A COMPARATIVE ANALYSIS OF WOOD-SUPPLY SYSTEMS FROM A CROSS-CULTURAL PERSPECTIVE

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(ABSTRACT)

An analytical tool must combine sufficient scope with cultural neutrality to be adequate for analyzing problems across technological style boundaries. The concept of a wood-supply system is proposed, defined as a mechanism generating a consistent flow of wood to a set of wood-consuming mills, beginning its work with the severing of trees and ending it by feeding a pulping digester or head saw.

The contrast in wood flow between the wood-supply systems of the Southern United States and Sweden is explored. The systems accommodate surges in wood-consumption rates and changes in wood-supply difficulty differently. The South maintains a small wood inventory by keeping considerable production capacity idle; Sweden keeps little capacity idle by maintaining a large cushion of wood inventories.

The implications of differences in relative cost between wood in inventory and forcibly idle production capacity are discussed. As a result of the historically motivated emphasis on accounting for capacity in Sweden and for wood in the South, costs associated with wood inventories and idle capacity appear to have been overlooked in a mirror-image pattern.

The transfer of equipment between harvesting styles whose evolution has been governed by different relative costs has a high risk of failure. Southern equipment is cheap, uncomplicated, robust, and dependable in order to survive forced idleness and to produce without buffer inventories. Swedish
equipment is expensive, complex, sensitive, and less dependable, due to the freedom to produce at capacity and the occurrence of large buffer inventories. Equipment manufacturers need to estimate the relative cost of idle wood and idle capacity when analyzing equipment exports across style boundaries.

Suggestions for further work include an exploration of the relative cost in each region, and the development of unbiased methods of accounting for idle resources. It is also suggested that the different interpretations of the concept of forestry in Europe and North America be explored.
ACKNOWLEDGEMENTS

This is not the typical dissertation in forest harvesting. It does not line up an array of figures, diagrams, tables, and printouts of computer programs. In a somewhat philosophical approach, its main objective was to identify new problems rather than to deal more effectively with the old ones.

Wood-supply systems are large-scale entities. The individual country or region is too narrow a basis for a study of wood-supply systems, yielding only one observation when at least two are necessary. Only by exploring a cross-cultural contrast was it possible to create the appropriate analytical tools and identify a problem of great and universal importance.

Exploring the contrast between two different cultures is no easy task. While the obvious may not be the important, the important is not necessarily the obvious. Unfaithfully served by one's own cultural idiosyncrasies, one must be on constant alert to avoid bias in observations and conclusions.

The key can be found, I think, not in ridding oneself of one's national perspective -- even if it were possible, I doubt that it would be desirable -- but in developing an awareness of how it influences one's thinking. Only when this awareness is fully developed is it possible to keep instinctive judgement in check.

If the path is difficult, the reward is considerable. The ability to be, at the same time, an insider and an outsider is useful not only in foreign locations, but also at home. The advance toward such a perspective of dual insight has given me the greatest personal satisfaction during this work. The future belongs to the international.

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CHAPTER 1. INTRODUCTION

What is the best way to harvest a forest?

This is one of the classical problems of forest harvesting. The product-length method (used in Scandinavia) and the tree-length method (used in North America and the Soviet Union) are among the main contenders. Although there is no lack of opinions on the matter, a conclusive answer has yet to emerge. Industrial foresters generally favor their locally established alternative, but scattered dissenters can be found in both camps. Andersson (1981, p.14) succinctly summarizes the state of the discussion: "It is as difficult to convince most Americans of the advantages of the product-length method as it is to convince most Swedes of the opposite".

Until recently, the problem of method preference has been mostly of intellectual interest. A battle of ideas has occurred, researchers have observed and evaluated "the other method", but the Atlantic Ocean and the "Iron Curtain" have kept the methods commercially separated from each other. This situation is now changing. Financially pressed equipment manufacturers are striving to globalize their markets, and in the near future the two methods may be competing on each others' home markets, challenging traditional ways of logging and calling for an answer to the preference problem.

The globalization trend is also a challenge to traditional ways of doing forest harvesting research. A set of new problems has arisen, best described as an ill-defined cluster. Is it appropriate for harvesting technology to converge in the same way that neighboring technologies have, such as grain harvesting, earthmoving, and transportation? If so, what ought to be the characteristics of a universal harvesting technology? If not, what kind of technology ought to be employed, and under what circumstances? How
can the outcome be predicted when a new harvesting technology is introduced where another one has long
been established? How do the current harvesting methods differ, and why do they differ? This dissertation
is a first attempt to deal with these and related problems.

In the remainder of this chapter, the problem of cross-cultural comparative analysis of harvesting systems
will be examined in greater detail. Chapter Two surveys and discusses the analytical frameworks used in
past approaches to related problems, concluding that they are inadequate for a cross-cultural analysis.
Chapter Three proposes the concept of wood-supply system as the core of a more general analytical
framework. Chapter Four examines a prominent but little discussed difference between the wood-supply
systems of Georgia, Maine, and Sweden: the tempo of the wood flow and the associated precision of supply
rate. The chapter concludes that the Swedish wood-supply system contains about ten times as much idle
wood as that of Georgia. Chapter Five explores possible reasons for this difference, and concludes that
production capacity tends to be idle to a greater extent in the Southern US than in Sweden, due to the small,
inventories. Chapter Six proposes that wood-supply systems can embark on different strategies for absorbing
surges in wood consumption and variations in logging difficulty. The Southern wood-supply system keeps
capacity idle; the Swedish system keeps wood idle. Chapter Seven summarizes earlier chapters and discusses
the different requirements that the contrasted systems pose for successful harvesting equipment.
1. THE CONCEPT OF TECHNOLOGICAL STYLE

Before approaching the problems associated with a globalization of forest harvesting technology, we shall introduce a useful analytical concept: the concept of system 'style'. The term shall be used in reference to the salient characteristics of a harvesting system, whether human, mechanical, institutional, legal, or belonging to any other domain. Hughes (1983, p.405) uses the concept in a similar sense: "the technical characteristics that give a machine, process, device, or system a distinctive quality".

The terms 'system' and 'method' are commonly used in forestry in a similar sense, such as in 'tree-length system' or 'short-wood method'. These two terms are commonly used for other purposes as well: 'system' to denote a set of interacting components, and 'method' for the way that a job is performed given a certain piece of equipment (such as a chain saw or a feller-buncher). To avoid ambiguity and to emphasize the broad realm of characteristics taken into account, 'style' will be used in place of 'system' or 'method'.

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1 In the following, the harvesting styles of the Southern US and Sweden will be contrasted. Clearly, forest harvesting technology is not homogeneous within such large regions. The styles will be contrasted with regard to features which are perceived as being typical, in full awareness that many deviations from the typical do occur.

2 Staudenmaier (1985, p.200) uses a more elaborate definition:

"A technological style can be defined as a set of congruent technologies that become "normal" (accepted as ordinary and at the same time as normative) within a given culture. They are congruent in the sense that all of them embody the same set of overarching values within their various technical domains."

Staudenmaier uses as an example the ideal of standardization and interchangeability of parts, suggesting that a whole series of technologies from the early 19th century can be interpreted as participating in a single style, "embodying a specific set of values within a specific world view". This may be an extension of Hughes’ definition, as it explicitly embraces the values which govern the change in a technology as possible parts of its style.

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Thus, 'style' includes, but is not limited to, equipment design. Equipment design evolves out of and embodies a certain technological style, but does not by itself make up more than a part of a harvesting style.

2. TWO DIFFERENT FOREST HARVESTING STYLES

For a layman forest harvesting is simply a matter of bringing logs from the forests to a mill site. In reality it is somewhat more complex. (Sundberg and Silversides, 1988, p.56)

The problem of forest harvesting is sufficiently complex to generate different solutions. Two of the most important are the different harvesting styles of North America and Scandinavia.

The North American style is typically associated with the tree-length method (although product-length methods also occur): the trees are not cut to logs until they have at least reached roadside, often not until they reach the mill. The Scandinavian style relies on the product-length method: the trees are cut to logs (products) before they are transported to roadside\(^3\).\(^4\)

The differences in equipment design and harvesting method between the two styles have received considerable attention since mechanization of logging began in the late 1950's (Walbridge, 1960; Skogsarbeten, 1988).


\(^4\) The inclusion of illustrations of these harvesting methods was considered but decided against for fear that they would give the Dissertation an inappropriate taint of kitsch. In a similar vein, philosophers tend to avoid using slides or overheads to illustrate their presentations, concerned that such displays would be considered "tacky".

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There was great concern in Sweden during the early 1960's that the country was lagging behind its competitors in forest mechanization. Swedes made many tours to America to study logging mechanization. The report by Ager (1962) is perhaps the most prominent of a long series of reports on this theme. A seminar in Luksa in 1963 brought the foremost North American harvesting experts to Sweden to share their knowledge of logging mechanization (Sundberg, 1978). Tree-length methods were introduced, and a survey in 1967 projected that tree-length and whole-tree methods would enjoy increasing success in Sweden during the 1970's (Troedsson, 1967). This projection turned out to be incorrect, however. As Swedish manufacturers developed equipment suited to the traditional product-length style, the longwood style began to decline in Sweden and has now all but vanished (Andersson, 1982, pp.11-12).

In the 1970's, the Swedish attitude quite reversed. Attempts to sell Swedish forest machines in North America were made, but met with little success (Elofson, 1987, p.235). The Swedish-based logging branch of the consulting firm Jaako Pöyry attempted to sell Scandinavian logging know-how in North America (Jaako Pöyry, 1973), and was invited in 1975 by the American Pulpwood Association to propose a pulpwood harvesting research organization for the Eastern US (Jaako Pöyry, 1975)5.

One can conclude that the contrast in harvesting methods between North America and Scandinavia has spurred considerable intellectual interest during the last three decades. At the same time, commercial confrontation has been limited. Both methods have dominated their home region, but enjoyed little success overseas.

There are signs, however, that the commercial separation of these two logging styles is about to end.

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5 This organization, which was to fill the void left by the dissolution of the APA Harvesting Research Project in 1973 (APA, 1984) was never implemented, despite the existence of similar organizations in Sweden, Finland, and Canada.

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3. **TOWARD A BATTLE OF STYLES**

Many equipment manufacturers competed in the regional markets in the 1960's - the era of early harvesting mechanization. They owed their survival to the large gains that mechanized equipment brought to new users, and to the initial uncertainty as to the best strategy for mechanization.

Reduced equipment markets are now spelling the end of the initial mechanization bonanza in both North America and Scandinavia. There are several reasons for this reduction. Virgin markets are getting saturated. Increases in productivity have reduced the number of machines needed, and increases in durability have reduced the replacement market. The pace of development in recent years has been too slow to make obsolescence a strong replacement motive. Kelly (1987, p.209) reports that skidder demand\(^6\) has decreased from 7000 units in 1978 to 3000 units in 1987, and the decline is projected to continue.

The shrinking markets are making it difficult for equipment manufacturers to achieve the mass production volume runs necessary to achieve cost competitiveness (Elofson, 1987, p.234). A consolidation of the forestry equipment industry has occurred\(^7\), but the relief seems to be only temporary\(^8\). Remaining manufacturers must either find ways to increase their sales, or perish. As a consequence, there has been a surge in the interest for exporting harvesting equipment.

Export of equipment is nothing new to North American or Scandinavian manufacturers. Exportation has been successful in markets without an established harvesting style, and in markets whose prevailing style

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\(^6\) No region is specified for these data.

\(^7\) See, e.g., Elofson (1987) and Hakkila (1989, p. 34).

\(^8\) The consolidation process is not yet completed. Crawford (1987, p. 237) reports that 45 different companies are building and/or selling some type of knuckleboom loader in North America.

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could be adapted to the imported equipment. Future export gains will have to come in a new and more difficult type of market, however: a market in which prevailing style differs radically from the one for which the exported equipment was designed. Such efforts have not been successful in the past.

Scandinavian manufacturing companies have recently purchased several North American ones, such as Timberjack, Gafner, and the VME Ranger Line (Hakkila, 1989; Southern Logging Times, 1990). These purchases appear to be part of a strategy to introduce the Scandinavian style of logging into North America. Elofson (1987, p.235) projects that

a shift from tree-length and full-tree to log-length systems is not going to come overnight, but because of changes in tree size on the West Coast, changes in sawmill technology and lumber production, changes in transport distances, and efficiency, the log-length system is going to account for a rather high percentage in 10 years' time, and therefore, we view segments of the North American market as our next target area [...].

The general trend seems to be towards an internationalization of equipment markets. Stuart (1987, p.203), observes that "few regional markets are sufficiently large to sustain the development of an equipment industry large enough to serve that market efficiently".

As a consequence, the traditional isolation of the harvesting-style regions is vanishing, or at least fading. A "battle of styles" may ensue, as equipment manufacturers anchored in different styles are brought together in multi-national corporations, targeting global markets.  

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9 It is not difficult to find people who disagree with this projection. Legg (1987, p.276) argues, for example, that "it is not possible to transplant Scandinavian systems into the Southeastern United States overnight. The reasons are both social, and economic." Elofson's projection is quoted here as an indication of the perceptions underlying the attempt at a Scandinavian comeback on the North American markets.

10 Compare Stuart (1988, p. 107): "The increased internationalization of the forest products industry is expected to bring with it increased internationalization of the forest equipment industry through expanded marketing efforts, purchasing local firms, cooperative marketing agreements and creating subsidiaries. This

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The profitability problems of the equipment manufacturing industry may perhaps seem trivial to some people in academia. Mere machines, they may think, do not constitute a technological style. Why be so concerned about something as mundane as the export of forest machines?

The answer is simple: without machines there could be but little forestry practiced.\textsuperscript{11}

Forest harvesting, and indirectly silviculture, is today totally dependent on machines to do the job. It is true that a harvesting technology is more than machines, but it is equally true that machines are the operative part of modern harvesting technologies. Almost all the action in today’s harvesting is provided by machines. Without dynamic and profitable equipment manufacturers, forestry will face overwhelming long-term difficulties. Financially strained manufacturers will not be able to set aside resources for the development of new products. Hence there is every reason for foresters to be concerned with the health of the equipment industry.

4. **ANALYSIS OF HARVESTING STYLES: A PROBLEM AREA**

The prospect of equipment transfer across style boundaries poses a new set of problems for forest harvesting research:

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process may result in a gradual dissolution of regional or national preferences and result in a greater homogeneity of forest equipment and operations."

\textsuperscript{11} Paraphrase of Wackerman (1949, p.xii) in his Tribute to American Loggers: "Without them there could be but little forestry practiced".

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If it is true that harvesting machines embody the harvesting style out of which they were born, then how will they fare when introduced into an area where a different style prevails?

If it is true that equipment markets must become global in order to sustain dynamic manufacturers, then what ought to be the characteristics of a global harvesting technology?

What are the reasons behind the evolution of different harvesting styles? Are they merely a product of regional isolation, or are there technically valid reasons why harvesting styles differ between regions?

Forest harvesting research has not had much reason to approach problems like these in the past. Yet, there have been indications of the need to do so.

Klander (1964, pp.37-38) has observed that the Swedish market is small in relation to the production runs necessary to keep manufacturing prices down. Andersson (1976, p.114) argues that it is risky for Sweden to maintain a harvesting style which differs from that of other major forestry countries. Long-term profitability may be negatively affected by high equipment prices. Another reason for Sweden to change styles, says Andersson, is that the product-length style is potentially inferior to the tree-length style with regard to cost reduction and product yield.

Andersson has later (1984) suggested that Swedish manufacturers use the wooded and sparsely populated inland to develop a globally suited line of equipment for harvesting boreal forests. Most of the boreal forest region is characterized by small trees, few people, sparse infrastructure, long distances, and severe winters. The similarity in physiographic conditions across this large forest region and the availability of idle

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manufacturing capacity in a representative part of Sweden (due to consolidation and restructuring) were believed to make such an approach worth consideration.

These ideas amount to a sharp criticism of the way that harvesting styles have been evaluated in Sweden. Andersson argues that style analysis ought to be done with an international perspective, at least in a region the size of Sweden.

Stuart (1987, 1988) contends that national evaluation schemes are inadequate in an international context - at least with regard to style-to-style equipment transfer. The argument is, in essence, as follows. Evaluations performed at the exporting end of an equipment transfer seldom provide adequate information for an evaluation at the receiving end. The reason is that most evaluations are context dependent, adapted to the needs of a local, regional, or national clientele. The product of such evaluations is difficult for the clientele of a different style region to use:

- Many factors which would be critical in determining design suitability are taken as fixed and not discussed, because they are not considered unusual or critical by the constituency. For example, "a system which imposes isolation on crew members accustomed to a more interactive working relationship may be plagued with minor downtime and delay problems not encountered in its native environment" (1987, p.1). The result of these omissions, "for those not familiar with the local environment, is reports which provide considerable technical information but little insight concerning the hows and whys that support the machine and activity" (1988, p.100);

- The conventions used, such as language and measurement units, are often not general in their domains of acceptance or applicability. Confusion may arise when commonly used terms, such as quota, stumpage, wage rate, or overheads, take on local definitions. Concepts and conditions

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vary widely. "A contractor in New Zealand operating under a three- to five-year performance contract from a single firm faces a different set of economic and operating pressures than a cut and haul contractor serving several mills in the American South or a functional contractor with a processor serving a Swedish landowner association." (1987, p.1).

5. A NEW APPROACH TO STYLE EVALUATION

A different perspective on systems evaluation has been growing along with the criticism of existing ways of analyzing harvesting styles and equipment transfer. A few quotes will demonstrate this new, but so far somewhat tentative, view:

A concept of "harvesting ecology" has emerged [...] to reflect a recognition that the environment of a harvesting operation is as crucial to its long term survival as the appropriate light, water, temperature, soil depth and soil pH is to the survival of a growing plant. If anything, the harvesting system is even more complex. It includes the normal range of natural factors—weather, soils and plant communities. These are further complicated by technological, social, business, financial and political factors. The terminology which describes these latter factors is less discriminating and definitive than that used to describe the natural factors.

International cooperation and exchange of technology, methodology and practices requires a greater understanding of these forces. A simple description couched in terms of productivity, availability and simplified costs for a machine provides only the initial explanation of the potential of a machine or system. The full potential cannot be assessed until the full "fit" with the operating environment is understood. (Stuart, 1988, p.111).
A similar thesis is advanced by Andersson and Laestadius (1987):

The efficiency of a wood harvesting system is highly dependent on the environment in which it is operating. This statement may seem self-evident, and one naturally thinks about technical factors such as tree-size and terrain configuration, including slope, roughness and bearing capacity. However, the operating environment for a harvesting system is a much wider concept than that, including economic, social, ecological, industrial and educational factors. The most crucial environmental factors in a wider sense include the local tradition and the prevailing harvesting systems. The efficiency of a new harvesting system depends to a great deal on its ability to adapt to these factors - i.e. its compatibility.

The bulk of the criticism concerns the inability of existing models to address the problems associated with equipment transfer across style boundaries. An ecological approach (for lack of a better word) is suggested as an alternative. The harvesting system is thought to interact with its environment, and the harvesting styles currently in place to be the result of a long evolution in which technology and environment have influenced each other. The focus of the analysis is on the processes of interaction between system and environment: i.e. on the "fit" between the two.

Stuart (1987, p.2) summarizes the new approach well:

Understanding the harvesting environment which gave rise to a machine or concept and appreciating the environment where it will be expected to work are key to the [...] process of machine and systems evaluation.
6. HYPOTHESES AND APPROACH

New research problems are raised by the prospect of harvesting machines being transferred across style boundaries and a possible globalization of equipment markets. Currently available approaches have been criticized as being too narrow in scope and concept to deal effectively with these problems. Understanding the processes of interaction between a harvesting system and its environment has been suggested as essential to a forest harvesting analysis adequate for future needs.

The overall objective of this dissertation is to provide increased understanding of the processes of interaction between a harvesting system and its environment.

The approach will be to explore the contrast between different forest harvesting styles, particularly the ones in the South and Sweden. Prominent differences will be identified, and their reasons investigated. Explanations will be sought in the realm of the past, as well as the present.

This approach, which may perhaps be called an exploratory comparative institutional analysis, was chosen for several reasons:

- A comparative approach seems to be the only way to get more than one observation on the interaction between style and environment;

- A comparative approach may reveal factors in the environment which are important to the "fit" of a harvesting system but have not been explicitly identified as such. Knowledge about such factors is crucial to the assessment of equipment transfer across style boundaries;
An institutional (historical, evolutionary) approach may reveal factors in the environment which have had a strong influence on the evolution of a harvesting style, but no longer are present. Such constraints of the past indicate possibilities for change;

An institutional approach may reveal past patterns of technological change which are caused by the nature of a particular technological style. Knowledge about such patterns can be useful when the viability of suggested technological changes is assessed. Such changes may include inter-style equipment transfer, but also within-style innovations;

An exploratory approach is needed because of the lack of previous work on the interaction between system and environment in forest harvesting. Another reason for an exploratory approach is the ambition to contribute something new to forest harvesting analysis instead of an elaboration of something old.

An analysis that spans well-established style boundaries must use analytical tools which are neutral with regard to style. Existing models for forest harvesting analysis are products of national or regional analytical frameworks. If they are not neutral with regard to technological style, they are not adequate for the approach chosen. It will therefore be necessary to survey existing analytical frameworks and to amend their weaknesses, if any.

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Thus, the path of the dissertation will be as follows:

- Existing models for systems evaluation will be reviewed and the underlying analytical frameworks critiqued;

- A framework suitable for analysis of the harvesting technology across style boundaries will be put forth;

- The suggested framework will be used to explore the contrast between the forest harvesting systems of North America and Scandinavia, especially those of the Southern United States and Sweden.
CHAPTER 2. SURVEY OF ANALYTICAL FRAMEWORKS

The currently used models for analysis of forest harvesting systems have been criticized as inadequate for analysis across style boundaries. In this chapter, their adequacy will be examined. At the outset, some methodological problems of such an examination will be discussed. The survey will focus on the concept of a system, and analytical models belonging to three different interpretations of 'harvesting system' will be discussed. The chapter concludes that the frameworks underlying these models are inadequate in several respects. Most importantly, they are products of a harvesting style, rather than style neutral.

1. MODELS OR FRAMEWORKS? - SOME DIFFICULTIES OF METHOD

The process of solving analytical problems goes under several different names in the area of forest harvesting. The term 'evaluation' is commonly used; 'analysis' is another common term. Less common is 'assessment'. These terms are typically used without any stringent distinctions or definitions. Whether the analysis pertains to the past or the future, or whether the data used is empirical or hypothetical, appears to make little or no difference in how the terms are used. Often they are treated as synonyms, as in the case of 'system analysis' and 'system evaluation'.

The reason for this vague usage is perhaps that analytical problems in the field have been approached almost exclusively by people immersed in or close to the practice of forest harvesting, as opposed to research scientists. The achievement of results has been more important and interesting than the making of distinctions.
In the following, the three terms will be used without strict distinctions, much along the lines of established tradition in forest harvesting research.

Many analytical problems of forest harvesting have been posed over the years, and many models have been created to solve them. Not all of these studies are available in the public domain. The competitive (commercial) nature of forest harvesting may have led to limitations on reporting in many instances. Anticollusion legislation may also have limited reporting.

Traditional (academic) techniques of literature search are not well suited for evaluation problems in forest harvesting. Many studies have been reported in *fora* which are commonly overlooked in the preparation of databases, such as trade journals or professional meetings without published proceedings. Evaluation studies tend to be written and distributed in a form that is geared toward forestry practitioners, rather than academics. Another reason why literature searches are of limited value is that the field lacks a commonly accepted structure. Few problems have been stable or general enough in time and space to attract an accumulation of research reports. This is due in part to the nature of the field, but also to the small number of researchers covering it.

The objective of this chapter is to survey the adequacy of existing analytical schemes. A survey of individual models would have to cope with the scattered and unstructured literature, the multitude of analytical problems and models, and the complex technical nature of many of these models\(^1\). Moreover, the level of resolution of such an approach would be unnecessarily high, given the survey objective. Therefore, individual models will be treated as indicators of underlying analytical frameworks, rather than as survey objects in their own

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\(^1\) Sobhany (1984) has made an attempt at such a survey of frameworks for data collection and reporting in harvesting evaluation.

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right. Thus, it is the underlying analytical frameworks, rather than the analytical models themselves, that
are the object of this survey.

2. THE CRUCIAL CONCEPT OF A HARVESTING SYSTEM

A technological system can be many different things. Hughes (1981, p.554) defines a system as "interacting
components coordinated by a common purpose - intellectual, economic, political, or other". Bromley (1969,
p.23) offers a similar definition: "a system is a group of interdependent items that together achieve a single
purpose".

Yet the two authors differ greatly in how they perceive a system. To Hughes, a historian of technology,
a system is almost an organism, consisting of "interacting components of different kinds, such as the technical,
and the institutional, as well as different values; such a system is neither centrally controlled nor directed
toward a clearly defined goal" (Hughes, 1983, p.6). To Bromley, an industrial forester, and his peers, a
system is a sequence of machines which together perform a certain job.

Thus, the term 'system' can have drastically different content, often without this ever being explicitly declared
by the people using it. The definitions quoted above are sufficiently generic to allow these differences.
This ambiguity makes the concept both convenient and problematic. The same word is used to mean very
different things, but these differences are not always apparent to the people using it.

In evaluations of forest harvesting, the term 'system' commonly has been interpreted or viewed in several
different ways, depending on the evaluation problem and the analytical framework of the evaluators:

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The abstract view. A system is regarded as an aggregation of production factors, such as capital and labor. The system is seen as performing a very abstract and aggregated job: individual logging tracts, for instance, are typically not identified;

The mechanistic view. A system is regarded as a linear sequence of interacting but not physically connected components, arranged along a flow of wood. These components, usually machines, are treated as sub-systems to the linear system. The system is typically seen as performing a discrete job, such as the logging of a tract;

The organic view. The system is regarded as a set of linear systems, most often under common control, which together generate a flow of wood. The system is typically seen as performing a continuous job with a spatial and a temporal dimension.

Each one of these views of the harvesting system has generated one or several families of evaluation models. In the following, these views will be used to organize a review of evaluation models and a critique of the analytical frameworks out of which they have risen.

3. THE ABSTRACT VIEW

The abstract view of harvesting systems is akin to a production-economics perspective. It has generated a family of evaluation models which have been used \textit{ex ante} to determine the optimal degree of mechanization in the system, and \textit{ex post} to analyze the system's productivity and to monitor aspects of technological change.

Chapter 2. Survey of Evaluation Frameworks
3.1. THE KOROLEFF/SUNDBERG APPROACH

The seminal model in this tradition was presented by Koroleff in 1960 (Koroleff, 1961a, 1961b), who defined logging as "the use of power to cut timber and bring it out" (1961a, p.138-15) and constructed a model for determining the economic efficiency of different mixes of logging power sources - the principal alternatives at that time being men, horses, and machines2.

The basic model is simple. Every production factor is represented by an amount of physical input per unit of joint physical production output for all production factors, and a monetary cost per unit of physical input. The product of these two factors gives the production-factor cost per unit of joint output, and the total production cost is the sum of the costs of individual production factors.

This model, as it has been applied in forestry, builds on the assumption that all production factors, as well as the production output, are homogeneous. This assumption is warranted for men and horses, but not for machines or for output.

The machines used in logging are, to use Koroleff's words, "numerous, diverse, individually powered and dispersed" (1961a, p.138-15). Koroleff suggested that rated horse-power hours3 be used as an aggregate measure for this diverse production factor, just as man-hours and horse-hours can be used for the other production factors. Koroleff's approach generated a lot of interest, but has "surprisingly enough not [been]

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2 Andersson (1988, personal communication) has suggested that Koroleff's interest in the power aspects of forestry stems in part from his familiarity with Russian logging mechanization (e.g. Koroleff, 1952), which included attempts to use electrically powered logging machines - an approach which indeed would focus attention on the input of power in logging.

3 Koroleff preferred rated horse-power hour to worked horse-power hour, as he felt the former unit to be analogous with man-hour and horse-hour, which, like rated horse-power hours, have the nature of a scheduled input potential rather than an actual input.
widely applied neither in research nor in practice" (Sundberg, 1979, p.1). Embertsén (1973, 1976) has used it to monitor technological change in Swedish forestry, and it was acknowledged as a standard method in the 1978 edition of the Nordic Agreement on Work Study Nomenclature (NSR, 1978).

In the discussion following Koroleff’s 1960 presentation, Silversides suggested "the concept of "constant energy" per cunit or per 1000 cunits regardless of size of machines" (CPPA, 1960). The Logging Committee of the CPPA subsequently suggested that "horse power hours can be more easily and accurately measured by fuel consumption than by rated engine horse power" (CPPA, 1962).

Sundberg and others have later worked to develop and refine the approach suggested by Koroleff. The model now allows a least-cost mix of labor input and machine input to be identified, based on the productivity and cost of these input factors (Sundberg, 1979). Fuel consumption has been tried as an aggregate measure of machine input. The hypothesis that "the aggregate cost of a forest machine is the same if expressed in terms of money per unit fuel consumed" has been tested with a somewhat ambiguous result (Sundberg, 1982; Svanqvist, 1985; Sundberg and Svanqvist, 1987)⁴.

3.2. THE DEGREE-OF-MECHANIZATION PROBLEM

A central evaluation problem in the late 1950’s and the early 1960’s dealt with the appropriate degree of mechanization⁵. How much and how fast should a company mechanize its operations? Koroleff (1961a)

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⁴ It is concluded that empirical data verify the hypothesis, but only after nine different classes of machines have been introduced to absorb the variation in the data. Herein lies the ambiguity of the conclusion.

⁵ The problem of finding the optimal degree of logging mechanization has not attracted as much attention in the Southeastern US as in Canada and Scandinavia. A possible reason for this is the lesser degree of central control in the South - a region in which companies traditionally rely on independent logging contractors rather

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suggested two measures for mechanization: the ratio between mechanical and manual work input (horse-power days per man-day, a physical measure), and the ratio between mechanical work cost and total work cost (a monetary-based measure).

Cost-based (monetary) measures of mechanization were used in Sweden by Kilander (1964), Kilander and Järnvall (1965), and Malmberg (1968), but do not seem to be in current use.

Authors relying on physical measures of mechanization have had to struggle with the difficulty of finding a practical aggregate measure for machine input. Despite the efforts by Koroleff, Sundberg, and others, this task has proven to be difficult. Two strategies have evolved: either machine input has not been measured at all, or it has been measured on a nominal scale (a process is either mechanized or it is not).

Man-days per unit logged is a measure of partial production efficiency only, and is therefore not an adequate measure of the production efficiency in forest harvesting as a whole (Järnvall, 1963). If, for example, the man-day consumption was decreased due to an inordinately large and expensive input of machines, it would still be perceived as an increase in production efficiency if judged alone by the partial measure of man-days per unit logged.

Yet this partial measure has been used extensively for productivity analyses of forest harvesting and for monitoring of technological change. Sundberg (1960, 1961a,b) compares the man-day consumption per unit of production in major forestry regions and concludes that Sweden must adopt a more rapid rate of mechani-

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zation in order to stay competitive on the world forest-products market. The fundamental assumption at this time was that the labor cost would increase much faster than capital cost. The partial efficiency measure was therefore adequate for an evaluation of strategic development needs.

Eventually, it was deemed necessary in Sweden to measure the ongoing process of mechanization. A physical measure for degree of mechanization was constructed (Nilsson and Svensson, 1971). Ever since its introduction, it has been the measure of logging mechanization in Sweden. The change in the degree of mechanization in Swedish industrial logging, measured in this way, is shown in Figure 1.

The Swedish measure of degree of mechanization is a weighted compound measure of the degree of mechanization in each of the four work elements traditionally distinguished in Swedish-style logging. For each work element, the degree of mechanization is determined as the fraction of the total volume of wood treated mechanically. This measurement is made on a nominal scale - either a logging operation has the work element mechanized, or it does not. The four values are then weighted together, using as weights a set of values which represent the share of the total time consumption typically associated with the individual work elements. The weights have been determined based on work studies from the early 1960's of the time

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6 Sundberg used the words "within the bounds of her own win her forestry back anew", paraphrasing the nationalistic poet who, after Sweden's loss of Finland to Russia, wrote that Sweden must "within the bounds of her own win Finland back anew".

7 See, e.g., Leijonhufvud (1961, p.8), Kilander (1963) and Nilsson (1971). This assumption has been a foundation of Swedish rationalization work in forestry well into the 1980's.

8 The construction of the Swedish measure of mechanization appears to have first been described by Boström (1972). No author is credited, however. It is likely, if not certain, that the original author of the measure is Bertil Nilsson.

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Figure 1. Changes in the degree of mechanization in Swedish industrial logging (after Freij and Tosterud, 1989).

consumption for motor-manual\(^9\) logging in Sweden (Boström, 1973). The following work elements and weights are used:

Felling 15 percent;
Delimming 55 percent;
Bucking 15 percent;
Piling 15 percent.

The Swedish measure of mechanization has proven to be a useful follow-up tool for the rationalization goal formulated in the 1960’s by Hans G. Lindberg, then the Director of the Swedish Forest Operations Institute

\(^9\) The term ‘motor-manual’ is used in Sweden to denote manual work with hand-held power equipment, such as a power saw (motor-manual logging) or a brush saw (motor-manual cleaning).
Skogsarbeten: "no man on the ground, no hand on the wood" (Sundberg, 1978, p.136). Nevertheless, it also has certain limitations:

- The domain of measurement and the weights are by definition part of the measurement. As these pertain specifically to the Swedish style of motor-manual logging, the measure cannot be applied outside Sweden and is therefore not suitable for international comparisons.

- The measure is capable of distinguishing only between unmechanized and mechanized operations, while being insensitive to any changes within these categories. As mechanization progresses, most operations will eventually be classified as mechanized and the measure thereby be "exhausted". The use of a nominal scale thus seems to limit its usefulness as mechanization progresses, as it will be insensitive to further changes (assuming that no shift back to unmechanized logging occurs).

No third category, representing the step beyond the state of being mechanized, has yet been suggested.

Measures of mechanization are sometimes used outside Sweden, often in a manner which is similar to that of the sub-measures in the Swedish compound measure. For example, Kelly (1987, p.206) uses a measure he calls "the rate of mechanical felling" in order to depict shifts in Canadian felling mechanization.

Soviet forestry uses a physical measure of mechanization, and possibly also one of machinization. It has not been possible for this author to find out where of they consist.
3.3. PRODUCTIVITY ANALYSES

In an analysis of Swedish logging during the period 1950-1980, Andersson (1983) juxtaposes the output per man-day, which levelled out during the 1970's, with changes in a set of other indicators: annual volume cut, degree of mechanization, and monetary cost per unit logged.

While the analysis leads to several important findings, it nonetheless suffers from consistency problems in the demarcation of the system studied:

- The juxtaposed indicators do not all pertain to the same domain of measurement. The data for man-day output refer to all silvicultural and logging work up to logs stacked at roadside, and also include indirect work. Degree of mechanization, on the other hand, measures only changes in relation to the work done by a man with a power saw. It does not include extraction or debarking; nor does it include silvicultural work or indirect work. For this reason and others, it is not necessarily correct to conclude, as does Hultkrantz (1983), that mechanization in Swedish forestry was a failure because the output per man-day curve levels off during the same decade (the 1970's) that the degree of mechanization curve raises drastically:

- The domain of measurement for the output per man-day is not consistently the same over the period in terms of work content. The measurement domain includes all work performed within the institutional boundaries of forestry, as defined in Sweden. Debarking was moved out of this domain as soon as the shift from river drive to land transport allowed, however, as it was seen as being better to perform this function at the mill than in the forest or at a landing. Thus, even though the

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institutional domain of forestry has been stable during the period, the work content has changed
due to rationalization efforts across institutional boundaries.

These weaknesses in Andersson’s analysis (which Andersson takes into account in his interpretation but others
might not) are due to the fact that available statistical data were used for the analysis, rather than custom
collected data, and emphasize the problem of a suitable criterion of systems demarcation. Official data tend
to be reported within institutional boundaries, which is appropriate for some purposes but not others. Many
people who enjoy full freedom to select a domain of measurement that suits their problem nevertheless show
signs of being constrained in their thinking by long-established institutional boundaries. As the work content
within institutional boundaries may change, however, it is precarious to use institutionally bounded data for
evaluations of productivity and technological change over time. Part of the increases in logging productivity
reported for the tree-length logging style in the South are undoubtedly due to the fact that the bucking function
moved out of the domain of measurement, although slashing did decrease the time and effort of bucking.

Furthermore, institutional boundaries are not necessarily the same in different parts of the world. Forestry
in Scandinavia is generally taken to include both the growing and the logging of trees, with logs stacked
at roadside landing as the cut-off point. Forestry in North America, on the other hand, includes the growing
of trees, but excludes all logging\(^\text{10}\). These institutional differences influence the way official statistics are
collected as well as the way people think about forestry, and make it difficult to use institutionally bounded
data for international comparisons.

\(^\text{10}\) An interesting indication of how the forestry concept is perceived in North America is provided by
Crutchfield (1989), who suggests the following "little jingle" about trees:

Trees, Trees, Trees, Trees, a forester grows trees!

Nothing’s more rewarding than a forest full of trees!

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3.4. THE PRODUCTION-RESULT PROBLEM

Another difficulty in the production-factor perspective on the system derives from the fact that the output of forest harvesting clearly is not homogeneous, neither in space nor in time: yet, homogeneity is usually assumed. Logging output is generally measured simply as units of volume (weight or area are other possibilities). This measure is insensitive to many changes in logging output, such as bucking quality and timing of deliveries. As Tirén (1952) said: "All cubic meters have the same mass, but, right or wrong, they can differ substantially in value". Logging mechanization led, in Sweden, to a temporary reduction in the quality of bucking, whereas it may have caused an improvement in the South, due to the centralization of the bucking process to the sawmills.

3.5. CONCLUSION

The production-factor perspective on forest harvesting has generally required that these factors be treated as homogeneous. This assumption is clearly not warranted for machine input or for production output, and it is problematic for the labor factor. These problems have not been solved in a satisfactory manner, despite efforts to find an aggregate physical measure for the machine factor.

Another problem, which is not confined to the production-factor view, is that of system demarcation. The commonly used demarcation principle is to respect institutional boundaries, but it is not satisfactory for some purposes of systems evaluation. The work content within such boundaries may shift over time due to technological change, and the institutional boundaries are drawn differently in different countries. The demarcation problem is twofold: to find an appropriate principle for demarcation and an appropriate position for the demarcation line. A more general problem, but no less important, is to foster an awareness that

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institutional boundaries are a product of people, rather than of nature. Consistently stable boundaries, such as that of forestry, tend to constrain thinking when accepted as natural.

It is interesting to note that neither Koroileff, nor other contributors to the abstract family of models, use the term 'system' to refer to their object of study: Koroileff consistently speaks about 'machinery aggregations'. Although no reason is given for this avoidance of 'system', it seems likely that the authors felt that this term should be reserved for the linear mechanistic systems interpretation - the archetype of a system in the field of forest harvesting.

4. THE MECHANISTIC VIEW

In the mechanistic view, a harvesting system is seen as a sequence of components, arranged along a product flow (wood flow). The components interact to produce a final product, but are not physically connected. We shall call this a linear systems interpretation.

The components of a linear system are either machines, people, or combinations of the two, and are sometimes referred to as 'man-machine' systems.

Thus, the mechanistic view distinguishes a hierarchy of two different systems: a harvesting-system level, which consists of a sequential arrangement of a set of physically independent man-machine systems, and the machine level. This two-level perspective is evident in the title of Walbridge's (1960) doctoral dissertation: "The Design of Harvesting Systems and Machines [...]", as well as in the title of two recent international workshops on evaluation: "Harvesting Machines and Systems Workshop" (Stuart, 1987; 1988).
The terminological distinction between a harvesting system and a harvesting machine is somewhat dubious, however. It is possible to replace a sequence of single-function machines with a single, multi-function machine. The job performed by these two alternatives may be the same. Yet, according to the terminological convention associated with the mechanistic systems view, we would no longer be dealing with a harvesting system. The multi-function machine differs from the logging system in that it physically connects the functions which together make up the job. Physical interconnection is "allowed" in prominent systems outside forestry, such as, e.g., an electrical system - yet not in a logging system. The customary definition of a logging system does not hold up well in the face of the increasing technical possibilities for arranging forest harvesting systems.

Yet, this interpretation is the interpretation of the harvesting system concept to most people in the forestry community. A harvesting system is a sequence of machines. This interpretation, and the models created to study it, emanate from the era of early mechanization. Sundberg (1978, p.136) describes the development in Sweden:

Up until the end of the 1950's, the technical development had mainly consisted in the mechanization of individual work elements in the chain from stump to mill. At this point, the possibility of a total mechanization begins to look like a reality, and the development is subsequently linked towards systems. [...] The systems approach results in harmonized work sequences, in which the different links in the chain of logging work are connected in the most appropriate way, so that losses of different kinds are avoided, or at least minimized.
In his textbook on pulpwood production, Bromley (1969, p.23) presents the concept of a harvesting system in the following way:

A pulpwood system is a method of grouping the various operational steps necessary for producing pulpwood. There are many different harvesting systems, but all must perform certain basic operations. However, these are not necessarily performed in the same order in each system. Systems differ because of the sequence in which operations are performed, the size of the pulpwood produced (5-foot sticks, 8-foot sticks, tree length, etc.), the degree of mechanization and the individual characteristics of the equipment used.

The linear interpretation is obviously close to the physical realities involved in the job of getting the wood from the stump to the mill. It is not a coincidence that the linear mechanistic interpretation is the only one in forest harvesting which carries the name ‘harvesting system’, nor that evaluation of linear systems has received a great deal of attention since mechanization started to become a reality in the late 1950’s.

The systems concept appears to have been introduced in forest harvesting some time in the 1950’s, judging by the occurrence of the term in the literature. When Mattsson Mårn (1945) presents an overview of the rationalization work in Swedish forestry, the term ‘system’ is absent. Brown does not use it in his 1949 textbook. Wackerman’s textbook, also of 1949, includes the heading ‘logging systems’ in an article (p.401) by Fritz on logging in the California redwoods. In this early occurrence, the term is used as a synonym for ‘method’.

Walbridge (1956) uses ‘system’ in a modern sense. In the late 1940’s, however, the explicit systems concept does not seem to have been adopted yet in forest harvesting. The term ‘method’ was used in a sense very similar to what is now termed a harvesting system, yet the dimension of interconnectedness was not emphasized. The shift in usage from ‘method’ to ‘system’ probably reflects an important and real change in the nature of forest harvesting as well as in the analytical framework. Mechanization was to make the
analysis of interactions in the logging chain more important by increasing the increments in which capacity
could be added or subtracted, by increasing fixed costs, and by making it possible to hasten the tempo of
logging.

This is not to say that thinking in terms of systems was absent before the 1950's. Matthews (1942, p.v)
clearly has a linear systems concept in mind when he opens his seminal work on cost control with the state-
ment that "control of cost in the logging industry must be affected, in the first instance, through selection
of the equipment and method best suited to conditions." Substitute 'machine' for 'equipment' and 'system'
for 'method', and the linear mechanistic systems view becomes evident.

The current terminological confusion between the concepts of a 'logging method' (such as the whole-tree
method or the shortwood method) and a 'logging system' (such as a whole-tree system or a shortwood
system) may have its roots in this earlier usage of the word 'method'.

4.1. THE TWO EVALUATION TRADITIONS

By the mid-1960's, forest harvesting was facing the problem of rapidly coming to grips with two
interdependent evaluation problems: how to design logging machines and how to combine them into logging
systems. In 1965, the Forest Operations Institute Skogsarbeten in Sweden was charged with the ongoing
task of systematically evaluating conceivable logging systems (Kilander and Järnholm, 1965, p.1). Early
in 1967, the Harvesting Research Project of the American Pulpwood Association was formed, one of its first
tasks being to "develop an analytical method of evaluating one system on many stands of timber, or many
systems on one stand." (Stuart, 1980, p.12). It is instructive to contrast the two national traditions of
mechanistic systems evaluation that grew out of this very dynamic period in the history of forest harvesting.
The mechanistic approach involves two problems: evaluation of machines and evaluation of systems.

Several models were developed in the South, such as the Auburn Pulpwood Harvesting Systems Simulator (Hool, et al., 1972), the Harvesting Analysis Technique (HAT) (Stuart, 1980; 1981), the so-called SAPLOS model (Johnson, et al., 1972) and a nameless model (Webster, 1975). A comparison between these and other models (Goulet, et al., 1979) indicates that the HAT model is a conceptually very highly developed model. It will therefore be chosen as an example of the American tradition in mechanistic systems evaluation.

The HAT model consists of three parts: the Harvesting System Simulator (HSS), which depicts mechanistic systems (physically not connected components); the GENMAC (generalized machine simulator) program, which depicts individual machines (physically connected components); and a forest data module, which allows the choice of data from three different sources: a data base of mapped stands, a tree-growth simulator, and forest data generator. The HAT model is thus capable of simulating three components: forest, machines, and system, all in one integrated program. Other American models also include this link between evaluation of machines and systems.

In the Swedish tradition, introductory work on machine costs and productivity was done by Kilander (1962) and Järvholm and Kilander (1964). The latter work was developed into what may be the first Swedish model for evaluation of systems (as opposed to machines) (Kilander and Järvholm, 1965). The works by Hedbring and Åkesson (1966) on final-felling systems (revised by Nilsson and Österblom, 1970) and Hedbring, Åkesson and Nilsson (1968) on thinning systems had a strong influence on future systems development in Sweden. The model presented by Frisk (1970) represents another step, more directed towards mechanization at the

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7 The generalized machine simulator program (GENMAC) developed as part of the Harvesting Analysis Technique was not reviewed in this context. See Stuart (1980, pp.182-196) for a response to the report by Goulet, et al.

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company level than previous models. The model presented by Gregersen and Jonsson (1977), and its further
developed version (Ahlgren, Gregersen, and Jonsson 1984), have been extensively used during the 1970’s
and 1980’s for systems evaluation. Lately, a new model with more emphasis on transportation and product
value than earlier models has been constructed (Bjurulf and Tibblin, 1988).

It is notable that the Swedish tradition for systems evaluation consists of a sequence of models in time, one
replacing another. The US tradition, on the other hand, is represented by several models with a longer life,
which more or less run parallel with each other in time. Another difference is that the Swedish models for
machine evaluation were developed separate from the ones for systems evaluation. In Sweden, machine
evaluation was seen as something separate from systems evaluation and the models developed do not offer
the possibility of integration that the HAT model does.

The Swedish tradition of machine evaluation is similar to the one developed in the US and Canada. A
substantial exchange of ideas took place in this field in the late 1960’s and early 1970’s, and the simulations
approach, supported by well-described type-stands, was adopted in both regions. Representative works which
correspond to, but are less developed than the generalized machine simulator GENMAC model in HAT, were
presented by Sjunnesson (1970), Almquist (1973), and Johanssen (1975). The latter study marked the end
of machine simulation research in Sweden. In the US, on the other hand, machine simulation is still an active
area of research (see, e.g., Winsauer and Kofman (1986) and Greene and Lanford (1986)).
4.2. CONTRAST OF APPROACHES TO SYSTEMS EVALUATION

The mechanistic approaches to forest harvesting evaluation in the South and Sweden have many characteristics in common.

In both approaches, a system is depicted as a linear sequence of machines, which together transform a work piece from its initial to its intended state. Generally, the initial state is a stand of trees, and the end product some form of wood at some specified place along the flow of wood to the mill, such as wood piled at roadside (in Sweden), or wood loaded on a truck at roadside (in the South).

The costs for each machine are calculated as the product of its time consumption and time cost, while total cost is arrived at by addition of the costs for individual machines. Revenue for each product is calculated as the product of its amount and price per unit. Profit is calculated as the difference between revenue and cost, and then related to the physical amount of output, measured in terms of pieces, volume, or area. Profit can also be calculated with regard to a certain time frame, such as an hour, a day, or a week.

The rate of production for individual machines, and sometimes the costs and the revenues, are modelled in such a way that they depend on the characteristics of the tract. The most commonly used influencing factors are probably tree size and tree density, but a variety of other factors have been used as well.

The mechanistic evaluation approach generally deals only with a small portion of the life of a system. The problem is reduced down to the logging of a tract, without any concern for the mechanisms which allow the system to appear on that tract. It is assumed that there will be a sufficient demand for the product, as well as an unlimited inventory space or unlimited transportation capacity at the end point of the system.

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The approach is a "green-field" one: the models build on the assumption that the system is introduced into a situation of emptiness as far as existing systems and traditions go.

There are distinct differences in the mechanistic approach to forest harvesting evaluation between the South and Sweden. The former region relies consistently on the simulation technique; the latter has been equally consistent in its use of analytical methods.

The difference in approach does not seem to have been noticed on either side of the Atlantic Ocean, judging from the works published in the field. No author explicitly explains why he has chosen the one approach over the other.

Hool and Hines (1980) devote an entire paper to the discussion of "considerations in developing/selecting a timber harvesting simulation model". While noting that analytical tools should be tried before the more complex simulation is resorted to, they do not discuss the fact that the Swedish approach builds exclusively on analytical methods, nor do they provide any conclusive reasons why an analytical approach could not have been used in the US. The very title of their article suggests that the concepts of 'harvesting evaluation model' and 'harvesting simulation model' are regarded as synonymous.

One gets the feeling that the choice of approach has been uncontroversial in both countries, and no explicit motivation has therefore been necessary. Yet, the reasons behind the choices and their lack of explicit explanation pertain to our problem, as they may be the result of different perspectives in the two evaluation constituencies. What are the reasons which made the Swedes consistently choose analytical techniques, and the Americans select simulation?

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The answer to this question is difficult to discover, as the authors do not provide it. Yet, three reasons will be hypothesized: a difference in research tradition; a difference in institutional structure in the system; and a difference in systems tempo (temporal integration of systems components).

4.2.1. TRADITION

The Swedish tradition has its roots in the extensive work-study activities which have been carried out in Sweden since the late 1930’s.

In the 1930’s, interest and pressure was growing for a system of collective bargaining in setting logging piece-rates, and in 1940 the first general agreement was concluded. Soon, a special "forest approach" to the problem of rate-setting was developed. In this approach, comparative workstudies were used to construct schemes for rating the logging difficulty of any logging tract in relation to that of a reference tract. The collective bargaining dealt only with the rate for the reference tract, and tract-specific rates were then deduced from the tract-rating scheme. The principle was that the same intensity of work should yield the same amount of compensation, regardless of the characteristics of the tract. The "forest approach" was a way to avoid the performance rating of individual workers typically associated with piece-rate systems. It was believed that such rating would be fraught with unacceptable subjectivity in the extremely variable working environment of a forest. Allegedly, the comparative approach made it possible to transfer the subjectivity from the time-study man to the negotiation table (where it belongs). The development of schemes for difficulty-rating of tracts was seen as an endeavor which could be approached with scientific methods, and regional
work-study organizations were set up to do the job (the first one in 1938). These organizations soon also became engaged in systematic rationalization work\(^{12}\).

The long Swedish tradition of work-study, emanating from the needs of the collective-bargaining system, has, in all likelihood, had a strong influence on the approach taken to systems evaluation. The same institutional body (the Forest Operations Institute Skogsarbete, formerly SDA) and some of the same influential people, notably Kjell Kilander\(^{13}\), were engaged in both activities. Certainly, substantial experience in identifying important tract factors and quantifying their influence on manual and motor-manual logging difficulty had been accumulated during these years. A large amount of empirical data had also been collected. These data did not apply to the new and often non-existent concepts of machines and systems that were to be evaluated, but they provided a solid empirical baseline from which to start, and there was a well-trimmed work-study system in hand for generating empirical data about any new machines that might appear. It should also be noted that the constituency was the same for the tract-evaluation research and the systems evaluation work.

The Southern researchers had no similar tradition or data base to draw upon, nor did they have any operational base which had had a continuing strong interest in harvesting studies for any length of time. The first systematic harvesting research effort in the South, which was commissioned by the American Pulpwood Association and performed by the Battelle Memorial Institute, lasted only between 1960 and 1963. The US


\(^{13}\) Kilander's doctoral dissertation of 1961 - the first one in Sweden in the area of forest harvesting - dealt with issues related to work-study and the construction of schemes for rating tracts with regard to logging difficulty.

Chapter 2. Survey of Evaluation Frameworks
Forest Service did not incorporate a forest engineering research program until 1961 (Brown, Biltonen, and Erickson, ca 1981, p.4).

4.2.2. INSTITUTIONAL STRUCTURE

Stuart (1980, p.11) argues that a model for forest harvesting evaluation must model the objective of profit maximization, rather than cost minimization. While the latter may be an acceptable objective in a manufacturing plant, only the former will allow an independent logging contractor to stay in business.

This suggests, albeit in a somewhat indirect fashion, that the Southern structure of independent logging contractors was an important reason to choose simulation. The contractor is generally operating with a very tight cash flow, and is dependent on earning enough every week to pay his crew, meet his equipment payments, buy supplies, pay taxes and put something in the bank.

Swedish models, on the other hand, assume that the result can be measured over a long period of time, without any concerns for cash flow. This industrial perspective was natural in the Swedish situation, with full company control over logging.
The Swedish evaluation constituency of large forest companies was content with having the Conservancy\textsuperscript{14} (\textit{skogsförvaltning}) and the logging season as the domain of result measurement. The Southern constituency of independent contractors, on the other hand, demanded that the domain of result measurement be one tract and one week.

In order to measure the result realistically, i.e. with a high resolution in space and time, it was necessary in the South to employ simulation rather than the average-driven analytical method.

4.2.3. TEMPO

Stuart (1980, p.13) provides a long list of factors influencing harvesting, and argues that only the simulation technique is comprehensive enough to depict them. Among the factors mentioned (but not emphasized) are "machine failures and delays, and inventory interactions". Herein lies another reason why simulation was preferred over an analytical approach.

Southern logging systems are generally "hot", i.e. operated with a high degree of temporal interaction between machines. The high tempo transforms the size of the buffer inventories between machines into a crucial factor for total systems productivity. As the buffer inventories depend on the relationship in production rate

\textsuperscript{14} The Swedish term \textit{skogsförvaltning} is derived from the verb \textit{förvalta}, which means to conserve or to steward, particularly the latter. The woodlands division of a Swedish forest company is typically organized into a number of forest conservancies or stewardships, which bear the responsibility for silviculture and harvesting of wood. There is a strong emphasis on the sustained integration between these two activities, but less of an emphasis on the integration between harvesting and the shortterm needs of the mills. The responsibility of the conservancy generally ends at roadside. Its domain is thus the same as that of the Swedish forestry concept.
between machines, it was essential to model shifts in productivity and availability with a very high resolution. Only simulation could provide a sufficiently high resolution.

In Sweden, on the other hand, logging was, for the most part, "cold". The links in the logging chain communicated by wood form only, not by wood flow. Productivity rates could be modelled as averages, as the resolution in time did not need to be high. The Swedish constituency may not have been interested in "hot" systems - in any case, the analytical models created in Sweden do not have any provisions for depicting the temporal interactions between machines, other than by somehow absorbing their effect in the average values used.¹⁵

4.3. CONCLUSION

The systematic difference observed between the Southern and the Swedish approach to mechanistic systems evaluation is interesting for several reasons:

- It has not been discussed by evaluators on either side of the Atlantic;

- It appears to be caused by differences in the context surrounding the systems to be evaluated. The Southern approach assumes hot systems (but can also depict cold systems) and independent contrac-

¹⁵ Thus, no models capable of depicting the work of a hot system were ever developed in Sweden. Whether this inability has punished hot systems compared with cold in Swedish evaluations is hard to tell. There seems to have been very little interest in hot systems after the discouraging experiences with delimming and debarking at upper landing in the 1960's.
tors, the Swedish approach assumes cold systems (and cannot depict hot systems) and strong company involvement;

None of these ascribed assumptions have been discussed in conjunction with the models.

The analysis suggests that the models for mechanistic systems evaluation are context dependent, and that the awareness of this cultural bias has been either weak or silent among the creators of these models.

There is also a terminological problem with defining a system as a sequence of machines. The choice whether to aggregate a set of functions to one machine or to several marks the terminological difference between a machine and a system.

5. THE ORGANIC VIEW

This third perspective regards the job of the system as a process, rather than a discrete event. The job is to harvest wood over a large area and over a large period in time. The harvesting system tends to be depicted as an organism, rather than a discrete, mechanistic, linear system. The systems view might therefore be called 'organic', for want of a better word.

Hamilton and Pugh (1963) employed an organic perspective when analyzing the causes of pulpwood shortages in the South\textsuperscript{16}. Dynamic programming was used to model the flow of wood from stump to mill as produced

\textsuperscript{16} This report was part of the so-called Battelle Study. In what appears to have been the first systematic forest harvesting research effort in the South, the American Pulpwood Association commissioned the Battelle Memorial Institute to investigate the causes of the 1955 and 1959 pulpwood shortages and recommend solutions. The project lasted from 1960 to 1963 (APA, 1984, p.32).
by a regionally defined harvesting system. The study dealt with the effects on pulpwood supply of the inventory strategies and workflow regulation systems of the wood consumers, rainfall, and the behaviour of the wood dealers and producers in the system.

Unfortunately, this approach appears not to have been built further upon, and no further Southern study employing the organic perspective has been found.

In Sweden, models based on an organic perspective were developed from the mid-1960's as a response to the increased needs for operational planning brought by mechanization. The purpose of these models was to evaluate planning alternatives, rather than harvesting systems per se. The models did not deal with systems choice or capital investment - they dealt with how best to utilize investments already made.

Unlike the mechanistic tradition of systems evaluation, which in Sweden did not generate a single academic title17, the organic approach gave rise to a number of Licentiat theses and Dissertations, among others Carlsson (1968), Lönn (1968), Andersson (1971), and Bucht (1972). It is important to notice that this perspective, which occurred at several levels of resolution, was born out of harvesting research rather than the fields of management economics or growth prediction. Although some models, such as Andersson’s, depict the system at an abstract and strategic level, and include elements of these neighboring fields, harvesting systems with costs and time consumption are always present in this family of models.

It is believed that no corresponding models created in the South are available in the public domain, if created at all. There are two plausible reasons for this:

17 Simulation studies of harvesting machines did generate some academic titles (Sjunnesson, Bredberg, Almqvist), but the analytical approach to systems evaluation did not.

Chapter 2. Survey of Evaluation Frameworks
The institutional structure in the South relied heavily on independent contractors (as opposed to company operations), and Southern harvesting is coordinated from the wood-consuming mills (as opposed to conservancies). One of the main goals behind the Swedish planning effort was to aid the conservancies in achieving a high utilization of the new equipment to keep the capital costs down. The South did not have such a powerful central coordination base. Any planning models created would likely not be available in the public domain, as they would be part of the competitive wood-procurement area. The Swedish models were conservancy-centered, rather than mill-centered, and grew out of collectively funded research - hence their open publication:

The lack of a strong institutional base for harvesting research in the South. Silversides, et al. (1988) note that only two percent of the US forestry research budget address forest harvesting problems, while the corresponding value for Sweden is 25 percent (Andersson, 1985, p.58). Ultimately due, perhaps, to the North American perception of forestry as growing but not harvesting trees, US planning models tend to come out of the "purer" and more academic fields of growth prediction and management planning, rather than the low-status and low-resource field of forest harvesting. US models tend to ignore the physical process of forest harvesting in a way that is foreign to the thinking in Sweden, where harvesting is an activity integrated in forestry and harvesting research is a full-status and resource-rich part of forestry research

The organic view of a harvesting system is included here for two reasons. Although the models that have been created from it are intended for planning, rather than evaluation, they represent an interesting attempt to enlarge the perspective on the harvesting system. Also, the occurrence of these models appears to be -

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18 It is difficult to present evidence to support this clearly felt difference. The fact that the last four Deans of the Swedish College of Forestry all have been involved in forestry operations research during some part of their careers seems to support the claim that this kind of research does not have a low status in Sweden.

Chapter 2. Survey of Evaluation Frameworks
again - context dependent. The Swedish approach grew out of the particular institutional structure in that country, including company operations and strong, cooperative research support. In the South, with independent contractors, less commitment to harvesting research, and generally a less centralized institutional structure than in Sweden, similar models probably did not evolve with the exception of the wood-flow model by Hamilton and Pugh (1963), a pioneering work of great merit.

6. THE NEED FOR A WIDER CONCEPT OF A HARVESTING SYSTEM

The survey of evaluation models has indicated that the current analytical frameworks are culturally and contextually biased. This should not be surprising, since the models have been conceived within particular harvesting styles to solve particular evaluation problems posed by a constituency immersed in that style. The problem of mechanistic analysis of harvesting systems was perceived and approached very differently in the South and Sweden, which strongly indicates that analytical frameworks are influenced by style. The following three style factors in particular seem to have influenced the way the problem was perceived:

- Institutional structure;
- Tempo; and
- Evolutionary history.

These three factors are clearly connected with each other, and they also clearly affect the possibilities and constraints influencing technological change within a style, including the transfer of equipment from other styles.

Chapter 2. Survey of Evaluation Frameworks
For comparative analyses across style boundaries, the analytical framework ought to be neutral to the styles involved. This could be achieved by widening the concept of harvesting system, so that style factors became part of the system instead of being silent assumption. Other factors also speak for a widening of the system concept. Harvesting systems ought to be compared doing the same job. As the systems structure may differ between different technological styles, the system concept must be wide enough to allow even very different systems to be compared on an equal basis.

Technological change often involves changes in system structure, such as the movement of the debarking function from forest to mill. Retrospective evaluations benefit greatly if they can be based on data which pertain to a constant domain. Only a wider system concept than the ones currently in use can yield a sufficiently stable measure of work content (i.e. include the same job) over time, despite technological change. One should note that stability is desirable not only toward the past, but also toward the future (to provide future evaluations with a stable domain).

Finally, it is necessary to adopt a concept of the harvesting system which is neutral with regard to the structure of the system. Only such a system concept can be neutral with regard to different harvesting styles.

The following chapter will present an analytical framework more suited to comparisons across styles.
CHAPTER 3. ANALYTICAL FRAMEWORK

As shown in the previous chapter, the current analytical frameworks are less than appropriate for our problem, and for some other problems as well. Their main deficiency lies in that they are style products rather than style neutral.

In order to explore the contrast between different styles of forest harvesting, we need an analytical framework which is neutral with respect to the compared styles. Such a framework will be developed in this chapter. Its main component is the concept of a wood-supply system, reaching from the tree to the boundary of the mills served by the system.

1. CRITERIA FOR A USEFUL CONCEPT OF A HARVESTING SYSTEM

The system concept must meet different criteria depending on the objective of the analytical problem.

An evaluation ex post of different harvesting styles would benefit from a concept of a system which provided a uniform measure of work content, regardless of technological changes. Only then can these changes be properly measured. This is a problem of system demarcation.

An assessment ex ante of proposed technological change needs a concept of system which is open enough to allow radically different system structures to be analyzed on an equal basis. This is also a problem of system demarcation.
In the previous chapter, the established notion of a logging system was criticized for being dependent on the structure of the system. If the agents (people, machines) which perform the functions of a harvesting job are physically separate, we are dealing with a system, but not if they are physically connected. In other words, if a logging job were performed by a feller-buncher and a delimber-bucker, we would have a system, but not if these two machines were replaced with a feller-delimber-bucker. This is a problem of the basis for a system definition.

Another desirable property of a system concept is that it allow important factors affecting the performance of a particular systems style to be identified and evaluated. The system views most often used were found to silently assume factors such as institutional structure and tempo as fixed and given, rather than allowing them to be analyzed in a neutral way. This is again a problem of system demarcation.

Thus, several problems are associated with the concept of a harvesting system. In the following, two concepts of harvesting system will be proposed, which together seem to meet the above requirements.

2. THE PROBLEM OF CONCEPT NEUTRALITY

The commonly used (but seldom stated) definition equates a harvesting system to a sequence of interacting but physically unconnected machines which are coordinated by a common goal. This definition can easily be extended to embrace people with hand-held equipment as well.

The problem with this definition is that it depends on the structure of the system. But evaluations are very often concerned with system structure. Mechanization brought a revolutionary change in system structure. Swedish harvesting systems consist of a few multi-function machines, Southern systems of...
several single-function machines. Harvesting systems have evolved by changing their structure, and systems in different regions of the world may differ in content. In order for a concept of system to be style neutral, it must be defined in such a way that its definition is independent of the structure of its components.

The term production can be defined as "an act which transforms the world from a less to a more preferred state" (Heathfield and Wibe, 1987, p.1). A production system, such as a wood-supply system, might accordingly be defined as a mechanism whose purpose it is to perform a transformation. These definitions suggest a distinction between transformation and system: the transformation is the task or job¹ to be performed; the system is the agent or mechanism which performs the job.

This distinction suggests a possibility for a structure-neutral system definition. If we were to define a system in terms of the job it does, or is supposed to do, rather than by its structure, we would be defining what to do, rather than how to do it. We would define the purpose of the system, rather than its content.

This approach accords well with the systems definition suggested by Hughes (1981) and others: a system is a set of interacting components, coordinated by a common purpose. By using purpose as the basis of definition, we free the systems concept from its content. Thus, a system is simply the mechanism (whatever it may look like) set up to reach a certain purpose. Systems evaluation is concerned with the content of the system, i.e. with how the mechanism does its job.

¹ In the following, the term 'job' will be used synonymously with the term 'transformation'.

Chapter 3. Analytical Framework
3. THE PROBLEM OF CONCEPT SCOPE

We have defined a system as a mechanism whose content is governed by its objective: to perform a certain transformation (job). It seems reasonable to conclude that a systems demarcation requires that the job be described. Heathfield and Wibe (1987) suggest that production be thought of as a transformation between two states of the world. Analogously, it seems reasonable to think of the task of job demarcation as consisting of describing an initial state and a final state. The difference between these two states constitutes the transformation (job) whose performance we are interested in.

The survey of evaluation frameworks indicated a need for an expanded system concept, such that it is suitable for comparison of systems which differ radically in structure, provides a stable measure of work content regardless of structural changes, and is wide enough to allow the effect of non-mechanistic factors to be evaluated.

There are at least two dimensions to a systems demarcation: "length" and "width":

- By "length" is implied the "distance" in terms of work content between the initial and the final state. From a growing tree to logs piled along a strip road would be a "short" system; from a growing tree to chips on the conveyer to the digester at the pulp mill would be a "long" system;

- By "width" is implied the scope of the state definitions in time and space. A "narrow" system would harvest a single tract; a "wide" system would be responsible for supplying wood to a number of mills from a region. A "narrow" system may perform a discrete job while the job of a "broad" system is a process.

Chapter 3. Analytical Framework
How far apart should we position our system boundaries, then, and how widely should we define them?

Beginning with the latter question, it seems that a distinction between two different types of systems would be useful:

- **A tract system**, which is a mechanism whose job is bounded by the tract in time and space. A tract system performs a series of discrete tract jobs, one after another, but never two at the same time, much like the linear mechanistic type of system discussed in Chapter Two. Unlike the mechanistic system, however, a tract system is defined by the job it performs, not by its structure. A similar type of system is known in the South as a 'producer system', i.e. the mechanism with which a producer performs a cut-and-haul service. This term is not suitable here, however, as it makes reference to system structure - in this case the institutional structure of the system;

- **A wood-supply system**, which is a mechanism whose job it is to generate a continuous supply of wood to a set of consumers from a certain set of tracts. This kind of system is similar to the organic systems view discussed in the previous chapter, particularly in the sense it was used by Hamilton and Pugh (1963). We will use it here for analysis of tract-system styles, rather than for operational planning for such systems (as is typically done in Sweden).

A tract system can be seen as a sub-system to a wood-supply system, which in turn can be seen as a sub-system to the forestry industry system as a whole.
A wood-supply system is made up of a number of tract systems, but also of a mechanism for organizing their work. Wood-supply systems can differ by the style of their tract systems, but also by the way that these are organized. The wood-supply system concept allows the analysis of many factors or problems which are not easily seen at the tract-system level, because they embrace many such systems. Chapter Two identified three such factors: institutional structure, tempo, and tradition. A tract system is too small an entity for them to be analyzed, and this is the likely reason why they have been "treated" as silent assumption, rather than objects of analysis.

Another problem which appears more clearly at the wood-supply level is the occurrence of idle resources, which may take the form of whole tract systems as well as wood inventories at the mill woodyard. It is important that analytical provisions be made for a comprehensive analysis of this problem. The combined use of the two suggested concepts of harvesting system allows such an analysis.

It remains to demarcate the "length" of these systems. We are interested in finding a demarcation which satisfies the following criteria:

- It should provide the system with a measure of work content which is stable despite such past and anticipated technological changes which alter its structure;

- It should allow the comparison of drastically different tract systems within points of product commonality;

- It should make it possible to study the use of capital invested in capacity as well as in wood inventories.

Chapter 3. Analytical Framework
These criteria all seem to indicate that a "long" system ought to be demarcated.

The "longest" job we could possibly consider would stretch from the seed of a forest tree to the final consumption of wood-based products. We might even begin with a forest-tree gene being engineered\(^2\) to produce better tree performance and end with the decomposition of consumed wood products. Forest harvesting is clearly part of this job, which is very complex and grand in scale, however, and therefore difficult to study. It would have to be treated at a comparatively low level of resolution, and with a strategic perspective, since systems of the size required as a rule change only slowly. It would be difficult to distinguish the style of tract systems within such a "long" system.

Yet, too "short" a demarcation will make it difficult to compare some already existing systems styles, let alone revolutionary alternatives, between points of commonality.

In Sweden, wood is generally debarked before it is chipped. Ever since the constraint of the river drive, requiring debarked wood, was lifted, mill-site drum debarkers have been used in Sweden. As a consequence, pulp chips have been produced at the mill site as well. Recently, a technique allowing tree-wise delimbing, debarking, and chipping of pulpwood immediately following harvesting was developed. In order to compare these two system styles, it was necessary to consider a job reaching from growing trees in the forest to chips being conveyed into the chip silo at the pulp mill (Fröding, 1987).

In the Southern US, chipping of pulpwood may commonly occur at three alternative sites: forest landing, concentration yard, or mill woodyard. To find a transformation which allows an evaluation of

\(^2\) This is the appropriate meaning of the term 'forest engineering', as opposed to 'forestry engineering', a subject with which this study is concerned.

Chapter 3. Analytical Framework
these three styles, we need to start with trees being selected for severance on the stump and end with chips being passed on to the chip silo.

Wood inventories and idle capacity can occur at all terminal points in the system between tree and final product consumption, and also during transport. A good treatment of the problem of idle resources would require that the entire tree-to-market system be considered. A more manageable, yet reasonable alternative would be to consider the job from living trees up to digester or head saw. The products found in inventories at the back end of pulpmills and sawmills differ substantially in value-to-volume ratio from the products inventoried between the forest and the mill.

The stability criterion is associated with technological inertia. We need to find two points between which the work content will remain stable despite technological change - two "nodes" in the production flow which are likely to change only marginally, despite radical changes around them.

The physical components of the seed-to-market system currently in place are very heterogeneous. They differ, among other things, in inertia. Pulpmills and papermills have historically been inert in their interface with neighboring components. Chemical pulpmills have relied on chipped wood for many decades, and ground mills on debarked bolts. Sawmills have been somewhat less stable in their interface with forest harvesting, at least in the South, where mobile "peckerwood mills" were common into the 1960's. As sawmills have become permanent and attracted more capital, they, too, seem to be stable.

Thus, there seems to be good reason to demarcate the system somewhere close to the pulpmill and the sawmill, where a stable node can be found. For a pulpmill, the most stable node is probably that of chips being fed into the digester. This point also marks the shift between mechanical and chemical
processing - a fundamental shift in processing technology. For the sawmill, there is no fundamental shift in processing technology until the wood passes into the dry kilns. Still, logs being fed to the headsaw appears to be a stable and "naively given" node.

Demarcation of the initial state is less problematic. The mature forest is the beginning point of the harvesting process, and there is every reason to believe that this node will remain stable. A fundamental shift in the nature of production also occurs when the tree is harvested. The identity of product and means of production is broken, changing the role of time from an indirect production factor to a cost factor.

In summary, it seems reasonable to demarcate the wood-supply job (and the wood-supply system) as beginning with living trees in the forest and ending at the digester and the headsaw. Doing so, we also demarcate the tract system similarly. When the evaluation problem does not call for the tract system to be that "long", we may choose instead to let the tract-harvesting job end at a point where the tract nature of the wood flow is lost - usually at a woodyard. Conversely, we may choose to enlarge the wood-supply job to also include the growing of trees, if called for by the evaluation problem.

In general, though, it seems that the two previously suggested concepts of a harvesting system - the tract system and the wood-supply system - should prove to be useful analytical tools for the evaluation of forest harvesting.

It is interesting to observe that the location of stable "end" nodes for the system coincide with the points where the wood passes into the controlled production environment of a factory. Beyond this point, the production environment is standardized and the different technological styles seem to have converged - more so for pulping than for sawmilling.

Chapter 3. Analytical Framework
In this context, it is necessary to emphasize, again, that institutional boundaries are unsuitable ground for demarcation, given our purposes. The reason is that institutional boundaries are part of the content of the system, and therefore should be made an object of evaluation, rather than an assumption. This is not always evident. Institutional boundaries tend to be taken as given by many people active in forestry and forest harvesting, and thus serve as constraints on problem formulation. Some researchers, such as economists, may find institutional boundaries to be appropriate for problem demarcation, however.

One of the most ingrained institutional domains is that of 'forestry', a term which differs in content between Sweden and North America. In Sweden, Finland and probably in much of Europe, forestry includes not only spontaneous biological growth and silvicultural manipulation, but also harvesting of the wood and delivery to a market point, such as roadside.

Consequently, forest harvesting tends to be operationally integrated with growth and silvicultural manipulation, and forest harvesting is regarded as a job which begins with growing trees and ends with logs piled at roadside, where the products of forestry are sold. Harvesting activities tend to be controlled from within forestry, rather than by the wood-consuming mills. This institutional boundary between 'forestry' and 'forest industry' permeates most of the Swedish forestry sector, and has a deeply constraining effect on problem formulation. Andersson (1982, p.58) remarks that "our boundaries between forest, industry, and market have to some extent resulted in the forest system not reacting to the raw-material requirements of industry and market."

Chapter 3. Analytical Framework
The forestry concept in the South, as in the rest of North America, embraces only growth and silvicultural manipulation. Wood is sold as stumpage, making trees rather than logs the product of forestry. The harvesting of trees belongs in a no-man’s land between forestry and industry, giving it a weak institutional basis. Harvesting is controlled by the needs of the wood-consuming mills, whereas the integration between wood-supply and silviculture mostly is less intense than in Sweden.

Sundberg (1976, p.39) remarks that "the split of forestry in two managerial systems, one with only long-term goals (silviculture and land use) and the other with only short term goals (timber harvesting) is bound to be detrimental for a fragile resource, especially since the latter is so much stronger in finance and personnel."

*The institutional boundaries in the forest sector are indeed important, and ought therefore to be made the object of evaluations, rather than being treated as assumptions, or worse yet: as silent assumptions.*

5. CONCLUSION

The analytical framework laid out in this chapter has three important features: It is *neutral* with regard to the object of analysis, it is *wide enough* to allow the analysis of factors which are common to whole sets of tract systems, and it is *long enough* to allow the analysis of structurally very different tract systems. The combined use of the two suggested concepts of a harvesting system - the *tract system* and the *wood-supply system* - will be used to explore the contrast between different harvesting styles. If the new framework is powerful, it will allow us to identify and analyze many components of harvesting.
styles which have entered earlier analyses as silent assumptions, escaping attention because a less powerful analytical framework did not allow them to be seen.

In the following chapters, the new framework will be used to explore the contrast between the wood-supply systems of North America and Scandinavia.
CHAPTER 4. TEMPO IN WOOD-SUPPLY SYSTEMS

Most people in forest harvesting research and many operations people are trained to analyze forest harvesting in terms of tract systems only. This is hardly surprising. Forest harvesting is performed by tract systems, and many important factors affecting forest harvesting technology are easily seen at this level of analysis. This perspective has greatly influenced the way that forest harvesting is typically viewed. This perspective, while adequate to address local or even regional problems, suffers from severe limitations when extended across style boundaries. The approach focuses on those items of special import in the local environment while leaving others unseen (or at best unreported). This latter category usually includes those elements considered as constant or fixed for the local conditions.

This approach, when extended across style boundaries, tend to emphasize the importance of differences in the mechanistic structure of individual tract systems, such as tree-length versus product-length logging. Cost and productivity projections or analyses then evolve from these mechanistic differences, adding further credence to their import.

Yet, the obvious isn't always the important. Many critical components of harvesting styles have escaped attention because they don't readily show up in these, rather narrow, tract-system based analyses. The failure of tree-length methods in Sweden, and Scandinavian product-length methods in North America, was not caused by inadequate analyses, but it clearly demonstrates that important factors were missing from the analyses made. The analytical concept of a tract system is simply not adequate to capture all the factors that must be considered in an analysis reaching across style boundaries.

Chapter 4. Tempo in Wood-Supply Systems
To amend this problem, a new analytical concept was suggested in the previous chapter: the wood-supply system. Its greater scope makes it suitable to analyze factors not easily seen at the tract-system level but still important to the success or failure of such systems.

1. CONTRASTING TEMPO IN WOOD-SUPPLY SYSTEMS

Using the analytical framework proposed in Chapter Three, the contrast between the forest harvesting styles of North America and Scandinavia were explored. Particular attention was given to the harvesting systems of the Southern US and Sweden. Several Southern harvesting operations and wood-consuming mills were visited, and many loggers and procurement officers were interviewed. In order to enhance the contrast, a study tour to several Swedish pulpmills and sawmills was conducted in November of 1989.

A striking contrast between the two systems was identified during the study tours: a difference in tempo, i.e. the pace at which wood moves between stump and mill. The large aggregation of pulpwood inventory at Swedish mills was a stark contrast to the much smaller ones maintained in the South. While there are many differences in the wood-supply style between these two regions, the difference in tempo was chosen for a targeted analysis. It possesses the rare distinction of being, at the same time, very obvious and largely undiscovered by forest harvesting researchers. One might say that it was a combination of curiosity and instinct that dictated the choice of style difference to be explored.

In the following, the discussion will be somewhat widened in that the wood-supply system in Maine will also be considered. Maine provides an interesting contrast both to the South and Sweden:

Chapter 4. Tempo in Wood-Supply Systems
- Maine belongs to the same country as the South, sharing with it many cultural features such as language, political system, and legal system. Many corporations maintain operations in both regions.

- Maine is similar in physical environment to Sweden. Both regions are glaciated, and enjoy the mixed blessings of long and cold winters. The forests are generally covered with snow for several months, making for a critical transfer period in the spring when the snow melts and the ground and the waters thaw. The dominating spruce-fir forest type in Maine is similar to the Swedish spruce-pine forest in tree size, tree form, and other factors. Another similarity is that both regions contain large rivers which have been used extensively for wood-supply purposes in the past.

Another reason to include Maine is that the data representing Sweden is too limited to allow the kind of analysis in which we are interested.

1.1. PRELIMINARIES

In the context of wood-supply systems, the term 'inventory' is generally used to refer to wood waiting to be processed. This usage corresponds well to the one common in the engineering theory of materials management: "stock at hand at a given time (a tangible asset which can be seen, weighed, and counted)" (Tersine, 1988, p.3). In one of the few works on inventory management in wood-supply systems, Holemo (1971, p.12) borrows his definition of 'inventory management' from an engineering monograph: "The sum total of those activities necessary for the acquisition, storage, sale, and disposal or use of material".
These definitions of inventory appeared perfectly adequate as the author set out to explore tempo contrasts. As will be shown later, their emphasis on material make them inadequate for a fuller understanding of the tempo problem. Only when inventory is defined as an idle resource (Tersine, 1988 p.3) or asset can the problem be effectively approached, as it involves a trade-off between keeping wood in inventory or keeping production capacity idle. In the sections immediately following, the term 'inventory' will refer only to wood, however.

Inventories can be measured in absolute or relative terms. In this context, it is most useful to relate the size of an inventory to the rate at which it is being consumed. Thus, inventory size will be expressed as time of consumption, most often days of consumption, whenever possible. In other words, the initial measurement values, which were made on an interval scale, will be converted to a ratio scale. This type of measure has two advantages:

- It allows inventory sizes to be expressed in a directly comparable unit without complex and sometimes dubious unit transformations;

- It allows inventory sizes to be compared in terms of their functional significance. In terms of absolute magnitude, a large mill may very well have a larger inventory than a small mill, because its rate of consumption is higher. When the inventory sizes at both mills are related to the respective rate of consumption, the measures are easier to contrast.

In the following, two data sets will be used:

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- Pulpwood data from the American Pulpwood Association, giving monthly regional values for the receipts, consumption, and inventory of pulpwood¹;

- Data from the Swedish Statistical Yearbook of Forestry, giving yearly values for the consumption and inventory of pulpwood.

The data sets differ in the domain of measurement. The American inventory data refer to wood belonging to pulpwood-consuming corporations, and are therefore contingent on the institutional structure of the wood-supply system. Pulpwood consumers generally own all wood at the mill wood yards, some of the wood at concentration wood yards, and none of the wood at road side. The Swedish data include all wood inventoried at mill wood yard, concentration wood yard, and road side, and some of the cut wood inventoried in the forest (Skogsstyrelsen, 1987, p. 127).

There is also a difference in the size of the regional domain between the data sets. The American data are aggregated to the state level, whereas the Swedish data are aggregated to the national level.

Due to the difficulty in obtaining data concerning sawlogs, the analysis will deal with pulpwood only.

1.2. INVENTORY SIZE: SUBSTANTIAL DIFFERENCES

The magnitude of the pulpwood inventories in Georgia, Maine, and Sweden is shown in Figure 2.

¹ A fuller description and discussion of the APA data is given in Appendix 1.
The inventory level in Maine is about three times as high as in Georgia (30 days vs. 10 days) and varies more (range of 20 days vs. 6 days). The inventory level in Sweden is much higher still (ca. 75 days) and shows even more variation (range of ca. 60-70 days). The cyclical variation suggests that business cycles are allowed to influence the level of pulpwood inventory in Sweden - something which does not appear to be the case in the US regions.

Two trends are evident in all three regions: the level of inventory is going down, and the absolute magnitude of variation in inventory level is diminishing. The relative magnitude of variation has not changed during the period, however, as shown in Figure 3.

The economic upswing in the US in 1972 and 1973 led to a severe competition for wood between sawmills and pulpmills, which caused a sharp decrease in inventory level (Muench, 1990). It is interesting to observe that when the competition eased, inventories returned to a pre-crisis level. Apparently, the wood-supply systems were unable or unwilling to maintain a lower level of inventory.

Maine differs from Georgia not only in the average level of inventory over the year, but also in its seasonal pattern of change. Figure 4\(^2\) and Figure 5 indicate a pattern of fairly mild seasonal variation in Georgia, a variation which nonetheless has diminished from the period 1967-71 into the exceedingly smooth pattern in the period 1985-89. The changes in Maine have been more dramatic. The very pronounced seasonal pattern and high average level during the period 1967-71 (Figure 6) have changed into the still seasonal but much smoother pattern and lower average level of the period 1985-89 (Figure 7)\(^3\).

\(^2\) In this figure and in others of the same type, the solid line connects the mean values and the dotted line the median values of the observations in each class (month). The ends of the vertical line represent the maximum and minimum values in a class, whereas the ticks on this line represent the quartiles within the class.

\(^3\) Please observe that the figures representing Georgia and Maine are drawn to different scales.

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The data suggest two conclusions: while inventory levels have decreased in all three regions during the period, the relationship in level between the regions has remained substantially the same.
Figure 2. End-of-month pulpwood inventories in Georgia and Maine, and end-of-year pulpwood inventories in Sweden, days of consumption.

Figure 3. Variation in end-of-month pulpwood inventories in Georgia and Maine, measured by within-year coefficients of variation.

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Figure 4. Seasonal pattern of end-of-month pulpwood inventory level in Georgia 1967-1971, days of consumption.

Figure 5. Seasonal pattern of end-of-month pulpwood inventory level in Georgia 1985-1989, days of consumption.

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Figure 6. Seasonal pattern of end-of-month pulpwood inventory level in Maine 1967-1971, days of consumption.

Figure 7. Seasonal pattern of end-of-month pulpwood inventory level in Maine 1985-1989, days of consumption.

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1.3. WOOD-FLOW PRECISION: SUBSTANTIAL DIFFERENCES

A very important criterion of wood-flow adequacy is that it be sufficient to feed the mill at all times. The nature of the industrial processes and the large investments required to sustain them - particularly the pulping processes - puts a very high penalty on running out of wood. In the following, we shall assume that ability to provide continuity of consumption is a necessary criterion of wood-flow adequacy.

In principle, there are two different ways in which an adequate wood flow can be maintained:

- The mill can be fed "hot", i.e. without any inventory of wood at all. A totally hot system requires that the rate of supply equals the rate of consumption at all points in time. If the supply is too small, continuity of consumption cannot be maintained; if the supply is too large, an inventory of wood will accumulate;

- The mill can be fed "cold", i.e. from an inventory of wood. The larger the size of this inventory in relation to the rate of wood consumption, the colder the relationship between supply and consumption, i.e. the less stringent the requirement for coordination between supply and consumption rates.

We shall use the term 'precision' to refer, in a loose sense, to the degree of coordination between the supply-rate and consumption-rate of wood. The better the supply of wood matches consumption, the higher the degree of precision.
Generally speaking, these two supply strategies are located at opposite ends of a continuum. At the one extreme, we find supply with absolutely no wood inventory at all. At the other extreme, we find supply from an infinitely large inventory. An absolutely hot system requires perfect precision in the relationship between supply and consumption. An absolutely cold system requires no precision whatsoever.

Because of the requirement for supply precision, absolutely hot systems normally require an extremely high degree of control and predictability and are therefore seldom found. A system for generation and distribution of electrical energy might serve as an example of a very hot system. In this case, there is no good alternative to a very hot system, as electricity is difficult to store.

Absolutely cold systems, on the other hand, can occur only if there is some factor present that limits the size of the inventory as it builds toward infinity. This situation sometimes occurs in the Swedish wood-supply system, where the logging of a tract can be completed several weeks before the first truck arrives to start, bringing the wood to the mill. In this case, no precision whatsoever is required in the relationship between the logging function (supply) and the hauling function (consumption). A library may perhaps serve as an example of a very cold system outside forestry, keeping information on stock just in case it might be useful to someone some day.

A wood-supply strategy at the wood-supply level will generally represent a balance between the absolutely hot and the absolutely cold extreme, since neither is practically viable. The problem is to find the appropriate balance point. Evidently, Georgia, Maine, and Sweden have all arrived at different solutions to this problem.

Thus, we can conclude that an inventory is the accumulated difference between receipts and consumption (supply and drain, inflow and outflow), and that increasing precision in the receipts-to-consumption relationship will lead to a decreasing size of the wood inventory. If this conclusion is correct, then we would

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expect to find a correlation between high levels of wood inventory and low levels of wood-flow precision, and vice versa.

The data appear to confirm the conclusion that the levels of wood inventory and precision are related, as evidenced by Figure 8. The match between monthly receipts and monthly consumption of pulpwood is much closer in Georgia than in Maine, which would account for the higher levels of wood inventory in the latter state. The magnitude of the mismatches has decreased in both regions, particularly in Maine, which experienced a much higher degree of mismatch than Georgia during the beginning of the period (Figure 9).

The preponderantly negative values for Maine during the last third of the period indicate a consistent undersupply of wood. Herein lies the reason for the decrease in Maine inventory levels, which is evident in Figure 2. Lack of precision, as it has been defined here, need thus not necessarily be the result of a lack of control over the supply.

The seasonal variation in receipts-to-consumption relationship has decreased in Georgia during the period. During the period 1967-71, there was a consistent inventory build-up in December and an inventory drain in August, both amounting to about 7 percent (Figure 10). This pattern is much less pronounced during the period 1985-89, although there are indications that an inventory build-up occurs during the fall and winter and a drain during the early summer months (Figure 11). The magnitude of the mismatches has clearly been decreased to the current level within a range of plus or minus three percent.
The receipts-to-consumption relationship in Maine varies in a decidedly seasonal pattern, with a much larger magnitude than in Georgia. During the period 1967-71 (Figure 12), receipts during the spring months were about 35 percent less than the consumption, while receipts during July and August brought an overrun of about 40 percent. The end of the year again brought undersupply, this time by about 20 percent.

This pattern has undergone a marked change (Figure 13). Undersupply during the spring has been reduced to about 30 percent in April and 15 percent in May, and is fairly even during the remainder of the year. The undersupply during the summer can probably be attributed to the general reduction in inventory level which has occurred in Maine during the last 10 years.

The evidence from the wood-supply systems of Georgia and Maine seems to suggest that the wood-inventory level depends on the level of precision in the receipts-to-consumption relationship. This implies that the choice of tempo strategy in a wood-supply system is strongly associated with willingness or ability to maintain a certain level of supply-rate precision. The higher the level of wood-flow precision that can be achieved, the lower the necessary level of wood inventory.

This conclusion makes it interesting to study the possibilities and difficulties involved in achieving a high supply-rate precision. It seems likely that herein lies the explanation of the different choices of balance point in the three wood-supply systems, as well as in the changes in balance point that have occurred since 1967. A study of the precision problem would most likely also yield knowledge which could support decisions concerning wood-supply strategies.

Please note that the figures for Maine are drawn to a different scale than the ones for Georgia.

The term 'supply' will sometimes be used as a synonym for 'receipts'. The term 'supply-rate precision' should be interpreted as having the same meaning as 'precision in the receipts-to-supply relationship'.

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The relationship of concern is between consumption and receipts of wood. In the following, we shall first examine the possibilities of controlling the rate of consumption, and then the rate of receipts.
Figure 8. Monthly relationship between receipts and consumption of pulpwood in Georgia and Maine during the period March, 1966 through December, 1989, percent.

Figure 9. Variation in the monthly relationship between receipts and consumption of pulpwood in Georgia and Maine during the period March, 1966 through December, 1989, percent, measured as within-year standard deviation.

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Figure 10. Seasonal relationship between monthly receipts and consumption of pulpwood in Georgia 1967-1971, percent.

Figure 11. Seasonal relationship between monthly receipts and consumption of pulpwood in Georgia 1985-1989, percent.

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Figure 12. Seasonal relationship between monthly receipts and consumption of pulpwood in Maine 1967-1971, percent.

Figure 13. Seasonal relationship between monthly receipts and consumption of pulpwood in Maine 1985-1989, percent.

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1.4. RHYTHM OF CONSUMPTION: SMALL DIFFERENCES

Typically, it is beyond the powers of a wood-supply system to control the rate of pulpwood consumption, as it is dictated by external factors, such as the market for pulp and paper products, the availability of raw material from alternative sources and/or in alternative forms, and the technical behavior of the pulp mill. Normally, the rate of consumption is a given, to which the wood-supply system must adapt its supply rate of wood.

It is therefore interesting to observe the variation in the rate of consumption, as supply must match this externally given rate if a high degree of precision in the receipts-to-consumption relationship is to be realized. It is also interesting to study the consumption rate to find out if it contributes to the different choices of balance point in the three contrasted regions.

The rate of pulpwood consumption shows a very similar pattern in Georgia and in Maine in terms of range of variation (Figure 14), as well as the amount of variation (Figure 15). It is notable that no particular changes appear to have occurred during the period.

An examination of the seasonal pattern of consumption supports the conclusions that there is little difference between Georgia and Maine, and that only small changes have occurred since 1967 (Figure 16 and Figure 17 for Georgia, Figure 18 and Figure 19 for Maine).

A questionnaire to the Swedish pulpwood industry (Rådström, 1987, 1988) reveals some seasonal variation in the demand for solid pulpwood. In Southern Sweden, the range in average monthly consumption, measured in relation to yearly total consumption, is from 7.5 to 8.5 percent, and in Northern Sweden from 7.5 to 9 percent. The only region that differs from the pattern of Georgia and Maine is Central Sweden, which shows
a range from 6.5 to 9.5 percent (Rådström, 1987, Appendix 6). This variation in the demand for solid pulpwood is caused by seasonal variation in the receipts of imported wood and, to some extent, by the receipts of sawmill residue (Rådström, 1988, p. 30).

The high degree of similarity in the pattern of pulpwood consumption between different regions can probably be attributed to the fact that pulping is a process which occurs in a highly controlled and standardized production environment. The production environment in a pulpmill is insensitive to changes in the external physical environment, so the rate of consumption of pulpmills therefore differs little between different regions of the world.

The substantial similarities in rhythm of pulpwood consumption between the regions suggest that the reason behind the different choices of strategy must be found elsewhere.

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Figure 14. Monthly consumption of pulpwood in Georgia and Maine during the period March, 1966 through December, 1989, percent of yearly total consumption.

Figure 15. Variation in the monthly consumption of pulpwood in Georgia and Maine during the period March, 1966 through December, 1989, percent, measured as within-year coefficient of variation.

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Figure 16. Seasonal pattern of monthly pulpwood consumption in Georgia 1967-1971, percent of yearly total consumption.

Figure 17. Seasonal pattern of monthly pulpwood consumption in Georgia 1985-1989, percent of yearly total consumption.

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Figure 18. Seasonal pattern of monthly pulpwood consumption in Maine 1967-1971, percent of yearly total consumption.

Figure 19. Seasonal pattern of monthly pulpwood consumption in Maine 1985-1989, percent of yearly total consumption.

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1.5. RHYTHM OF SUPPLY: SUBSTANTIAL DIFFERENCES

The small differences in the pulpwood supply indicate that the different tempo strategies are due to differences on the supply side. As one would expect, given the relatively constant rhythm of consumption, the rhythm of receipts (Figure 20) shows a pattern which is similar to that of the receipts-to-consumption relationship. The difference between the two regions is striking.

In Georgia, the pattern of receipts is about the same throughout the period, varying for the most part within a range of one to two percent. In Maine, the rhythm of receipts changes dramatically from an initial pattern with larger, slower fluctuations to a pattern with smaller and more rapid fluctuations, mostly within the range of three percent.

A study of the variation in the rhythm of receipts confirms these indications (Figure 21). The level of variation has remained about the same in Georgia, whereas it has been greatly reduced in Maine from an initially very high level down to a level of about twice that of Georgia.

The pattern of receipts in Georgia showed a slightly seasonal rhythm during the period 1967-71 (Figure 22), with more wood being received during the spring, particularly in March, and the late fall, and less wood during the late summer and early fall. In the period 1985-89 (Figure 23), the seasonal pattern is less evident, but still present. The period of low receipts during the late summer and early fall has disappeared, but more wood is still received during the spring and late fall.

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The rhythm of receipts has changed in Maine from a very pronounced seasonal pattern during the period 1967-71 (Figure 24) to a much smoother pattern during the period 1985-89 (Figure 25), similar to the pattern in the receipts-to-consumption relationship. During the first period, the very low receipts in the spring were compensated by very high receipts during the summer and early fall, whereas during the later period, the receipts in the spring are not as low and are compensated by higher receipts during the winter.

Thus, the rhythm of supply has changed in both regions towards a lesser degree of seasonality. In Maine, the initially highly variable pattern has become increasingly smoother, but even after this change, its level of variation is about twice that of Georgia, which has maintained a comparatively low and stable level of variation throughout the period.

\[\text{footnote}{\text{a}\text{ Please observe that the figures representing Georgia and Maine are drawn to different scales.}}\]

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Figure 20. Monthly receipts of pulpwood in Georgia and Maine during the period March, 1966 through December, 1989, percent of yearly total receipts.

Figure 21. Variation in the monthly receipts of pulpwood in Georgia and Maine during the period March, 1966 through December, 1989, percent, measured as within-year coefficient of variation.

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Figure 22. Seasonal pattern of monthly pulpwood receipts in Georgia 1967-1971, percent of yearly total receipts.

Figure 23. Seasonal pattern of monthly pulpwood receipts in Georgia 1985-1989, percent of yearly total receipts.

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Figure 24. Seasonal pattern of monthly pulpwood receipts in Maine 1967-1971, percent of yearly total receipts.

Figure 25. Seasonal pattern of monthly pulpwood receipts in Maine 1985-1989, percent of yearly total receipts.

Chapter 4. Tempo in Wood-Supply Systems
1.6. CONCLUSION

The differences in wood-flow pattern between the contrasted wood-supply systems are striking. The system in Sweden contains ten times more wood than the one in Georgia. The system of Maine assumes a position in the middle with three times the wood inventory of Georgia.

The key to these differences appears to lie in the different rates of wood-flow precision in the systems. The wood-supply system of Maine is unable or unwilling to maintain the high rate of precision found in Georgia and must therefore keep larger inventories to insure that the mills have access to wood at all times.

The difference in precision cannot be attributed to different patterns of pulpwood supply. On the contrary, the rhythm of supply is very similar in Georgia and Maine. The difference in precision rate is due to differences in the willingness or ability in the two systems to make the supply of wood match consumption.

The systems have converged during the period of study. The wood-supply systems in Maine has approached the system of Georgia in inventory size and supply precision, and the inventory reduction in Sweden suggests a similar development. The changes in Maine appear to have been produced by a drastic reduction in the seasonal dependency of the system.

There are also indications that the trend of convergence has levelled out. The wood-supply system of Maine has stabilized at levels of inventory and precision which are much smaller than they were in the late 1960's but still clearly exceed those which exist in Georgia.

The following chapter will examine possible reasons for the differences in wood inventory and supply precision.

Chapter 4. Tempo in Wood-Supply Systems
CHAPTER 5. INVENTORY OR PRECISION:

A MATTER OF TIME

The wood-supply systems of Georgia, Maine, and Sweden respond to similar patterns of consumption and face similar commercial pressures. Yet, they operate with very different levels of wood inventory and supply precision. The differences are much smaller in the late 1980's than they were in the mid-1960's - at least in absolute terms, but are still evident. What could the reasons be for these contrasts?

There seems to be no inherent benefit to having a low level of supply precision. An inventory of wood for seasoning purposes can be maintained even at the highest level of precision, but low precision produces inventories just as an undesirable by-product, increasing costs without increasing benefits to the wood-supply system. If cost or physical possibility did not present any constraints, the contrasted wood-supply systems would all very likely select the supply pattern which yielded the highest level of precision.

Only in one case does low precision have a positive value: when inventories are reduced. The substantial inventory reduction in Maine occurred due to low precision. Thus, low precision need not always be the result of unwillingness or inability to maintain high precision.

We shall assume that all the systems share the objective of maintaining a high level of wood-flow precision, i.e. of matching supply with consumption. It follows that the contrasted systems must differ in their willingness or ability to maintain a high level of precision. This appears to be the core of the problem, and we shall therefore examine the precision concept in somewhat greater detail.
1. **THE PERIOD OF PRECISION: A KEY CONCEPT**

A high precision occurs when supply matches consumption, i.e., when the inflow per unit of time equals the outflow per the same unit of time. The length of the unit of time is of crucial importance here. All that is required for the precision to be perfect is that (accumulated) supply equals (accumulated) consumption within the chosen time unit. The longer the time unit, the larger the tolerance for short-term mismatches. As long as the accumulated values equal each other after a certain period of time and the mill does not run out of wood, differences in the rate of accumulation are of no consequence. A strict definition of precision must therefore make reference to the time period of measurement.

The requirement that the mill not run out of wood puts a heavy constraint on the freedom of supply to deviate from consumption. The longer the precision period, the greater the risk that a short-term mismatch will lead to a wood shortage. If a constant level of risk is to be maintained, one would expect that the size of the wood inventory must be increased with the length of the precision period.

This suggests a possible explanation for the differences in tempo in the contrasted systems. It might be so that the systems differ in the precision period for which they are managed. If, for example, a system is managed for a precision period of a day, the inventory cushion need not be larger than a day at the most. If the precision period is a month, a considerably larger inventory cushion is necessary to ensure that the mill does not run out of wood, should consumption happen to accumulate much faster than supply in the beginning of the period. This suggests the following relationship:
Given a certain level of risk to run out of wood, the required size of wood inventory decreases as the period of precision for which a wood supply system is managed decreases.

The larger the size of the wood inventory, the greater the permissible length of the period of precision.

In other words: the larger the size of the wood inventory, the weaker the temporal link between supply and consumption (the longer the supply can be allowed to differ from consumption without the mill running out of wood)\(^1\).

If this hypothesis holds, we would expect to find the wood-supply system of Sweden to be managed at a much lower level of time resolution than that of the South, given the much larger inventories of wood kept in Sweden. There are many indications that such is indeed the case.

2. THE MANAGEMENT OF PRECISION: A MATTER OF RESOLUTION

In Sweden, wood is sold at roadside in the form of logs. Regional roadside prices for sawlogs and pulpwood are centrally negotiated on a yearly basis (Lönnstedt, 1977). Rådström (1988, p.39) bluntly remarks that "within a wood year, demand does not influence supply". In the South, wood is sold as stumpage and prices negotiated on a tract-by-tract basis. The difference in resolution in the wood markets is striking.

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\(^1\) It is not necessarily so that the inventory size must increase in proportion to the period of precision. It seems likely that supply and consumption will balance each other at a "natural" period of precision, unless a special disturbance occurs. The length of this "inherent" period of precision probably depends on the pattern of changes in wood consumption and in supply difficulty.

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In the South, forest harvesting is coordinated by procurement organizations which typically are built up around each mill. In Sweden, the coordinating agency is the conservancy, responsible for land management and harvesting. Southern pulpmills issue wood orders at the beginning of each week. These are followed by correction orders later in the week to ensure that the supplied amount of wood equals the weekly target.

The harvesting of wood in Sweden appears to be governed less by the needs of the wood consumers and more by the internal needs of the conservancies. Harvesting and transportation are planned separately. Judging from the literature, it is unclear to what extent the actual rate of wood consumption (as opposed to the planned rate) influences the coordination of the transport function. The link between wood consumption and harvest planning appears to be very weak, while the integration between silvicultural and harvest planning is very strong\(^2\) (Ericson and Westerling, 1981). It is notable that Ericson and Westerling, in their state-of-the-art report on Swedish forestry planning, hardly ever mention actual wood consumption as a factor influencing harvest planning. The period of precision in the wood-flow management in Sweden appears to be several months long, if not longer.

Thus, the Southern wood-supply system is managed at a substantially shorter period of precision than the Swedish one. This supports the hypothesis that that low resolution and large inventories go together.

The relationship between period of management and inventory size can be regarded from two different perspectives, as indicated above. On the one hand, one might argue that the Swedish wood-supply system is forced to accept large and costly inventories of wood, due to a low period of precision. On the other hand, one might argue that the large size of the wood inventories allows the wood-supply system the benefit of

\(^2\) The integration between silviculture and harvesting (as far as logs delivered at roadside) coincides with the Swedish understanding of the concept of forestry. Traditional institutional boundaries strongly influence the way that the wood-supply system is managed.

**Chapter 5. Inventory or Precision: A Matter of Time**
being managed at a long period of precision. Clearly, the perception of what is the optimal period of precision differs between the wood-supply systems of the South and Sweden.

In the following, the advantages and disadvantages of a long precision period will be discussed. First, historical reasons for the difference in precision period will be explored. If there is any merit to the hypothesis that wood-supply systems evolve in interaction with their environment, an institutional approach should yield important insight. Current costs and benefits of different precision periods will also be investigated.

3. INVENTORY OR PRECISION? - REASONS OF THE PAST

The Swedish wood-supply system of old offered little choice but to accept a long period of precision.

There were strong seasonal constraints: labor was available mostly in the winter when agriculture was inactive due to frost and snow; snow was essential to reduce friction so that the wood could be transported out of the forest and down to the river landing; the spring flood had to be used in order to bring the logs through the small rivers down to the mainstream. Thus, the means of transportation was very much a batch-type system, where the size of the batch corresponded to one year of logging.

The cost of carrying inventory was low. Inventory space was practically unlimited, whether in the forest, at river landing, or in the lake where logs were stored at the mill. Inventory space was also cheap, since little preparation or maintenance was necessary. The wood experienced little deterioration when stored on land during the winter, or during the summer when immersed in water. In many cases, storage of wood

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could not be avoided: in the forest, after debarking, to increase the buoyancy of the wood, and at the mill site, in order to season the wood for the sulphite process of pulping.

Transportation and exchange of people were slow. The seasonal character of the river drive - the unidirectional artery connecting the forest with the mill - made it pointless to attempt to control the pace of logging to match the consumption of the mill, since the time lag between harvest and consumption often exceeded a year. Logging camps presented a fixed cost which discouraged anything but the highest utilization of harvesting resources. No alternative occupation was available in the remote forests around the camps. A logging manager would have found it impossible to know the current needs of the mill, due to the poor status of communications. The Swedish wood market seems well adapted to these conditions.

Thus, very strong forces prompted the Swedish system to adopt a long precision period. Many decades of no alternatives made the wood-supply system adjust very firmly to operating with large inventories, and fostered a perception that this style was superior to any other style.

The situation in Maine was in many ways similar to that in Sweden, with logging camps and river drive being prominent style features.

The situation was different in the South. The Southern pulpwood-supply system evolved around the railroad, while the generally ice-free rivers were used for barge transportation of wood (rather than for driving of loose logs). The abundance of railroads made it possible to operate with a short period of precision. The size of the delivered batch was small (compared to a northern river). Train movements were not affected by seasonal changes, and could easily be controlled using the telegraph lines which lined the railroads. The railroad and telegraph connections made it possible for the railroad accumulation yards to exchange people

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and information with the mills on a weekly or even daily basis. The railyards could serve as well-informed bases for wood-flow control in a way that was denied to the Swedish river landings.

Southern logging had no direct seasonal restrictions, but was very sensitive to rain, which would make the forest floor impassable for the small trucks that brought wood from stump to railyard. The disturbance of rainfall was short-term and local, however - not long-term and regional like the seasonal constraints of the north. The interspersion of farms and woods, and the dense road network, made logging camps unnecessary and allowed the woods labor to seek other occupation if logging was halted for wood-flow reasons. A slight drawback with this proximity between logging and agriculture was that labor would be in short supply when needs in agriculture were high.

The choice of harvesting technology limited the possibilities of keeping a large inventory cushion in the South. Trucks were loaded by hand at the stump and off-loaded by hand at rail landings, often by the same people. Railroad sidings would often serve as rail landings, which limited inventory capacity to the the rack cars and the ground adjacent to the siding. The land woodyards and log ponds used by the mills were of limited capacity, whereas the rivers and lakes used in the north were more limitless. The rapid deterioration of wood in storage through a loss of by-products, staining, insect infestation, and rot provided a strong incentive to limit the size of inventories.

A tradition of hot logging evolved. Company-independent loggers were engaged on a short-term basis by cut-and-haul contracts with payment upon delivery to a railyard. The wood flow was controlled on a weekly basis by engaging more loggers to increase supply and by imposing delivery quotas to have it decrease.

Clearly, the Southern and Swedish wood-supply systems have evolved out of very different conditions. It was feasible in the South to maintain a short precision period, and the technology used was not suitable for

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keeping large inventory cushions. Seasonal constraints and poor communications in Sweden made it impossible to maintain a short precision period, while the technology used made it feasible to maintain large wood inventories.

Keeping in mind the changes in inventory size and precision which have occurred since the mid-1960’s, the mode of operation which evolved during the long and fairly technologically stable period before mechanization bears a striking resemblance to the way that the systems are managed today.

This resemblance is somewhat curious. The changes in technology during the last three decades have removed many of the constraints on wood-flow management that forced the Swedish wood-supply system to adopt a long precision period. Intensive roadbuilding, a change from river drive to transportation by truck and rail, the mechanization of logging operations, and the ability to transmit information by telephone and radio have given the system new possibilities of managing wood-flow for a shorter period of precision. Some inventory reduction has indeed occurred, as shown in Figure 2, but inventories are still ten times as great as in the South, amounting to a cushion of about 100 days of consumption. It is also curious that the wood-supply system of Maine maintains a cushion of only 30 days of consumption, although it is faced with physiographic constraints similar to those in Sweden.

This suggests that there might be some reason other than tradition and inertia as to why the wood-supply system of Sweden has not taken advantage of the new technical possibilities to reduce the period of precision. One is prompted to ask: Are there any benefits inherent in a long precision period?

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4. THE FREEDOM TO PRODUCE: A MATTER OF INVENTORY CUSHION?

The wood-supply policies of Southern pulpwood purchasers strongly favor a tight management of the wood flow. The wood-supply system is adjusted to being managed at a short period of precision. The inventory cushion is small, and so is the surge capacity of the inventory facilities. As a consequence, the pattern of supply must closely mimic that of consumption.

If the rate of consumption is stable and the difficulty of supply is stable, this problem can easily be overcome. Conditions are seldom stable, however. The rate of wood consumption varies: partly because of shifts in the product choice of the mill, partly because the mill may experience technical difficulties. The rate of supply difficulty also varies. Rainfall will make it impossible to log many tracts, either for physical or for environmental reasons. Logging tracts differ in many respects which affect the difficulty of work, such as the species, size, and density of the trees, the distance to road, the distance to the mill or mills supplied, the product mix-potential and the type of harvest. Thus, the rate of consumption is not stable, and neither is the flow of wood generated by a constant logging capacity.

The rate of consumption does not always change in the same direction as the difficulty of logging. Procurement foresters will generally claim that extended periods of rainfall typically coincide with periods when mills set new production records. Loggers tend to argue that the combination of easy logging and production problems in the mill is a much more common occurrence.

The virtual absence of an inventory cushion in the Southern wood-supply system means that the rate of supply must be controlled so that it mimics closely that of consumption. In principle, there are four different ways that this can be done:

Chapter 5. Inventory or Precision: A Matter of Time
- **Tract allocation** (changing the output by changing the work difficulty). The difference in characteristics between tracts can be utilized to regulate the flow of wood. When a high flow is needed, tract systems are allocated to tracts which are close to the mill and have a high density of large trees. A low flow can be achieved by sending the tract systems to remote tracts with small and scattered trees. Tract allocation as a means for short-term regulation requires that the tract systems have a low moving cost and are flexible with regard to tract characteristics. An efficient mechanism for tract allocation is also required;

- **Capacity sizing** (reducing the amount of output by having production capacity move in or out of the system). The flow from a wood-supply system can be changed by varying its capacity. This strategy requires that the capacity has an alternative value for use outside the wood-supply system, and that the institutional resistance to capacity moving across the system boundary is not too great. Commonly applied before mechanization when forestry shared labor with agriculture, capacity sizing has tended to become less viable due to the increasing specialization of equipment and labor;

- **Work intensity** (changing the output per hour worked at a constant difficulty of work). A constant nominal production capacity working constant hours can generate different rates of wood flow depending on how hard it works;

- **Capacity utilization** (changing the number of hours worked by keeping capacity more or less idle). The rate of wood flow can be changed by changing the utilization of available capacity. Lesser utilization will result in a lesser flow and more idle capacity.

Chapter 5. Inventory or Precision: A Matter of Time
As the Southern wood-supply system operates with a small period of precision, and does not tolerate large inventory surges, it must rely on some combination of these four levers to ensure that the rate of wood supply matches that of consumption.

There is little evidence available to indicate the extent to which the different levers are relied upon. Given the specialization and indefatigability of mechanized logging equipment, one must assume that it is difficult to manipulate capacity size and work intensity. If this is true, then the Southern wood-supply system is confined to manipulating tract allocation and capacity utilization to regulate the wood flow.

There is some evidence that the Southern wood-supply system does indeed contain idle capacity due to a low degree of utilization. It is often claimed that there is an overcapacity in the South. Curtin (1988, p.21) claims that "most areas in the United States enjoy a significant surplus of harvesting capacity", and Stuart (1990) concurs.

Corwin (1987) presents longitudinal production data from five Southern feller-buncher/grapple skidder tract systems used for thinning and pre-logging. The weekly production of these systems shows such a magnitude of variation that it seems very unlikely that it is all due to differences in logging difficulty. A picture of tract systems ranging in weekly utilization from 100 percent down to 25 percent emerges from this work. Corwin selected the tract systems either as being typical or being particularly successful. Although they are not representative in a statistical sense, there seems to be good reason to believe that they do represent a typical picture of the way in which the capacity of many Southern tract systems is utilized.
The 1987 survey of Southern logging contractors (Watson, et al., 1989) shows that the most productive 1/3 of the contractors produce 4/5 of the wood. There is reason to believe that many (but far from all) of the remaining 2/3 of the contractors are being held back from fully utilizing their capacity.

If the capacity of the Southern wood-supply system is dimensioned so that it can yield an adequate flow of wood in the most strained situation possible (a situation when a high flow requirement coincides with a high logging difficulty), then part of this capacity will have to be idle at all times other than peak strain. The evidence is not conclusive, but sufficiently strong to indicate that the short period of precision and unwillingness of Southern wood consumers to allow inventories to surge does lead to an inventory of capacity instead of an inventory of wood.

The situation is different in the Swedish wood-supply system, which is managed at a long precision period and in which large inventories are allowed to surge. Fluctuations in wood consumption and logging difficulty are absorbed by wood inventories instead of by capacity utilization. Consequently, a consistently high utilization of capacity can be maintained. Ericson and Westerling (1981, p.24) mention full utilization of people and equipment as one of the goals of Swedish forestry planning.

5. CONCLUSION

The pulpwood data explored in Chapter Three showed that the Swedish wood-supply system keeps an inventory cushion about ten times the size of the inventory in the South.
Without disputing the fact that this is a very large cushion, it can still be argued that a large inventory brings one important advantage: the freedom of the capacity in the system (men and machines) to work consistently at capacity without being disturbed by surges in wood consumption. There are strong indications that the Swedish wood-supply system is buying the opportunity to keep its resources fully utilized by maintaining a long period of wood-flow precision and a large inventory, which is allowed to surge. The strong emphasis in Sweden on capacity utilization may be part of the reason why the possibilities of wood-flow control brought by new technology has not been utilized to the same extent as in Maine.

Conversely, the Southern wood-supply system appears to buy its low level of inventory by keeping idle capacity to absorb surges in wood consumption and changes in logging difficulty. In other words:

*The Southern wood-supply system inventories capacity, whereas the Swedish wood-supply system inventories wood.*

This suggests that there might be a trade-off between the two. Keeping wood in inventory may be the key to a high capacity utilization and keeping capacity idle may be necessary to avoid wood inventories.

This hypothesis will be explored in the following chapter.

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Chapter 5. Inventory or Precision: A Matter of Time
CHAPTER 6.  CAPACITY OR WOOD? A PROBLEM OF ALLOCATING IDLE RESOURCES

The wood-supply system of Sweden maintains an inventory cushion which is about ten times as large as that of the Southern US. One reason for this is surely that the Swedish system faces a set of seasonal constraints which are absent in the South. Some tracts are only available during the winter, many roads are not trafficable during the spring thaw, and many silvicultural operations can only be performed during a few months in the summer. The Swedish inventories seem very large even when these difficulties are considered. The wood-supply system in Maine, which is facing many of the same physiographic and climatic constraints, has reduced its inventory cushion to one-third of that in Sweden.

Sweden is deriving one major benefit from its large inventory cushion: it allows the wood-supply system the freedom to fully utilize its production capacity. The Southern wood-supply system, on the other hand, must produce at a rate which closely mimics wood consumption, due to the limited size and surge capacity of the wood inventories. When changes occur in the rate of wood consumption at a mill or in the difficulty of logging, the capacity of the system must somehow accommodate. There are strong indications that this accommodation is done, at least in part, by changes in the utilization of the capacity. Keeping capacity idle carries a cost, however, and this is the cost that the Swedish wood-supply system avoids by maintaining a large inventory cushion.

Having advanced this far in the exploration of style differences, we must expand our definition of 'inventory'. The commonly used definition of 'inventory' as stock or material at hand makes it difficult to perceive this very fundamental style difference because of its narrowness. From now on, we shall define 'inventory' as "an idle resource" (Tersine, 1988, p.3). Alternatively, we may think of inventory as idle asset.
Briefly put: Sweden inventories wood, the South inventories capacity.

In the following, the contrast between the wood-supply systems will be further explored. A powerful analytical perspective is offered by the isoquant-isocost model typically found in the theory of microeconomics. In the following, this model will be used to conceptualize and further explore the problem. A strict exploration, let alone an attempt at quantification, is beyond the scope of this dissertation. It is felt, however, that even a cursory and tentative treatment can be of some use, as it can contribute to the way that the problem is identified and formulated.

1. A MODEL FOR ANALYSIS OF TWO-FACTOR INPUT

The two contrasted wood-supply systems have adopted different solutions to the problem of allocating idle resources to cope with variations in wood consumption and supply difficulty. There appear to be two major alternatives: production capacity can be kept idle or wood can be kept idle (in inventory). It also appears that these two alternatives can be substituted for each other.

In microeconomics, an isoquant map with an isocost line is often used as a way to describe the problem of finding the optimal mix of two substitutable inputs (see Figure 26). In the following, we shall use this model to conceptualize our problem of exploring the choice between idle capacity and wood inventory. Similar approaches have been used in the context of forestry by Duerr (1960, p.86), in a textbook example, to analyze the choice between two types of labor input into an operation of crop-tree release, and by Sundberg (1979) to analyze the problem of capital allocation between labor and capital in forestry.

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This way of addressing the problem involves several assumptions. The following are of particular importance to our discussion:

- It is possible to divide the problem into a technological and an economical realm. "The isocost curve shows the market opportunities that a producer faces, whereas in contrast the isoquant shows the technological opportunities available to the producer." (Sher and Pinola, 1986, p.48).

- The production process is characterized by a constant or decreasing marginal rate of technical substitution (MRTS). The latter is commonly assumed and makes the isoquant curve convex to the origin as shown. It seems very likely that a decreasing MRTS applies in our case. Marginal changes in very large wood inventories would probably make no difference to the utilization of the
production capacity. The larger the amount of capacity standing by, the lesser would be the effect of a marginal change in idle capacity on the amount of wood inventoried:

Each point on the isoquant curve represents a combination of input factors that yields the same output. The output in our case would be a certain volume of wood supplied over a period of time to a set of wood consumers. One would have to add the requirement that no consumer must ever be allowed to run out of wood;

Only efficient points of production are represented by the curve. An inefficient point of production uses more of at least one input but not less of any other to produce the same quantity as another production point (Sher and Pinola, 1986, p.28). The definition of (in)efficiency without reference to the relative cost of the inputs is necessary to maintain the distinction between technology and economics;

All production points represented by the isoquant curve are feasible. Strictly speaking, this requires that both input factors are infinitely divisible in the interval of the curve. The curve shown should be regarded as an archetypal example showing an unrealistic special case. The curve need not be particularly smooth, and it need not be continuous;

Only two input factors are variable. This is a reasonable assumption in the short run. In the long run, our problem involves a third input: investments in making the wood-supply system less sensitive to changes in its production environment. The change from river drive to transportation by trucks eliminated much of the seasonal dependence in the northern wood-supply systems, which seems to have decreased the amount of idle resources. Investments in all-weather roads would have a similar effect. In a more general sense, the third input is one of technological change.

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In short, the model attempts to depict the technical possibilities (isouquant curve) and the economic factors influencing the choice between them (isocost curve). The economic choice is represented by the point of tangency of the two curves which is closest to the origin. Given a fixed pool of technology, the economic choice is determined by the relative cost of the input factors, i.e. the slope of the isocost curve.

The distinction between technology and economics is difficult to uphold unless the model is seen as strictly static. Wood-supply technology can change by reducing the cost per unit of input instead of the number of units used, however. The location of an inventory may, for example, be moved from woodyard to roadside, where less money has been invested in it and the capital cost per unit of wood therefore is less. Wood which is sprayed by water when in inventory has a much slower pace of deterioration than dry wood. A shift in technology to spraying would cause the cost per unit of wood in inventory to drop.

Another problem is that the isouquant curve is not known, except at points close to the ones currently used. The wood-supply systems have evolved during many decades to reach their current production points, and drastically different production points have not been realized. While it is possible to imagine the kind of technology that would be used at such points, it does not exist other than in the world of imagination.

Keeping these reservations in mind, the model remains a powerful analytical tool. It allows the analysis of wood-supply systems in terms of equilibrium of production. This approach will be taken in the following section.

Chapter 6. Capacity or Wood? A Problem of Allocating Idle Resources
2. THE WOOD VERSUS CAPACITY PROBLEM

A wood-supply system must somehow accommodate changes in the rate of wood consumption and in the difficulty of wood-supply work. The solution to the accommodation problem appears to call for resources being idle somewhere in the system. Two main alternatives seem to exist: either production capacity is kept idle or wood is kept idle. The choice between the alternatives is governed by their relative cost.

There is conclusive evidence that the Swedish wood-supply system keeps more wood idle than the Southern one. There are strong indications that the Southern system keeps more capacity idle than the Swedish system does. Thus, the Swedish system is producing at a point at the upper left of Figure 26, while the Southern system is in the lower right corner.

If it is true that wood-supply systems evolve toward a production point which gives the lowest cost of idle resources, we would expect the relative cost between wood inventory and capacity inventory to be very different in Sweden and in the South. It ought to be cheaper to inventory wood than capacity in Sweden and to inventory capacity rather than wood in the South.

It is important to observe that it is the relative cost of the substitutes which are available to a wood-supply system that is important to our analysis. It may for example appear, from a Southern perspective, that the cost of inventorying wood in Sweden must be very high, considering the much higher wood prices and the higher rate of interest in Sweden. Consequently, one might think, Sweden ought to inventory less wood.

The Swedish wood-supply system is affected by the relationship between the wood-inventory cost and the cost of substitutes. The rate of interest affects all investments in Sweden, and there are no indications that
the price of wood in Sweden is high *in comparison with prices for other items in the Swedish economy*. Thus, Southern wood-prices and interest rates are irrelevant to the decision situation in Sweden. The relevant comparison pertains to the costs of substitutes *within an economy*. The comparison between inventory costs in Sweden and the South, however interesting, is not relevant to the problem of finding the best point of production in the contrasted wood-supply systems. Each region would have its own isoquant-isocost map.

It is difficult to establish whether the relative costs faced by the two wood-supply systems actually support their point of production.

Historical data are not available in a form that fits our formulation of the problem. This may indicate that the problem has not been perceived as important, or that it simply has not been identified as a problem. The emphasis on wood in the South and production capacity in Sweden was established long before the process of mechanization began, and has not been fundamentally altered by it. While historical indications of the relative cost could surely be constructed, attempts to estimate the relative cost would probably be more useful if directed toward the future.

Even future evidence will not be easy to find, however, as the costs are not easy to define in their full extent. Some costs of wood-inventories, such as the cost of capital and the cost of handling and facilities are easy to identify, if not necessarily to measure. The costs of wood deterioration are more elusive, partly because they don't occur at the same time and place as their causes and partly because the cause-effect relationship is complex.

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1 Pulkki (1990) gives an overview for northern conditions of the wood-quality effects on pulping.
Some costs of idle production capacity are also difficult to identify. The direct cost is reflected in the price for the service of that capacity, at least in theory. In actuality, many owners of logging capacity in the South tend to operate with small financial margins. The smaller producers in the South, constituting two-thirds of the total number of producers, produce only one-fifth of the wood. The intermittent production and financial weakness of many of these producers makes it difficult for them to keep a stable crew, to invest in safety equipment and training, to adapt logging practices which minimize negative effects on soil and water, to maintain the image of a professional businessman. The inability to produce consistently at capacity produces a strong incentive against large investments in new equipment - a problem also experienced by large producers.

Some of the costs of idle capacity (over-capacity) thus show up in other forms than the direct cost of logging services. Rates for workers' compensation insurance are escalating (Wilson, 1989), while liability insurance rates are increasing. Best management practices and other types of logging regulation are introduced to reduce negative environmental impacts of poor logging, but also for reasons of poor public image.

Many costs are inadequately accounted for. Interestingly, there seems to be a mirror-image bias in the systems of accountability in the Swedish and Southern wood-supply systems. The Swedish system has a well-developed system for planning and follow-up of equipment use. Machine utilization is generally planned and followed up on a daily basis: the latter increasingly by means of an on-board computer (Johansson, 1986).

Inventories of wood, on the other hand, generally occur at the interfaces between different business domains or organizations. The structure of these tends to be the same whether it is internal or external to a large land-holding forest company. The roadside inventory in Sweden separates the concervancy from the transportation department, which in turn is separated from the wood-room by the woodyard inventory. The

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use of production capacity is optimized within each one of these institutional domains, and inventories tend to be residuals of this planning.

The Southern system, in contrast, has a well-developed system for planning and control of wood flow. The wood is scaled for weight when it passes through the gate to the purchasing point, and inventory status is reported at least weekly from all inventory points in the procurement system (state-of-the-art technology uses on-line computer systems for constant communication). The flow of wood into these inventories is controlled by weekly wood orders. Delivery quotas are typically used to regulate the supply, and the resolution in this control can in rare cases be as high as a single truck load per day (Stuart, 1990).

The ability to account for wood in inventory is dependent on its location in relation to the scaling point. In the South, the wood is not inventoried until it has been scaled (for weight) at a purchasing point, as the loggers only store marginal quantities of wood. In Sweden, the first inventory point is at an often remote roadside, to which the wood arrives weeks or months before the wood is scaled (for volume) at the mill gate. This makes it difficult for the wood-flow planner in Sweden to know the size of the roadside inventory.

Rådström and Edlund (1989, pp.92-93) report that the data used to coordinate hauling from roadside inventories to the mills tend to be one and a half to two weeks old and fraught with considerable uncertainty. This is attributed to the high time consumption of inventory estimation at roadside and the tepid interest of the concervancy foremen for this task.

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2 In some instances, it may be appropriate to regard mature trees as inventory "on the stump". Clearly, one would like to inventory all wood "on the stump" if possible, as no harvesting cost has yet been invested, there is no deterioration, and growth may occur. This type of inventory can hardly be regarded as an idle resource, however, and is therefore not included in 'inventory' as defined for the purposes of this Dissertation.

3 The observation by Rådström and Edlund pertains to a major land-owning Swedish forest company with a high degree of control of logging operations. The information about roadside inventories produced by private land owners is in all likelihood of worse quality.

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The utilization of the production capacity has received considerably less interest in the South than the wood inventories. Logging capacity is generally owned by contractors who are nominally independent of the forest companies. These have traditionally had little interest in the degree of utilization of the production capacity, other than being interested in maintaining sufficient capacity to generate an upsurge in wood flow, should a short-term critical need arise. The dealer system contributed to the remoteness of the production capacity from the companies, and established a tradition of company disinterestedness which has outlived the dealer system.

A crude but clear generalization characterizes the situation well:

*In Sweden, production capacity is "on the book" while wood inventories are not. In the South, wood inventories are "on the book" while capacity utilization is not.*

Thus, the mirror-image bias in the way that idle resources are accounted for agrees well with the production point to which the systems have evolved. It appears that production capacity has been perceived as costly in the Swedish system, which has evolved an efficient mechanism to minimize its being idle. The Southern system has perceived wood in inventory as costly and subsequently strived to minimize wood inventories.

It is not inconceivable that the relative costs in Sweden and the South differ in the direction indicated by the production points chosen. The South has a hot climate (rapid deterioration) and no labor unions among loggers (less formalized [weaker] employer responsibility for consistency of employment, perhaps lower compensation rates); Sweden has a cold climate and strong labor unions. Yet, the question remains: Is the difference in relative cost really large enough to "justify" the striking difference in the allocation of idle

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resources? This question cannot be answered until wood inventories and idle capacity are accounted for in a balanced fashion.

3. SOURCES OF DISEQUILIBRIUM IN PRODUCTION

Wood-supply systems can be said to produce at the equilibrium point if the mix of idle resources is such that it minimizes the total cost of idle resources to produce a certain output. We have hypothesized that wood-supply systems evolve toward production points which minimize cost with regard to the relative price of inputs. This does not necessarily mean that a situation of equilibrium is at hand, however. Three important sources of disequilibrium can be identified:

- The perceived relative cost may deviate from the actual one, causing the system to produce at a point which is not optimal;

- Changes in relative cost over time may cause disequilibrium if the system does not respond to them, either because the shift is not perceived, or because the system is too inert to respond;

- Disequilibrium may arise if technology, such as harvesting equipment, is transferred between regions which differ in marginal cost.

In the following, these three sources of disequilibrium will be somewhat elaborated upon.
3.1. BIAS IN THE PERCEPTION OF RELATIVE COST

If the evolution of a wood-supply system is directed by a perceived relative cost which differs from the actual one, the system will tend toward a point of production which is not optimal. There are strong indications that a mirror-image bias exists in the way that idle resources are accounted for in the contrasted systems.

If it is true that the Southern system does not fully perceive the cost of idle capacity, one would assume that it has evolved toward a production point with too much idle capacity. The situation in Sweden is the opposite: the full cost of inventorying wood has not been perceived, resulting in a production point with too much inventory.

If the assumption of declining MRTS holds, it would probably be possible for the two wood-supply systems to move toward the optimum without much disturbance in the traditional mode of operation. Wood inventories may have been pushed so low in the South that even a small increase could yield a large improvement in capacity utilization (assuming that the system remains on the curve of efficient production points, i.e. uses the inventory increase in a wise way). The size of the wood inventories in Sweden could probably be decreased without much negative effect on capacity utilization, considering the current size of the inventories.

Thus, we can formulate the following hypothesis: The bias in the way that idle resources are accounted for has caused the systems to evolve towards production points which are not optimal. A move toward the optimum would yield very positive results without significantly disturbing the current operating mode of the systems. *Herein lies a large potential for improvement.*

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3.2. SHIFTS IN RELATIVE COST OVER TIME

The relative cost of different types of idle resources may change over time. The wood-supply system must adapt to these changes, if it is to continue to produce at the equilibrium point.

A process of shifting the relative cost of capital and labor began some three decades ago. The wood-supply systems responded by mechanization, which can be interpreted as a shift in production point along the isoquant curve toward the new equilibrium point indicated by the shifting isocost curve. Sundberg (1979) has used the isoquant-isocost model to analyze this process.

The relative costs of idle production capacity and wood inventory appear to have been fairly stable in both of the contrasted wood-supply systems. The mechanization process did not change the fundamental operating mode of the systems. Will this relative cost remain stable, or will it shift in a way that calls for a response of the same fundamental kind as mechanization? A more immediate question is this: is it possible to construct an "early-warning system", capable of detecting important changes in the relative cost at an early enough stage that the wood-supply system has time to adapt?

3.3. REGIONAL DIFFERENCES IN RELATIVE COST

There is currently a strong trend toward globalization of the markets for forest harvesting equipment (as mentioned in Chapter One). Manufacturers are naturally interested in assessing the probability of success of transferring equipment across style boundaries. The problem is to know how the characteristics of a harvesting style will influence the performance of equipment which is foreign to it.

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This study has identified a conspicuous difference in the harvesting styles of the South and Sweden. There is strong evidence that the wood-supply systems of the South and Sweden differ in the relative cost of idle capacity and wood inventory. The difference in perceived cost is probably larger than the real difference. Should this difference be considered when suggested export of equipment is assessed? In general: is there a connection between the relative cost of idle capacity and wood inventory on the one hand, and the characteristics of successful equipment on the other?

There are significant differences in harvesting equipment between the South and Sweden. These differences may be due to the difference in relative cost, but also to other differences between the styles. They may also simply be the effect of isolated evolution.

The possibility of other factors causing the difference in equipment style cannot be excluded. Some of the differences appear to fit well into the basic operating mode of the wood-supply system, however. The production capacity in the South is better adapted to being inventoried than the capacity in Sweden. This adaptation occurs in several characteristics: a lesser fixed cost, a lesser degree of specialization, and a greater degree of short-term dependability.

The lesser fixed cost is due to several reasons: lower purchase price, longer equipment life; lower labor cost, and less rigid (secure) employment contracts than in Sweden. The equipment in the South requires fewer and more general operator skills, thus making it possible for labor to move to alternative employment in fields such as earthmoving and agriculture. The lower skill requirements are due to simpler and more robust machine designs than in Sweden (single-function versus multiple-function machines) and the allocation of the crucial bucking function to the sawmill rather than to the stump. The high dependability of the equipment allows it to operate in tightly integrated ("hot") systems, where mechanical failure in one machine would cause downtime for the system as a whole.

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Swedish equipment and labor, on the other hand, are highly specialized. The complex Swedish equipment requires the operator to be highly skilled. So does the complex and critical bucking decision which, in Sweden, is made by the operator of the harvesting machine. Swedish job-security legislation and other administrative rules make it more difficult for Swedish labor to shift temporarily to employment in neighboring industries. The occurrence of large buffer inventories between machines limits the impact of mechanical failure to the broken machine. The Swedish production capacity does not appear to be well adapted to being inventoried, or run in very "hot" systems when utilized.

This should not be surprising, given the hypothesis that wood-supply systems evolve toward the perceived point of equilibrium. Production capacity is not inventoried in Sweden, and Swedish equipment is consequently not well adapted to forced idleness. The high purchase price renders it a high fixed cost. Its complexity calls for highly specialized and trained operators. Its sensitivity makes it inappropriate for "hot" applications. Equipment which has sprung out of the Swedish style with its high priority on utilization does not appear to be well adapted to an environment where successful equipment must be able to survive being idle.

The chances of Swedish equipment being adopted on a broad scale in the South thus appear to be slim, unless the Southern wood-supply system changes its basic mode of operation. This does not appear to be a likely prospect for the near future.

Generally speaking, it seems that the relative cost of idle resources does influence the characteristics of harvesting equipment. It follows that it is important to assess the slope of the isocost curve as part of a feasibility analysis for a transfer of equipment across style boundaries.
4. CONCLUSION

This study began with the problem of assessing the transfer of equipment across harvesting style boundaries, and it ends with this problem. A long intellectual path connects the two.

The existing framework for analysis of harvesting systems appeared to be near its limit of usefulness, at the same time as the internationalization of forest harvesting poses new analytical challenges. A new analytical concept of a harvesting system was developed: the wood-supply system.

Contrasting the wood-supply systems of the South and Sweden, an important difference emerged:

_The South inventories capacity, while Sweden inventories wood._

This difference can be attributed to a difference in the relative cost of inventoring capacity and wood in the two systems. Neither system seems to possess a method of accounting which is capable of measuring the actual relative cost, however. A mirror-image bias exists: the Southern system emphasizes the measurement and minimization of wood inventory cost, while the Swedish system prioritizes the measurement and minimization of idle-capacity cost.

Consequently, Swedish equipment is well adapted to an operating mode which accepts inventories to allow its production capacity a high degree of utilization. Expensive, complex, and sensitive equipment has evolved out of this environment.

Southern equipment is well adapted to being inventoried. Low-cost, simple, and robust equipment has proved successful in the Southern operating mode, with its high priority on wood-inventory minimization.

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The relative cost of wood inventories and idle capacity appears to be an important factor shaping the design of harvesting equipment. This should not be ignored when proposed transfers of equipment across style boundaries are being assessed.

Nor should it be ignored in development work within a harvesting style. It is important that the system produce at a point close to the equilibrium point given by the relative cost. A bias in the way that this cost is measured, or a failure to identify and react when it shifts, may lead to production far from the equilibrium point and eventually to substantial extra costs.

There are indications that both the Swedish and the Southern wood-supply systems currently produce at points which are far from equilibrium. The possibilities of reducing the size of the wood inventories in Sweden and the amount of idle capacity in the South should therefore be seriously investigated.
CHAPTER 7. SUMMARY AND DISCUSSION

1. SUMMARY

*New challenges have emerged in the area of forest harvesting research.*

The concept of technological style is useful to describe this yet rather ill-defined cluster of problems. A style refers to the salient characteristics of a harvesting system, whether human, mechanical, institutional, legal, or belonging to any other domain. Equipment design evolves out of and embodies a technological style, but is still only one facet of the complex arrangement of factors necessary to make forest harvesting happen.

Different harvesting styles have evolved in North America and in Scandinavia. Strong economic pressure is forcing manufacturers of forest harvesting equipment to challenge traditional style boundaries in an attempt to widen markets. The traditional problem of "how to log where" is taking on a new dimension as commercial pressure is forcing a transcendence of long-established boundaries of thinking and doing. Forest harvesting analysis must go international.

*Current methods of analyzing forest harvesting systems are not adequate for addressing the new problems.*

Earlier attempts at analysis across style boundaries have not been successful. The traditional focus on tract systems is poorly suited for analysis of factors which are common to all tract systems of a style.
A tract systems approach is adequate if the style factor is constant (the traditional mode of forest harvesting evaluation), but not if the analysis stretches across style boundaries.

In order to deal adequately with the new problems, the analytical framework must be broadened so that it allows all pertinent factors to be seen. It must also be neutral with regard to factors which differ between styles.

A new analytical framework is proposed.

The concept of a wood-supply system is proposed as a necessary addition to the analytical framework built around the tract system. A wood-supply system is a mechanism charged with the long-term responsibility for supplying wood from a large set of tracts to a large set of mills. To allow the analysis in space and time of radically different systems, the wood-supply system must be defined by points which are reasonably universal and stable. The suggested definition reaches from the severing growing trees in the forest to chips in the digester at the pulpmill and sawlogs in the headsaw at the sawmill.

Institutional arrangements tend to differ between harvesting styles in ways that are easily overlooked but of extreme importance. The concept of 'forestry' is a prime example. In North America it means growing trees (but not harvesting them); in Scandinavia, it means growing and harvesting trees (but only as far as delivery of logs at roadside). The conception of 'forestry' permeates all aspects of the respective harvesting styles, and must not be allowed as a silent assumption in cross-style analyses.

The new framework is used to explore the contrast in wood-flow pattern between the wood-supply systems of North America and Scandinavia, particularly the Southern US and Sweden.
The tempo of wood flow is one of the most striking but yet overlooked differences between the wood-supply systems of the US and Sweden. The pulpwood inventory cushion is currently ten times larger in Sweden than in Georgia: roughly 100 days of consumption versus 10 days, while Maine (in many respects similar to Sweden) adopts a middle position with 30 days. The inventory levels have been reduced in all regions during the last 25 years, probably due to the mechanization of logging. The change in Sweden and Maine from river drive to truck transportation has allowed particularly drastic cuts in inventory size.

The precision in the wood flows is much higher in Georgia than in Maine\(^1\) (measured as the match between the monthly accumulated supply and consumption of pulpwood). The precision has increased in both regions, indicating that technological change has made the wood-supply systems less sensitive to changes in weather and season and more amenable to control.

The resolution of wood-flow management is much higher in the South than in Sweden, and there is also a difference in structure in the mechanisms for wood-flow control. In Sweden, wood is sold at roadside at prices which are fixed per region and year. Forest harvesting is planned to mesh well with silvicultural needs, while transportation is planned separately as a "conciliatory" function between the unmatched wood flows of wood production at roadside and wood consumption at the mill. Mismatches are absorbed by surges in wood inventories.

\(^1\) No comparable data are available for Sweden. In all likelihood, Sweden resembles Maine in its pattern of supply precision.

Chapter 7. Summary and Discussion
In the South, wood is sold as stumpage and prices negotiated on a per tract basis. Wood supply planning is coordinated from the wood-consuming mills, and production is matched with actual consumption on a weekly basis. Short-term intervention is preferred to allowing inventories to surge.

There are strong historical reasons for the current differences in tempo and precision. A severe lack of communication and transportation (remote forests) and a very strong seasonal influence (on both logging and river drives) forced the Swedish system to adopt a low-resolution mode of wood-flow management. The availability of a good network of communication (railroad, telegraph, roads) and a much more short-term and local weather sensitivity (rainfall) allowed the Southern system to evolve a high-resolution style of management.

The new technology for wood supply has lifted most of the constraints on the management of wood flow in Sweden. Communication and transportation can be established between mills and tracts, and some of the seasonality is gone (roads are still sensitive to thaw, some tracts can only be accessed during the winter, and silvicultural work is highly seasonal). Yet, Sweden has not used the technical possibilities to reduce inventories in the same way that Maine has done.

The strong emphasis on resource utilization is very likely the reason why Sweden has not reduced inventories as drastically as Maine. (Tradition may also play a role.) There are strong indications that the tight management of wood flow in the South is accompanied by idle capacity in the system. This leads to the following conclusion:

Chapter 7. Summary and Discussion
The Southern wood-supply system inventories capacity to keep a low inventory of wood. The Swedish wood-supply system inventories wood to keep a low inventory of capacity.

Apparently, the relationship in cost between idle production capacity and idle wood is perceived very differently in the two systems. This difference in perception can be rationalized to some extent. The cost of wood deterioration is higher in the South, due to the much hotter climate. A large part of the inventory in Sweden is kept at roadside, where the facilities cost is negligible and the cost of transportation not yet invested in the wood. The production capacity in Sweden is more expensive to keep idle than that of the South, due to its higher degree of capitalization.

Contributing to the difference in cost perception is a "mirror-image" bias in the systems of accountability. Southern procurement organizations are held strictly accountable for the inventoried wood (which they own), but not for the production capacity (which they don’t own). As a consequence, the cost of idle capacity is in part externalized.

Idle capacity carries many costs which do not show up directly on the books, however, such as escalating workers compensation rates, increases in general liability insurance, demands for best-management practices, and the poor image of production forestry in general and the logger in particular. A contractor who can only realize part of his production potential has difficulty affording such "niceties" as safety equipment and training, work practices which reduce the risk of litigation, techniques which minimize harvesting impacts on soil and water, and the resources necessary to give the impression that logging is a serious and respectable business.
Swedish forestry planning, on the other hand, aims at keeping the production capacity within the planning domain fully utilized. Inventories tend to occur between domains, however, and become less visible as they are shared between conservancy, transportation department, woodyard, and mill. Many negative effects of wood inventories are externalized, as they occur outside the domain in which they were caused. Wood losses in debarking, higher bark content, substance losses, by-product losses, and increased consumption of bleaching chemicals result in increased mill costs, but are caused by wood being inventoried earlier in the production chain.

The Southern system of accountability seems to be more sensitive to wood-inventory costs, whereas the Swedish system appears biased toward idle-capacity cost.

The Southern and the Swedish wood-supply systems thus provide very different contexts for harvesting machines and tract systems to operate in. Swedish equipment has evolved in an environment of high utilization. To survive in the South, machines must have the capability of surviving periods of less than full utilization.

2. DISCUSSION

2.1. CONSEQUENCES FOR EQUIPMENT MANUFACTURERS

Wood-supply systems appear to differ as equipment markets, depending on whether they inventory capacity or wood. Keeping capacity idle will require a larger stock of machines and a lower rate of replacement than if wood is inventoried. It will call for equipment and people which can be kept idle at
a low cost, i.e. which have low fixed costs. It will call for equipment which is very dependable, since only small wood inventories are available to cushion technical breakdowns. It will call for equipment which is mobile enough and flexible enough to respond well to rapid moves between different types of tracts. It will call for equipment which is robust and simple enough to function well with low-cost operators.

A wood-supply system which inventories wood need not consider the cost of keeping capacity idle, as the inventories allow it the freedom to produce. Higher-cost equipment and operators can therefore be used. Inventory cushions will allow less dependable equipment. Higher-cost operators may be able to handle more complex and sensitive equipment. The equipment does not need to provide short-term responsiveness and mobility.

A wood-supply system which keeps capacity idle will absorb a large number of machines but also hold on to them longer than a system which avoids idle capacity. By not inventorizing capacity, as in Sweden, a wood-supply system can absorb higher purchase prices for the equipment, and will wear out the equipment more rapidly. The higher rate of replacement will allow the system to benefit more rapidly from changes in equipment technology: an advantage if the pace of change is rapid and perceived as beneficial.

Equipment which is well adapted to a "cold" environment (large wood inventories, little idle capacity) need not be well adapted to a "hot" environment (small wood inventories, much idle capacity).

Large inventories of wood may be part of the price that the Swedish forest companies have had to pay in order to develop and maintain a technological style of logging which differs from that of other major public forests.
forestry regions. By inventorying enough wood to keep utilization high, the Swedish companies have allowed a sophisticated and specialized equipment industry to develop within a market of limited size.

If the equipment market and hence manufacturing is to become a global, rather than regional, undertaking, equipment developers must be concerned with the nature of wood supply systems in the major forestry regions. These systems, which arise from a complex of physiographic, cultural, and economic forces, will ultimately dictate equipment choice. The difference in application (from sub-boreal to tropical), industrial tradition, and the relative cost of labor and capital in the local economy may require that several harvesting styles be supported simultaneously.

2.2. THE POSSIBILITY OF INCREASING CAPACITY FLEXIBILITY

It has been suggested above that a wood-supply system has to choose between keeping wood idle or keeping capacity idle. Neither prospect is attractive. Other opportunities, if available, ought to be explored.

A combination of the following two current trends may offer a partial solution:

- The segregation of forestry machines into generic carriers and specialized attachments;

- The segregation of the producer force into core contractors and other contractors.

Segregated equipment offers the possibility of combining flexibility with specialization in much the same way that the rural worker of old could use a scythe in agriculture one day and an ax in the forest.
the next. Equipment which is developed along these lines may acquire a sufficiently high alternative value that it can find employment outside the wood-supply system when not needed there. This would require a carrier that is generic enough to function well in applications within agriculture, roadbuilding, earthmoving, or some other related field.

Such a carrier may not be well suited to all jobs in forestry. Tracts differ in characteristics, and some tracts may require equipment which is fully custom-made for forestry applications. Forestry would probably need to maintain a core of specialized equipment for difficult or otherwise special applications. It would be necessary to create a mechanism of tract allocation such that "easy" tracts were reserved for general-use equipment, i.e. equipment which is custom-made to be adequate for a wide range of applications, and which would "migrate" in and out of the system depending on shifts in needs (alternative value).

The regularly occurring accommodations in production rate of a wood-supply system are seldom so large that all producers need be affected. It is possible, of course, to let a change affect all producers, but it is also possible to defer all accommodation to a special group of producers: producers who are especially adapted to serve this function. In other words, just as it might be a good idea to have some specialized and some migratory equipment in the system, it might be a good idea to have some producers who specialize in full-time forestry applications, and some producers who specialize in absorbing changes.

The latter producers face the problem of designing a production system which has a high degree of flexibility, and must also be skilled in several different applications. The wood-supply system may find it appropriate to compensate them for their special skills in flexibility in return for not having to bear the cost of idle production capacity or wood inventories.
Speaking in very general terms: the work in a wood-supply system is affected by the very substantial variation which occurs in its uncontrolled, out-of-factory production environment. Stratification of production capacity has been employed to meet some dimensions of this variation, such as thinning versus final felling. It appears very likely that stratification might also be a useful tool to cope with the problem of adapting the production capacity to the changing needs in a wood-supply system.

2.3. SUGGESTIONS FOR FURTHER RESEARCH

The study has indicated differences in the systems of cost accounting in the contrasted wood-supply systems. The Swedish system does not perceive the full cost of carrying wood inventories, whereas the Southern system has a limited perception of the cost of idle capacity. Only when the full costs of all idle resources are known is it possible to evaluate whether a wood-supply system is operating at a reasonable point of balance or not.

It is therefore important that the indication of bias is pursued. Inventory costs need to be investigated in Sweden, as well as costs of idle capacity in the South.

The extent and the forms by which capacity is inventoried in the South are not well known. This appears to be another area in need of research.

The operation of the Swedish wood-supply system is strongly affected by its institutional structure. The integration between mill and forest needs to be improved. One way to accomplish this would be to extend the domain of forestry up to and including the mill woodyard. The production process at a mill
woodyard does not fundamentally differ in nature from that of forest harvesting. Debarking used to be
done in the forest, and chipping of wood fuel still is.

A widening of the domain of forestry could bring substantial advantages by improving the link between
wood supply and wood consumption. It is clear, however, that such a change would be very difficult to
accomplish. The Swedish system contains considerable institutional inertia. A research effort in the
field of planning, similar to that of the late 1960's, but founded in the wider perspective, could prove
very beneficial in the long run.

Finally, it would be very interesting, and potentially very useful, to gain a deeper understanding of the
concept of forestry. It appears to be understood differently in North America and in Europe. As a
consequence, the Southern wood-supply system looks to the distant forest from the wood pile at the
mill; the Swedish wood-supply system looks from the forest to the distant mill wood pile. The
difference in the concept of forestry affects the way that forests are used, researched, and debated in the
two regions, and also complicates cross-cultural intercourse. The fundamental nature of this difference
may explain why it has received so little attention in the past, but it does not provide an excuse for
continued oversight in the future.
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APPENDIX 1. PULPWOOD DATA MATERIAL

1. INTRODUCTION

The analysis of tempo is mainly based on pulpwood data collected by the American Pulpwood Association from all consumers of pulpwood in the United States. The APA has kindly made the data set available for this project. No analysis of the kind presented here has ever been made available in the public domain, nor is the author aware of the existence of any such analysis.

2. DATA PRESENTATION

Every month, each pulpwood consumer in the US is asked to report about the receipts, consumption, and inventory of raw material for pulp production. The reporting is to be made by representatives of individual pulpwood consumers (mills) no more than five days after the end of each month. All data are reported in the unit of thousands of standard cords.

The APA aggregates and presents these data on a fact sheet called Monthly Pulpwood Summary, which, as the name suggests, is issued monthly. Data at the regional level of aggregation have been presented in this fashion since 1957, if not earlier.
Data at the state level of resolution were first presented for the month of March, 1966. This data includes fewer variables than the regional data - only three variables are presented:

- Pulpwood receipts;
- Pulpwood consumption;
- Pulpwood inventory.

Pulpwood includes wood suitable for pulp or fiber processing within a range of forms and from a range of sources, such as tree-length, shortwood, whole-tree chips, and sawmill residue.

This study uses the APA data at the state level. The entire time period covered by such data was used for the study: from March 1966 through December 1989. The data set thus consists of monthly values for three variables for a time period of 23 years and 10 month.

3. DATA QUALITY

The data set used in this study is the result of an aggregation of data reported by each individual pulpwood consumer in the states of Georgia and Maine. The collection and aggregation of the data is performed by the American Pulpwood Association.
Several important criteria of adequacy can be posed for these data:

- They should accurately represent the entities they purport to measure;

- If not, they should err in a way that is consistent over the whole time period of study.

Several sources are possible for any error that may occur in the data set:

- The measurements may not be representative of the population they purport to measure (error of representation);

- The definition of the population may have changed during the period of study (error of definition);

- The measurements may not have yielded correct values (error of measurement);

- Errors may have been made in the processing of the data (error of processing).

3.1. ERROR OF REPRESENTATION

APA reports a response rate corresponding to 95% of the total consumption of pulpwood in the United States.
One can reasonably assume that this value pertains equally to all the three variables presented by the APA at the state level. For the wood consumers, the reporting is a routine activity concerning data which are most likely systematically produced as a component of the regular reporting within the corporation. It is not likely that any wood-user would report only on some of the variables requested.

It is possible that the response rate is unevenly distributed over the U.S., and it is also possible that there have been geographical shifts in the reporting pattern during the period of study. Thus, the response rate may not be consistent for particular areas within the U.S., such as Georgia and Maine.

The APA uses a particular procedure to extend the reported data so as to pertain to the total values for the U.S. This procedure has the nature of a practical "fix", and is designed by senior APA officers, who know the pulpwood industry very well. There is every reason to believe that this procedure is build on good knowledge and judgement, and gives a result that is reasonably accurate.

The procedure appears to be used as a standard measure in the APA treatment of the reported data. There is reason to believe that both the reporting pattern and the procedure have been consistent in the short term. Yet, it is likely that the reporting pattern has changed several times during the period of study. It is not known to what extent the correction procedure has reflected such changes.

In the matter of the representativeness of the data, one is forced to rely on the judgement of the responsible APA officials. There seems to be good reason to believe that, for the purposes of this study, this judgement has been good enough to render the data adequate.

One further point needs to be made with regard to the representativeness of the data. The variable inventory measures the amount of pulpwood owned by the wood consumer on the last day of each

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month, as opposed to the variables consumption and receipts, which measure monthly accumulated
wood flow. Thus, the variable inventory samples the amount of wood owned approximately once every
30 days, while the magnitude of the other two variables accumulate events during the whole month. It
is difficult to say how well the actual behavior of the variable inventory is represented by this
systematic sample in time, since nothing is known about its behavior between sampling points. It is
conceivable that the reporting wood consumers may have an interest in manipulating the level of
inventory on this customary day of internal reporting. If this is true, the reported data on inventory size
may not be representative of its general behavior.

There seems to be good reason to regard the variable inventory with some skepticism. This point will
be further emphasized in the following.

3.2. ERROR OF DEFINITION

The variables consumption and receipts are similar in nature; they measure the flow of pulpwood across
a boundary. The variable inventory, on the other hand, is different; it measures the amount of wood
residing between the boundaries of receipts and consumption.

Errors of definition can occur in two regards:

- The boundaries used to define the variables of measurement may have changed;
- The boundaries of the geographical regions to which the reported data are aggregated may have
  changed.

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The second possibility may be promptly dismissed. The boundaries of the states have not been changed during the period of study.

The first possibility is more critical - particularly for the variable inventory, since it measures the amount of wood residing between two boundaries.

The variable consumption measures the flow of wood across the point beyond which the wood user has decided that the wood can be regarded as consumed. In case a wood user has an organizational boundary between woodyard and mill, this is most likely the boundary across which consumption is measured. In any case, the measuring point is located somewhere in the interface between woodyard and pulpmill. There is no reason to believe that the definition of the consumption point differs in any significant way between different reporting wood users, nor that it has undergone any significant changes during the period of study.

The variable receipts (in this study also referred to as supply), measures the flow of pulpwood across the point or points at which the ownership of the wood passes into the hands of the wood user. In case the wood is owned before it is transformed into pulpwood, the measuring point is the first point at which the wood gets stacked in the form of pulpwood. These is good reason to believe that the positioning of this point in the flow of wood from stump to mill differs not only from wood consumer to wood consumer, but also that individual wood consumers use several different points. Furthermore, there is a possibility that there are systematic differences in the definition of the receiving point between the two compared regions.

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For example, pulpwood may be bought at the gate to the pulpmill, at the gate to a set of cutlying woodyards, at river landings, or at roadside landings (decks), depending on the procurement strategy of the wood consumer and the general institutional structure of the wood-supply system.

In Georgia, most companies traditionally relied on wood dealers for their supply of wood. A consequence of this strategy was that the wood users did not own the wood until it passed through the gate to the pulpmill. During the last decades, a shift has taken place towards direct-purchasing systems, implying a movement of the purchasing point toward the forest.

It is likely that changes in the institutional structure of the wood-supply system have occurred also in Maine. They are, however, not known at this point.

The movements of the purchasing point affects the two variables affected - receipts and inventory - in different ways.

The variable receipts measures the accumulated flow of wood during one month into the ownership of the wood consumer. Changes in the ownership boundary will affect the value of this variable, but only during the time period of change. Unless there is a dramatic build-up of inventory somewhere between the old measuring point and the new measuring point, the effect should not be of such magnitude that it affects the usefulness of the data on receipts for the purposes of this study.

The variable inventory measures the amount of pulpwood owned by the wood consumer. In other words, it measures the amount of pulpwood received but not yet consumed, i.e. the amount of wood contained between the two measuring points for wood flow. If the measuring point for receipts moves,
it will change the domain of measurement. As a consequence, the total amount of pulpwood inventory in the wood-supply system may be measured to different degrees at different points in time.

This is the crucial matter with the variable inventory. For the purpose of this study, we would like to measure the total amount of pulpwood inventory in the wood-supply system. The inventory measure used by the APA refers only to inventories owned by the reporting wood consumers. The APA does not provide any estimate as to the size of company inventory in relation to total inventory. This very interesting piece of knowledge would have to be estimated from on other sources.

In Georgia, it is likely that the variable inventory includes a greater fraction of the total inventory at the end of the period of study then it did at the beginning. The wood-supply system of Georgia has undergone a change in institutional structure that coincides with the period of study. The change from dealer systems to direct-purchasing systems may have increased the domain of inventory measurement from only including mill woodyards to including also outlying woodyards. Thus, if there was an actual decrease in total inventory of pulpwood during the period, if would not appear as strongly in the data, due to the concurrent increase in the measured fraction of total inventory.

There is reason to believe that the decrease in inventory in the wood-supply system of Georgia has been greater than the data shows, but it is very difficult to estimate the extent to which the data distort this change.

It is not unlikely that there have been institutional changes also in the wood-supply system of Maine that could influence the fraction of total inventory reported by the wood consumers.

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3.3. **ERROR OF MEASUREMENT**

Measurements are taken at many different points in the wood-supply system, and by different people. Measuring methods may differ between these points and the way of performance between these people. The taking of these measurements is a routine activity at most places and for most people involved. Measuring methods are likely to be standardized within the organization of each wood consumer, in order to allow for comparability and consistency.

Measuring methods may have changed over the time period of study. It is possible the a larger relative volume was scaled by weight in the end of the period than in the beginning.

Pulpwood is measured in many different units. Standardized factors of conversion are given by the APA on the monthly pulpwood report form.

3.4. **ERROR OF PROCESSING**

Errors of processing include such things as typing mistakes and calculation mistakes. There are many opportunities for processing errors to be introduced into the data set:

- The reporting wood consumers may make mistakes;
- The APA may make mistakes in the aggregation and reporting of the data;

*Appendix 1. Pulpwood Data Material*
Mistakes may have been made in this study in entering data into the computer, and in the transformations made.

It is impossible to know whether any mistakes have been made in the reporting of individual pulpwood consumers. The APA checks whether the summations are correct, but has no possibility of checking the data beyond that. A high amount of consistency can be expected in the reporting by the wood consumers, however, since the compilation of the monthly report is a routine activity, most likely performed by the same individual month after month.

The same applies to the data processing at the APA. It is a routine activity, performed by the same individual for several years in a row. The APA checks the correctness of the data by using summations as a means of consistency test.

In order to avoid typing mistakes in entering the data into the spreadsheet computer program used for the analysis, a special data form was designed which automatically summarizes individual entries into the same totals given on the APA monthly pulpwood reports. The use of this procedure allowed the detection of several typing errors, both in the computer data entry and in the APA typing of the pulpwood summaries. As a rule, the data reported by the APA was consistent enough to allow corrections to be made.

All calculations have been made using a spreadsheet computer program (Quattro Pro), which makes the probability very high that all transformations were correctly performed, as specified by the user of the program. Special care has been taken to check the accuracy of specified formulas. A small possibility remains that errors may have been made. If so, the systematic nature of the spreadsheet program makes it likely that the errors are consistent through the data set.

Appendix 1. Pulpwood Data Material
To summarize: it is highly likely that errors of data processing exist in the material, although care has been taken throughout the processing chain to avoid mistakes by careful work and consistency testing. However, one can safely assume that these errors are few, and it seems likely that they are of minor magnitude.
VITA

Born in Stockholm, Sweden, on February 21, 1956, the author completed primary schooling at Högdalens skola and secondary schooling at Bandhagens gymnasium, both in Stockholm. Having served a compulsory term in the Swedish Army, he subsequently studied Russian for two years at the University of Stockholm and also pursued East Europe Area Studies at the University of Uppsala. Beginning his Forestry studies in the fall of 1977 at the Swedish University of Agricultural Sciences in Garpenberg and Umeå, he obtained a Jägmästare Degree in December of 1981. In 1986, he participated in the Young Scientists' Summer Program at the International Institute for Applied Systems Analysis in Laxenburg, Austria. Enrolled in the Industrial Forestry Operations program at Virginia Polytechnic Institute and State University since the fall of 1988, he completed a Doctor of Philosophy Degree in the Forestry Department in 1990.

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