Cut-To-Length: The Next Decade

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ABSTRACT

This paper discusses the logging system where the logs are made at the stump from a harvester and carried to the landing by a forwarder. The focus is on Sweden, yet with an international outlook. Trends in forestry in the last decades are described and used to envision the next decade. In our analysis we consider the call for sustainable forest management, the demand and supply on the wood market, system productivity and utilisation, as well as operational organisation, operator education, health and safety and technical development.

A comparison is made between three mechanised logging methods as well as between three different forest worker education systems. Hindrances found when introducing cut-to-length are operator education, work crew organisation, supply of maintenance service and capital bound in other logging systems.

The trend towards purpose built harvesters is discussed. The possibilities following advanced electrohydraulics and GPS/GIS are discussed regarding machine control, maintenance, operational planning and supervision.

INTRODUCTION

It has been said that predictions are hard to make, especially about the future. Still, we think it can be worthwhile to reflect on the potential development of the cut-to-length logging system (CTL) in the next decade. We refer CTL as the logging system where the logs are made in the forest at the stump, and carried to the landing by a forwarder (also called the short-wood system). The focus is on Sweden, yet with international outlooks. Trends in forestry during the last decades are described and used to envision the next decade. In our analysis we consider the call for sustainable forest management, the demand and supply of the wood market, system productivity and utilisation, as well as operational organisation, operator education, health and safety and technical development.

We have interviewed representatives from forest enterprises, manufacturing companies and researchers, as well as browsing the relevant literature.

CUT-TO-LENGTH (CTL)

Since the early days of Scandinavian forestry, stems have been cut to logs in the forest, as this has been the most rational approach to handling and transport. Especially for log floating, which was important well into the 1970's, logs were preferred to stems.

When the rubber tire forwarder came in the early 1960's it was immediately accepted. It inherited the characteristics of its predecessor, the horse-cart, to handle logs rather than stems (as opposed to other places were skidding was the prevalent method of extraction). The forwarder was also a response to achieve year around logging. A couple of forest enterprises used the whole stem system for a period. Today however, almost 100% of the logging in Sweden and Finland is carried out by CTL systems. The fact that a CTL system enables the forest enterprises to have a firm grip on the wood flow contributes to its use [22].

Andersson [1] expected a development towards the use of tree-parts and central processing involving simpler and less expensive terrain machines. However, this has not (yet) been the case. Forestry machines have continued to develop in sophistication.

The harvester

The increasing flow of timber, year around logging and smaller clear-cut areas caused operational planning problems. Large hordes of manual loggers or a big fleet of machines were difficult to manage. There was a need for multipurpose machines (see Table 1).

The US Bush Combine from 1959 was the first machine able to both harvest and transport trees. However, it was designed for a special assortment and was not suitable for Scandinavian terrain. The two-grip harvester, developed from the feller-buncher and the processor (delimbing-crosscutting), suitable for final felling in rough terrain, was introduced in the middle of the 1970's. The one-grip harvester head came a few years later, pushed by the need to make thinning profitable (see Table 2).

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Table 1. A comparison between three ground-based logging methods.

<table>
<tr><th>Cut-to-length at stump</th><th>Cut-to-length at landing</th><th>Whole-stem to mill</th></tr>
<tr><td rowspan="3">Multifunctional machine;
Expensive machine;
Requires educated operators;
Requires efficient maintenance;
Measure log at stump;
Forwarding to 30% in slope;
Ability to use strip-roads;
Less traffic in the stand;
Possible to drive on slash;
Less ground damage;
Thinning possible;
Neck/shoulder problems;
Gives clean wood;
Allow smaller landing area;</td><td colspan="2">Simple machines;
Extraction by skidder;
Able to operate on slopes;
Costly terrain transport;
Risk of soiled wood;
Slash removal problems at landing.</td></tr>
<tr><td>Requires large cuttings;
Risk of soiled wood;
Can assess the whole stem;
Require larger landings;
Costly sorting and piling;
Higher accident risk at landing area and on public roads.</td><td rowspan="2">Few pieces in forest;
Bulky truck loads;
High breakage losses;
Much higher accident risks on public roads;
Costly sorting and slashing;
Better value recovery.</td></tr>
<tr><td colspan="2">Utilise the trucks' axle weights;
Compact truckloads;
Assortments directly to mill;
Allow smaller wood yards at mill.</td></tr>
</table>

Table 2. Design reasons behind parts of the Nordic harvester.

Machine part or quality	Reason behind the construction or quality
Ten meter boom	20 meter between strip-roads in thinning
Weight of harvester head under 1200 kg	A ten meter boom – machine stability/weight
Small size of the harvester head	Most trees' felling diameter less than 0,65 m,
Confined delimbing capacity	Trees with rather small and uniform limbs
Good terrain accessibility	Rocky terrain; Most slopes less than 40%; Great variation in ground bearing capacity.
Multi-functional machine	Thinning and smaller clear cut areas; Must be easy to plan, supervise, control and transport; Shortage of labour; Less ground damage.
The flexibility of the harvester concept	The variation in tree-sizes and terrain factors.
The high safety and ergonomic standard	The few operators are key persons; A multi-functional machine requires an easy to use and comfortable work place.

Problem areas when up-scaling the one-grip head were delimbing, log measurement, and the operators' ability to assess the log. The one-grip harvester has gradually been developed and today there are just a few new two-grip harvesters on the market.

Nordic harwarders (harvester-forwarder) with a useful harvester/grapple head are now available. These machines can be profitable in small wood-lots and when harvesting seed trees and wind thrown trees [11].

ENVIRONMENT

Increasing environmental concerns have modified Swedish forest management towards smaller and irregular final felling areas, and necessitated several different types of thinning operations. In the coming decade, logging systems need to be developed that are able to selectively handle both small and large trees, as well as trees of different species. According to the environmental schemes, this must be done without damaging the remaining stand, the soil nor water streams, as well as protecting cultural values. The systems must also be able to operate over larger areas, since less volume will be harvested per area unit.

The environmental load caused by the consumption of fuels, lubricants and metals by forest machines and trucks has to be reduced. The power efficiency of the machinery needs improvements, as well as the efficiency of the logistics system.

Health and safety

A very positive result from the mechanisation of forest work, is the drastic reduction of serious accidents and injuries [4]. However, a discord in the use of CTL machines is the neck/shoulder health problems among the operators. A future key issue is to keep the logging business profitable, without jeopardising the workers health. Advice regarding ergonomic design of the forest machine and maintenance work is given in the new Nordic ergonomic guidelines for forest machines [8].

THE WOOD MARKET

There is a wood surplus in Europe today, especially for spruce. The total stumpage volume in Europe has increased significantly the last decades [25]. In European Russia there is a possible annual cut of 250 million m^3, where today maybe only one quarter is utilised [26]. If Eastern Europeans start to build in wood and consume more wood fibre products, another situation will occur.

The storing of wood has been heavily reduced since the log-floating era ended, often to only a few days of production. Reasons are capital-costs and a higher appreciation of storage defects. This has resulted in "hotter" logistic systems with buffers of logging capacity instead of logs. The "hotter" system probably has contributed to the increased feeling of insecurity among the contractors, as it requires a surplus of log-

A trend in the Baltic Sea region is towards more specialised sawmills with fewer assortments and also towards bigger sawmills. This has given an increasing demand for timber with certain specifications. Instead of optimising the whole trunk, the operator will produce the requested log, and the rest will be pulp, energy wood or waste.

In Finland the wood measures made from the harvester is utilised to determine the payment to the forest owner. This will probably be accepted in Sweden as well in the coming decade. It is also tested in Germany. Today reliable measuring exists for diameter, length and taper. In the next decade, hopefully, we also can measure sweep, ovulate and root rot from the harvester.

An energy wood market for large district heating plants have been established in Sweden and Finland in the past decade. In harvesting energy wood, the current trend is towards multi- handling of small trees and central processing of trees and logging residues. A promising method is to separate pulp chips and energy wood after the chipper at the pulp mill [21]. This would enable harvest of tree parts. A dilemma, however, is how and where to delimb the timber part of the tree.

CONTRACTING GOES BIGGER

A new generation of contractors is under way in Sweden. They are hard working, without necessarily operating the machine at night and completing maintenance work at weekends, as their fathers did. The contractor has become a businessman and employer, with responsibilities towards both employees and a client. They are also aware of the family life in another sense then earlier generations. "Don't call me - call a repair man", is a statement you seldom heard in the past.

In 1998, about 20% of forest machine operators in Sweden were employed by forest enterprises, the remainder were contractors or contractor employees. In 1985 two third of the machinery were owned by the enterprises [20]. The trend among the contractors is towards bigger business, able to take care of whole logging operations. A full 80% of the machine operators in the Mid and North Sweden in 1998 worked in operations where all machines belonged to the same owner [2]. The combination of logging and trucking, however, does not seem to be at hand.

The trend to organise forest enterprises into divisions such as Forest and Supply, with their own management and budget, has reached Sweden. There the Supply division organises the harvesting and logistics of wood and works closely with the mills. How this will impact on the silviculture part of a logging operation is unclear.

Keep the machine running

The contractors of today are more vulnerable to delays and machine stops than earlier. To meet that, the workers are educated to operate and repair both the harvester and the forwarder. Among the machine operators in the Mid and North Sweden, 40% operated both the harvester and the forwarder [2]. Sixty percent of the operators were also completing other work than operating the machine, at least two hours a day. These figures will probably decrease in the short term, as the current trend is towards specialisation.

For severe breakdowns, electrical and computer problems, the contractor usually has an agreement with a workshop (a mobile service van). Today it is a matter of course to get overnight delivery of spare parts and a repairman until ten o'clock at night. The next step could be the same day delivery, however, that probably involves a too expensive local storing of spare parts. Maintenance has also become more important because the depreciation period for the base machine has increased from 15 000 to 20 000 hours the last decade. A wish regarding in advanced technology is to have on-line maintenance service with a possibility to use images.

EDUCATION AND TRAINING

There is very little supervision in Swedish forestry operations. The forest enterprises have reduced the number of supervisors and intermediate managerial posts and rely on the logging crew instead. The logging crew has the responsibility to organise and plan the work according to given frames, to complete follow up, administrative work and some customer contacts. During the course of this change the machine operator has gone from an individualist to a team player. In the coming decade, this trend towards multi skilled work crews probably will continue.

However, enlarged work tasks require a further education of each crew member, e.g. in silviculture. Forest enterprises and the vocational schools provide courses for contractors and employees, to make them able to make biological and ecological decisions during the course of their work.

The proportion of the elderly in Swedish forestry has increased during the last decades. The trend of young rural people moving to the cities will cause problems when recruiting to forestry. A broad and useful vocational education and work with many degrees of freedom may attract some to choose forestry.

Three education systems

We have compered the possibilities of the forest workers education systems in Sweden, Germany and US, to supply the CTL method with skilled workers (see Table 3).

The study period at the Swedish forest vocational schools is three years, with the major part of the last year usually spent in forestry operations. The number of examined students was 380 in 1995, and is expected to be 300 year in 2000 [15]. The education gives a broad competence, access to university studies and is nationally accepted. The student has moderate skills in operating the machine and in maintenance and good knowledge about "green" issues and computers. The schools have different focusses toward machine operating, contracting business or farm forestry. A given is that the student should learn to learn.

In Germany there exists a dual education system with an apprenticeship part at forest enterprises (mainly state forest) and one part at a public vocational forestry school. The study period is three years giving a national accepted diploma. A problem is to find enough practice places for running forest machines. Schools have started to offer courses in operating forwarders and harvesters, some use simulators. According to Höfle [14], the number and the quality of these courses will increase in the coming years.

In North America there are a couple of forest worker training systems, with different governing bodies and

Table 3. Three different forest worker education systems.

	Sweden	Germany	North America
Where are the education and training situated?	Inside the general educational system	Dual system	Outside general educational system
Costs for the society	High	Medium	LOW
Number of skilled workers	High	High	Low
Usefulness in mechanised CTL forestry	High	Medium	Medium
Usefulness in other occupations	Medium	Medium	LOW
Status in society	Medium	Low	Very low

different opinions about the contents in the courses. Local or regional enterprises usually drive the contents in the training programmes. A major part of the training is shorter courses or on-the-job training. The company or the worker himself pays for the training. These training programmes do not give a national accepted diploma, and are perceived by society as having a very low status. Compared to the institutional systems, this system tends to give lower skills or a narrow specialisation. The number of student places is dependent on short-term market conditions, In the long run, this education system gives too few skilled workers.

Experiences from the manufacturing industry show that workers who only have had short courses and "on-the-job" training were difficult to fully utilise [27]. These workers tended to become less motivated, more bored and fatigued, had more absence and were harder to co-operate with, compared to workers who had gone through an education programme. On-the-job training is an aggregation of skills on the same level, and does not give the worker an overview. The lack of a broad competence demands a division of labour and requires a comprehensive supervision. This does not suit an efficient use of the mechanised CTL logging.

TECHNOLOGY

The possible development of technology is earlier discussed by Guimier [9] in this Journal. Therefore we only consider a few items here.

The use of CAN (Controller Area Network) in the logging machines, which link several microprocessors, started a new era of rationalisation. Electronic control is an expensive step to take, however, after the basic installations it becomes relatively cheap to add a lot of productive functions. Some of the advantages of these are not even known today. Most of the forest machines built in Sweden and Finland after 1995 are equipped with advanced electrohydraulics. In North America, Jansson [16] expects a raise from 5% to 70% in the use advanced electrohydraulics in new forest machines until 2005.

The conversion efficiency in the coupling between mechanics and hydraulics need improvements, e.g. in the boom or the harvester saw. This can not be solved only by mechatronic solutions. Promising ideas exsist, however, lack of capital and of young mechanical engineers make it difficult to realise them.

Solutions in Geographic Information and Global Positioning Systems (GIS/GPS) and tele communication today has the possibility to link customer order, stand inventory, the harvester and the forwarder as well as a road database and the truck [18]. Such a linking of the wood supply chain enables a more accurate control of the wood flow (in grades and volumes). Among the problems are the lack of standards, and the quality and security of the data in the system. Motivation and education of all personal involved are required to achieve efficiency.

Towards purpose built

The one-grip harvester head has been attached to rebuilt forwarders, excavators, farm tractors and backhoe loaders. However, the trend has been to-

wards purpose built harvesters. This has led to high purchase prices for the harvesters, because of the small manufacturing series. To meet that the specialised machines, such as the two-grip and the smallest harvesters, are no longer manufactured.

Excavators and backhoe loaders as a base for the harvester head, are used in very small numbers in Sweden and Finland, mostly due to poor efficiency (see Table 4). Of the 1700 harvesters in Sweden, only 30 are mounted on excavators or back-hoe loaders [17]. However, there is a need for a forestry machine able to perform alternative work tasks. Reasons are that some forest machines stand idle a small part of the year, due to seasonal reasons or the lack of a logging contract.

THE CUT-TO-LENGTH MARKETS

We could not find any significant trend in the total number of purchased CTL machinery. The average annual numbers of purchased machines on the global market the last decade is estimated to be: 1400 rubber tyre forwarders, 800 purpose built rubber tyre harvesters, and 2000 separate harvester heads. Of the harvester heads about 40% were attached to purpose built rubber tyre harvesters [3].

The prices of the machinery have been stable in the last decade, with a decrease in the last years. The higher price for the log merchandising and machine control systems has been balanced by reduced cost through the use of component co-ordination in several products and more efficient assembling lines.

The mature cut-to-length market

In the Nordic countries, the trend is towards fewer harvesters in use, as the production per machine has increased. The productivity of the forwarder, however, has not at all followed the harvester. Yet, there are efforts in developing faster forwarders with better ergonomics and flexibility in the load width.

The harvesters' higher production is partly explained by a better understanding of the machine functions by the operators, a higher work rate and a more precise planning and communication with all parts involved. Another factor raising the productivity is that the average machine has increased in size. Furthermore, the technical utilisation (TU) of the harvester today is 80 - 85%, an increase of at least 5% since 1988 (1% TU is said to correspond to 10 000 ECU in purchasing price). The TU for the forwarder has raised from 85% to 90% for the same period. Of the 50 - 65% increase in annual production for a harvester during the last decade, approximately a tenth is explained by technical development of the machine.

The machine utilisation in Sweden during the last decade has increased 500 hours to 2500 in-service hours/year. According to Andersson [2], 60% of the operators in Mid and North Sweden 1998 used an overlapping work-shift schedule. An increase to 3100 hours per year is expected. That figure seems to be an upper limit within the present cultural frame in Sweden.

Table 4. A comparison between purpose built rubber-tyre harvesters and tracked excavator harvesters.

Factor	Purpose built rubber tyre	Tracked Excavator
Purchase cost		+
Salvage values		+
Work posture and movements [7, 19, 6]	+	-
Visibility [7, 19, 6]	+	-
Handle big trees		+
Simplicity; spare parts; maintenance	-	+
Ground pressure	-	+
Root damage [23]	+	-
Ground clearance	+	-
Stability on uneven terrain	+	-
Mobility and speed in terrain [10, 24]	+	
Operate on slope [28]	+	-
Additional tasks	-	+
Transport between sites	+	-
Boom configuration	+	
Swing space reauirement	+	

Contractors and manufacturers perceive their own benefits over the last decade as smaller than for previous periods [3, 12].

The next cut-to-length market

In Central and Western Europe the volume of CTL logged wood is expected to be doubled within ten years. Ireland has for example taken big steps in mechanisation and has today 88 purpose built harvesters and57 harvester headsonother machine types [21]. Contractors in United Kingdom have recently started to replace their excavator-mounted harvesters with purpose built ones [13]. However, lack of skilled machine operators, distrust between the contractors and the forest enterprises, and maintenance problems hampers the profitability of the CTL system.

In Germany, 20% of the 1997 cut was done with mechanised CTL (30% of the conifer), and is supposed by forestry representatives to be doubled within a decade [30]. Reasons named are the rise of labour costs and short-wood demands from the sawmills. According to an estimate by KWF [14] the German number of forwarders is 1000, harvesters 700 and separate harvester heads below 100. The utilisation of the CTL machines are in most cases around 1500 in-service hours. The aim is to increase the hours to between 2000 and 3000 in the medium term. Maintenance is mostly organised with a 24-hour service delivery agreement, from one or two points in Germany. However, according to Höfle [14] this does not work in most cases.

Limits when introducing mechanised CTL in Germany are presently, opposition from the green movement, difficulties as regards tree species, tree size and steep terrain as well as lack of skilled operators, and maintenance problems. The final outcome of the ongoing environmental certification discussion is open Mechanised CTL of deciduous trees is already practised in all park in Germany, and will increase. However, the harvester head must be better in delimbii. Rubber tyre CTL machines are used on slopes up to 40%. In Germany there is also a growing awareness of the benefits from a multi-skilled work crew.

North America

In North America about 20 - 30% of the harvested volume 1998 was cut-to-length at the stump [16]. A general shift to CTL is not likely in the short term. One reason is that capital for years has been invested in whole stem systems, e.g. in the trucks transporting whole stems. Most forestry contractors still purchase the traditional big, powerful and solid machine [28]. Remote areas require simple mechanics that are easy to keep running, due to the lack of support for advanced technology. The low level of the forest workers' education, the many small family contractors, low earning capacity and the low social status conserve the technology. However, CTL is growing in relatively urban areas, especially in Canada.

Most likely CTL will increase because it allows less impact on ground and the remaining stand. The State of Michigan, for example, has declared a direction towards CTL due to environmental reason. East of the Cascade Mountains there is a need for the efficient logging of small trees, suitable for CTL machines [5].

Other markets

CTL machines are used in the Brazilian Eucalyptus harvesting, which usually involves debarking. The terrain is flat and the ground bearing capacity is quite good. The big flow of timber requires high productive machines enabling an easier operation management, compared with manual logging. Eucalyptus harvesting may need other solutions, but there are not so many alternatives available.

In South East Asia a forwarder can be more useful on swampland, compared with a skidder. The forwarder has the possibility to build strip-roads from logging residues, a matter that is more costly in a skidding system.

Many Radiata pine loggers have bought a harvester head instead of a processor head. The reason is to have the possibility to alternate between felling and processing. One bottleneck when logging the Radiata pine, is the difficulty for the operator to scale the timber from the cab. With on board scaling equipment and operators able to assess timber, ground based Radiata pine CTL logging has a huge potential to reduce costs.

CONCLUSIONS

There is an incongruity between the wish to assemble efficient harvesters with locally available components, and at the same time depress costs by making greater numbers of fewer products out of standard components. The forest machine manufacturers have to keep clear lines of communications with the machine user. Together they may find the combination

between purpose built and standardisation, giving the most productive machine. However, the forest enterprise involvement has ceased, which may slow down the rate of product development.

More precise planned and completed logging operation will probably also in the next decade be the major way to achieve cost reductions. This requires motivation of the work force. A crucial element when creating a profitable work crew has been to invest in building mutual trust between all parties concerned. The last years rationalisations have, however, deteriorated industrial relations.

We can not see any drastic change from the cut-to-length logging system in the Nordic countries during the next decade. In ten years time, the harvester and the forwarder will probably still dominate the logging operations. World-wide, the use of cut-to-length logging systems will probably increase. With cut-to-length the forest enterprises can better control the wood flow through a more reliable scaling from the cab, and tele operated log merchandising and GPS/GIS systems. However, poor operator education systems and lack of maintenance support are problems to solve before cut-to-length can prosper.

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