PARKS AND NATURAL RESOURCES MANAGEMENT: A SYSTEMS STUDY*

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Abstract

A study of the management structures for state parks and natural resource protection areas is presented in this paper. The analysis vehicle is a system dynamics model of a typical park encompassing flora and fauna natural resources, cultural heritage resources, and recreational areas. Such systems are complex feedback structures where management goals must be drawn to achieve desired ends within fiscal and personnel constraints. The model is used to suggest methods of measuring the tradeoffs between goal accomplishment and resource constraints. The model was developed through an extensive study of the Parks System of Florida. (Key words: Goal Management, System Dynamics, Simulation, Natural Resources Management)

Introduction

The management of state parks is addressed in the study reported in this paper. Park systems are complex feedback structures that encompass flora and fauna natural resources, cultural heritage and historical resources, and recreational facilities. Typically, maintenance and development of the facilities and resources are labor intensive requiring careful allocation of personnel to competing functions. A methodology to evaluate goal development, allocation of personnel and subsequent system performance and measurement is presented and discussed.

The state park system has three basic responsibilities: conserving natural and cultural resources, providing recreational services for the public, and representing to the public the significance of natural and cultural features. These three responsibilities form the basis for the various operational functions in the system.

The basic unit in the system is a State park. The macrosystem is the sum of the various parks in the state and their interacting functions. Given this, initial analysis focused on the nature of various types of parks and whether or not the individual parks had unique structure. A later phase of the research will focus on the interaction among parks.

An accepted tenet of the system dynamics approach is that progress in early stages of a study does not require extensive data gathering and statistical analysis (Forrester, 1961). In the case of the park system, this was true, as a causal diagram, discussed in the next section, could be developed with only limited contact with operating managers. Progress beyond the causal analysis phase of the research required statistical information about the hypothesized relationships. An extensive questionnaire, therefore, was developed and administered with the objective of gathering data that would better define the major areas of a dynamic model and the quantitative relationships among the system variables. The data were subjected to extensive factor and regression analysis.

The factor analysis supported the structure of the system incorporated into the dynamic model discussed in a later section. Regression analysis was used to better define the transfer functions between the elements and to provide quantitative values for a number of the parameters and equation elements (Clark, a1987). The equation set that resulted has been extensively tested with the objective of designing measurement structures that allow management to allocate limited staff among simultaneously competing functions and to evaluate the results of the allocation decisions. In the remainder of the paper, the results of the tests and a recommended measurement structure are discussed and a more detailed discussion of the system elements presented.

Causal Analysis

Accepted methods of causal analysis were applied to develop an initial model of a typical park [Coyle, 1978; Pugh & Roberts, 1981; Hall, 1983]. An overview of its structure is shown in Figure 1. There are seven major management areas in a typical park. These deal with the management of natural resources, maintenance and development of cultural and recreational facilities, the people who visit the park, the revenue visitors generate, and the people and vehicles necessary for park protection and maintenance. The individual variables chosen to represent these areas are shown in the more detailed causal diagram of Figure 2.

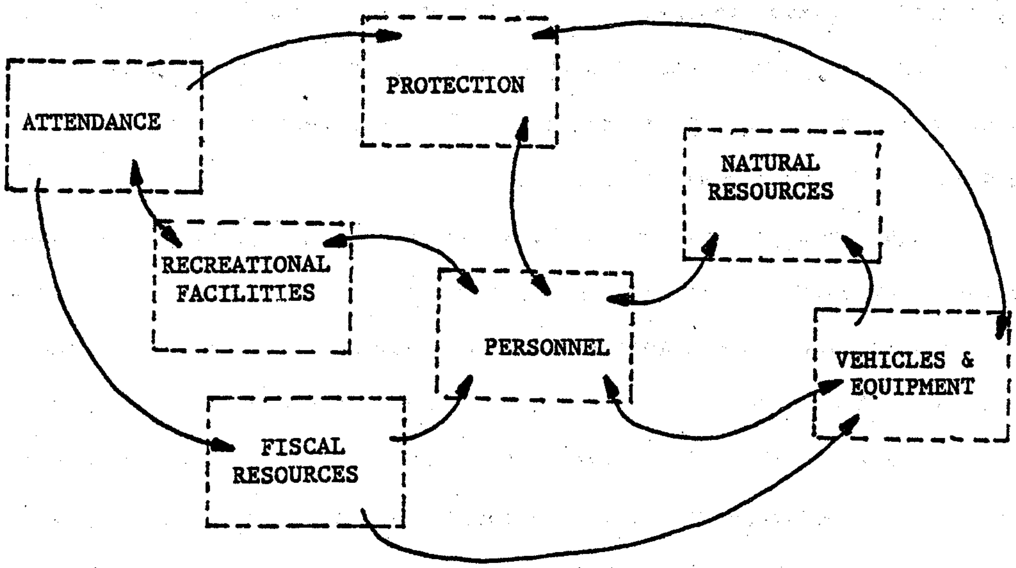

Figure 1. Sector Structure of the Park System Causal Model

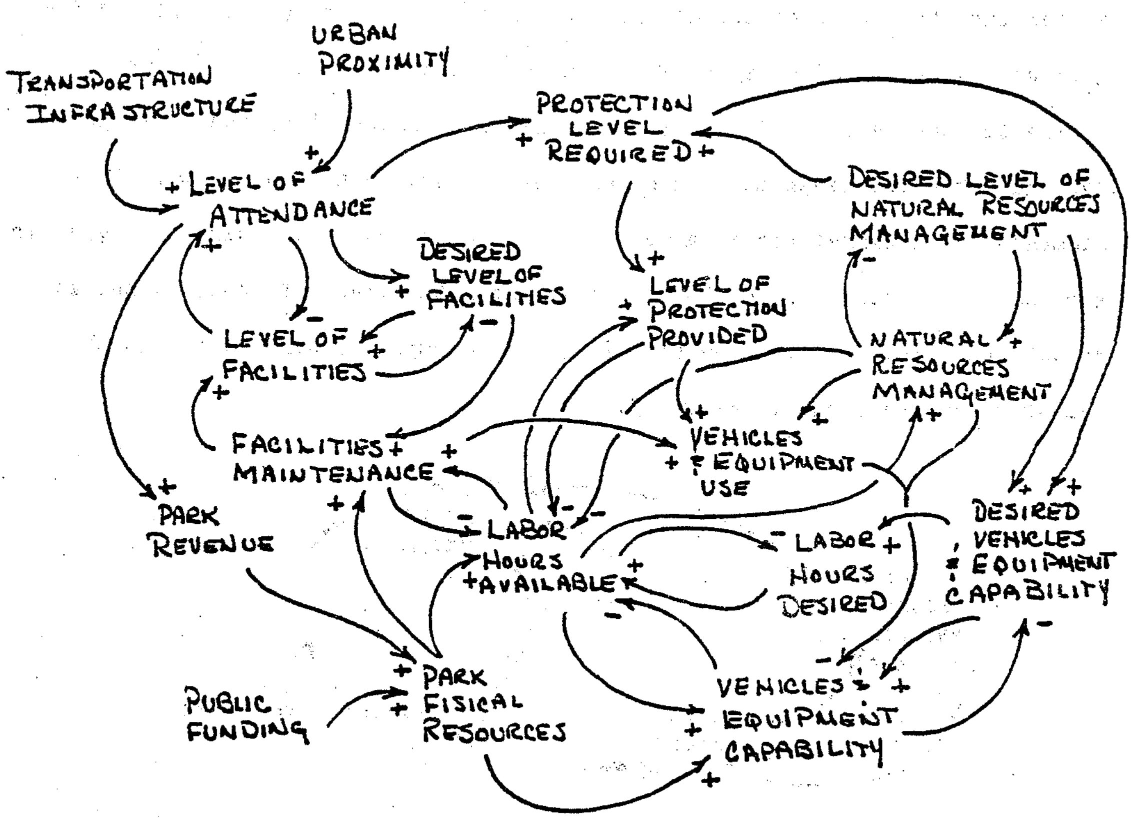

Figure 2. System Causal Structure

The complex feedback structure of the system can be seen in the diagram as can the structural relationships between the competing goals that vie for limited resources. The key elements in the system are the labor hours available, the level of facilities, the level of protection, the level of natural resources management, and vehicles and equipment capability. These elements are interrelated in a way common to such systems. There is a goal in each area, a decision function that translates the goal into action, and an actual resulting output [Roberts, 1963]. An example is highlighted in the causal structure shown in Figure 3.

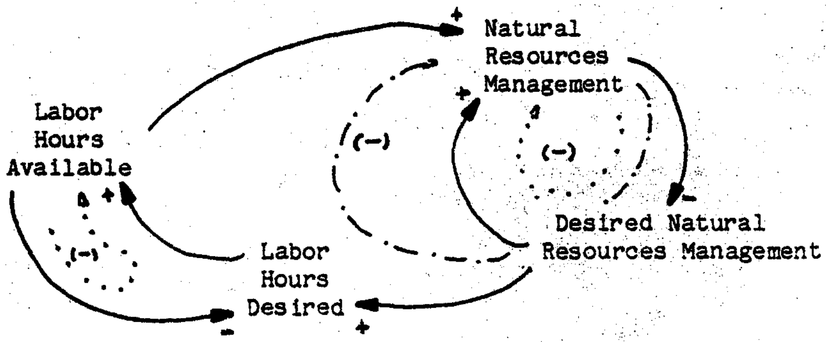

Figure 3. Typical Feedback Structure

Three loops are detaialed in the figure. There is one highlighted by the dashed line and two with dotted lines. All three are negative loops indicating stability at some performance level. This assumes, of course, that the fiscal resources required to purchase labor in sufficient quantities to meet desires are available. Management must balance the system's resources to achieve, as nearly as possible, all of the competing goals. The translation of these typical causal structures into a dynamic model provides management with a vehicle to evaluate goal changes and comcomitant resource requirements. Such a vehicle was the primary objective of the park study.

The causal diagram contains a number of variables that obviously are difficult to measure, especially in the ratio scale. Part of the research was directed at developing meaningful quantitative representations for things like natural resource management, protection, equipment capability, personnel capability, and facilities. A value of the research approach came from having managers focus on the structures and provide suggestions for their measurement [Richardson and Pugh, 1981]. The measures and more detailed variable representations will be addressed in the next section where the structure of the parametric model is discussed.

Parametic Model Structure

The causal model introduced in the last section was the basis for the parametric model discussed in this section. A modified flow diagram for the system is shown in Figure 4. As can be seen, there was a direct translation of the elements introduced in the causal model. The concept for several levels in this particular model is somewhat different than that normally thought of in the system dynamics approach [Forrester, 1986; Richardson and Pugh, 1981]. This stems from the measurement structure chosen for qualitative variables and the particular nature of parks management.

There are three levels of the nine shown which have quantitative measures that can be directly observed in the system. These are the two levels for available labor hours (in training and fully qualified) and for attendance. These can be measured in the ratio scale and directly included in the model. Measures in the ordinal scale for the other levels were developed and refined in extensive discussions with park managers. The general approach to measurement will be illustrated by using on the "level of resource management" as an example.

The initial value of the variable was set by assessing a particular park's land mass, flora and fauna. A complexity index for flora was developed

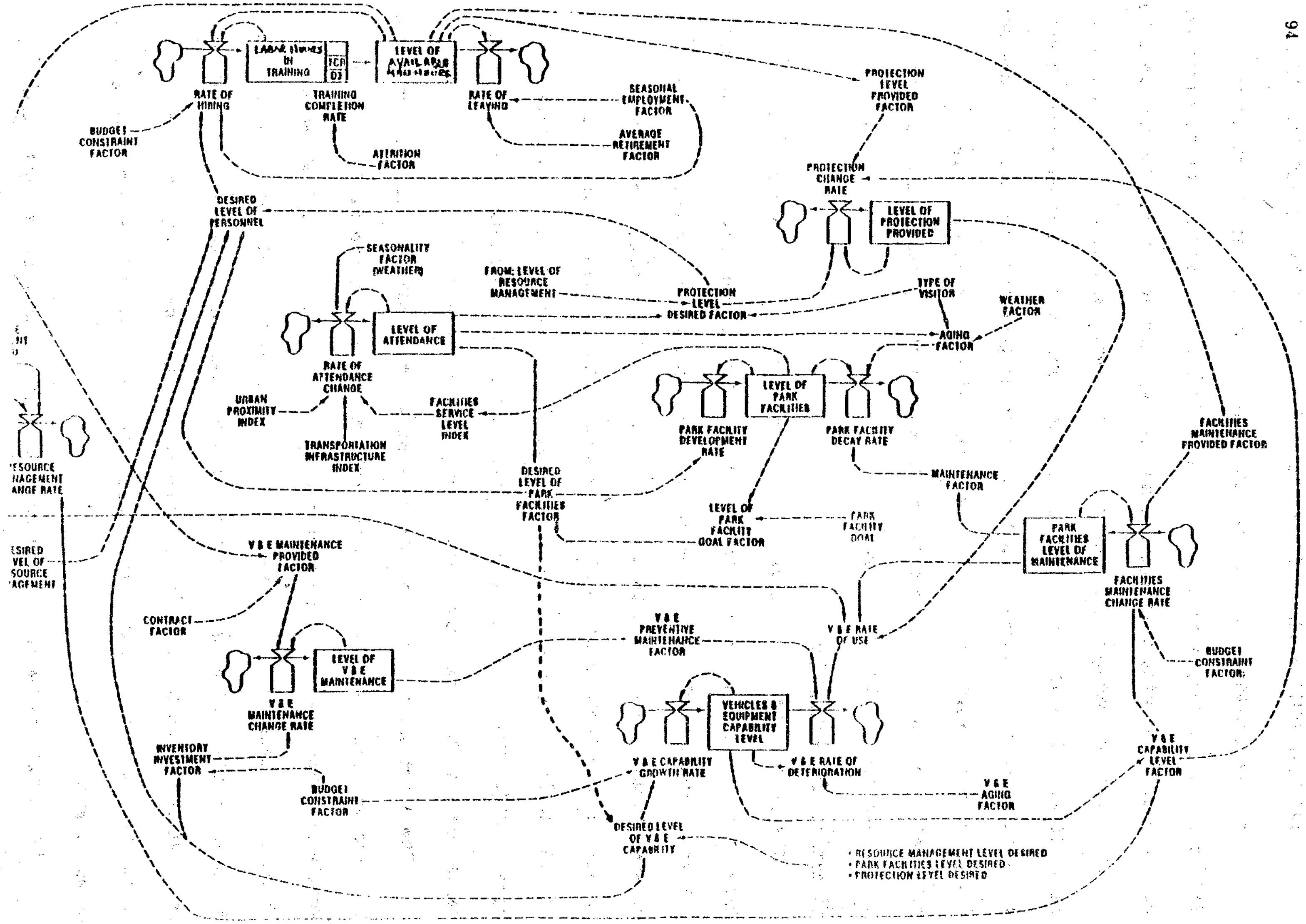

Figure 4. Modified Flow Diagram

using an eleven point Likert scale (0-10) from "open land in a natural state (no management required)" to "diverse flora requiring extensive management." The managers assign a number based on the amount of ecological burning required, the need for exotic plant control, the requirement for native plant management, and the need for erosion control. Each element could be graded separately, of course, and a composite score derived but this was not done in this phase of the study. For fauna, a similar index from "natural state" to "extensive wildlife management required" was employed. The number is assigned by evaluating the need for exotic animal control and native animal management. In Florida, saltwater can have a significant impact on management requirements, so a similar index is used to assess its influence. The initial value for the level is then formed by solving the following equation:

Level of Resource Management = ((Size *(Flora Complexity Index + Fauna Complexity Index)) * Saltwater Influence Index

The absolute value given is not particularly important rather its magnitude relative to other parks, and over time, its relative change within the park. The change is controlled through the rate variable "resource management change rate." The rate variable is a percentage multiplied times the level and developed in equations of the following form.

LRM.K = LRM.J+DT*(RMCR.JK)
RMCR.KL = LRM.K*(RMPF.K+VECLF.K)

where:

LRM	Level of Resource Management (Dimensionless Units)
RMCR	Resource Management Change Rate (Units/Time)
RMPF	Resource Management Provided Factor (%). This variable is a table function that translates labor hours available into functional output.
VECLF	Vehicles and Equipment Capability Level Factor (%). This variable translates the vehicle and equipment capability of a park into its contribution to resource management output.

The level is then free to rise and fall as personnel and equipment are applied to achieve a given output. This structure is common in the model. Normally, a level is a physical accumulation within a system. Here it represents an abstract, at least in terms of ratio measurement, concept. The change in the level and not its absolute value is of importance.

Considerable testing of the model was directed at balancing the functions, such as the resource management provided factor, so that personnel were allocated among the various management areas. The goal in this analysis was to have the model stabilized at the initial level values and to have the managers involved agree that the model reasonably represented, over time, park behavior. This was done by testing the four components of the variable "desired level of labor hours" and the separate functions that allocate effort to the management areas. The structure can be seen in Figure 4 and the form of the desired labor hours equation is:

DLOLH.L = LHRFRM.K+LHRFFM.K+LHRFP.K+LHRVEM.K

where:

DLOLH	Desired Level of Labor Hours (# of hours).
LHRFRM	Labor Hours Required for Resource Management (# of hours).
LHRFFM	Labor Hours Required for Facilities Maintenance (# of hours).
LHRFP	Labor Hours Required for Protection (# of hours).
LHRFVEM	Labor Hours Required for Vehicle and Equipment Maintenance (# of hours).

The typical structure of the four components of the equation is shown in the table function of Figure 5 using the goal variable "desired level of facilities factor" as the independent element and "labor hours required for facilities maintenance" as the dependent element. The table is structured so that, in each calculation period the exact amount of labor hours necessary to maintain the initial value of the facilities is added to the desired labor hours variable. The "desired level of facilities factor" is a ratio formed by dividing the goal for the level of the facilities established by management by the actual value for the level. It is modified by attendance.

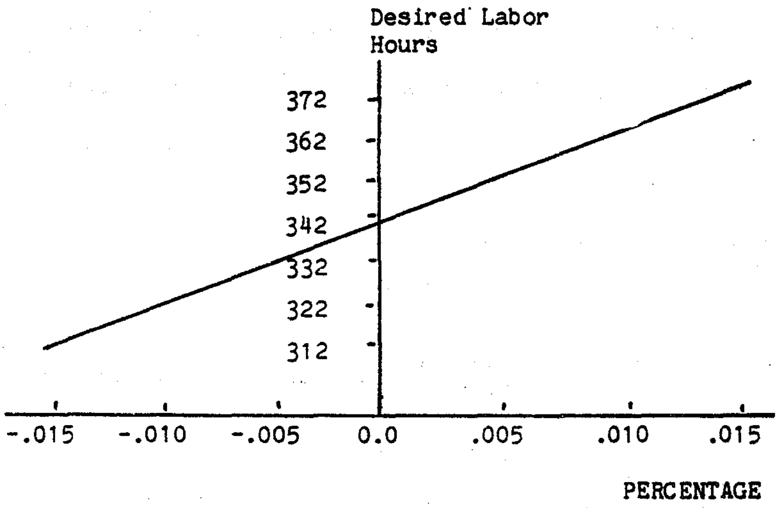

Figure 5. Typical Labor Hours Required Function

As long as management does not change the goal, the function along with the others similar to it will produce stability. The complex feedback nature of the system only partially is illustrated by this equation structure. The feedback loop for the entire structure is isolated in Figure 6. It shows the translation of a goal into the resources required to attain it. The nature of the structure also illustrates the considerable delay in translating the goal into a facilities change. When a goal is changed, it is compared to the actual level and more people hired through the effect on desired personnel. As new people are added, a proportion of their labor hours would be devoted to maintenance thus raising the absolute value of the level. If management intended all of the new personnel be allocated to maintenance, the allocation table function that provides effort in maintenance would have to be changed. That table function controls the facilities maintenance change rate.

The parametric model contains four of the type of loops illustrated in Figure 6: one for facilities, one for resources, one for protection, and one for vehicles and equipment. Managers provided estimates of the percentage of labor hours allocated to each area. These percentages were used to partition the labor hours using table functions. The results of operation of the model given these structures will be discussed in the next section.

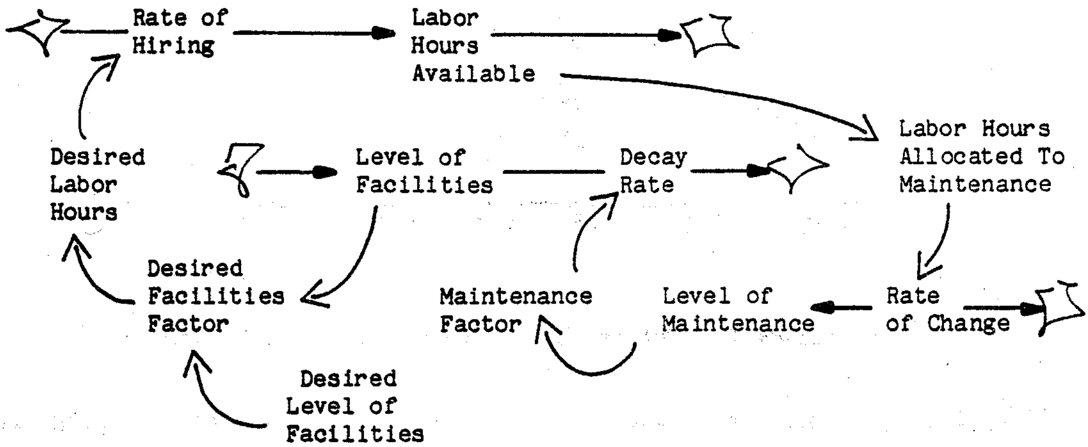

Figure 6. Typical Feedback Structure

Model Operation and Results

As with most system dynamics models, the park model was designed to be stable under initial conditions. As noted, the goal functions were specifically structured to provide stability that would remain unless the goals were changed or the environmental variables shifted. As a result, experimentation with the model focused on changes in the goals and environmental variables. The initial run of the model under basic conditions is shown in Figure 7. There is growth in attendance that produces growth in the various parts of the system as long as the system is not resource constrained. The structure that produced this output was extensively tested using the methods suggested by Forrester and Senge (1980). The testing procedure established confidence that the model was useful for its stated purpose.

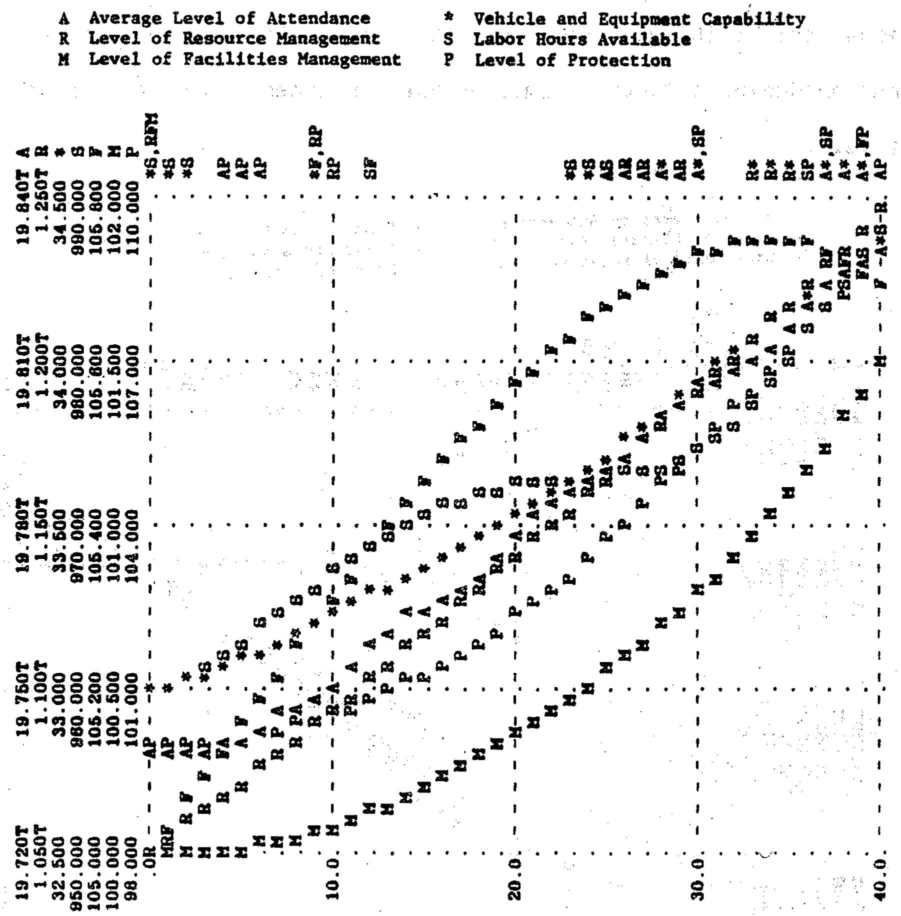

Figure 7. Basic Model Output

Three examples of the types of experiments performed with the model will be discussed. The first involved inducing a 3.0% growth goal in resources management. The response, shown in Figure 8, was predictable given the nature of the model. The resources management level (R in Figure 8) responded to the changed goal by increasing slowly over the period. The response was not as rapid as expected because the level of vehicle capability (*) declined slightly providing a limit to the growth goal. Resources in this area would be required to sustain the growth. The level of labor hours (S) increased to a new level and stabilized. The increase in facilities indicated some of the additional capability was channeled into the facilities maintenance activity (F) thus producing a further limit on the resources management growth objective.

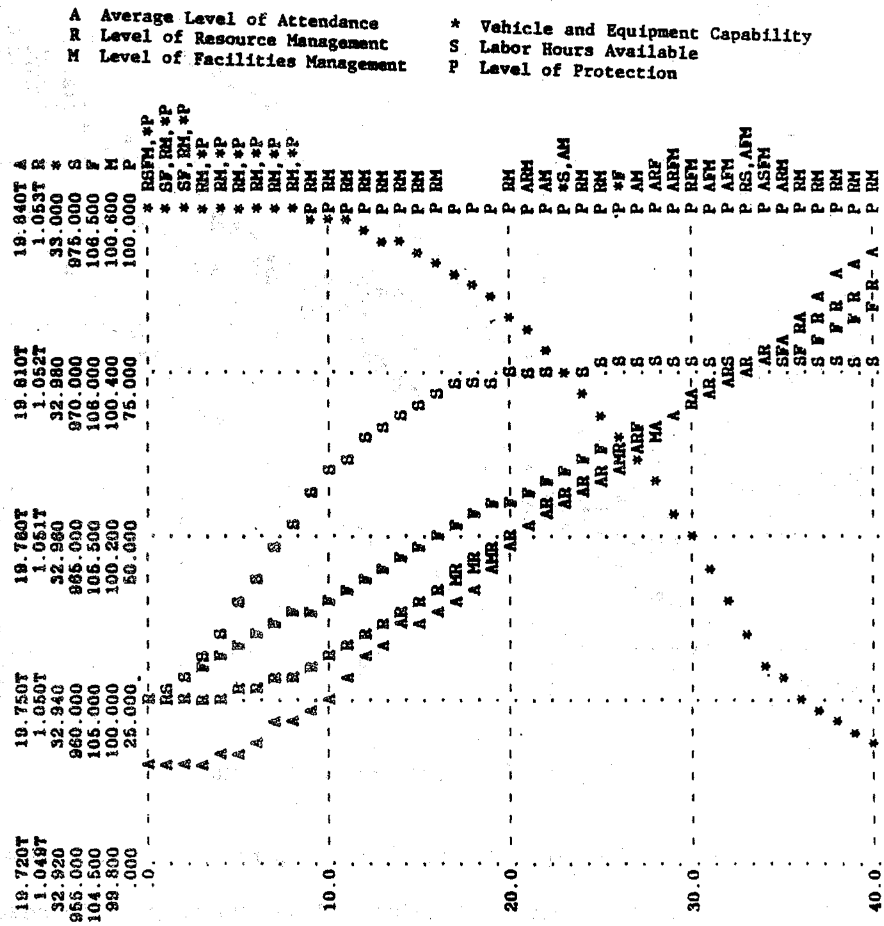

Figure 8. Resource Management Growth Experiment

The second experiment involved increasing the goal for the level of facilities by about 4% and adjustment of attendance growth to remove any effect that was exogeneous to the system (new roads, for example). The results are shown in Figure 9. Facilities increase and after a brief "take-off" phase attendance also increases. As the effect of facilities use produced by the increased attendance is felt, the growth begins to decline. The levels of vehicle capability and available labor hours responded as they did in the system because no specific effort was made to allocate the added labor hours to only facilities. This condition was described by managers as common in parks. Increase of goals in one area produced additional (unintended) requirements and responses in other areas.

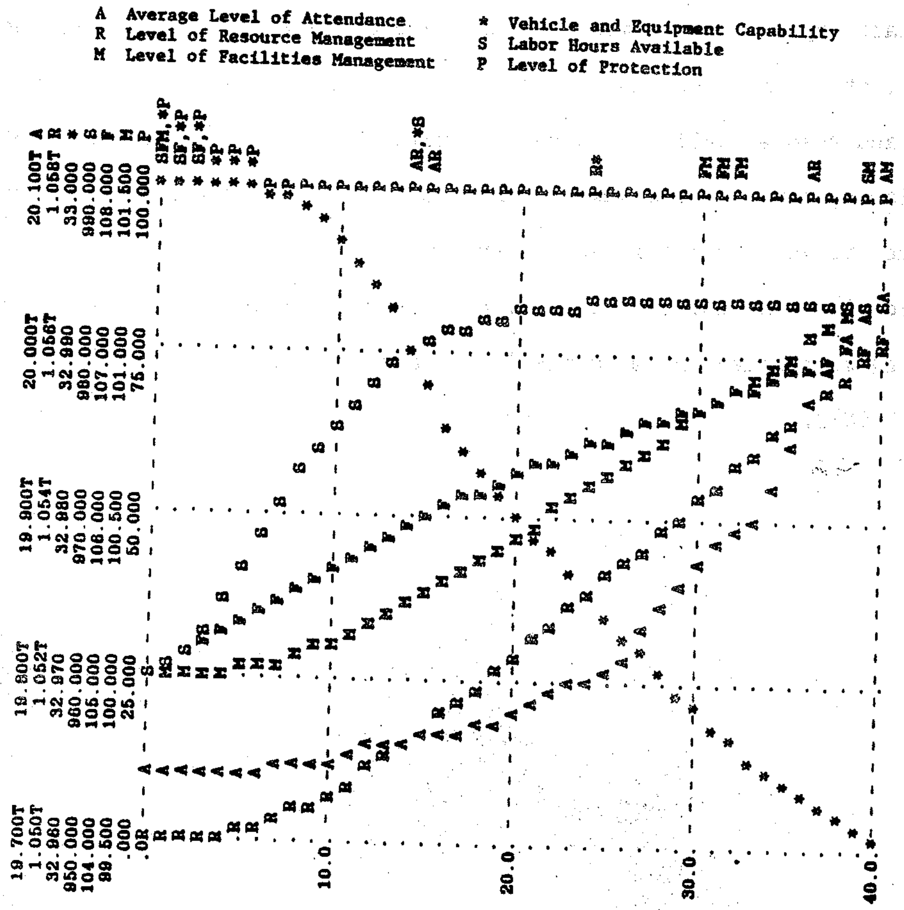

Figure 9. Facilities Growth Experiment

In the third experiment, a budget constraint factor was added to limit the labor hours that could be added while the facilities growth goal was increased. The results, shown in Figure 10, were to reduce the labor hours growth and predictably, to produce slower movement toward the increased goal for the level of facilities. Because of the slight percentage reduction the changes were not pronounced. These and other tests further raised confidence that the model was a suitable device for evaluating managerial initiatives and would be useful in increasing understanding of park dynamics.

Conclusions

The results discussed in the paper indicate that system dynamics is an appropriate approach for a model of the type of service system presented. As illustrated, the model may be practically employed to develop personnel budgets and theoretically to experiment with the nature of the effect of goals in service systems. These uses of the model are currently under evaluation. The issues of measurement in such a system are especially interesting and are discussed more completely in a fully documented version of the model. A paper describing measurement more completely is available upon request (Clark, b1987).

A Average Level of Attendance
R Level of Resource Management
M Level of Facilities Management
* Vehicle and Equipment Capability
S Labor Hours Available
P Level of Protection

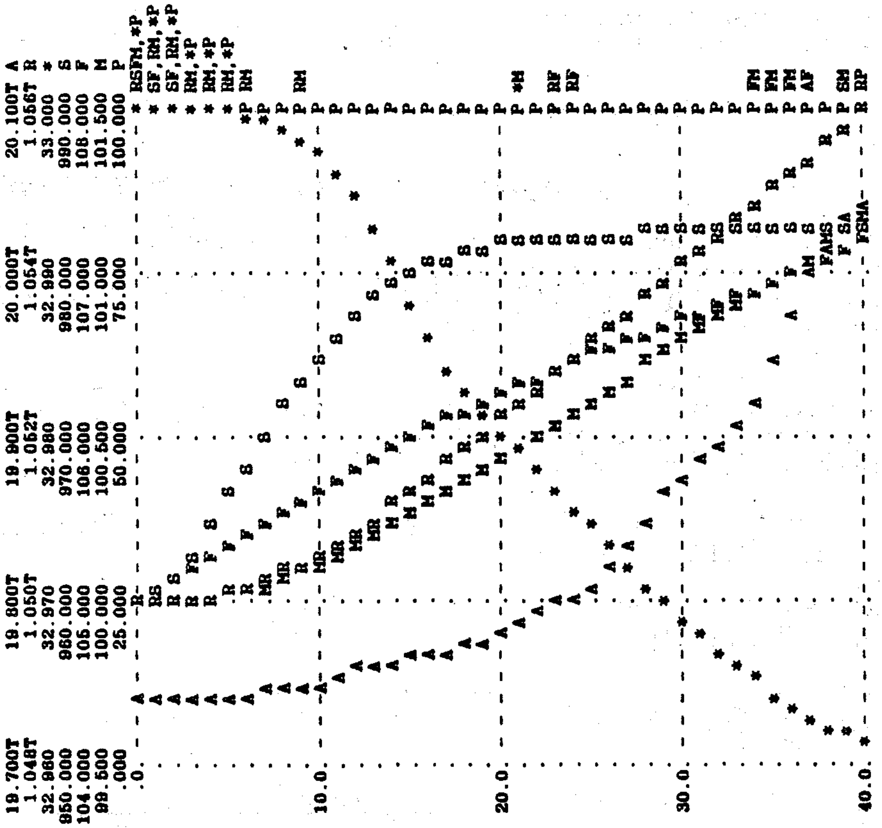

Figure 10. Budget Constraint Factor Experiment

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