THE TRAFFIC POLICE MANAGEMENT TRAINING GAME

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Abstract

The Traffic Police Management Training Game was designed for Northwestern's Traffic Institute with the following basic objectives: (1) to provide police officers of supervisory rank with more insight and experience in traffic problems; (2) to show the importance of intensive analysis and planning; and, (3) to teach certain patrol enforcement concepts. The game requires three ingredients: the game administrators, the game players, and the computerized game model. The game model provides the framework within which the administrator may specify any type of urban model he believes meets his teaching objectives. The game players input decisions on allocation of manpower for patrol enforcement. The game model generates violations, which stochastically result in accidents. The frequency of these violations is assumed to be a function of parameters selected by the administrators and the enforcement applied by the players. If a violation does not result in an accident, the model computes whether or not an available unit detected the violation. The model does not pretend to be realistic, but rather aims to achieve verisimilitude. The object of the game is to achieve some "best" allocation based on criteria set up by the administrators. Organizational aspects of the game include: administrator and player briefings, instructions, decision forms, and critiques.

1.0 Introduction -- An Overview of the Game

The Traffic Institute of Northwestern University trains police officers from all over the world in the most modern techniques of traffic police administration. The Traffic Police Management Training Game was designed to integrate the principles, tools, and techniques taught in the Institue's program. The object of the game is to achieve some "best" allocation of the traffic police department's manpower and resources, based on measures of performance such as a reduction in the number of accidents, an increase in the detection of violations, etc.

The remainder of this section will be an introductory overview of the Traffic Police Management Training Game. The next section of this paper presents a basic definition of a management training game along with general objectives and characteristics of gaming. The Traffic Institute and the integration of its objectives into a training game are next delineated. The specifics of the Traffic Police Management training Game will then be discussed. The game model and simulation, administrator and player input, and the output of the game will each be presented. Some final notes from an actual experimental game session at the Institute will complete the paper.

Basically, the Traffic Police Management Training Game provides an opportunity for the player to formulate traffic control policies, allocate available resources and evaluate the results of his decisions within the context of a responsive gaming situation which is designed to react, or at least appear to react, realistically to his command decisions. Although the underlying relationships, as presented in the model are relatively simple, the total appearance of the game presents the players with a complex system.

The game model provides the framework within which the administrator may specify any type of urban traffic environment he believes best meets his teaching objectives. In addition, the administrator specifies the length of the simulated time period the game is to operate and the different daily patterns within the period. The basic unit of time assumed by the model is one hour, but the minimum length of an operating period is one day. Depending on how the game is to be used, it may be run for a simulated day, several days, a week, a month, etc.

The administrator is free to divide the class into several groups, each dealing with distinct urban systems, or to allow the class as a whole to "play" against one larger system. Once the urban system(s) have been specified, the administrator gives the class a city map, a brief demographic sketch, periods of operation, daily patterns, and whatever additional information about the city he may deem necessary.

The players must now organize their traffic departments for effective deployment of traffic units. This may include establishing line command structures, dividing the city into districts, etc. Having done this, the players are required to make initial manpower allocation for each daily pattern in the decision period.

Both the administrator and player forms are now keypunched onto computer cards in a prescribed format. This "input" card deck together with the actual program deck are submitted to the computer for processing.

The game model produces traffic violations with the simulated urban environment over time. The frequency of violations at any particular intersection is a function of the parameters inputed by the administrators and the enforcement applied by the players. Accidents are assumed to be the result of violations. When an accident occurs the closest (in time to respond) available unit is assigned to respond. If an accident has not occurred, the model computes whether or not an available unit observed the violation. If the answer is yes, a detection has occurred. Thus, the probability of detecting violators increases with an increased manpower allocation.

The object of the game is to achieve some "best" allocation based on the criteria the players select to measure performance. Each play of the game generates data in report form for analysis and use in making decisions in subsequent plays of the game.

The next section of this paper presents the basic management game theory which underlies the Traffic Police Management Training Game.

2.0 Management Gaming Background

2.1 Definition

> Management games are "games" in the sense that there are participants, a set of rules, and a method of scoring.[15]

A management game consists of four elements. There are the players who assume roles in an organization. There is the model which simulates the environment in which the organization operates. There is the input which consists of decisions by the players and there is the output which is generated by the model and provides feedback to the players from which to "score" the results of their decisions.

A management game puts players into a simulated environment where they assume roles in an organization characteristic of this environment. In their roles as administrators, the players make decisions applying their experience and knowledge to achieve certain objectives for the organization. Through decision-making they become aware of the interrelatedness of administrative actions in the organization.

When a decision is made the simulated model of the environment uses the decisions as inputs and generates changes in the conditions of the environment. Reports are produced by the model and the players now must make new decisions using this feedback from the game. The player is, thus, actually living with the consequences of his decisions. Several plays of the game may simulate a year's operation of the organization. The player, thus, has an opportunity to make decisions, see their results but not suffer the real world consequences, such as, bankruptcy, war, or famine.

2.2 The Objectives of Management Games

Searching through the literature on management games a list of objectives of management games in education can be compiled. While any list would be only partial, we have found the following general objectives:

1. to provide a dynamic, reacting time dimension
2. to provide objective feedback
3. to provide an opportunity to learn from experience
4. to provide an opportunity for experimenting with different decisions
5. to provide an opportunity for an overview of the organization
6. to provide an opportunity to integrate knowledge and experience
7. to provide an opportunity to learn to work together

A brief description of each of these follows.

Dynamic

Kibbee has said,

> The two unique characteristics which enable games to contribute so powerfully to management education are the novel use of the time dimension, and the objectivity of the feedback. [15]

The management game is virtually alive. Its state is constantly changing in response to decisions. Further, the management game condenses a large amount of decision-making experience into a relatively short period of time. As Thorelli has said about business management games:

> While a case study of the traditional type provides an essentially static snapshot of a business problem situtation, a game yields a moving, multi-dimensional picture. [22]

Feedback

Objective feedback is provided

> in a mangement game by a set of programmed relationships which transform the input decisions into performance reports. It enables the participant to analyze the actual responses of a business environment. [15]

The objective of providing feedback is linked closely with the dynamic aspect of management games. When the player makes his decision, the management game proceeds to implement it, the simulated environment changing in response to the players' inputs. The player, thus, has the results of the application of decisions. In effect, business management games, thus, are like "case studies with feedback and a time dimension added". [31]

<u>Absence of real-world consequences</u>

Closely linked with the dynamic time dimension is the management game objective of providing an opportunity to learn from experience without paying the price that would result from wrong decisions made in real life, for example, being fired.

As Kibbee points out:

> The player is learning by implementing decisions without disrupting established operations, incurring the cost of mistakes, or inviting the resistance of vested interest. [15]

<u>Experimentation</u>

Management games can make experimentation possible, because it is always possible to return to a previous point in the simulation and proceed again from that point, making a different set of decisions to determine their advantages and disadvantages in comparison with those previously tried. Clarkson College, [15] put this feature of management games to a unique use by permitting those participants who said, "I wish I had it to do all over again", to <u>do</u> it all over gain, by resuming the exercise at the point where they feel they went wrong.

<u>Overview</u>

A vital purpose of management games in education is to provide the players with an overall perspective of their organization and to improve their feel for the interrelatedness of the various functions. By dynamic role playing, the player is forced to think about the interrelated aspects of functions and responsibilities. The players also become aware of the interrelatedness of short-and-long range planning for the successful operation of their organization.

<u>Other objectives</u>

Several other objectives are claimed for management games in education. Management games offer an opportunity for applying and testing knowledge gained from reading and other experiences.

The players can become personally involved in a simulated situation and find ways to work together under pressure in developing their decision-making abilities.

One final purpose for using management games, when programmed for a computer, is that the games are often a good way to introduce management to the realm of electronic data-processing equipment and computers. [15]

2.3 Characteristics of Management Games

Management games exhibit a degree of polarity in the individual characteristics which can be developed in the game. An enumeration of these includes:

Simple	Complex
Manual	Computerized
Deterministic	Stochastic
Functional	Total organization
Non-interactive	Interactive
Qualitative factors included	Only quantitive factors
Use for single play	Use for repeated plays
Disconcinuous play	Continuous play
	Verisimilitude
	Special features

Simple or Complex?

Complexity in a management game may manifest itself in the game rules, in the structure of the decision forms, in the simulation model itself, in the number of decisions to be made and so on. In a complex game, "undue anchorage of the model in the details of a specific industry, or specific parts of the world, may cause disputes about institutional facts and relationships of no real consequence to the objectives of the game and very well may divert the attention of the participants to peripheral matters". [22]

A review of the literature clearly indicates that range from the depth and complexity of the Carnegie Institute of Technology Game, in which as many as 300 decisions may be made each "month" to the simplicity of the original American Management Association's Game, in which only six decisions were required.

The question of whether simple management games can be used to illustrate management principles has been frequently asked. In a study of the educational value of management games by Anthony Raia [51], the hypothesis that a relatively simple game provides essentially the same benefits as one that is more complex, in terms of learning, attitude, and levels of interest and motivation was accepted. [51]

The choice of a simple or a complex management game rests primarily upon the particular objective of using a management game in a course, seminar or wherever.

Manual or Computer

Management games can be classified as manual or computer on the basis of how the computations, required to convert the decisions made by the players into the performance reports returned to them, are made.

Kibbee defines a manual game as one "in which the computations are made by clerks, or by the participants themselves, usually with the help of desk calculators". [15] Similarly, computer games are ones in which the computations are performed by electronic data processing equipment, analog and digital computers.

Greenlaw states:

> Both approaches (manual and computer) to the computation of decision results have their advantages and limitations. Although complexity can be more easily incorporated into computer-designed models, results calculated more quickly, and more comprehensive reports produced, manual calculation is much less expensive and permits more flexible game administration. [8]

The basic factors involved in deciding upon computer or manual methods for management game computations have been discussed by Greenlaw [81], Kibbee [15], thorelli [22], and others. The factors include:

1. speed and complexity of the model
2. accuracy required
3. cost
4. flexibility
5. reports generated
6. ease of experimentation
7. glamour

Deterministic or Stochastic

In a management game, the mathematical model is the set of relationships from which the output report is computed from the input decisions. Some management games are completely deterministic models--models in which operating results are determined solely by the decisions made by the players, and not by chance. Others, utilize stochastic or probabilistic models, in which chance plays a role in one way or another and influences the outcome of the game. A business game with stochastic elements, for example, may put certain variables, such as the fluctuations in the general level of business activity beyond the control of the players. Games are usually a mixture and seldom purely stochastic. [23]

Functional or total organization

"A general management game is designed to teach decision-making at the top management level where all major functional areas of the total organization are involved in achieving fundamental organizational objectives."[31] In the business management games, called total enterprise games, the basic problem is the management of a complete company. Typical decisions to be made in total enterprise games include:

1. price of product
2. marketing budget
3. research and development budget
4. maintenance budget
5. production volume scheduled
6. investment in plant and equipment
7. purchase of materials
8. dividends declared

Functional games are intended to teach specific skills in a particular management area. These games are highly specialized, confined largely to problems within a relatively narrow area. Functional business games may deal specifically with:

marketing
maintenance management
material flow and inventory
production scheduling
personnel
physical distribution
toolroom operation
manufacturing scheduling
finance, asset management
procurement and supply
salesmanship
and so on [8]

Interactive or non-interactive

According to Greenlaw, a game is classed as interactive "if the decisions made by one group of participants have a specific mathematically determinable effect upon the results achieved by other groups of participants". [8]

Kibbee has stated this characteristic very interestingly:

> A game with interaction is like tennis; a game without interaction is like golf. [15]

Further, he gives examples from business management games.

> In the Univac Marketing Game the various teams are in competition for a common market, and the action of any one team, say in its pricing policy will affect all the other teams; there is an interaction between teams. In the Westinghouse Inventory Control

Game, on the other hand, each team is attempting to achieve the best performance beginning from the same conditions, but there is no interaction between teams; the performance of one team has no effect on the other teams. [15]

Qualitative or only quantitative factors

In a management game, the relationship between a particular decision and its effect usually results from computations performed using mathematical relationships built into the game model. It is possible, however, to use human beings and introduce qualitative factors, their "rational" judgements as to the results that should ensue on a particular decision. These people are called judges, referees, or umpires. [8]

Another type of qualitative factor occurs in the information flow in management games. The management game may generate standard reports from inputs or may include a qualitative decision as to the quantity and quality of reports the players would like to have. The players decide upon what information they will buy from the available quantity of data.

Single or repeated plays

Management games are played in "periods". This interval of time, e.g., a week, a month, a quarter, a year, is called the simulated time period and decisions are made for the length of a period of play. Decisions are made in real time for the simulated time period. Management games may, thus, last in real time for an hour or a month, while the simulated time period may be a quarter or a year.

In a single play, the players make their decisions for the simulated time period, receive the outcome, and the exercise is over; the feedback from decision-making cycle is two step. In repeated plays, decisions are made, feedback results, new decisions are made with the feedback contributing to decision-making, more feedback, and the cycle goes on.

Discontinuous or continous play

Decision-making in management games may be continuous or discontinuous. In continuous decision-making game sessions, decisions are made at one sitting, uninterrupted by other work or adjournments. Discontinuous decision-making takes place over many days or weeks. Usually in discontinuous sessions, the management game is an adjunct or a complement to other course or training activities, rather than being the only activity, which is the case in continuous play.

Verisimilitude

Verisimilitude is the appearance of reality to the player, but it does not imply realism of the model. Complexity is not necessary for verisimilitude, the desired effect can be easily achieved by very simple models. [15]

As Kibbee points out,

> When a game is to be used solely for training purposes, it is not necessarily important that the mathematical model be realistic, but only that the game appear realistic to the players. The appearance of realism is known as verisimilitude, and this is an essential feature of management games. The men who play management games react to the business simulations very much as they do in real life. [15]

Using an adapted version of the game outline developed by Greenlaw, et al. the Traffic Police Management Training Game can be summarized in the terminology of this section, as follow:

I. Organization: Northwestern Univeristy Traffic Institute

II. Name of game: Traffic Police Management Training Game

III. Characteristics of the model:

- A. Specific: deals only with traffic violations
- B. General view: Not functional, rather aims to interrelate organization, management, planning, statistical analysis, etc.
- C. Stochastic: Major events occur stochastically
- D. Non-interactive: Decisions of one team do not effect the other teams
- E. Entirely quantitative, except for administrator input

IV. Characteristics of the Administrative process:

- A. Role positions suggested but not assigned by the administrators
- B. Computer
- C. Use for repeated runs
- D. Discontinuous play

2.4 A procedural Point in Using Management Games -- How to Choose a Game

The method of systems analysis lends itself to selecting the appropriate management game for any organization. The first step is to set forth the educational objectives expected of the game. Then, certain criteria may be imposed, for example, the game must have discontinuous play. Next, establish any constraints on the game, such as the abilities and interests of the players and administrators. Now, determine the resources available for the program in terms of finances, time, staff, computing facilities, and such. On the basis of information from published material, professional organizations, or game builders on all games being considered, a list of alternatives can be proposed. The list of alternatives may include one specific game, a modification of an existing game, or the design of a new game. Now the administrators must select one alternative and schedule it in the overall program in such a way as to achieve maximum impact on the players. Finally, the administrators should apply the systems analysis approach to the game to see whether the teaching objectives were reached, and to learn how the program can be improved. [15] [18]

In the next section of this paper we will discuss the Traffic Institute and how its objectives lead to the development of the Traffic Police Management Training Game.

3. The Traffic Institute and Its Objectives

Police administrators across the United States, today, realize the need for command and supervisory officers capable of assuming responsibilities in the administrative function. These officers must understand the scope of the entire traffic accident prevention program, its coordination, and the interrelation of such programs. They must know the principles and techniques necessary to reduce the number and severity of motor vehicle collisions and how to cope with the problems of congestion created by more drivers and more vehicles.

The Traffic Institute of Northwestern University, through its nine-month Traffic Police Administration Training Program, provides specialized training that can prepare law enforcement officers to meet the demands brought about by today's conditions. Following the Northwestern University quarter system, the fall quarter is devoted to subjects of common interest with specialized study in the selected areas beginning in the winter and continued through the spring. The full program provides the student with a general education background as well as specialized study in selected areas such as traffic programs, management and training.

Municipal, county, and state police officers come to the Institute from all over the world sent by their home police departments. These police departments have recognized the need for having supervisory staff trained in the most modern concepts, tools, and techniques of traffic police administration. An officer who has completed the program typically returns to his home department to set up training programs, teaching the techniques he has learned at the Institute.

Analysis of the Traffic Institute's program yields the following general objectives:

1. to instill in each participant the knowledge to operate successfully

in and contribute significantly to the operation of the police organization of which he is a part;

2. to provide detailed instruction for students with special interests in the areas of police management, traffic administration or police training;
3. to provide an educational base in areas related to police work such as oral and written communications, sociology, law, etc.;
4. to provide the instruction in and the opportunity for independent research in areas of interest. [72]

The staff of the Traffic Institute expressed interest in using gaming techniques in their program, in the Fall of 1968. This interest stemmed from the wide acceptance business games had received in business management training programs. Business games could provide an atmosphere for applying general management principles. Thus, we could expect that such games would contribute to the management aspects of police work. We might expect a contribution in the following areas:

1. Principles of modern management
2. Organization
3. Planning
4. Analysis for decision-making.

During discussions that Fall with members of the Traffic Institute staff, a number of qualitative arguments were raised against the use of any existing business management game for police training purposes. Some of these were:

1. police training objectives are distinctly different from business training objectives (although some overlap of principles exists);
2. the real-life systems are radically different resulting in a loss of the highly important verisimilitude concept for police trainees participating in a business game;
3. unlike the police system, the business system is highly interactive.

In short, a business game is not directed toward police activities, so it would seem that a management game directed at police systems to serve police training objectives would be desirable. Such a game did not exist.

It was at this point that the original ideas for the Traffic Police Management Training Game were put forth. The game would be limited to the traffic department of a city police department. One objective of the game would be to focus the player's attention on the interrelationships between various methods of allocating policemen in a city to achieve a "best" effect in terms of accident reduction and violation detection. Other objectives would be to stimulate the player's thinking about organization, management, planning, and statistical analysis. The objective of the game would be to achieve a set of "normal" short and long range operating conditions within the department by applying sound police management principles. In this game, the emphasis would be on sound management decisions and planning based on the use of data analysis techniques. The game would contribute to the following objectives of the training program:

1. Principles of modern management
2. Organization
3. Planning
4. Analysis for decision-making
5. Traffic direction and control
6. Analysis and use of traffic records
7. Use of statistics and budgeting

In addition to contributing to these objectives, the designers hypothesized that the game experience for students who would later be training policemen in their own departments would provide an opportunity to evaluate the use of games in their own programs. At this point the game designers began to formulate a model of traffic to be used in the game.

4. The Model for the Game

The most significant problems associated with the operation of a traffic division are associated with the optimum allocation of the available resources of time, manpower, equipment, and budget to cover urban traffic control and accidents, and with the formulation of police policies for dealing with traffic flow situations, accidents, violators, issuance of citations, etc. The game model must, thus, establish the cause and effect relationships between allocation of manpower to the various functions and the community response and reaction.

Kibbee [81] points out that the most important requirement in a management game model which is used solely for training is verisimilitude: The appearance of reality. Verisimilitude can be achieved with amazingly simple mathematical relationships. Although the underlying relationships may be relatively simple, the total appearance of the model presented to the players is that of a complex system. In this section the mathematical equations which describe the environmental response to enforcement allocations made by game participants are presented. [76]

The objective of the model is to simulate traffic violation occurrences in time and space. The model also keeps track of the movement of patrol units in their assigned areas. Detection of a violator requires the simultaneous presence of a non-busy patrol unit and a violation occurrence. In addition, the model simulates accidents and assigns the closest (in time, not space) patrol unit to respond. While the model is capable of generating many types of statistics, currently it generates the following:

1. detected violations, by type, location, time
2. accidents by time and location
3. response times
4. service times
5. unit assigned to accident or handling violation

To begin, a definition is required.

Definition--Enforcement cell (i,j)

By an enforcement cell (i,j) we shall mean the one half block in all directions from intersection (i,j). This concept is illustrated in Figure 1.

For discussion purposes, it is sufficient to consider the development of one hour n within the daily pattern p (a definition of daily pattern is given in the Input section). The model will range over each hour n for all days $d = 1,2\ldots,N_p$ in pattern p and all patterns p.

Determining violation events

We shall assume that the number of violations occurring in cell (i,j) during hour n obeys a Poisson distribution with parameter $V_{ij}(n)$. The time t of occurrence of each violation is selected from a negative exponential distribution (n-1 to n). It remains to describe the variation in $V_{ij}(n)$ with enforcement and time.

Police enforcement

Assume that patrol unit k has been assigned to area $A_k(n)$ and will weight his time according to the intersection flow rates, $Q_{ij}(n)$, where $(i,j) \in A_k(n)$. Thus, we assume that the probability of finding unit k in a particular cell (i,j) at time t during hour n is given by

$$P[k \in (i,j) \in A_k(n) \text{ at time } t] = \frac{Q_{ij}(n)}{\sum\limits_{(i,j) \in A_k(n)} Q_{ij}(n)} . \quad (1)$$

Definition -- Enforcement level $E_{ij}(n)$

We define the enforcement level, $E_{ij}(n)$, in cell (i,j) during hour n as the sum of the probabilities of finding a patrol unit in cell (ij) at any time t during hour n. That is,

$$E_{ij}(n) = \sum_{k \in K_{ij}(n)} P\,[k \in (i,j) \in A_k(n) \text{ at time } t\,]. \quad (2)$$

In particular, if only <u>one</u> unit k has been assigned to spot patrol at intersection (i,j), then

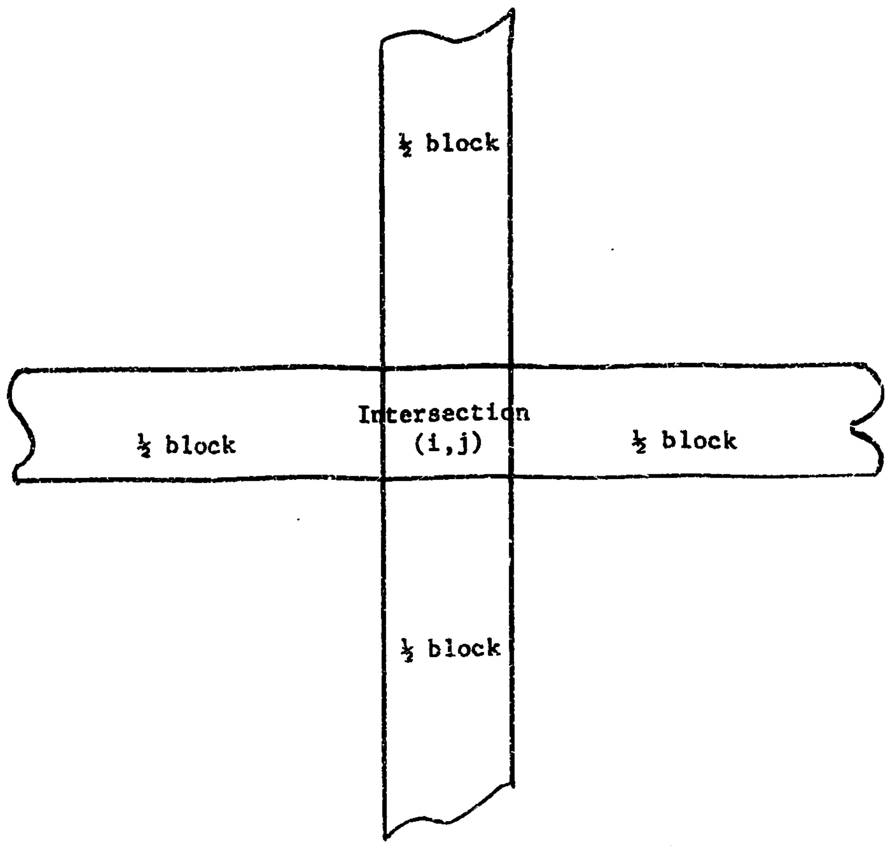
$$K_{ij}(n) = k\ ,\ A_k(n) = (i,j),\ P[k \in (i,j) \text{ at } t] = \frac{Q_{ij}(n)}{Q_{ij}(n)} = 1,$$

and $E_{ij}(n) = 1$.

We are saying that applied police enforcement, i.e., number of units assigned to

Figure 1

Enforcement cell



cell (i,j), is the sum of the probability defined in (1) for all units assigned, for the same hour of each of the same pattern day types. Thus, there is an applied police enforcement for each cell (i,j), as a function of intersection flow rate, number of units assigned, and previous duplicate pattern days' enforcement at the same hour n.

Community perceived enforcement

Following Fisher and Mosher [6], we assume that the violation rate, $V_{ij}(n)$, will decay exponentially as a function of both enforcement and time. For the present we may drop the indices (i,j) and n.

First, we allow V to vary exponentially between $\overline{V}$ and $\underline{V}$ as follows:

$$V(E) = \overline{V}\, e^{-\gamma E} + \underline{V}\left[1 - e^{-\gamma E}\right]. \qquad (3)$$

To determine the free parameter γ, let

$$V \quad V^E = \left[1 - \frac{K^E}{100}\right] \overline{V}\ , \qquad (4)$$

and require for E = 1 that

$$V^E = \overline{V}\, e^{-\gamma} = \underline{V}\left[1 - e^{-\gamma}\right] \qquad (5)$$

$$= \underline{V} + \left[\overline{V} - \underline{V}\right] e^{-\gamma} \qquad (6)$$

or $$e^{-\gamma} = \frac{V^E - \underline{V}}{\overline{V} - \underline{V}} \qquad (7)$$

or $$\gamma = -\ln \frac{V^E - \underline{V}}{\overline{V} - \underline{V}} . \qquad (8)$$

Note, that we have defined a "community" response to a change in enforcement. However, the neighborhood generally has to be exposed to a change in enforcement before the complete effect is realized.

To describe this "time delay" response, let $V^{(0)}$ be the violation rate at an old enforcement level $E^{(0)}$, and $V^{(1)}$ be the violation rate at the new enforcement level, $E^{(1)}$. Again, assume an exponential decay after d days exposure to the new level $E^{(1)}$ as follows:

$$V(d) = V^{(0)} e^{-\tau d} + V^{(1)}\ 1 - e^{-\tau d} \qquad (9)$$
$$\text{where } V(0) = V^{(0)}.$$

To determine the free parameter τ, recall that N^E is the number of days of continuous enforcement a $E = 1$ required to drop the violation rate from $\overline{V}$ to V^E. Thus, we require

$$V^E = \overline{V}\, e^{-\tau N^E} + \underline{V}\left[1 - e^{-\tau N^E}\right], \qquad (10)$$

or

$$\tau = - \ln \frac{\dfrac{V^E - \underline{V}}{\overline{V} - \underline{V}}}{N^E} . \qquad (11)$$

Such curves describe how quickly (in terms of days) a community responds to a change in enforcement.

Generating the Master Violation Table (MVT)

Equations (3) and (9) allow for the computation of violation rates for all cells (i,j) for each hour n. The number of violations, N_{ij}^v, of each type occurring in each cell (i,j) during hour n, for each n, is now determined from a Poisson distribution with parameter $V_{ij}(n)$. For each cell (i,j) we select the violation occurrence times from a negative exponential distribution with parameter $1/V_{ij}(n)$.

For simulation purposes, we wish to string violation occurrences on a time line in minutes during one hour n. To accomplish this, we construct a master violation table (MVT) of violations ordered in ascending time of occurrence. The first entry in this MVT is the time of occurrence of violation, the second is type of violation, the third is avenue number where violation occurred and the fourth is street number where violation occurred. Once the MVT is sorted in time sequence, we are ready to run the simulation for hour n by sequentially processing each violation in the MVT.

Patrol unit location

In order to keep track of patrol units in space and time we shall assign to each unit the following attributes:

1. t_F -the time the unit is available for reassignment;
2. t_L -the time the unit was last located;
3. i_L -the avenue index when the unit was last located;
4. j_L -the street index when the unit was last located;
5. the current area assignment.

When attempting to locate a unit at time t, we encounter three cases:

1. $t_F > t$-the unit is busy;
2. $t_F < t$-unit is available and inside its area;
3. $t_F < t$-unit is available and outside its area.

For cases (2) and (3) we wish to compute the unit's new position (i,j) at the present time t.

For case (2), we assume the unit has been patrolling its area since last located at time t_L. However, if t_L is recent relative to t, it may not be reasonable to expect that the unit could be in every cell of $A_k(n)$. Thus, we require the following:

Definition--Region of influence $R_k(t)$

We define the region of influence of unit k at time t as that coordinate rectangle in which unit k can be realistically located. Let

i_R^A = right (east) boundary of the coordinate rectangle $A_k(n)$

i_L^A = left (west) boundary of the coordinate rectangle $A_k(n)$

j_T^A = top (north) boundary of the coordinate rectangle $A_k(n)$

j_B^A = bottom (south) boundary of the coordinate rectangle $A_k(n)$.

Similarly let,

i_R^R = right boundary of the coordinate rectangle $R_k(t)$

i_L^R = left boundary of the coordinate rectangle $R_k(t)$

j_T^R = top boundary of the coordinate rectangle $R_k(t)$

j_B^R = bottom boundary of the coordinate rectangle $R_k(t)$.

Assuming some average patrol speed, v_p, we can compute the bounds on $R_k(t)$ as follows:

$$i_R^R = \min\left[i_L + v_p\,(t-t_L),\ i_R^A\right]$$
$$i_R^R = \max\left[i_L - v_p\,(t-t_L),\ i_L^A\right]$$
$$j_T^R = \min\left[j_L + v_p\,(t-t_L),\ j_T^A\right]$$
$$j_B^R = \max\left[j_L - v_p\,(t-t_L),\ j_B^A\right]$$

This concept is illustrated in Figure 2.

We now select the current location of the unit from the probability function

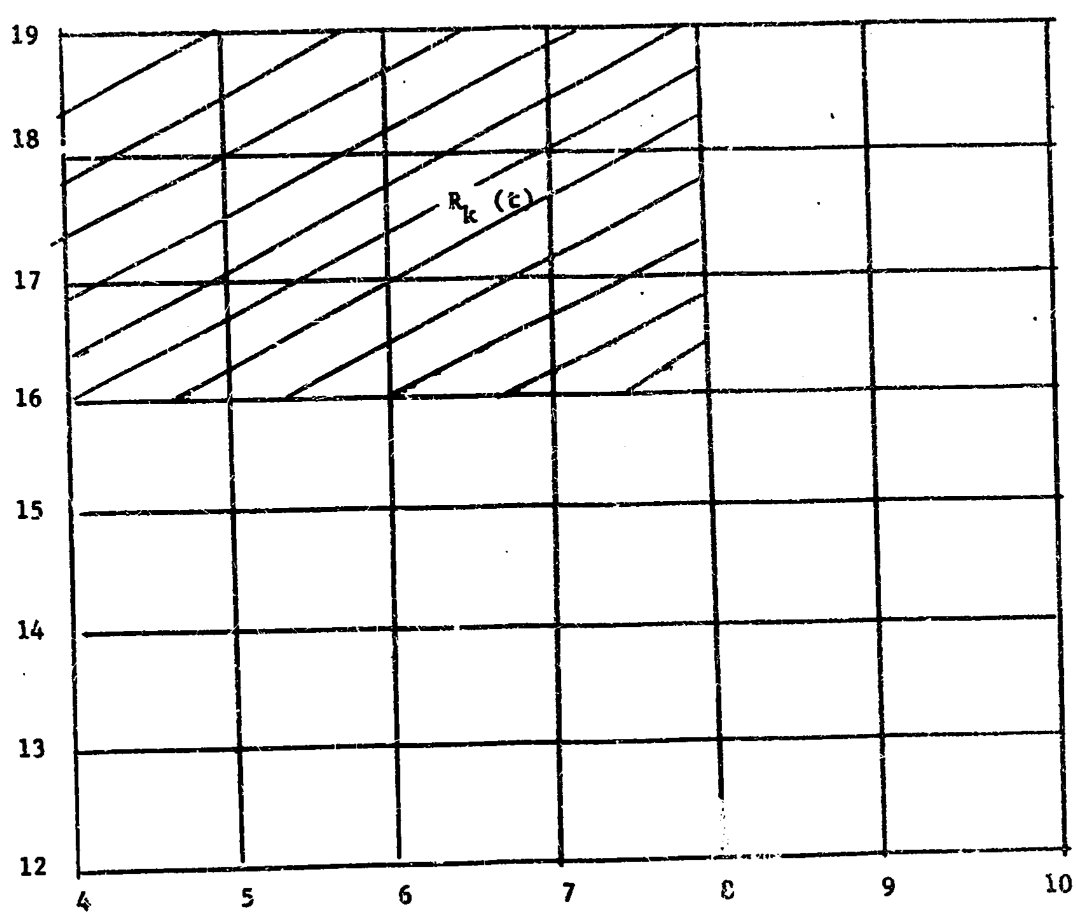
$$\sum_{(i,j)\,\epsilon\,R_k(t)} P\left[k\ \epsilon\ (i,j)\ \epsilon\ R_k(t)\right] = \frac{Q_{ij}(n)}{\sum_{(i,j)\epsilon R_k(t)} Q_{ij}(n)} \qquad (12)$$

This probability for each $(i,j)\ \epsilon\ R_k(t)$ is compared to a random number from a uniform

Figure 2

Region of influence

$A_k(n)$



distribution. When the probability in (12) is greater than the random number, this (i,j) becomes the cell where he is.

For case 3, unit is not busy, outside area, we assume the unit returns to its area by the shortest route possible. Here, we have three subcases as depicted in Figure 3. In each case, the model computes whether or not the unit has had a chance to return to its area. If not, it will compute the unit's position along the route of shortest return. If the unit has had time to return, its time and location of entrance into the area will be used to compute a region of influence and the current location will be selected as described previously.

Event accident

When a violation is selected from the top of the MVT list, the question of whether it resulted in an accident must be decided. The model assumes accidents happen with a uniform distribution. For each violation type v, a number is inputed (see the next chapter, Input section) representing the percentage of violations of type v that result in accidents. When a violation is selected from the MVT, the model checks whether the uniform number is greater than this percentage, indicating no accident occurred.

If an accident occurs then the model computes the response time for all non-busy units and assigns the unit with shortest response time to cover the accident. Service time is negative exponential with mean $1/S_v$, where S_v, average service time for an accident resulting from this violation is also inputed. The model updates the servicing unit's location, i_L, j_L, availability attribute, and time available for reassignment, t_F.

Event No Accident

If no accident occurs as the result of a violation, two further possibilities remain. Either the violation is detected or not detected. The model requires the unit to be at the same location where the violation occurs in order for the violation to be detected. The test for detection involves locating each unit, determining whether it is available or not and, if it is available, locating the unit, as described in a previous section, cases (2) and (3). Once located the probability of detection becomes:

$P = 0$ if $i_L, j_L \neq$ iviol, jviol and

$P = 1$ if $i_L, j_L =$ iviol, jviol, where iviol, jviol is the cell where violation occurs.

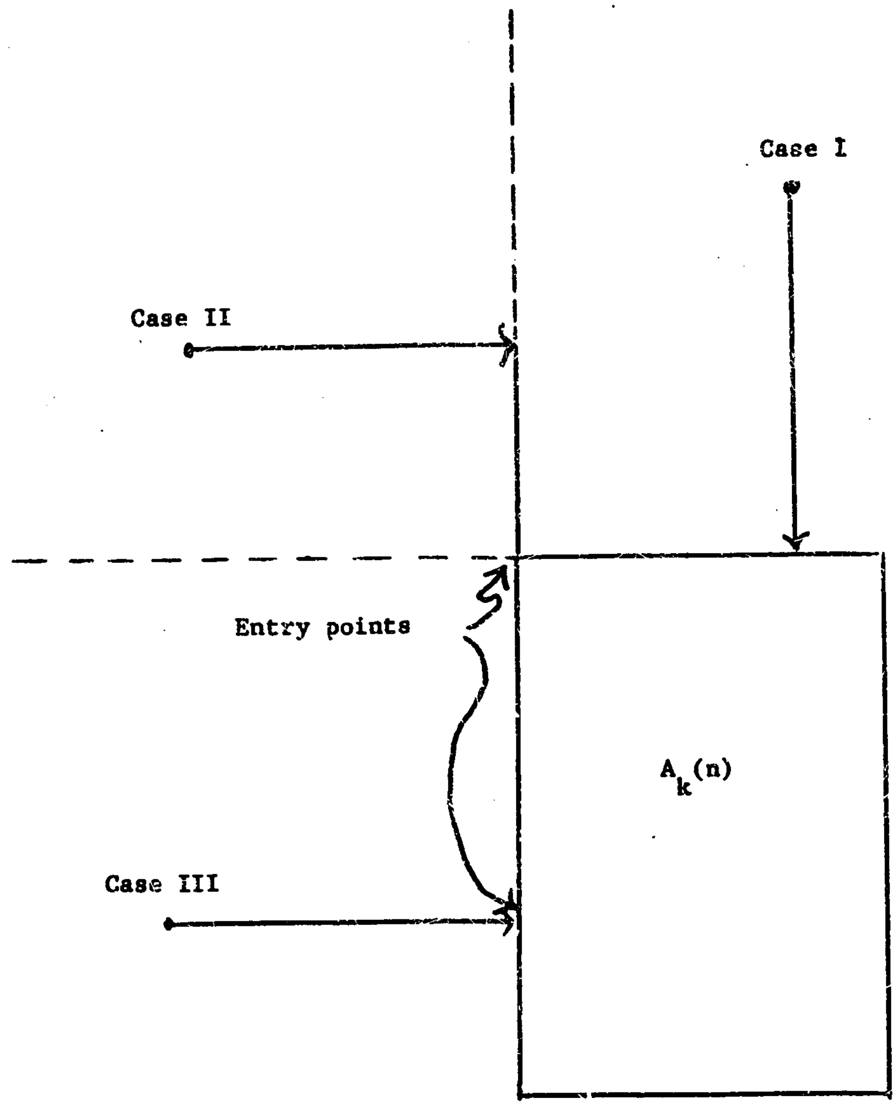
Model Logic

It is now possible to define the logical sequence of operations the model must execute.

1. Compute police enforcement
2. Compute community perceived police enforcement

Figure 3

Return Routes to Assigned Area



3. Generate Master Violation Table
4. Select violation from the top of the MVT
5. Did an accident occur?
   a) If yes, go to 6
   b) If no, go to 7
6. Locate all available units at time t and assign closest to respond to accident. Record response time, service time, accident, violation type and unit responding.
   Take unit out of service. Go to 4.
7. Locate available units $k \in K_{ij}(n)$ and for each, test if unit location is (i,j).
   a) If no, test if $K_{ij}(n)$ is exhausted.
      i) If yes, go to 4, violation undetected
      ii) If no, continue search on units $k \in K_{ij}(n)$
   b) If yes, record violation type, service time, unit responding.
      Take unit out of Service. Go to 4.
8. The end.

5. The Simulation

The simulation is written in Fortran IV and was developed for use on the CDC6400 digital computer at the Vogelback Computer Center on the Evanston campus of Northwestern University. The simulation is based on the model just presented.

Applying some of the terminology of simulations, the Police Traffic Management Training Game's simulation basically has the following entities, entity attributes, and events events.

Entities	Attributes
Active:	
Patrol unit	District to which it belongs
	Patrol speed
	Response speed
	Busy or not busy
	Inside or outside area
	Time of day it was last located
	Location (i,j) where last located
	Time of day when it will be non-busy
	The area to which it is assigned for the current hour and daily pattern
Passive:	
Region	Avenue and street boundaries
	Qualtative attributes (i.e., ghetto,

	industrial, etc.)
Districts	Avenue and street boundaries Police Headquarters An allocation of patrol units
Intersection (i,j)	Region in which it is located District in which it is located Area in which it is located Traffic flow rates for each hour of daily pattern
<u>Events</u>	<u>Comments</u>
Violation	The basic event generated by the Traffic System. It has the following characteristics: Type Average time to service a detection Average time to service an accident resulting from this type violation Maximum violation rate ($\overline{V}$) for this type Minimum violation rate ($\underline{V}$) for this type Percentage of this type of violation resulting in an accident
Accident	Requires a violation to occur first, the system generates accidents probabilistically
Detection	Requires a violation to occur first, the system generates non-accident violations which the structure defines as detected if the unit is available and at that intersection (i,j)

6.0 The Input

The Traffic Police Management Training Game involves two kinds of input, as indicated in the overview section. There is administrator input and player input.

6.1 Administrator Input

The administrator by inputing parameters defines the simulated urban environment in which decisions will be made by the players. Some of these parameters will be made known to the players, others are useful only to the model for generating violations, accidents, and so on, but would be of no value to the players even if known, for example, $\overline{V}$ and $\underline{V}$ for each v, since they represent subjective judgements for the administrators. Clearly, the administrator defines the reference city by his inputs for city parameters. He specifies whatever type of urban traffic environment he believes best meets his teaching objectives. Further, the administrator establishes the length of the simulated time period.

The following elements are required to specify the urban traffic system:

1. City limit definition
2. Violation table
3. Daily pattern table
4. Composition definition
5. Region definition
6. Composition to region assignments for each daily pattern.

A brief description of each of these follows:

City limit definition

The basic unit of geographic area is a rectangle whose sides are parallel to a coordinate axis system. The city, for the sake of simplicity, is thought of as one large coordinate rectangle. City boundaries are thus specified by the dimensions, in terms of avenues and streets of a rectangle. The city limit definition thus is designated "from avenue_____ to avenue ______ and street ______ to street______". Figure 4 illustrates this terminology.

Violation table

The violation table is merely a list of all the violation types to be considered in game play. They are identified by an eight character code and a description of at most sixty characters, including blanks.

Daily pattern table

The daily pattern table introduces the time dimension into the game. The daily pattern table serves to define the different daily patterns which are to be considered and how many of each pattern are to be included in the play period. A daily pattern might be a particular day of the week, like Monday, or just the category weekday, or Saturday, or Sunday.

Composition definition

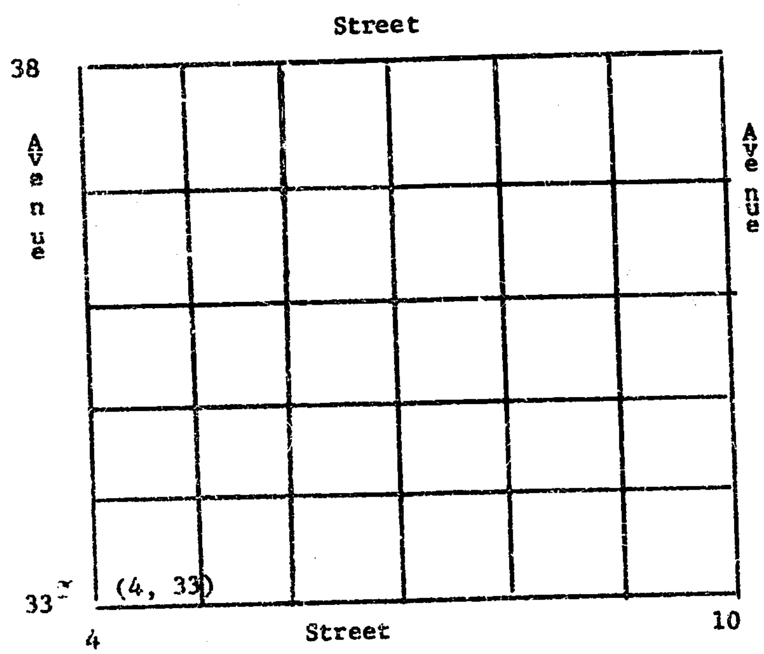
Game "parameters" are input in a block termed a "composition". A composition is an artifical device for assigning constant parameters over time and space. It is a particular set of parametric values that can be assigned to the time and space dimensions where appropriate.

Associated with each composition are the following parameters:

1. intersection flow rate in vehicles per hour
2. patrol speed (miles per hour)
3. response speed (miles per hour)
4. the percentage of vehicles which will

Figure 4

The Coordinate Rectangle City Limit Definition



be in violation if the drivers have the knowledge that they will be not observed or stopped by a patrol unit (i.e., zero level enforcement)

5. the percentage of vehicles which will be in violation if the drivers have the knowledge that they will be continuously observed and violators will be stopped by a patrol unit (i.e., unlimited enforcement)

6. the reduction in violations that can be expected, due to a single patrol unit being continuously assigned for a specified number of days at a particular intersection (defined as an enforcement level of unity)

7. the number of days a patrol unit must be assigned to achieve the reduction of (4) above (this parameter defines the time response to patrol)

8. the expected percentage of violations of this type resulting in accidents

These parameters are sufficient to give not only the physical flow rates, but also allow for a description of the community response to enforcement over time. A community with respect for traffic law will have a low violation rate, regardless of enforcement. A community with respect (or fear of traffic enforcement) will quickly respond to patrol activity. Problems arise in communities where one or both of these conditions is not the case. The composition then becomes a vehicle by which the administrator may define traffic "problem" situations in the environment.

The manner in which compositions are used to specify the complete time and spacial environment is discussed below in Composition to Region Assignment.

Just as the hour is the basic time unit, the "region" is the fundamental unit in the environmental specification. That is, composition environmental parameters are assumed constant over both regions of the city <u>and</u> hours of the day.

A region is a subset of the city area. Like the city limit definition, the boundaries must be constructed from sides of a coordinate rectangle. Regions may take the form of a single intersection, lengths of streets, or areas in general. They are defined to achieve the desired spacial distribution of parameters over the city. Each region is identified by a unique integer and constructed from coordinate rectangles. Examples of regions include:

1. residential areas
2. commercial areas
3. main arterials
4. trouble intersections

These regions do not take on "life" until the compositions containing their environmental characteristics have been assigned as described below in the next section.

Composition to region assignments for each daily pattern

The assignment of composition to regions for each daily pattern is the linkage which ties together the previous elements and completes the description of the urban traffic system in both the time and space dimensions. It is here that the advantage of using the artificial device of the composition to reduce the amount of information input is fully realized. The same composition can be sprinkled throughout the city at various hours of the daily patterns.

Composition assignment is probably best understood through an example. Suppose region 1 consists of residential areas. Composition 1 represents offpeak hours in these areas, with a low intersection flow rate and few types of violations. Composition 2 represents peak hours and has higher intersection flow rates and more types of violations, for example, speeding on the way home from work. During daily pattern weekday except for rush hours Composition 1 might apply, Composition 2, during the rush hours. Clearly, in a commercial area Composition 1 might never apply, or perhaps only apply in the wee hours of the morning.

The administrator can, thus, use the six tools discussed with which to create a seemingly real urban traffic environment.

6.2 Player Input

The objective of the players in the game situation is to allocate their available manpower through beat definitions which "solve" the problems the administrator has built into the environment. The player varies unit assignments and concentrations with each game play in an effort to achieve an "optimal" system, in terms of time and space distribution, patrol beat size, etc. Manpower must be optimally allocated to cover routine traffic control problems or normally congested streets or intersections, as well as accident coverage and normal or emergency patrol activity within each traffic area. Given an initial report and reports generated after each play, the team must establish policies and allocate given, limited manpower during each play. The players are, thus, forced to absorb large amounts of data, gain an overall perspective, and acquire a sense of interrelationship between the total system and its parts. The following elements make up the decision input by players at each step in the discontinuous play.

1. district definition
2. area definition
3. beat assignment

A discussion of each of these follows:

District definition

After the players have been presented with the urban traffic environment, they must organize themselves into a traffic department. While organizing their departments, the players have the option of dividing the city into districts.

A district is defined in a manner identical to that used by the administrator to define regions. That is, it is a subset of the city area constructed from sides of coordinate rectangles. At this point, the district headquarters' location can also be inputed by the players.

Area definition

The game model assumes three eight hour shifts as follows:

1. 12 midnight to 8 a.m.;
2. 8 a.m. to 4 p.m.;
3. 4 p.m. to 12 midnight.

Each shift commander in each district must designate areas within the district he thinks are important for the assignment of patrol units. One or more patrol units will be assigned to each area for at least one hour during the shift. The collection of area assignments for one unit during the shift is the "beat" for that unit. It is assumed that these areas will usually vary with each game play as the district commanders strive for a "best" area designation.

Areas are defined by district commanders for all shifts within each daily pattern. Areas are limited to coordinate rectangles for simplicity. This limitation does not appe - severely restrictive, as the commander has the flexibilit to change a unit's area assignment hourly, as discussed below. Coordinate rectangles can be selected for spot (one intersection), line (a length of street), or area patrol.

Unit beat assignments

A unit beat is a time ordered collection of areas assigned to the unit during the shift period. The district shift commander has the ability to assign units to different areas for each hour of the shift. A unit may be assigned to a different rectangle for each hour, to the same rectangle for the entire shift, or any combination thereof. Beats, thus, have a time and a space dimension.

It is expected that the player commander will vary unit beat assignments with each game in an effort to achieve an "optimal" system operation.

It is believed that these three facilities, just discussed, provide most of the controls exercised by a commander in a real life situation. It is worth emphasizing once again, that the game model has been constructed to provide a definite response to controls, so that the student can derive meaning from playing the game. It is hoped that this response has the appearance of reality, but the model itself does not represent a real life environment. Thus, model responses should not be construed as those which may occur in a real life situation.

7. The Output

Using example traffic reports from Ficher and Mosher [6] and the Traffic Institute, the following format has been created for the output of the game. This output presents feedback in response to the decisions made by the players on effective police allocation throughout their reference city.

The report generated is called an Activity Summary. One Activity Summary Sheet is provided for each shift on each day of each daily pattern type. Suppose the game is being played for a simulated month, then, for example, if there are four Sundays in this simulated month, an Activity Summary is generated for Sunday number 1, Shift 1, 2, 3, Sunday number 2, Shift 1, 2, 3 ..., Sunday number 4, Shift 1, 2, 3. The output on the Summary includes: Time, located, violation, accident, response time, service time, and unit identification, which are discussed below.

Time

Time of the violation which was detected or resulted in an accident. Time is the hour of the day where:

1 a.m. is 1

2 a.m. is 2

.

.

12 noon is 12

1 p.m. is 13

.

.

.

12 midnight is 24

The fractional part of the hour, i.e., five minutes after, etc., is indicated by a number from 1 to 59. Thus, if the first entry in the time column is 2-54, this would indicate the first accident or detected violation occurred at 2:54 a.m.

Location

Location simply indicates the avenue and street intersection where the detected violation or accident occurred.

Violation Identification

Violation ID is the identification number assigned to the violation by the administrators.

Accident

A "Yes" entry indicates an accident resulted from this violation. A "No" entry indicates a detected non-accident producing violation.

Response Time

Response time is the time required for the closest (in time) patrol unit to move from his present location to the scene of the accident, in minutes. A "0000." entry appears when a detected violation has occurred, since by the structure of the simulation, violations are detected only when the unit and the violation are simultaneously at the same intersection, i.e., instantaneous response time.

Service Time

Service time is the time required in minutes to service the violation or accident. Detected violations receive tickets and may involve intoxication tests, short lectures, or radioing and waiting for car and license identification. Accidents may involve first aid, calls for ambulance, call for towing, interviews with witnesses, and so on, including issuing tickets.

Unit Identification

Unit ID is the identification assigned by the player to the patrol unit, indicating to the shift and district commanders what unit covered the violation or detection.

Thus, the information contained in this

Activity Summary provides the players a basis for analyzing the effectiveness of their past decisions and directing their next decisions.

8. Summary

In summary the logical flow of the game is as follows:

1. Administrators make decisions on the parameters for the reference city
2. Players participate in a briefing Players make their decisions on organization, planning, manpower allocation, areas, and beat assignments.
3. Administrator and player inputs are keypunched onto data processing cards.
4. Deck submitted.
5. Model from section 5 generates feedback in the form of Activity Summary Sheets.
6. Certain administrator and player input stored on tape for use in next play of game
7. Reports returned to players, who base new decisions on them
8. New player decision made and deck resubmitted, etc.

The logical flow assumes the city is the same, unless the administrators call a new briefing for a new city.

Notice that the administrators always have the option to change certain parameters when they want to, i.e., increase intersection flow rates on side streets on the day of a parade.

9. Some Final Comments

The Traffic Police Management Training Game, as presented in the preceeding sections of this paper, was played as an experimental effort at the Institute during the final 3 weeks of a year's program. The general reaction from the Traffic Institute staff was extremely favorable.

The administrators are sold on the use of a management game carefully integrated into their curriculum in the future. Since, as far as can be determined, the Traffic Police Management Training Game is unique, the administrators can foresee many possibilities of its use by major Police Departments, state and city, across the country. Further, they can see numerous applications and adaptations.

The player reaction was equally enthusiastic with the positive reservation that they felt more time should be devoted to the game, so that it becomes an integral mechanism for tying the total program together.

The future of the Traffic Police Management Training Game, thus, depends on the successful alteration of the Institute's program to incorporate the game as a teaching tool.

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