FORMEC 2010
Forest Engineering: Meeting the Needs of the Society and the Environment
July 11 – 14, 2010, Padova – Italy

SIMULATION-BASED VALIDATION OF NEW CONCEPTUAL CABLE HARVESTING SYSTEMS

Tetsuhiko Yoshimura[1], Bruce Hartsough[2]

[1]Faculty of Life and Environmental Science, Shimane University
1060 Nishikawatsu-cho
Matsue 690-0823, Japan
e-mail: t_yoshimura@life.shimane-u.ac.jp

[2]Department of Biological and Agricultural Engineering, University of California
One Shields Avenue
Davis, CA 95616, USA
e-mail: brhartsough@ucdavis.edu

Keywords: cable harvesting system, computer simulation, independent device for lateral yarding, system dynamics

Abstract: *Forest harvesting on the ground with a harvester or harwarder made a significant stride in the productivity while cable harvesting systems used on steep slopes have not greatly changed since the combined yarder/processor was developed. In this study, we proposed a cable harvesting system using an independent device for lateral yarding, which was expected to improve the productivity with less intensive investment. Then, we estimated the productivities when an independent device for lateral yarding was introduced to the conventional gravity system and gondola cable system. As a result, the productivities of both of the new cable harvesting systems were better than that of the conventional gravity system for all distances (20-300m). However, the effect of the independent device for lateral yarding was limited when logs were yarded for relatively short distances (20-100m). The gondola cable system had the great advantage in the productivity when the yarding distance was 120-300m. On the other hand, the total yarding time of the conventional gravity system increased in proportion to the yarding distance. In conclusion, both of the new cable harvesting systems had the advantage in the productivity over the conventional gravity system when the yarding distance was 120m or more.*

1. Introduction

Modern technology in forest harvesting on the ground such as a harvester or harwarder achieved the higher productivity than ever before. On the other hand, cable harvesting systems used on steep slopes have not greatly changed since the combined yarder/processor was developed. Harvesting costs on steep slopes especially for thinning or collecting small trees must be reduced by introducing innovative techniques to cable harvesting systems. In the previous study (Yoshimura and Hartsough 2007a), we proposed new concepts of cable systems that could improve the productivity of harvesting forest biomass: gondola cable system, draw-well system, double-track system and double-carriage system. These studies were done based on the belief that developing such innovative techniques required revolution rather than incremental improvements to existing cable systems. However, these new concepts have not yet been brought to realization because intensive investment is necessary for the development of basic technology and production of test models. There is a similar cable harvesting system that has been experimentally developed and examined by Tasaka et al. (2006) and Aruga et al. (2009). This system uses two carriages, and they are combined in the middle of the cable to transmit the load from one to another carriage. Thus, the total time for carriage travel can be reduced. However, two carriages must slow down before they are combined, and this means for the middle or long span yarding. There may be a mismatch between loading and unloading time, and waiting time of carriage cannot be entirely eliminated. To cut down these problems, we proposed a cable harvesting system using an independent device for lateral yarding, which was expected to improve the productivity with less intensive investment.

In this study, we also estimated the productivity by using computer simulation. A system dynamics simulation was employed to make a flexible and customizable model to better fit the actual conditions as we did in the previous studies (Yoshimura and Hartsough 2007a and Yoshimura and Hartsough 2007b). McDonagh et al. (2004) applied system dynamics simulation to select an appropriate harvesting system for a given stand by comparing the productivity of several harvesting systems: manual fell/cable skid, mechanized fell/grapple skid, shovel bunching/grapple skid and cut-to-length harvesting/forwarding. Nitami (2005) showed the possibility of making a model of forest operations based on the transition probability by using system dynamics. Nitami (2006) applied system dynamics simulation to estimate the productivity of a harvesting system that included forest road construction, felling by chainsaw, extraction to forwarder trails by grapple-equipped excavator, bucking and delimbing by chainsaw, log collection by forwarder and log piling. Sugimoto et al. (2010) compared the operation time, cost and productivity between a flow harvesting system and a disjointed system by using system dynamics models. The current analysis used system dynamics simulation to predict the productivity when an independent device for lateral yarding is introduced to the conventional gravity system and gondola cable system, and we considered the advantages and disadvantages of this system prior to the actual development of equipment.

2. Materials and methods

2.1 Independent device for lateral yarding

It is known that lateral yarding lowers the productivity of cable harvesting systems. Actually, line thinning is very popular in Japan because it eliminates time for lateral yarding when logs are transported by using a mobile yarder. Therefore, we proposed a new cable harvesting system using an independent device working exclusively for lateral yarding. By using this device, we can transport logs on the skyline while lateral yarding is going on. When the carriage arrives at the point of loading, lateral yarding has already been completed. It is expected that this system improves the productivity of cable harvesting systems. Figure 1 shows the combination of the independent device for lateral yarding and carriage, which can work separately. The independent device has an engine or motor to pull a log up to the skyline. When lateral yarding of logs is completed, these logs are transferred to the carriage automatically (Figure 2). Log transfer system needs to be developed to realize automatic log transfer between the independent device and carriage. After the logs have been transferred to the carriage, it starts to move up to the unloading point or landing. While the carriage moves up and down, lateral yarding is carried out with the independent device. When all logs have been harvested at the loading point, the independent device is relocated to the next loading point by connecting it to the carriage and moving it with the power of the carriage (Figure 3). All such operations can be done by using the remote control system.

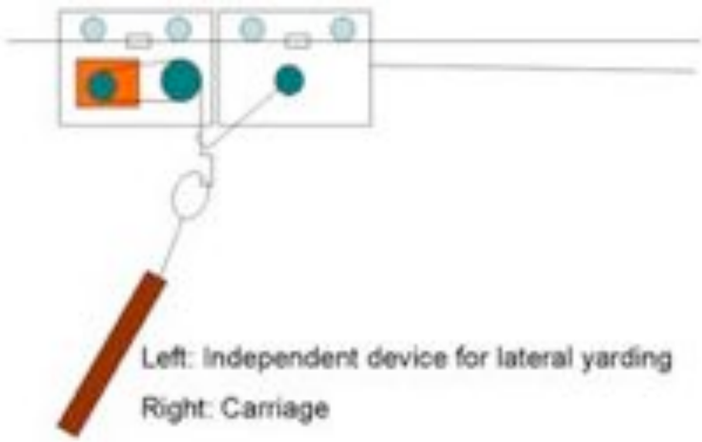

Figure 1. Combination of the independent device for lateral yarding and carriage

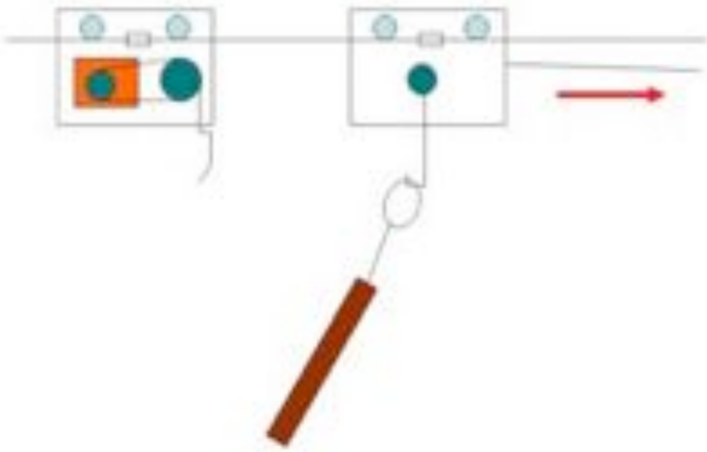

Figure 2. Log transfer system between the independent device and carriage

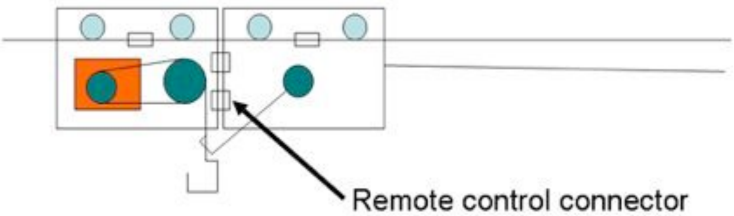

Figure 3. Relocation of the independent device using the remote control connector.

2.2 Application of the independent device for lateral yarding

Figure 4 illustrates the concept of a new cable harvesting system using an independent device for lateral yarding. In this system, the independent device was exclusively engaged in lateral yarding, which was expected to improve the productivity. In addition, the independent device for lateral yarding was also introduced to the gondola cable system as shown in Figure 5.

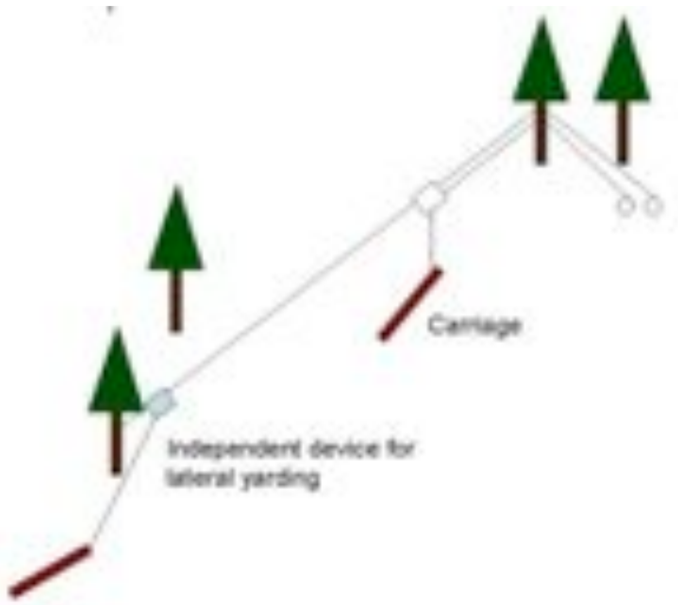

Figure 4. A new cable harvesting system using an independent device for lateral yarding.

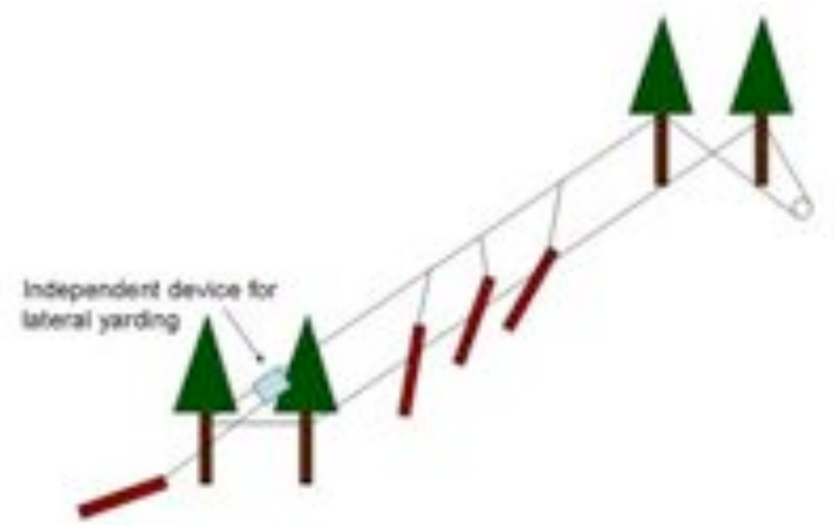

Figure 5. A new cable harvesting system with an independent device for lateral yarding applied to the gondola cable system.

2.3 Method of simulation

We evaluated the new cable harvesting system in terms of productivity by using system dynamics simulation, which helps us understand the behavior of complex systems over time. System dynamics also has the advantages of high compatibility, interchangeability, understandability and simplicity of models. It is also characterized by its methodology for modeling complex feedback systems, which mean a closed system influenced by its past behavior. For modeling the new cable harvesting system, we used STELLA 9.1.3 (ieee systems), a visual diagram-based simulation application program for system dynamics models. Figure 6 shows the four crucial components used in STELLA: stock, flow, converter and connector. The definitions of these components are explained as follows:

Stock: Memory that accumulates or drains materials over time.
Flow: Movement of materials from one stock to another.
Converter: Auxiliary variables to give values from constants, algebra or graphs.
Connector: Information carrier from one element in a model to another element.

In addition, we used two more components derived from the stock for modeling cable harvesting systems (Figure 6):

Conveyor: A derivative type of stock into which materials flow and in which materials stay for a fixed amount of time, then exit.
Oven: A derivative type of stock that acts like an oven. When the limit of the oven is reached, the oven closes and holds the inflow for a certain time. Then, the oven lets the contents out through the outflow.

Figures 7, 8 and 9 show the models of the conventional gravity system and the new cable harvesting system cable harvesting systems.

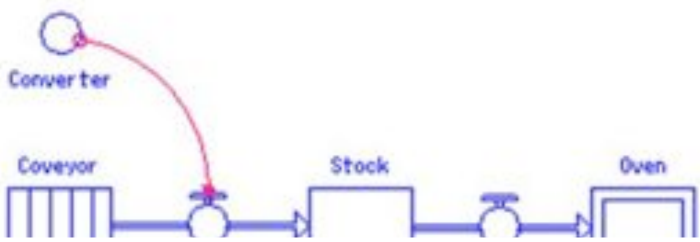

Figure 5. Four crucial components and two additional components derivative from the Stock.

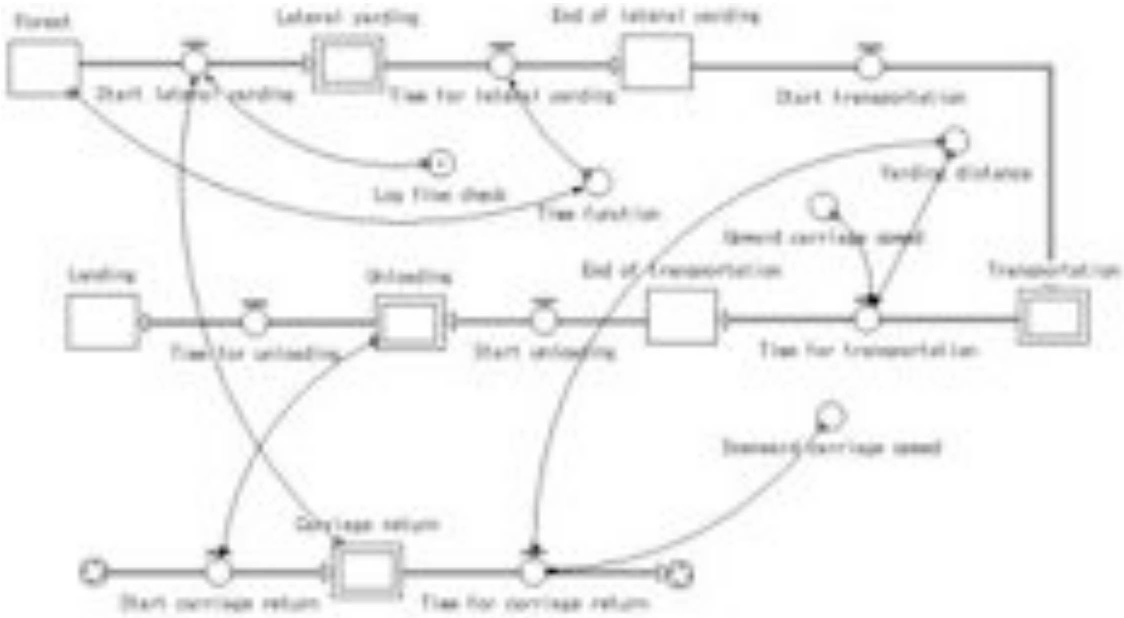

Figure 6. Simulation model of the conventional gravity system.

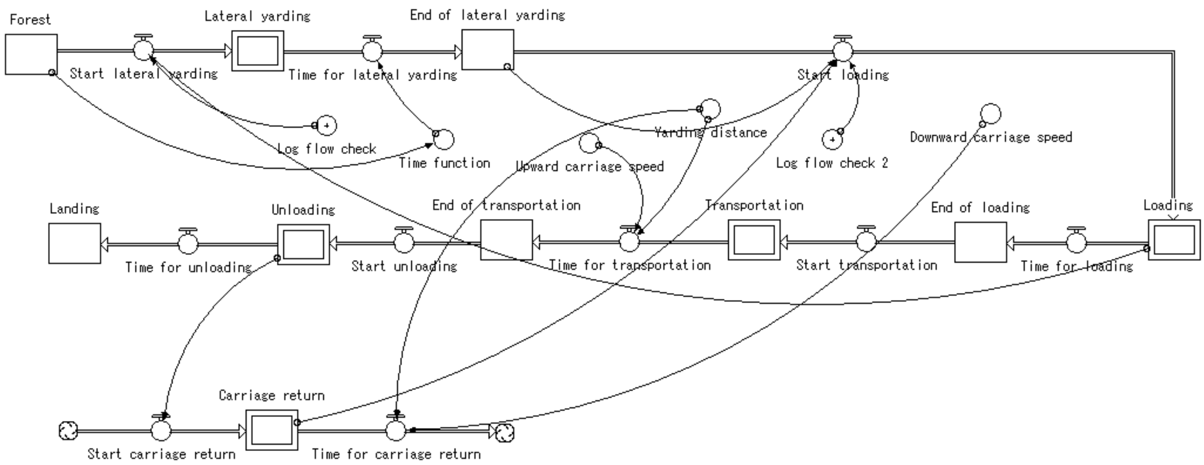

Figure 7. Simulation model of the new cable harvesting system using an independent device for lateral yarding.

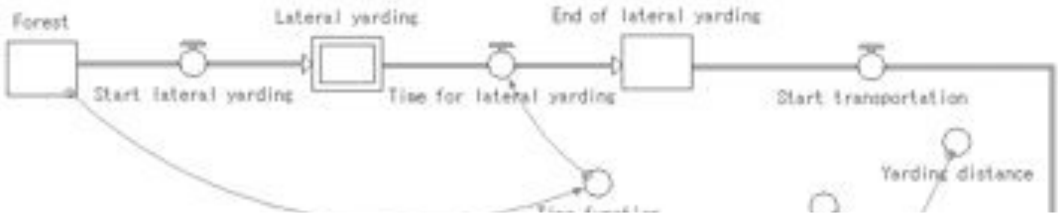

Figure 8. Simulation model of the new cable harvesting system in combination with the gondola cable system.

2.4 Conditions of simulation

We made a system dynamics simulation model of the new cable harvesting systems as ell as the conventional gravity-return system with, as an example, a Koller yarder and its carriage. It is assumed that the total volume of harvested logs is $100m^3$ and yarding distance is 20-300m. The uphill (travel loaded) and downhill (travel empty) carriage speeds are set to 1m/s and 8m/s, respectively. The carriage speed for the gondola cable system is set to 1m/s. The weight of load or logs is $2m^3$. It is $10m^3$ for the gondola cable system. In this model, time for lateral yarding increases from 100sec to 200sec as harvesting process goes on to reflect the increase of lateral yarding distance. Time to transmit the load from one to another carriage is set to 10sec, and unloading time is set to 30sec. To simplify the models, we did not consider empirical time relationships or stochastic time distributions. We do not believe that it is necessary to incorporate time distributions into the models because the goal of this study is conceptual evaluation in terms of productivity.

3. Results and discussion

Figure 9 shows the comparison of the productivities of the conventional gravity system vs. new cable harvesting systems. In this figure, the yarding distance varies from 20 to 300m. As a result, the productivities of the new cable harvesting systems were higher than that of the conventional gravity system for all yarding distances for all distances (20-300m). However, the effect of the independent device for lateral yarding was limited when logs were yarded for relatively short distances (20-100m). It was obvious that the gondola cable system had the great advantage in the productivity when the yarding distance was 120-300m. On the other hand, the total yarding time of the conventional gravity system increased in proportion to the yarding distance. In conclusion, both of the new cable harvesting systems had the advantage in the productivity over the conventional gravity system especially when the yarding distance was 120m or more.Of course, such results depend on the conditions other than the yarding distance. We can calculate the optimum yarding distance on the various conditions by using the system dynamics model we proposed in this study. We will further explore the new concept of the cable harvesting system in future studies.

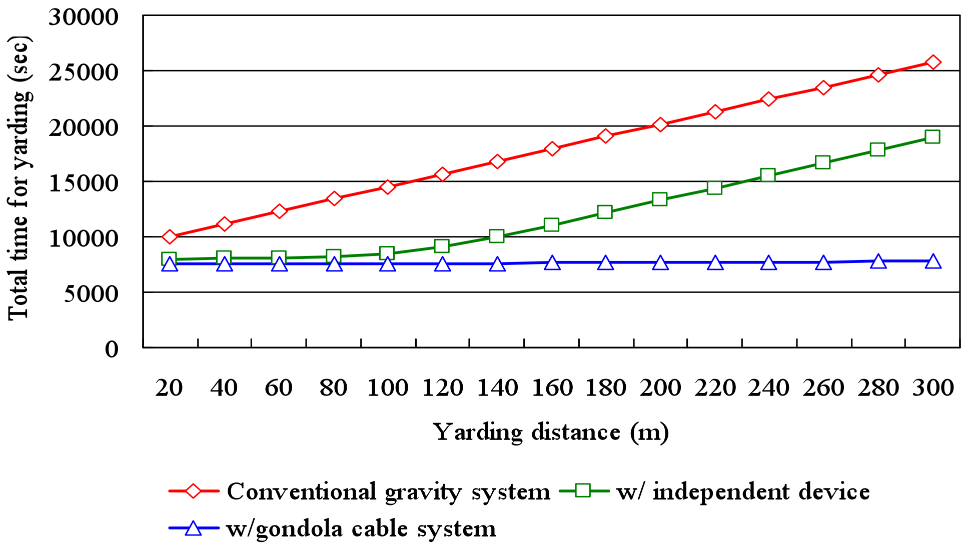

Figure 9. Comparison of the productivities of the conventional gravity system vs. new cable harvesting systems.

References

Aruga, K., Tasaka, T., Nishikawa, A., and Yamasaki, T. (2009). Development of a new operation system with carriages for turn back yarding system. Proceedings, Environmentally Sound Forest Operations 32nd Annual Meeting of the Council on Forest Engineering: CD-ROM, 2009

McDonagh, K.D., R.D. Meller, R.J.M. Visser and T.P. McDonald. (2004). Harvesting System Simulation Using a Systems Dynamic Model. Southern Journal of Applied Forestry 28(2):91-99.

Nitami, T. (2005). System dynamics representation for forest operations and the application – utilizing transition probability of element work –. Journal of Forest Engineering 19(4):271-273. (in Japanese)

Nitami, T. (2006). Modeling of timber harvesting operation by system dynamics and the productivity estimation function. Journal of Forest Engineering 20(4):281-284. (in Japanese)

Sugimoto, K., Niinaga, S., and Hasegawa, H. (2010). Consideration on flow harvesting system utilizing system dynamics. Journal of Forest Engineering 25(1):5-14. (in Japanese with English summary)

System dynamics in education project. Road maps glossary, http://sysdyn.clexchange.org/sdep/Roadmaps/RMGlossary/D-4498.pdf

Tasaka, S., Aruga, K., and Kojima, T. (2006). Development of a new carriage for turn back yarding system. Journal of Forest Engineering 20(4):225-228. (in Japanese)

Yoshimura, T. and Hartsough, B. (2007a). Conceptual evaluation of harvesting systems for fuel reduction and biomass collection on steep terrain using system dynamics. Proceedings of the International Mountain Logging and 13th Pacific Northwest Skyline Symposium: 94-102

Yoshimura, T. and Hartsough, B. (2007b). Conceptual evaluation of ground-based harvesting systems for fuel reduction and biomass collection using system dynamics. 3rd Forest Engineering Conference: CD-ROM