maximum payoff is desired) which may tell us something about the model's assumptions. However, the expected net payoff's given in Table I only represent the 'value of the game' over a great number of trials. The whims of the dice in any one game may cause drastically different decisions to be made. Although in a single trial the highest payoff may not be achieved (i.e. through 'chance'), the most 'rational' course of action is to invest where the best 'odds' are.

In all fairness to the traditional point of view this much ought to be said: It is a well known phenomenon in many branches of the exact and physical sciences that very great numbers are often easier to handle than those of medium size. An almost exact theory of a gas, containing about $10^{25}$ freely moving particles, is incomparably easier than that of a solar system, made up of 9 major bodies; and still more than that of a multiple star of three or four objects of about the same size. This is, of course, due to the excellent possibility of applying the laws of statistics and probabilities to the first case.
This hypothetical example demonstrates that the gaming simulation framework is capable of generating an optimal solution to a problem and constitutes a refutation of the null hypothesis.
Some Assumptions of the Model

The playing of the gaming simulation involves the spending of resources (investments) in order to receive rewards (payoffs). It is evident that this involves a drastic simplification of reality which may seem to be so severe as to negate the usefulness of the model for all but the most academic of purposes. However, this simplification is very closely related to the notion of utility in economics which is discussed by the fathers of 'Game Theory' - Von Neumann and Morgenstern:

"It is sometimes claimed in economic literature that discussions of the notions of utility and preference are altogether unnecessary, since these are purely verbal definitions with no empirically observable consequences, i.e. entirely tautological. It does not seem to us that these notions are qualitatively inferior to certain well established and indispensible notions in physics, like force, mass, charge, etc. That is, while they are in their immediate form merely definitions, they become subject to empirical control through the theories which are built upon them - and in no other way. Thus the notion of utility is raised above the status of a tautology by such economic theories as make use of it and the results of which can be compared with experience or at least with common sense." 8

This notion of utility has generated much academic discussion which must not be allowed
to cloud the basic characteristics of the model. Other disciplines have faced similar problems but have forged ahead nonetheless.

However, while little progress has been made to-date in the actual measurement of utility, there is some evidence to suggest that it might have a numerical character that would support its treatment in the game.

It can be shown that under the conditions on which the indifference curve analysis is based very little extra effort is needed to reach a numerical utility.

"It has been pointed out repeatedly that a numerical utility is dependent upon the possibility of comparing differences in utilities. This may seem - and indeed is - a more far reaching assumption than that of a mere ability to state preferences."
Footnotes - Chapter III

1 As mentioned in Chapter II, a planning department may receive an application for rezoning by a developer for a major development. The planners may well prefer not this exact proposal but an altered one. The gaming simulation framework allows them to start off with the original proposal and to systematically work towards achieving the improved (desired) scheme.


3 One example of the substitutability of these 'investments' is the use of 'in house' talent instead of spending money to hire consultants.

4 "Role playing and strategic analysis, rather than complementing each other, turn out to be incompatible behaviors: one requires immersion and loss of perspective, the other requires stepping back and objectivity". p. 89.


5 "We described ... what we expect a solution - i.e., a characterization of 'rational behavior' - to consist of. This amounted to a complete set of rules of behavior in all conceivable situations. This holds equivalently for a social economy and for games. The entire result in the above sense is thus a combinatorial catalogue - which we expect from a solution - permits a very brief and significant summarization: the statement of how
much the participant under consideration can get if he behaves 'rationally'."


"It should be noted that the simulation of a stochastic process does not necessarily imply grave uncertainty as to the outcome. Repeated runs of a Monte Carlo simulation may yield results so closely clustered as to be, for all practical purposes, determinate."


8 Ibid., p. 9.

9 "All this is strongly reminiscent of the conditions existant at the beginning of the theory of heat: that too was based on the intuitively clear concept of one body feeling warmer than another, yet there was no immediate way to express significantly by how much, or how many times, or in what sense... It turned out that heat permits quantitative description not by one number but by two: the quantity of heat and temperature. The former is rather directly numerical because it turned out to be additive and also in an unexpected way connected with mechanical energy which was numerical anyhow. The latter is also numerical, but in a much more subtle way; it is not additive in any immediate sense, but a rigid numerical scale for it emerged from the study of the concordant behavior of ideal gases, and the role of absolute temperature in connection with the entropy theorem."

Ibid., pp.16-17.

10 Ibid., p. 17.
CHAPTER IV

CONCLUSIONS

Advantages and Disadvantages of the Framework

Since the model essentially constitutes an amalgam of several other techniques, it shares many of their corresponding advantages and disadvantages. Among the former would be:

1. The model is manipulable - any variables, probabilities or relationships may be inserted in the model to test alternative assumptions.
2. The model is able to accommodate extremely complex situations - it can penetrate systems which would otherwise be prohibitively complex.
3. The model does not require as much voluminous data gathered by sophisticated questionnaires and other such costly techniques as 'pure' simulations but may partially rely on the systematic use of expertise.
4. The model will generate solutions which can indicate the optimal strategies to be followed.

Some of the disadvantages would include:
1. The model has all the weaknesses of both economic and probability theories. For example, the notion of utility is highly controversial and yet plays a fundamental role in the model.

2. Since many games are based on orthodox theories, they may mitigate against the use of daring or innovative strategies.

3. The mathematical structure of the game may be sufficiently rigid as to limit the players to following the prescribed routines. These comments can be levelled not only at the model developed in this Study but at most gaming simulation models. However, these techniques deserve to stand until more effective alternatives are devised. The evolution of the physical sciences was characterized by the proving and disproving of successive theories and without such a succession, little progress would be possible.
Areas for Further Research

The primary thrust of future planning research in the field of gaming simulations should be directed at the problem of devising gaming simulation models which will be capable of testing alternative strategies. This is a broad recommendation but any narrower suggestion would not do justice to the task.

This Paper has attempted to accomplish this by bridging the gap between mathematical game theory (games of strategy) and simulation gaming (games of skill or chance). The problem with the former has been that it has centered around a relatively limited field of transactions (e.g., parlor games) which were difficult to relate to the more complex everyday world. The latter has been hampered by the fact that such models usually constituted abstractions from reality which were merely assertions in mathematical form which were not subject to clear proof; these were limited in their use in planning research and policy making because they could not be used to evaluate alternative strategies. The players merely tested their wits and, at best, sharpened their skills.
The gaming simulation framework developed in this Study provides a first step towards the integration of these two approaches. This integration is critical if gaming simulation models are ever to be used in the policy aspects of planning or in the research context. Otherwise, this type of model will be impotent as an applied technique for solving practical planning problems. The ability of a technique to provide a 'solution' to such problems greatly enhances its usefulness as a day-to-day tool and brings it down from the more esoteric levels of 'pure theory'.

It also goes without saying that future research by planners should be directed at improving the particular model developed in this Study. Efforts should be directed at two general areas:

1. The assumptions of the model, including:
   a. the reward structure of the game and its relationship to utility theory in economics (discussed earlier in this Chapter).
   b. the nature of the 'investment' as used in the model. This would be closely related to l.a. above (an outlay is essentially a negative receipt).
c. the strengths and weaknesses of probability theory which forms an integral
c PART OF THE MODEL, AND

2. THE APPLICABILITY OF THE MODEL TO PLANNING, INCLUDING:

a. what type of data are most amenable
to being used as inputs in the model.

b. how the model can best be set up for
everyday planning use ( e.g. should it be played manually on a board,
through the formalities of the computer technician or on a computer time sharing console ).

c. what types of planning problems can best be tackled using this particular approach. Major urban landmark developments hopefully represent only a minute fraction of its potential applications.

The gaming simulation framework also permits hypotheses to be made about the operation of the model and to be subsequently tested. The results may then be related back to the real world to examine the extent to which they apply.
All these suggestions represent many areas for further research which might endow planning with a useful new technique. However, it would be easy to be diverted by making detailed improvements to the model from the broader goal of developing quantitative techniques for planning which will enable it to cope more effectively with urban phenomena. In this setting, many of our existing quantitative techniques are incapable of accommodating much of the basic urban data which often is qualitative or subjective in character. This Study has attempted to defend the ability of the gaming simulation model to be potentially an effective tool for these purposes. Its strengths and weaknesses have already been tediously explored but these may best be summed up in a phrase which bears the dynamic essence of gaming:

"In a nutshell, a...\text{simulation} game is a dynamic and live case."
Footnote #1, Chapter IV

APPENDIX I

THE NATURE OF SIMULATION GAMING

The Purposes of Simulation Games

A rash of simulation games have appeared in recent years focused on a variety of subjects, but they generally fit into one of three categories:

1. Entertainment,
2. Education, and
3. Research

1. Entertainment

The traditional attitude towards games was that they were a 'waste' of energy, resources, and time. Games have usually been equated with 'play', a viewpoint which is espoused and, perhaps, best articulated by Roger Caillois:

A characteristic of play, in fact, is that it creates no wealth or goods, thus differing from work or art. At the end of the game, all can and must start over again at the same point... Nothing has been harvested or manufactured, no masterpiece has been created, no capital has accrued. Play is an occasion of pure waste: waste of time, energy, ingenuity, skill, and often of money for the purchase of gambling equipment or eventually to pay for the establishment. As for the professionals... it is clear that they are not players but workers. When they play, it is at some other game... In effect, play is essentially a separate occupation, carefully isolated from the rest of life, and generally is engaged in with precise limits of time and space.
Exceptions do occur, however, where the game is in some degree simulational. In such cases, the participants may acquire some degree of familiarity with the topic of play.

2. Education

Simulation games are increasingly being used as a heuristic tool for educational purposes. They provide, to some extent, a realistic setting for gaining experience in decision making in a particular field.

The introduction of the educational element into gaming requires a shift of emphasis in the game design:

The design of educational games is different from that of games designed primarily for entertainment, although their forms may be similar. An educational game's objective is to educate, not to entertain. Entertainment becomes an instrumental value rather than the design objective. In entertainment games it is just the opposite: for achieving the maximum of entertainment, the players must be "educated" in the game's possibilities.

The advantage that gaming appears to enjoy over other educational techniques is its conduciveness to student involvement, an important factor in learning:

"The technique used to maximize student motivation for participation in the simulation, and thus learning the analytic model,
is to turn it into a game. The game combines elements of dramatic conflict, curiosity over the outcome of uncertain events and direct emotional expression through role playing. The game may be viewed as a dramatization of an analytic model of the situation to be studied, enacted by the students themselves in the roles of the decision-makers. To achieve an effective balance between analytical 'truth' and dramatic communication, some degree of simplification is needed to form the basic 'plot' of this sociodrama or game. Choices must be made about which subplots, characters, and events most lucidly dramatize the material to be conveyed. These choices will be influenced by the school situation, constraints on time, space, student number and student capacity. Classroom time and student capacity for abstraction are the most common limiting factors.\(^4\)

In addition, the 'control' of a player over his own environment, as opposed to luck, is extremely important in the learning process. Stochastic elements may make the game more exciting; however, if they are allowed to prevail, they may frustrate the student to such an extent that he will no longer be motivated to developing an effective strategy. Thus 'control' refers to control over his strategy and over his environment.\(^5\)

Furthermore, the 'reinforcement' or 'reward' structure is of critical importance if the goal formulation and achievement are to foster learning. One of the important characteristics of simulation
games is that the behavior of the players is guided only by expediency. Games are amoral; any behavior is justified that is rewarded. Of course, in many cases, it is the 'long range' expediency that will be important. Otherwise, nothing else is intrinsically 'good' or 'bad'.

The omission of a reward structure which does not motivate the players in the direction intended by the game designer may have serious consequences for the usefulness of the simulation:

"The principal defect of the no-winner variety of the no-final-score approach is that it assumes what is hardly true: that the player can understand and internalize the goals of persons in the role he is playing in the game, when those goals are not given to him by the rules of the game, and then evaluate his performance on the basis of these assumed goals. For if he cannot, his behavior will be aimless, that is without a goal, or will be directed toward incorrect goals, thus destroying the value of the simulation."

The educational value of simulations [in planning] however, is very hard to measure. There is a problem in understanding exactly what they teach. The most conservative estimates suggest that such games merely indicate to the players that there is a need for some long range planning and control for development. The more aggressive suggest that the players accomplish the following:
1. Learning 'facts' expressed in the game context and dynamics;
2. Learning 'processes' simulated by the game;
3. Learning the relative costs and benefits, risks and potential rewards of 'alternative' strategies of decision making.  

3. Research

A gaming simulation may be used in two ways as a research tool:

1. To test existing theory, or
2. To generate new theoretical propositions.

However, the assumptions which underlie its use in research are similar to those made when it is used in education:

"There are two assumptions...that are the basis for the use of game simulations in research: first, that the simulation can reflect the important contingencies of real life, and second, that these contingencies shape the strategies of the players."  

The development of simulation gaming for research purposes in planning represents relatively 'uncharted waters' when compared with its application in planning education. The initial impetus for its introduction into research came from its military application (which will be discussed later in this chapter) where it was used to evaluate the strategies of both friends and enemies.
This slow development in research can be partly explained by the lack of mathematical rigour which is characteristic of gaming and which is often essential for the accurate replication of social, political and economic processes:

"Operational games are highly effective teaching and communication devices but their utility for prediction and replication tends to be low...it does not seem likely that their utility as predictive devices will be increased until they are linked with highly detailed and sophisticated mathematical models."¹⁴

The purpose of this paper was to develop a mathematical framework which might serve as the basis for a gaming simulation in the planning context.
Reasons for the Choice of the Simulation Gaming Format.

There are no fixed rules to guide the researcher in the choice between using a 'pure' simulation or a 'gaming' simulation. The ultimate decision usually rests on both the characteristics and the amount of data. Generally, if the information is readily quantifiable and there are a large number of transactions, the former is used; if the data is more qualitative in nature, then the latter may apply.

As a general rule of thumb, the decision criteria are as follows:

1. IF: the basic data are produced by natural phenomena or a large number of small, independent transactions...

"THEN: a sampling procedure can be developed which fits into an outline description of the total system (that is, a model of the system) that can be manipulated with the aid of a computer...

2. IF: the problem seems to be that of acquiring insights into organizational behavior under conditions in which resources are truly scarce, so that competition becomes intense, and the essential data are qualitative or subjective...

THEN: a gaming procedure can be developed which allows surrogates of the chief competitors to test the principal strategies open to them and so discover what new and unexpected situations may arise. These anticipations should suggest the use of interventions of various kinds (i.e. by the
players) which prevent the worst from happening and increase the likelihood that a more desirable outcome will eventuate...

3. **IF:** the planning context includes budgeting, marketing, or some other well-formed procedures for routinized decision-making, and a variety of poorly defined situations,  

**THEN:** the simulation should employ a mixed strategy that allows the combination of a simple computer simulation with a series of gaming exercises where representative roles designed to serve the public interest are pitted against a variety of actors maximizing self-interest.\(^{15}\)

It is the third approach that is used in this Paper (except that the game is hand-played) which is an amalgam of the other two. The basic framework for the simulation (as outlined in Chapter II) may be computerized in order to more easily accommodate the myriad interrelationships in the model. However, the gaming aspects have been introduced to make the simulation more amenable to the subjective or qualitative aspects of the problem (of public/private interactions in major urban landmark developments).

The utility of the hand-played game in simulating these qualitative factors has long been recognized in war-gaming and has been noted by Sidney Giffen: \(^{16}\)

> The 'hand-played' crisis game provides, in fact, no more than an additional qualitative tool for the examination of essentially qualitative questions. Aspects of such questions that can be quantified or computerized are not the important ones. This is unfortunate, for analysis along non-quantitative lines is often less than satisfying
in that it is not subject to clear proof. But it has to be accomplished, nevertheless, in connection with problems that are frequently of greater import in human affairs than those that can be solved beyond argument through statistics or the intersections of curves.17

These qualitative matters have been the bane of the social scientists who have regarded, with considerable envy, the analytically precise and mathematically rigorous theories of their cousins, the physical scientists. The latter seemed to enjoy the advantages of working with many phenomena which could be both observed and measured and which were subject to many quantitative techniques. Furthermore, they often had the advantage of the laboratory setting for their experiments where all the variables could be carefully manipulated and controlled.

The social scientist not only lacks a laboratory but is also hindered by the fact that many problems require an interdisciplinary approach for their solution:

He is also hampered by the nature of the urban scene which is not exclusively a social, economic or political phenomenon. Full comprehension is difficult with the tools of a single traditional discipline, yet multidisciplinary approaches, when tried have usually proved frustrating because participants lack either a mutual frame of reference or a common vocabulary.18
Thus, most research in the social sciences must be subject to less exacting standards of analysis and proof. This leaves the researcher with two alternatives:

1. To observe the natural phenomena rather than devising some sort of laboratory-type setting for experimentation:

The natural experiment has the advantage of providing data from the empirical system itself. Here the researcher can observe the operation not of a model but of the actual system; validity is assured. Natural experiments, however, have two serious drawbacks from the point of view of the requirements of a scientific methodology:

(1) An experimental situation cannot always be found in nature which definitively confirms or unconfirms hypotheses, and
(2) when natural experiments are found, it is unlikely that they will be found in sufficient number to provide statistically useful samples; reliability becomes a problem.19

2. To relax the degree of scientific rigour required in experimentation:

If we adopt a strict definition of 'experiment', i.e., controlled observation, repeated trials, and systematic manipulation of crucial variables, this basic scientific procedure -- for the present at least -- has relatively little application to the study of human behavior outside of psychology. Indeed, it is sometimes asserted that for most social phenomena -- including individual behavior -- there can be no scientific analysis because the conditions of rigorous experimentation cannot be fulfilled. On the other hand, if we allow for degrees of rigor and for quasi-experimental exploration, the trial and error of everyday political and social life and the semicontrolled exercises in contrived situations may fall within our purview.20
House and Patterson suggest that one of the possible escapes out of this dilemma is to resort to the simulation gaming technique where the game setting may be designed as a human laboratory. Here the behavior and interaction of the players may be observed in their various roles and the stimuli may become the reward mechanisms in the game. The 'environment' is incorporated by:

1. letting each player act as part of the social environment, or
2. embodying it in the rules of the game.

The views of House and Patterson are reinforced by Clayton and Rosenbloom who suggest that:

"Games should be conducive to discovery and intuitive thinking because they provide a laboratory-type setting where independent variables can be freely manipulated to test consequences of guesses and hypotheses."

A further possibility is to use gaming in an inductive capacity to reveal insights into human behavior and interaction:

"There is the challenge of using a new instrument of research inductively rather than deductively. In other words, by incorporating institutional and behavioral features into our game models, we may begin to learn things about the relationships between ... structure and ... strategy that we never knew before. At least we may begin to view these new relationships in a new light, which is sorely needed."
The potential for gaming to be used as a research tool has been barely recognized let alone exploited. For teaching purposes, its use is already well advanced; here it has been likened to a case study, except that the decision environment is always changing:

"In a nutshell, a... game is a dynamic and live case." 25

It is for this reason that the simulation gaming format was developed in this Paper to complement the case-book on major urban landmark developments and to permit planning departments in the future to better evaluate alternative courses of action with respect to these developments.

The gaming simulation format provides a recursive framework which will accommodate a series of simple variables and their interrelationships (inputs) and will generate the final result of the various interactions (outputs). In a sense, simulation games conform to the dictum of Simenon's Maigret who said that:

"people are simple; they cannot afford but to be simple. But the relations between people are very complicated." 26
An example of this phenomenon in the urban context is the developer's simple desire to make a profit which may motivate him to incredibly complex patterns of behavior.

The Relationship Between Gaming and Human Behavior.

There is some evidence to suggest that gaming is a fundamental part of human behavior. This forms the basis for its usefulness as an ingredient in the simulation process of activities which involve extensive human interaction. This human interaction is a major component of the public/private interaction in major urban landmark developments.

Eric Berne outlines the role of gaming in human behavior from its earliest manifestations in childhood:

"From the present point of view, child rearing may be regarded as an educational process in which the child is taught what games to play and how to play them. He is also taught procedures, rituals and pastimes appropriate to his position in the local social situation, but these are less significant. His knowledge of and skill in procedures, rituals and pastimes determine what opportunities will be available to him, other things being equal; but his games determine the use he will make of those opportunities, and the outcomes of situations for which he is eligible. As elements of his script, or unconscious life-plan, his favored games also determine his ultimate destiny (again with other things being equal): the payoffs on his marriage and career, and the circumstances surrounding his death."
Berne regards the "pastime" as the social equivalent of games. This term he defines as:

"a series of semi-ritualistic, simple, complementary transactions arranged around a single field of material, whose primary object is to structure an interval of time." 29

He stresses the importance of ritual, both formal and informal, where transactions proceed in a programmed series. An example of this phenomenon would be our short everyday exchanges between acquaintances — 'How are you? I am fine!' etc. in which each participant exchanges a series of virtually predetermined phrases which ostensibly communicate nothing, but which are most functional in social interaction. Berne notes that a satisfactory exchange involves a question and reply of approximately the same magnitude. The 'How are you?' should not be countered with a lengthy dissertation of how the other person is. The 'I am fine!' is not only adequate but anything longer would unbalance the interaction.

In the planning context, many rituals were evidenced in the public/private interaction processes. In fact, the very essence of bargaining is ritual where both parties start from widely divergent positions and proceed to narrow the gap. The endless negotiations over floor area ratios, the sale of public streets and lanes and the stormy open meetings were mostly rituals in the planning process.
The Origins of Gaming Simulation

The earliest recorded use of simulation gaming was for military purposes and took the form of a stylized battle on a chess board. 30

"Crisis gaming is in one current of a notable gaming history that goes back to chess, and therefore of course to such progenitors of that ancient pastime as draughts or checkers. The Russians, whose regard for chess equals that of others for football, cricket or the late, late, show, have nevertheless modestly neglected to claim its invention. Their restraint seems well justified, because chess appeared in an approximation of its present form a millennium before the Swedes, by organizing Muscovy, in effect invented Russia.

"Most authorities are agreed that chess originated in India. It had the Sanskrit name chaturanga, which describes an army composed of elephants, horses, chariots, and infantry. Pieces used in the original Hindu game represented the same four elements of an army, and the supporting frame of the chessboard employed today presumably symbolizes the wall of a fortified city."31

The technique was later improved by the Germans in the 17th and 18th centuries and became increasingly complex. One of the most popular versions was called Helwig's game:

"Helwig's game used a modified chessboard which carried 1666 movable squares variously colored to represent terrain features. Thus, black and white indicated level ground; red, inaccessible mountains; green, impassable swamps; and blue, lakes or rivers. A string
of blue squares defined a river demanding passage by pontoons. Numbers on the squares were employed to indicate special terrain features. Dividing the board was a dotted line that marked the frontier between the opposing camps, and each theater of operations was composed of a number of provinces identified by letters. The object of the game was to capture the opponent's fortification, in one corner of his side and marked about with symbols to suggest such defenses as ditches and parapets.

"Sizable forces were assigned to each side; for example, sixty battalions of fusiliers, or infantry, doubling on occasion as artillery, eight squadrons of dragoons, or cavalry, and 100 pontoon boats. The game progressed under a director who enforced the application of strict rules defining the movement and employment of infantry, artillery, cavalry, and the remaining specialized pieces."32

This development of chess was culminated in a game called 'neue Kriegsspiel' (which literally means 'war game').

"This one had 3600 squares and was accompanied by a sixty-page book of rules. The complexity of the game was exceeded only by its tedium, which may be one reason why the development of the war game took a subsequent sharp twist."33

The limitations of a chess-based game became all too obvious and the military tactitioners transferred the simulation to a map, upon which the various forces could be manipulated. These developments later progressed to the sand tables and finally to simulated or 'mock' battles. The mock battles characteristically reflected, often humourously,
the cultural values and attitudes of the nation which designed them:

I have a theory that, while the battles the British fight may differ in the widest possible way, they have invariably two common characteristics -- they are always fought uphill and always at the junction of two or more map sheets. 34

The mock battles represented 'free games' which differentiated themselves from their ancestors by being controlled by an umpire rather than rules. These 'free games' spawned a development which was later to become important in educational gaming.

The lack of rules meant that the participants usually gathered around the umpire to discuss both his decisions and their actions. This post-game critiquing session was later to become a key ingredient in many teaching games covering a variety of topics.

The new free game, uncomplicated as it was by rules, placed a heavy burden on the umpire or director. But his decisions could be questioned following each exercise, as the decisions of dice and a rule book could not, and while military propriety and discipline kept the questioning within bounds, it now became possible to conduct illuminating critiques after each play of a free game. 36

The Impact of Military Gaming on the Social Sciences

These developments in military gaming had little direct impact on the administrative or social sciences. However, these exercises were soon computerized and
used for political as well as military purposes, and the technology involved soon spread to other disciplines. This process was aided by the fact that certain military experts in gaming, notably Clark C. Abt, began to devote their energies to civilian problems.

"Like computer war games, business games, especially those employing mathematical models, demand that the problem be thought through before the model can be designed. Training objectives must be clearly drawn, the situation or case history well defined, all pertinent facets of information flow and decision processes covered, etc." 37

From the early business applications, gaming spread to the field of international relations and thence into the social sciences.

The applications of simulation gaming (including the early chess-board versions) to the problems of war stemmed from two basic needs:

1. Training needs -- the need to have a less costly alternative (in terms of money, human lives and national prestige) for training troops and officers than actual battle. The latter would be disastrous and might be difficult to arrange to fit into training schedules.

2. Tactical needs -- the need to test alternative strategies in order to find the most advantageous. This required the simulation of
human behavior which was most easily accomplished by using the gaming format.

These same two needs are present in the planning research context today:

1. Training needs -- There is a challenge to the Profession to better educate its members in new and effective planning techniques:

"The immediate pressures upon planning result from a recognition that the traditional measures -- principally civic design, the control of land use, and the allocation of subsidies -- do not cure the ills for which they were prescribed."

However, increased technical skills must not be achieved at the expense of a wide perspective, a trait that has characterized planners in the past:

Increasing complexity presses a profession toward simultaneous development in two directions: one, specialization of technique and subject matter into slightly overlapping cells of sufficient simplicity for individual decision making; and two, the elaboration of new models and devices for achieving an overview. This division of labour within the field of planning permits one to address specifically the difficult task of achieving a comprehensive overview of metropolitan regions. Simulation is of greatest value for this purpose in that it provides a means of coping with complexity; its primary value is that it enables one to abstract the critical structure or process involved and to specify the components and their interactions.

2. Tactical needs -- As planners encounter an increasingly complex environment, they will no longer be able to proceed in the time
honoured 'trial and error' method and will have to resort to evaluating the impact of their policies in advance of their implementation.

Fortunately, the simulation is particularly amenable to the testing of policy alternatives.

"The fact that manipulation takes place in a model of reality can itself be considered an advantage. Changes in a system can be tried...which might prove excessively expensive and dangerous if they were introduced into... operation. Simulation allows the study of induced variable change in situations where it might be otherwise difficult or undesirable to induce this change -- which might be the case for many, if not most, social systems."

The development of strategies in planning may well lead the way for the growth of a body of planning theory:

"The advantage of cultivating the area of 'strategy' for theoretical development is not that, of all possible approaches, it is the one that evidently stays closest to the truth, but that the assumption of rational behavior is a productive one. It gives a grip on the subject that is particularly conducive to the development of theory. It permits us to identify our own analytical processes with those of the hypothetical participants in a conflict; and by demanding certain kinds of consistency in the behavior of our hypothetical participants, we can examine alternative courses of behavior according to whether or not they meet those standards of consistency."
This paper will devote itself to the second area, namely: the development of a simulation gaming format for the testing of strategies and, possibly, theories. This technique is particularly well suited to this task, especially in the urban setting:

"The most practical use of a gaming simulation is for operational gaming. This involves data from a real city introduced in order to throw light upon the implications of policy alternatives."45
Footnotes - Appendix I

1 Roger Caillois, Man, Play, and Games, (New York: Free Press, 1961), pp. 5-6

2 For example, 'Monopoly' (real estate), and 'Stock Ticker' (stock market).


4 Ibid., pp. 74-75


6 Ibid.


8 This opinion was expressed with regard to all planning educational games but special reference to the 'Cornell Land Use Game' in: Francis H. Hendricks, "Planning Operational Gaming Experiment" (paper presented to the Northern California Chapter of the American Institute of Professional Planners on New Ideas In Planning, November 19, 1960).

9 Clark C. Abt, "Games for Learning," p. 77

10 These two uses are presented in: E. O. Schild, "The Shaping of Strategies."

11 Ibid., p. 153.
"Neither can we lose sight of this fact that the prime motivation behind the development of new games in the past has been their use for educational purposes. An often heard observation on the campus is that the exigencies of educational application will tend to hold back the use of games for research in the absence of a clear-cut policy to the contrary."


For example, in World War II the naval strategies for the whole Pacific area were 'gamed' to the extent that nothing which subsequently occurred came as a surprise (with the exception of Pearl Harbor, which precipitated the war, and the use of suicide pilots by Japan).


The term 'crisis game' is specifically used here by Giffen to mean 'war game'.


Ibid., p.6.
The use of the game setting as a human laboratory is argued in:

James S. Colman, "Social Processes and Social Simulation Games."


Maigret is the latter day Sherlock Holmes of French literature and this quotation by the author was in:


Ibid., p. 58.

Ibid., p. 41.

cf., n. 16.


Ibid., pp. 17-18.

Ibid., p. 18.

"The new free game, uncomplicated as it was by rules, placed a heavy burden on the umpire or director. But his decisions could be questioned following each exercise, as the decisions of dice and a rule book could not, and while military propriety and discipline kept the questioning within bounds, it now became possible to conduct illuminating critiques after each play of a free game."

Ibid., p. 28.

Ibid., p. 28.

Ibid., p. 50.

H. Guetzkow, et al., Simulation in International Relations.

"The highest objective of the war game has generally been to train future military commanders to arrive at sound decisions despite inadequate knowledge of the enemy and despite inevitable and hence normal, errors and miscarriages on the part of friendly forces. Games of this type can of course best be conducted as field maneuvers using live men and real equipment, if not, as czarist troops are reported to have used, live ammunition. Maneuvers are manifestly expensive and, at some times of the year in some locales, are likely to prove impracticable. For convenience, substitutes for war and even field exercises have accordingly long been devised on the basis of cards, maps, or sand tables. Nowadays, using maps having transparent overlays, forces can be readily maneuvered with grease pencils. The practice in the past, by no means wholly abandoned, was to move pins or blocks, the latter often made to scale and representing bodies of troops, ships, etc. March tables, firing tables, and similar 'canned' aids are employed to assist in defining combat possibilities, although an umpire or umpires may also decide the issue on the basis of judgment. Where probabilities are involved, which is not infrequent, cards have been drawn or dice thrown."

Sidney F. Giffin, The Crisis Game, pp.15-16

An interesting example of this use of the simulation game occurred at the 'Total War Research Institute' in Tokyo in 1941. A massive game was
played which involved teams representing the European Axis Powers, the United States, Great Britain, the Soviet Union, China, Korea, Manchuria, Thailand, French Indochina and the Netherlands East Indies.

"The exercise was instrumental in determining certain courses of Japanese action, primarily the decision on expansion to the southeast; and at least one of the domestic policies instituted in the game, involving economic controls, was subsequently placed in effect by the Imperial Government."

Ibid., p. 60


42 Ibid., p. 3.


APPENDIX II

'LANDMARK DEVELOPMENTS'

The Origin of the Simulation Game - Landmark Developments

The Game - 'Landmark Developments' - was developed to illustrate the application of the gaming simulation framework, presented in Chapters II and III. 'Landmark Developments' is the product of the author's participation as a research assistant in a study commissioned by the Canadian Council on Urban and Regional Research on public/private interactions which accompanied major urban Landmark Developments in Canada (see Footnote #8, Chapter II).

This study was produced as a case-book from which the variables for 'Landmark Developments' were derived. The extraction of these variables was essentially a subjective, and therefore academically tenuous, process and there is no intention here of defending them as being anything but expedient. However, they did serve two purposes:

1. to illustrate how the framework might be applied using 'live' data, and
2. to ensure that 'Landmark Developments' was free of 'bugs' (i.e. the game was 'playable').
The framework was applied to such major developments principally because the public/private negotiations often seemed to be guided by 'ad hoc' considerations. The use of quantitative techniques by the planners involved was sadly lacking, with the exception of such crude notions as 'floor space ratios' and simple traffic forecasting techniques. The simulation game seemed to hold promise as an analytical tool to fulfil a quantitative role. Furthermore, the interrelationships between the various interactions associated with such developments appeared to be very complex, which indicated that planning 'intuition' might prove inadequate in coping with such phenomena.

'Landmark Developments' has been played five times and has evolved in response to inconsistencies and oversights which were discovered in the course of play. The Game was played manually on a board illustrated in Figure I.

In fact, this diagram illustrates only one of four identical boards which were used to indicate the continuously changing probabilities.
<table>
<thead>
<tr>
<th></th>
<th>White</th>
<th>Blue</th>
<th>Beige</th>
<th>Organe</th>
<th>Red</th>
<th>White</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beige</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organe</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The format of the Game is designed to focus on its primary purpose - the interrelationships between the various events. The probability of a particular event's occurring is visually apparent on the board in the form of a marker bearing the same number, which can be moved up or down a probability scale graduated in 20% intervals. The choice of this interval was made on the basis of convenience and reflects the essentially qualitative nature of the data.

The players are visually aided by a system of colour coding which is used for the probability markers, the 'Issue Cards' and the probability scales. At the outset of the Game, the markers are initially placed on their own colours. Thereafter, they may be moved in any direction. The colours are as follows:

- Blue 80%
- Beige 60%
- Orange 40%
- Red 20%

The principal reason for colour-coding was to be able to identify a variable's 'starting probability'
because the latter indicates the amount of payoff that should be made when an issue is decided, in accordance with the payoff scale given in the rules. 0% and 100%, which represents decided issues, are not colour coded (i.e. they are white) in order to avoid confusion. At the end of the Game, a profile of the Landmark Development is indicated by the probability markers for the 'Project Cards' which have been moved to 100%. The remaining probability markers which have moved to 100% represent the related events which occurred in conjunction with the Project. This particular layout was adapted to 'Landmark Developments' from a corporate planning game developed for Kaiser Aluminum and Chemical Corporation (see Footnote 14, Chapter II).

Figures II and III show the front and back respectively of a typical 'issue card' being played in the Game. The former illustrates the variable under consideration while the latter indicates the related variables. The use of these cards will be discussed in the rules.
THE PRESENT SITE IS ALREADY EARMARKED FOR SUCH A DEVELOPMENT IN THE CITY'S PLAN.

PROBABILITY - 20%
Figure III

POSITIVE:
(7) The city planning director actively solicits developers to consider the site.
(12) A formerly deteriorating area is upgraded by the new development.
(18) The city widens certain of the surrounding stress in anticipation of such a development.
(42) The city subsidizes the underground pedestrian links.
(46) Development capital is attracted to the vicinity of the project.
(61) The developers agree to the floor space ratios set by the city.

NEGATIVE:
(17) Rezoning is applied for and is accepted by council.
(26) Land acquisition is a cloak and dagger affair.
(47) Many concessions are made to the developer because of a lack of explicit policies on the part of the city.
(60) A stormy public meeting is held which is hostile to the development.
(69) The project stands idle while awaiting suitable political or market conditions (for loans, or for the occupancy rates or public opposition).
The Variables in the Game

The variables have been broken down into two major categories: the 'Project Variables' which relate directly to the specifications and characteristics of the projects themselves, and 'Event Variables' which deal with the related events which accompanied these developments. The latter is further broken down into those events which were controllable by the various parties involved and those events which were uncontrollable and formed the background or setting for the Project. The controllable events represent those events which were in some way initiated, influenced or controlled by the various parties involved in public/private interactions and those events which occurred irrespective of the existence of the projects. The uncontrollable events constitute what was basically the political, economic, social and aesthetic environment for these developments.

For each of these basic headings, the variables have been further broken down into specific classifications. It should be recognized, however, that these are not 'discrete' and, in fact,
many of the variables might justifiably be classified under some other heading. For example, if a project upgrades the surrounding area, it is difficult to say whether this is an economic, social or aesthetic effect. In this case, it was classified as aesthetic effect.
TABLE I
Inventory of Variables

I. Project Variables.

1) Location.

1. 60% Project located at centre of C.B.D.
2. 40% Project located at periphery of C.B.D.
3. 20% Project located at waterfront of C.B.D.
4. 40% Project located on railway land.
5. 80% An open air plaza forms an integral part of the development.

ii) Land Use.

19. 40% The project incorporates residential use (apts.).
20. 80% The project incorporates offices.
21. 80% The project incorporates a shopping centre.
22. 40% The project incorporates a hotel.
23. 80% The project incorporates underground parking.

iii) Finance.

37. 40% The developer is in partnership with a large financial institution.
38. 20% The developer finds a large financial institution willing to lend money for the project.
39. 40% The developer forms a partnership with other developers.
40. 20% The developer goes into a joint venture with a crown corporation.
41. 40% The development is financed by non-Canadians.

iv) Transportation and Access.

55. 80% The project is serviced by bus connections.
56. 60% The project is serviced by subway.
57. 60% The project is serviced by a freeway.
58. 40% The project is serviced by commuter trains.
59. 60% The project is serviced by enclosed pedestrian links.
II. Event Variables.

A. Controllable.

1) By Municipal or Other Governments and Agencies.

7. 20% The city planning director actively solicits developers to consider the site.
8. 20% The National Harbours Board owns most of the site and can only lease it.
13. 60% No performance bond or other guarantee is required by the city.
17. 40% Rezoning is applied for and is accepted by council.
18. 20% The city widens certain of the surrounding streets in anticipation of such a development.
25. 20% The city blocks the use of overhead pedestrian walkways.
28. 20% The city performs a thorough investigation into the capabilities of the developers.
34. 80% The city has a policy of not expropriating one private owner in favour of another.
42. 20% The city subsidizes the underground pedestrian links.
43. 20% The Federal Government decides to participate by building a complementary project.
47. 20% Many concessions are made to the developer because of a lack of explicit policies on the part of the city.
65. 20% The city gives a three year moratorium on taxes for projects costing over $1 million.
67. 60% The approval of the Board of Transport Commissioners is required for track clearances and specifications vis a vis the air rights over the tracks.
68. 40% The city has little control over the developers because the latter is operating within the zoning restrictions.
2) By The Developer.

9. 20% The developer is primarily interested in a speculative profit.
26. 60% Land acquisition is a cloak and dagger affair.
27. 20% In face of public opposition, the developers hire exotic architects to soothe the outcries.
31. 20% The developers hire one of the more vocal objectors.
35. 40% The developers are able to obtain very low interest rates on their borrowing.
45. 60% The developers go bankrupt or sustain several years of losses.
48. 20% The original proposal is overly promotional.
49. 20% The former head of a city department takes a top position with the developers.
50. 20% A design-build concept is used where the developers, the architects and the construction engineers thrash out the design of the project as it is being built.
51. 20% The developers by-pass the planning department and deal directly with the mayor and his executive advisors.
54. 80% The air rights over the railway tracks are leased to the developers.
61. 60% The developers agree to the floor space ratios set by the city.
62. 20% The developers and the city have an assessment battle which ends up in the courts.
64. 20% The developers purchase the former buildings of new prestige tenants as a form of inducement.
71. 60% The development is to be built in stages.

3) By the Public.

30. 20% A handful of landowners attempt to hold the developers up for ransom.
53. 40% A public outcry results from the traffic implications of the project (automobile).
60. 40% A stormy public meeting is held which is hostile to the development.
4) By The Planning Department.

11. 40% The city's technical and planning departments call for significant modifications to the proposal.
14. 40% A city plan exists and is in operation.
36. 20% The present site is already earmarked for such a development in the city's plan.
52. 60% A previous consulting study indicates that the site would be ideal for this type of development.

B. Uncontrollable.

1) The Political Environment.

24. 20% A federal policy discouraging foreign investment in Canada delays the project.
63. 20% There is a conflict between the metropolitan and the city governments which stalls the development.
70. 20% The Federal Government requires a deferment of Capital Cost Allowance for all new buildings in the city.

2) The Economic Environment.

6. 60% The developer has had previous successes with similar projects.
44. 60% Leasing rates by the National Harbours Board are much lower than the city's tax rates.
46. 60% Development capital is attracted to the vicinity of the project.
66. 40% Interest rates rise dramatically during the initial stages of the project.
69. 20% The project stands idle while awaiting suitable political or market conditions (for loans, or for the occupancy rates or public opposition).
72. 80% The project is built in a period of galloping inflation.

3) The Social Environment.

10. 20% The project will retard the growth of the surrounding area.
16. 20% The project provided better access to the waterfront.
29. 20% An open meeting is declared illegal by the courts because of a procedural fault.
32. 60% Studies indicate that the presently existing transportation system would be overloaded.
33. 20% The underground parking is inadequate in the complex.

4) The Aesthetic Environment.

12. 60% A formerly deteriorating area is upgraded by the new development.
15. 20% The project provided better access to the waterfront.

It should be noted that the probabilities mentioned above were based solely on their 'relative frequency' in the case-book, rounded off to the nearest 20%. Again, their determination was a subjective process but was essential to the playing of the Game.
A PROFILE OF PLACE VILLE MARIE

Table II below represents a profile of the public/private interactions associated with Place Ville Marie in terms of the 72 variables mentioned in Table I:

TABLE II

Profile of Place Ville Marie

I. Project Variables.

1) Location.

1. 60% Project located at centre of C.B.D.
4. 40% Project located on railway land.
5. 80% An open air plaza forms an integral part of the development.

2) Land Use.

20. 80% The project incorporates offices.
21. 80% The project incorporates a shopping centre.
23. 80% The project incorporates underground parking.

3) Finance.

39. 40% The developer forms a partnership with other developers.
41. 40% The development is financed by non-Canadians.

4) Transportation and Access.

55. 80% The project is serviced by bus connections.
56. 60% The project is serviced by subway.
57. 60% The project is serviced by a freeway.
58. 40% The project is serviced by commuter trains.
59. 60% The project is serviced by enclosed pedestrian links.
II. Event Variables.

A. Controllable.

1) By Municipal or Other Governments and Agencies.

13. 60% No performance bond or other guarantee is required by the city.
18. 20% The city widens certain of the surrounding streets in anticipation of such a development.
25. 20% The city blocks the use of overhead pedestrian walkways.
67. 60% The approval of the Board of Transport Commissioners is required for track clearances and specifications vis a vis the air rights over the tracks.

2) By The Developer.

45. 60% The developers go bankrupt or sustain several years of losses.
51. 20% The developers by-pass the planning department and deal directly with the mayor and his executive advisors.
54. 80% The air rights over the railway tracks are leased to the developers.
61. 60% The developers agree to the floor space ratios set by the city.
64. 20% The developers purchase the former buildings of new prestige tenants as a form of inducement.
71. 60% The development is to be built in stages.

4) By The Planning Department.

52. 60% A previous consulting study indicates that the site would be ideal for this type of development.

B. Uncontrollable.

24. 20% A Federal policy discouraging foreign investment in Canada delays the project.
2) The Economic Environment.

6. 60% The developer has had previous successes with similar projects.

46. 60% Development capital is attracted to the vicinity of the project.

66. 40% Interest rates rise dramatically during the initial stages of the project.

72. 80% The project is built in a period of galloping inflation.

3) The Social Environment.

32. 60% Studies indicate that the presently existing transportation system would be overloaded.

4) The Aesthetic Environment.

12 60% A formerly deteriorating area is upgraded by the new development.
Interrelationships Between the Variables

The interrelationships between the variables were postulated on the basis of the case-book. Their selection was essentially based on intuition, the role of which was discussed in Chapter II. What the Game accomplishes is to systematically incorporate planning intuition into an essentially quantitative framework. Figure III presents the related events to the variable presented in Figure II.

It should be noted that the occurrence of one variable will simply make the occurrence of related variables more (or less) likely. Direct causality is not implied.
The Rules of the Game

The rules are essentially similar to those for the hypothetical example presented in Chapter III but are slightly more explicit in order to elaborate on the actual playing of the Game. The payoffs and possible investments are not scientifically determined and, as mentioned earlier, closely parallel the notion of 'utility' in economics. The main criterion for their selection in the Game was that they permit orderly play.

The rules stated below are meant for the manual playing of the Game, but these could easily be adapted for the computer. They are as follows:

1. Any number of players can play and they may choose to participate individually or as a group. There is no necessity for one player or group of players to play "against" another.

2. A banker is selected from among the players and he has the responsibility both for the "issue cards" and the distribution and collection of money.
3. Each player is given 25 chips by the bank which are readily exchangable for paper money. If a team is playing, it is also given 25 chips.

4. The "Issue Cards" are comprised of:
   i) "Event Cards" - these represent the public/private interactions which are generated by the Project, and
   ii) "Project Cards" - these indicate the basic specifications of the Project (e.g., it incorporates an open-air plaza.)

5. The players select a number of cards from the 72 variables which constitute a profile of a particular major urban landmark development (see Table II for a profile of Place Ville Marie).

6. The banker collects the chosen cards and places them in the center of the board after shuffling them; the game is ready to commence.

7. The player on whose board the top card appears (the issue player) reads the
issue on that card aloud. The team may then influence the probability of this issue by 20% (positively or negatively) by paying 3 chips to the bank. However, in no case may they move the issue's probability either to 0% or 100%.

8. At this point, all the players may invest up to 4 chips (positively or negatively) in related issues anywhere on the board but subject to the limitation of one chip per issue.

9. The issue player roles the icosahedron (twenty-sided) die. If the issue's current probability appears, then the issue will occur and the marker must be moved to 100%. If the probability does not appear, then the issue will not occur and the marker must be moved to 0%.

10. The issue player then turns the card over to reveal what the related events are. If the issue occurred, then the positive probability markers are moved
up 20% and the negative ones down 20%. If the issue did not occur, these probability changes are reversed.

11. If the players have correctly predicted both the related events and the direction of the probability change (through the investment), then they receive 2 chips from the bank and the invested chip remains on the board. If the prediction was incorrect, they lose the invested chip to the bank. Furthermore, the probability markers are moved up (or down) an additional 20%.

12. At the end of the game, all unresolved issues are decided by moving the probability markers to the nearest end (100% or 0%).

13. Payoffs or resolved events are made by the bank.

   1) If the players made a positive investment and the issue occurred the payoff is as follows:
ii) If the players made a negative investment and the issue did not occur, the payoff is as follows:

<table>
<thead>
<tr>
<th>Initial Probability</th>
<th>Payoff per Chip Invested</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td>8 chips</td>
</tr>
<tr>
<td>40</td>
<td>4 &quot;</td>
</tr>
<tr>
<td>60</td>
<td>2 &quot;</td>
</tr>
<tr>
<td>80</td>
<td>1 &quot;</td>
</tr>
</tbody>
</table>

At first glance, it would appear that the players should invest positively in variables with high probabilities (and vice versa). However, the reward structure is designed to discourage so simplistic a strategy.
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