A GPSS PLANNING MODEL FOR LARGE SCALE STRIP HARVESTING

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ABSTRACT

The degree of mechanization in timber harvesting throughout North America has been so complete that the once highly hand-labor intensive practices can now be characterized as becoming devoid of human effort, personal risk, and climatic discomforts.

As this age of mechanization continues to advance, the regular application of vigorous planning approaches will understandably increase. Simulation offers high potential in this regard.

A GPSS (General Purpose Simulation System) application has been developed that can prompt innovative analysis, under a flexible modular formate, of equipment requirements and operational schedules for a large scale logging system.

I. INTRODUCTION

A firm involved in large scale pulpwood harvesting has cooperated in the development and testing of the model in application to their specific operation. In this operation, trees are harvested in paralled strips, 66 feet wide and 132 feet apart, extending perpendicularly in both directions from an all-weather haul road. Trees are felled and piled behind by a feller-buncher with articulated boom on a crawler-tractor chasis. An off-road whole tree processor follows in the path of the feller, delimbing, topping and repiling tree lengths. Large wheeled skidders equipped with hydraulically operated grapples transport bunches of whole trees to roadside storage where they await trucking to the mill.

II. NEED FOR A MODEL

Several specific planning problems had arisen at the time the model design was undertaken.

--How would the system be effected by a policy change which would call for the cutting of a wider distribution of tree sizes?

--What would be the effect of changing the depth and width of the harvest strip?

--If the operation were to be expanded by purchase of more machines similar to those now being used, what kind of equipment balance could be achieved?

--How well would new equipment with different operational specifications fit into the present operating system?

Generally speaking, the firm was faced with critical decisions regarding the operation and expansion of an increasingly capital intensive harvesting system which was complex enough to resist conceptual simplification by means of existing analytical tools. A harvesting operation is a fluid system in which "machine layout" changes continually as the work proceeds. Conflict between machines can occur at many different points, and one machine's activity is often critically effected by the previous activities of another machine. Because of this complexity and variability inherent in the system, simulation was deemed an appropriate approach.

III. DESCRIPTION OF THE MODEL

The primary purpose in developing a discrete simulation of this operation was to fulfill the need for a planning tool which could be used to examine the effects upon overall efficiency of proposed changes in operating procedures, equipment types, and environmental conditions. It was felt that the model must be sensitive to changes in spacial arrangement and shape of the harvesting strips, to changing forest condition, to individual machine specifications and to different equipment mixes. The physical location of most simulated activities and entities would have to be specified and maintained in order to realistically handle first, the interaction among machines and second, the effects of ranging the size and shape of the harvesting pattern.

This need was fulfilled by the superimposition over the harvesting area of a two-dimensional coordinate grid to which all simulated activities and entities could be tied in order to maintain relevant spacial relationships. Although GPSS has no explicit provision for implementing such a concept, it proved readily programmable. While this

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provided for a more detailed simulation of the real system it also conveniently generalized the output format of the model so that it can be interfaced easily with models which carry the wood procurement process into further stages. For example, the inclusion of a tree-length trucking phase which would further illuminate machine interaction on the haul road could be accomplished with little modification of the existing program.

This coordinate grid also facilitates the interfacing of existing program modules and simplifies the development of replacement modules which represent machine types with a different operational logic. For example, the interface between the feller and the limber in the model is accomplished by maintaining a "feller-tree matrix" which records the location and size of felled trees. Although the mechanical delimber module is effected by the position of other machines and by the way in which felled wood is arranged on the strip, limber logic does not require further interaction with the feller module. In general, it is felt that the coordinate grid concept while serving its original purpose has also added a degree of flexibility to the model which will be of continuing benefit as further uses of the model are perceived.

Due to the detail which was necessary to adequately model machine interactions, the geographic scope of the model was reduced from the entire logging chance to a segment of haul road with 6 included harvest strips as in Illustration 1. On this area any reasonable number of machines of the three types (feller, limber, skidder) might be defined. The model is flexible with regard to the extent of this geographic scope which is limited only by the capabilities of available digital computing facilities. It is foreseen that most simular experimentation will focus on one or two strips and that external effects from other parts of the system will come primarily from activities on immediately adjacent strips. This adjacent activity can be modeled under the present 6 strip setup if the simular experiment is stages on the two center strips.

Illustration 2 depicts the general organization of the program with an emphasis upon the I/O characteristics with which the user would be concerned. As illustrated, the program consists of 3 modules, corresponding to the three major work elements in a logging operation, i.e., felling, limbing and skidding. The output of each module is in turn considered input by the following module. This is the basic internal I/O arrangement. But each module also requires external inputs, i.e. ones provided by the user. For example, the feller module can simultaneously simulate any number of different fellers, but for each feller, the module requires a feller description, a set of feller control information, and a feller initiation card. Similarly, each limber and skidder which is created also needs a machine description, a machine control, and a machine initiation. At least one punch card modification or addition is needed for each of these tasks. Another set of inputs fall into the general category of environmental conditions. Some of these are as follows:

- --tree size distribution over the area
- --volume table for the area
- --average volume per acre
- --resource map defining the spacial layout of harvest strips and log decks along the haul road
- --average elapsed times for various machine operations typically as functional relationships to other variables

Two types of output are produced by the model as shown in Illustration 2. First, each module produces output which can be used as input to the next module. This output is always recorded and may be used for analysis of certain phases of the operation. Second, the model generates accumulated statistics by means of standard GPSS reporting procedures. These outputs need to be explicitly defined for each particular application; they have typically included such things as production rates for individual machines, percentage of a given machine time spent idle, and number of machine conflicts on haul roads.

The model as it is written is limited in its application to a mechanical tree-length harvesting system with mechanical delimbing, topping, and bunching by an off-road processor, and with grapple skidding to road-side landings. By substitution of other modules, however, variations of this system can be modeled. For instance, the changes in the model required to simulate hand delimbing would mostly occur in the limber module. Certain changes in the skidder module would also be necessitated, but the overall program organization would still be valid. To model a system which employed cable skidders would just require changes in the skidder module. Only a change in machine control information is needed to simulate with a harvest strip of another size or shape. However, more radical departures from this basic mechanical tree-length system (such as a system involving selective harvesting by a conventional chain saw operation) would require more elaborate program alterations and might raise questions as to the appropriateness of the basic model.

IV. USE OF THE MODEL

This model should be thought of as a management tool designed specifically to meet the needs of an individual firm on their particular operation. The first design objective was to produce an accurate and useful model of a situation with which a firm was constrained to deal. Having fulfilled this objective, every effort was made to make the model flexible enough to apply to other closely related situations, both for the benefit of the particular firm involved who might want to consider system changes, but also in an attempt to

ILLUSTRATION 1

Resource Map with Superimposed Coordinate Grid

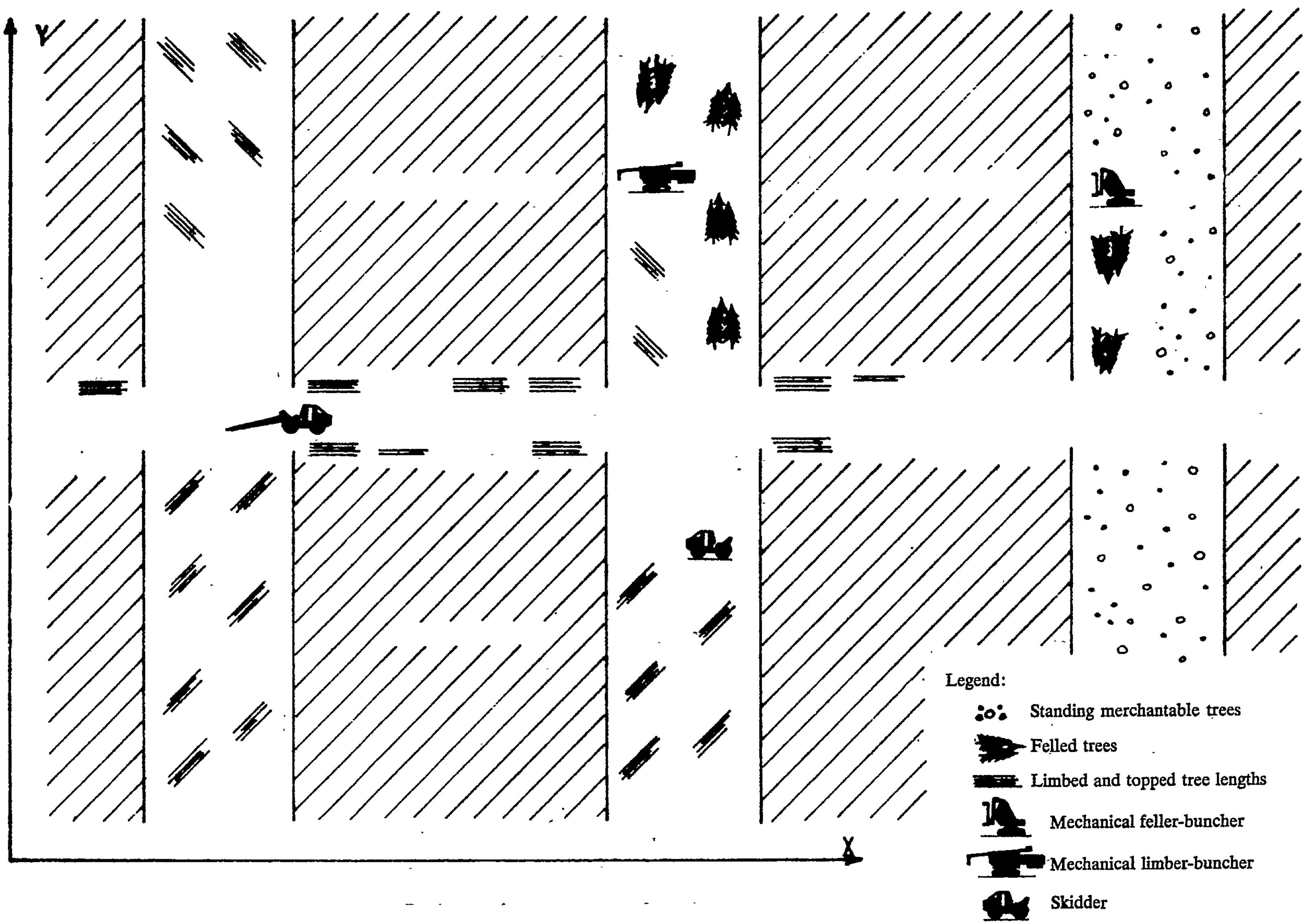
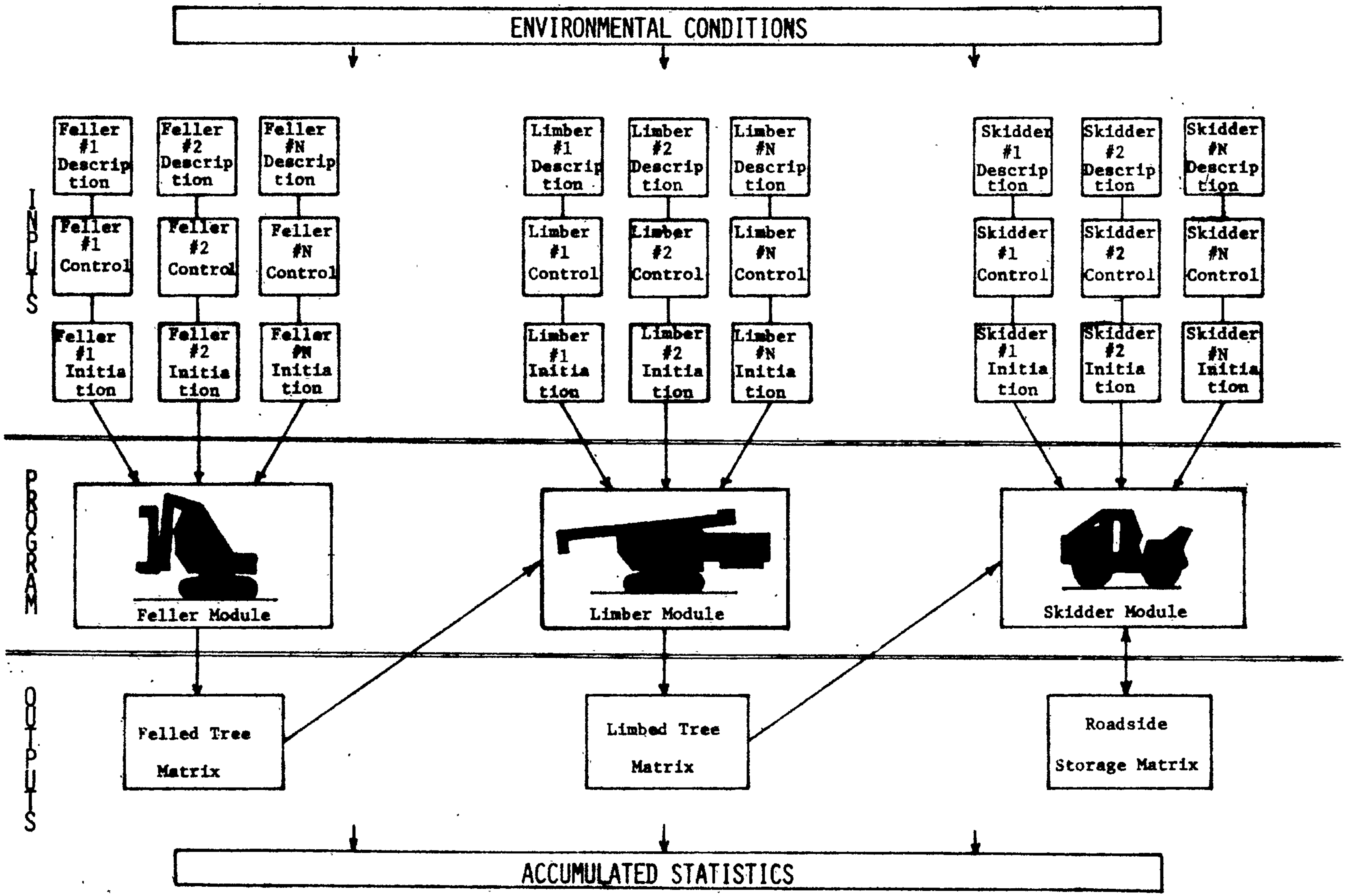


ILLUSTRATION 2

Computer Program Organization



benefit other firms with related operations. Application of the model to the operations of another firm would probably require a certain amount of revalidation in light of the inevitable differences between operations.

The primary use of the model as a management tool is to predict how the system would react to proposed changes in operational policies and conditions and thus to aid in making planning decisions. Costs are never specified in the model in terms of machine rates or wage rates, so that further analysis of the model output is usually required before a decision is suggested by the results.

The model is also being considered for use in conjunction with other models which simulate other phases of the wood procurement process in an attempt to create a procurement model of a larger scope. A mill-yard simulation is now being developed which might be linked with this model through a simulation of pulpwood trucking. (1) A reliable model encompassing all wood movement into a mill from the stump to the mill room could prove to be a valuable tool for the illumination of questions regarding truck scheduling, system design, and inventory control.

As an indication of the programming structure of the GPSS model and independent of truck-scheduling routine, the following quantity of GPSS entities have been employed with the range increment detailing the inclusion of the mill-yard module.

Blocks	232 - 332
Facilities	26 - 31
Storages	26 - 29
Function	3 - 6
Variables	43 - 53
Matrix Savevalues	24 - 26

The validated model, besides meeting needs implied in the questions posed earlier, can prompt a greater willingness to explore broader alternatives as well as currently unforeseen problems that will be encountered during day-to-day operations. GPSS has shown it can be a convenient and powerful analysis tool for forest industry.

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