Standardizing on Forest Operation System and the Accurate Estimation by System Dynamics

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Abstract
In order to keep forest operation under environmental tolerance and to have accurate estimation on the operational efficiency, a flexible model is inevitable and the system control is also expected to be discusssible on it System Dynamics, SD, represented the model and showed which was useful, which was based on Flow, Storage and control/interaction among them and the other value/events. The modeling method provided a standardizing for kinds of forest operation systems at various site conditions. This flexibility is the major merit of the modeling method to utilize at difficult terrains. Expects of system operation output had reliable accuracy. Control and maneuver on the system were discusssible as well, and the environmental and productive feedbacks were also adoptive and numerically suggestive.

1. INTRODUCTION

Log harvesting operations were conducted by various ways the place with complicated landform and different road basis service degree. As for the way of work’s there being, each of the scenes were various and to be standardized even if it was possible to divide them roughly according to the method into the cable system or the vehicle system, it was difficult to estimate productivity. Also, the productivity of the individual work is statistically estimated from the business result but it was not easy to improve estimate precision because the condition of each operation field is often different. It tried to estimate work efficiency by modeling log production operation system with the System Dynamics method in this research through presenting the work itself on the computer. Moreover, it made it possible to review improvement about the element work and the link which forms the balance of each process quantitatively.

2. THE MODELING OF A SYSTEM DYNAMICS AND A TIMBER PRODUCTION OPERATION SYSTEM

The System Dynamics is the model representation to show how the factor which composes a system. It influenced the flow, putting a change with two pieces of quantity and flow among them quantitatively in the whole system causality. The flow, the stock and the valve which becomes a main element when composing a model are shown in figure 1. As for the flow, the quantity (number of the felled tree and so on) which occurs with the other component is the continuation of the process and the one (the felling and so on) which controls it is equivalent to

the valve. The flow is stored up at the stock (all the trees which lay on the forest ground and so on) (1). The model to show timber production operation by this is shown in figure 2. This modeled to introduce a processor into the tree processing process of the operation system; the organization of the system consists of operation road opening by an excavator, manual felling, and tree hauling by a small grapple crane, tree processing and the forwarder log transportation to pile up them at road side landing. It separates into the timber production process at lower section from the road opening process in the upper section on the figure 2. Also, it gives value such as the size and the standing tree density of the operation block which is necessary to set the site condition to the entry format table by the condition setting parameter as shown in figure 3.

It shows the process that box b1 in the figure 2 upper section opening up road for operation. It makes extend from until the road reduces the maximum reach distance in the object forest block to the goal value. It sets a goal value and establishment work efficiency with maximum reaching distance to the concerned parameter in the entry table of figure 3. The state of the progress of the concerned process is shown in figure 4. It achieves the goal on the 10th day and which shows that the whole area became accessible at equal to or less than 80 m of the maximum reach distance. Box b2 shows manual chain saw felling work. The number of felling tree is calculated from the size of the cutting block, the standing tree density and the thinning intensity and the process is conducted by the felling efficiency. The actual felling work was done by line thinning method and the number of feller was three. The number of feller was set as a parameter. Felling work wasn't done simultaneously with road opening work considering on the safety and their interference.

It decided to begin felling work if the opening road work moved ahead by 200 m. The actual work was conducted as same way.

Box b3 shows the process of full tree hauling from in-stands to road side. The work draws out felled tree from on the felled line in-stand to the road side by a small grapple crane. It advances to the next felled line after one line have finished. Operational efficiency to finish a line was set to the parameter. However, when the amount of the one day felling process doesn't fill one day ability of the post process, it doesn't work the day. That is, a process is always designed to operate without dull condition.

Box b4 shows timber processing process. In the actual work, it was done by manual work but the model was improved to utilize a timber processor to the process to discuss on the operational efficiency by that. Because the processing contents are same, the structure of the model doesn't change. However, so as not to make the machine play occur like the tree hauling at the preceding process, it judges whether to work or not to evaluating the rest amount of the precedent process and the work efficiency. The model this time set equally three logs are produced from one tree when a full tree is processed.

Box b5 shows log forwarding process. It carries out the logs, which were bunched onto the operation road side in the woods, to transport by the forwarder to the beginning of the operation road at the forest road side to pile them up. It works when there is more amount of one day work than the precedent process so as not to make play occur. It sets work efficiency in the entry in the site condition setting table as the parameter. The process of this box differs to the other precedent ones, because the precedents handle "the tree" before it is processed. This process offers a processing process which changes flow quality from tree to log and also the quantity depends on this process. In the System Dynamics which models flow with quantity, the operation system becomes the expression to handle ones with different quality even if it
cooperates in process. As for the processing process, generally, the number of logs differs in each tree due to the quality of the individual trees such as the curve and the decaying. It is efficient to estimate the number of logs which can be obtained from single tree after judging of the quality. It is inevitable to give the parameter value of the model seem to be valid.

The various operation systems can be composed by the sub model of the process which depends on such System Dynamics structure and even if it supposes that it was a complicated structure, they can be expressed by it being standardized form.

3. THE ESTIMATE AND THE APPLICATION OF THE TIMBER PRODUCTION OPERATION SYSTEM

The state of the work progress when introducing a processor into the processing process of the timber harvesting operation is shown in figure 5. The operation simulation result showed pile amount, \( f_w \), did not increase after 51st day from the beginning of road opening, \( f_l \), to finish the harvesting operation. Tree hauling process, \( h_l \), and timber processing process, \( p_r \), cooperated with the work at the precedent process. In case of actual operation (2), the number of the operation days was same approximately. As for the model which processes timber by manual work, it showed 6.7 m\(^3\)/the man-day for the productivity and it was about 7 m\(^3\)/the man-day by the model. It revealed reliability for the estimation. When applying a processor, it was estimated that it became the productivity of 10 m\(^3\)/the man-day through total process. It was expected that the operational productivity will be improved by about 1.5 times by introducing the processor.

4. SYSTEM PRODUCTIVITY ESTIMATION

It is possible to make a table as shown in the figure 6 that the productivity of the whole timber production operation system and the partial process can be glanced when assembling and showing the work productivity on the same figure. These changes dynamically with the condition of the system and also is able to estimate the system productivity correctly. This is named System Productivity Estimation. The effect of the improvement of the process which composes a work system can be quantitatively evaluated easily. Moreover, it seems to be valid and useful when the terrain is difficult and complicated in operation condition just like as that in Japan.

5. CONCLUSION

The modeling of an operation system by the System Dynamics made good estimation with high precision. However, it needs favorable tuning on the model with highly accurate relationship between processes which enables by simulation to reproduce operation advancing and production accurately. Also, at present, it makes display a table at the same time as much as the work condition table, the progress graph, the success of the work on the one screen of PC like figure 7 and it makes it easy to grasp a change as much as the success by the work condition.
When making a system as the package software, the design of the interface to enable mutual reviewing on operation system for the reviewing manager seems to be important.

![Figure 1. The main component of System Dynamics model. (a): flow, (b): valve and (c): stock](image)
Figure 2. The System Dynamic model of timber harvesting system.
Figure 3. Table to set values for site conditions.

Figure 4. Progress of operation road opening.

Figure 5. Progress of timber harvesting operation.
Figure 6. System Productivity Estimation.

The left end column is the number of the work days and the center is done the production m³ of the whole work squad., the right end is productivity m³/day.

Figure 7. A display of multi-output for interactive reviewing.
6. LITERATURE CITED