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Forest fuel systems utilising tree sections

System evaluation and development of evaluation methodology

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Abstract

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This study had two main aims. The first was to increase knowledge of forest fuel systems utilising tree sections, especially that concerning interactions with factors external to the system. The second was to develop the technique of 'retrospective position analysis' as a means of evaluating projects.

Position analysis is identified as an adequate evaluation method and is retrospectively applied to the evaluation of projects. Position analysis permits broad-system studies and process evaluation of each project, which gives a good base for understanding the effects and outcome of projects and of the system as a whole.

The main conclusion from evaluation of tree-section systems is that, although there was much activity in the mid 1980s, utilisation decreased in the early 1990s, owing to low oil prices and to the low price of other biofuels. An increase in the quality requirements of pulp and primary paper products during the evaluation period, made it difficult for tree-section systems to attain the new grades. The technical development of tree-section systems is also lagging behind. However, a few local tree-section systems still are competitive.

Key words: position analysis, forestry, tree-section terminals, case studies, Sweden.

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Definitions

Forest industry: The pulp and paper industry, sawmills and particle board industry.
Forest fuel: "wood fuel which has not been used previously" (Swedish standard SS 18 71 06).
Wood fuel: Fuel originating from biological material (biofuel), the origin of which was trees or parts of trees. The term "*bioenergy*" is superordinate to the terms "*biofuel*" and "*wood fuel*".
Tree section: "part of a tree-trunk (with branches) which has been cut off but not processed" (Skogsordlistan, 1994) and which could be processed to pulpwood in standard lengths or varying log lengths and forest fuels.
Tree section system: "the felling, transportation and processing of tree sections" (Hillring, 1995*a*).
Tree-section terminal: "a plant (stationary debarking unit, separate stationary unit or mobile unit) for processing tree sections" (Hillring, 1995*a*).

Introduction

The late 1960s saw the beginning of the environmental debate, which is still in progress. The use of fossil fuels (primarily oil and coal), conceived to be a threat to the long-term survival of mankind, is one of the issues involved.

In the early 1970s, the Swedish forestry sector found itself in a situation in which a future wood shortage was feared, largely because of the expansion of the industry's capacity in the 1960s. The expected shortage resulted in a series of measures, among them investment in the utilisation of a large proportion of tree biomass for industrial purposes (Projekt Helträdsutnyttjande, 1975).

Energy prices also increased sharply in the 1970s, owing to the oil embargo imposed by OPEC (Organisation of Petroleum Exporting Countries). The forest industry acted to reduce its relatively heavy dependence on oil. Efforts were made to utilise part of the wood raw material for energy purposes, and to increase its utilisation for industrial purposes.

The Swedish government introduced incentives to reduce dependence on oil. These incentives were often combined with industrial aid. By the late 1980s, fulfilment of the environmental ambitions introduced some 20 years earlier had become increasingly important.

A commercial market for forest fuels has become established, as a result of various measures and events. In 1993, the district heating market utilised energy corresponding to ca. 8 TWh (terawatt hours) or 29 PJ (10^{15} Joules) of forest fuel.

Tree section systems were developed in the 1970s and 1980s. In 1984, the Swedish government introduced investment support for the expansion of tree section terminals (SFS 1983:1108), as a consequence of both trade and labour market policy and energy policy.

The aims of the study reported here were

- to increase knowledge about forest fuel systems which utilise tree sections, by evaluating projects which had been carried out. In particular, the interaction between the forest fuel system, and external factors that affect the system, was analysed.
- to test and develop a method – denoted here *retrospective position analysis* – for evaluating projects which involve a transition to complex systems.

Methods

Evaluation techniques

To evaluate is "*to establish or assess the value of or the result of an experiment, etc.*" (SAO, 1986). Evaluation is based on the term "result analysis" and involves some ambiguity. This covers a range of expressions such as follow-up ("*to follow the continued development or to continue or to develop further*", SAO, 1986), revision, consequence analysis, etc. These expressions can be summarised in the term '*ex-post* studies' ('*ex-post*' evaluation), which covers various types of retrospective study. *Ex-post* effects are actual effects, which are measured afterwards. The term 'retrospective' is used synonymously with evaluation (*ex-post*) in the present study. The converse of this term, i.e. *ex-ante* studies (*ex-ante* effects are expected future effects), is used in the study of future activities such as planning or evaluation. The planning or evaluation of various options for future action (*ex-ante*) is most commonly found in analyses of economic methodology. The English-language term 'evaluation' covers both the prospective and the retrospective aspects.

Evaluation is regarded as part of the decision-making process, which comprises decision preparation, decision-making, implementation, evaluation and feedback. The term 'evaluation' can be characterised as:
"*Normative retrospective assessments with the objective of improving future activities.*" (translated from Swedish; Lind, 1979).

A literature survey, made before the evaluation of forest fuel systems (Hillring, 1995*a*), showed that the systems developed in a complex environment, in which political decisions and tactical timber considerations were commonplace. An evaluation method must therefore be employed, in which a comprehensive view, understanding and 'system thinking' are emphasised. The method should also be capable of dealing with factors other than those purely monetary. In addition, it should be possible to use the method wherever environmental factors are of great significance. The profitability of burning forest fuels largely depends on the formulation of the energy tax system, on investments in incineration plants, on control of the wood supply, etc. These factors are, in their turn, based on evaluations and political decisions made by various interest groups and interested parties. Knowledge existed about the way in which these phenomena interact with tree section systems, comprising tree section terminals, but needed to be supplemented.

For the reasons given above, the method of project evaluation of forest fuel systems which utilise tree sections should:

- stimulate multi-sector and multi-disciplinary viewpoints which provide an overall perspective on the problem;
- consider qualitative analysis to be equal in importance to quantitative analysis;
- highlight the interaction with the world around the systems;
- reveal facts about power and interests;
- emphasise the evaluations made by various players, and the interaction between such players.

A number of possible evaluation methods was studied by the present author (Hillring, 1991; 1995*a*). Of those studied, position analysis is the method which can be expected to fulfil most of the above requirements. Position analysis may be considered as the system-oriented method within evaluation research (Lind, 1979), in which understanding of the interaction of the systems is emphasised and where a central task is to obtain a useable system description.

From a theoretical point of view, the approach used for evaluation can be assigned to the formation of theories designated as 'qualitative' methods (Alvesson & Sköldberg, 1994). Within this area, case studies are often used to provide a better understanding of phenomena and contexts (Lennerlöf, 1981). This implies that understanding is placed at the focus, that the individual case is emphasised, and that the individual works on the level of the whole, when searching for explanations on a detailed level, and *vice versa*.

The case studies in this investigation can be described as a form of 'historical hermeneutics' in which it is important to clarify what took place in the project (Ödman, 1979). Historical documentation was scrutinised and the relevant informants interviewed. Data and proposed interpretations were traced back on one or more occasions to the informants.

Position analysis

Position analysis (Söderbaum, 1973) has its roots in the institutional economy (Myrdal, 1973; Hodgson, 1988) and emphasises comprehensive views, rules of play and the significance of power ratios, together with interdisciplinary science. The method is also based on general systems theory (Bertalanffy, 1968). A phenomenon (or organism) is viewed as an open system which interacts with the environment and which comprises interacting sub-systems.

The economic concept is given meaning additional to that in neo-classical theory, and one characteristic of position analysis is the endeavour to achieve disaggregation. The underlying philosophy is to show all the effects of a decision in both monetary and non-monetary terms. Attempts are made to achieve a holistic view, in which a parallel study of monetary and non-monetary consequences would be the ideal situation (the converse is 'monetary reductionism').

Positional thinking is central to position analysis. 'Position' is used as a synonym for 'state', and refers to conditions at a certain point in time ('state' emphasises changes in the system). The converse is 'flow', which refers to conditions during periods of time.

The role of the investigator is characterised by an attempt to illustrate the subject area comprehensively, and in consequence, to illustrate the associated selection situations. The investigator compares and analyses various options, but leaves the decision-maker to draw conclusions from the investigation.

Retrospective project evaluation

Retrospective position analysis has the same general properties as those described above for position analysis, and includes the following stages of evaluation:

- Identification of problems;
- Description of systems;
- Determination of positions;
- Analysis of effects;
- Analysis of activities and goals;
- Summary and conditional conclusions.

Identification of problems. Relevant institutions, rules of play, interested parties and players are identified here. The selected option, alternative development paths and historical background of the project are described. The problems of various players and interested parties are specified. A project development for the selected option is drawn as a time chart. The most crucial times for the project are identified.

Description of systems. The systems and subsystems which will be affected at some time by the project, as compared with a fictitious zero option ('business as usual'), are identified on the basis of the problems and the development of the project. The systems selected are central, because they form the starting point for both the dimensions of the effect and the determination of positions.

Determination of positions. Each system is analysed with respect to position, i.e. state. Determination is carried out in terms of both space and time. Positions are given with varying levels of detail (cursory or more detailed). The level of detail depends on the level of knowledge. The objective is to list all the knowledge available on the project. It is therefore of greater interest to list all cursory knowledge, than to omit it.

Analysis of effects. When the effect of an optional action (planned or implemented) is to be described, this is done on the basis of the system structure defined previously. The systems are studied and analysed with respect to which dimensions are affected and in what way, as compared with a fictitious zero option.

Analysis of activities and goals. This analysis is divided into two sections. The first consists of the investigator's identification of the interests and how these were satisfied. The development of the project is studied, and activities carried out are listed. An assumption is made about the objective, which, together with the activity, defines the interest. The analysis is carried out to varying depths, depending on the knowledge available. The second section comprises an analysis of interested parties, in which the main interested parties are permitted to specify the fulfilment of their objectives by means of the project studied. Both analyses end with summaries, comments and conclusions.

Summary and conditional conclusions. The final stages of retrospective position analysis summarise the project and the conditional conclusions. The investigator provides a proposal for a summary, and puts forward conclusions which may be accepted or rejected by the reader or decision-maker.

Retrospective position analysis can be viewed as a check list, which makes it easier for the researcher or investigator to obtain an all-round view of the project studied.

Position analysis was first implemented for the purposes of evaluation in Hillring (1991). The present study summarises five years' participation in 'Forestry action projects', which aimed at increasing rural employment with the forest as a base.

To illustrate the method of retrospective position analysis, as applied to tree section terminals, a case study (Hillring, 1995*a*) is given as Appendix 1.

Case studies of forest fuel systems utilising tree sections

Introduction

At the end of the 1970s, there was still great uncertainty with respect to the supply of oil, and the price of oil, viewed historically, was very high. At that time, the testing and conversion began of stationary debarking units in plants owned by the pulp industry. It therefore became possible to process tree sections. This was done in a number of places – for example, at Gruvön, Lövholmen, Iggesund and Skutskär. Stationary, separate units were also built at Lycksele, Dombäck and Boden. Mobile equipment for processing tree sections was also developed.

Evaluations (Hillring, 1995*a*) of projects which received subsidies for building tree section terminals in accordance with government support for investment in such plants (SFS 1983:1108), are summarised here. The purpose of the projects was to separate industrial raw materials from fuel raw materials. The overall investment amounted to ca. SEK 340 million (1985 values), of which the support made up ca. SEK 45 million, according to the Swedish Energy Authority (Statens energiverk, 1986).

Figure 1 shows the location, and status with respect to SFS 1983:1108, of terminals built up to 1986. No investments have been made in new tree section terminals since that time. Terminals are named after the places where they are situated.

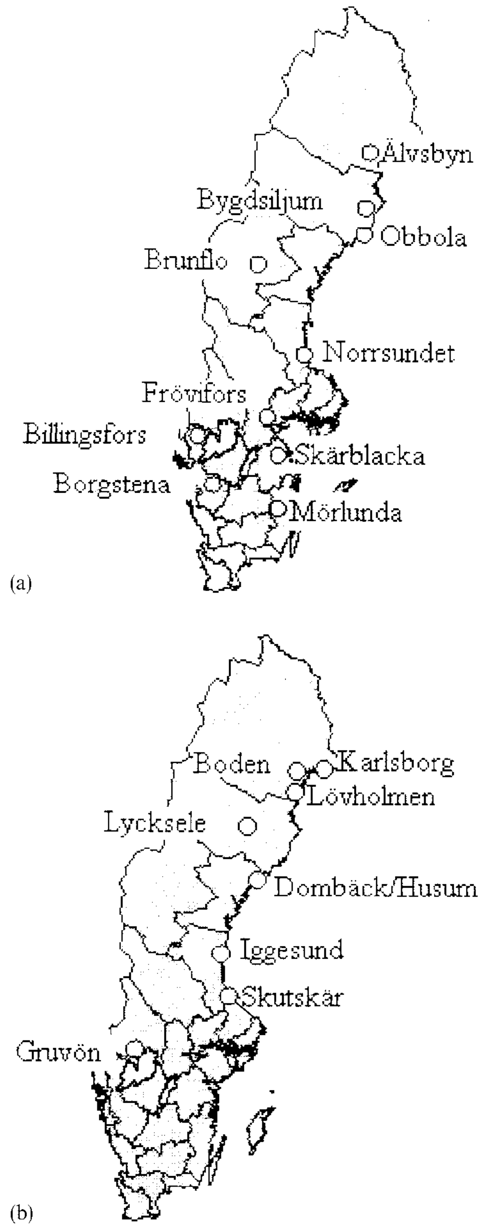

Fig. 1. Distribution of the evaluated tree section terminals (a) which received government grants according to SFS 1983:1108 and (b) which did not receive government grants according to SFS 1983:1108.

Stationary delimbing machinery comprised various technical solutions, according to two main trends: (*a*) modified debarking drums in the pulp industry's conventional debarking units, and (*b*) separate, specially constructed delimbing drums, in separate units. The predominating type of special debarking drum was manufactured by KMW at Örnsköldsvik.

AC-Invest bundle delimbers and Bruks bundle delimbers were mobile delimbing units. They were used at some of the terminals studied before the permanent plant had been completed.

Forest fuel systems utilising tree sections: an evaluation

Government investment support in accordance with SFS 1983:1108 was paid to ten companies, and a further eleven companies applied for investment support. Of the latter applications, four failed and seven were withdrawn. Projects which obtained Government support (Fig. 1*a*) were selected for evaluation. Four of the projects were thoroughly evaluated by the method of retrospective position analysis. Experience gained from the evaluations was later used to evaluate more superficially the remaining six projects which received support.

The connections between energy policy and the development of society in general, on the one hand, and forest fuel systems that use tree sections, on the other hand, are discussed on the basis of the knowledge obtained.

Case studies

The four projects evaluated by retrospective position analysis were those at Bygdsiljum, Brunflo, Frövifors and Älvsbyn.

The terminal at Martinsons Trävaru KB, Bygdsiljum, is a stationary unit at the company's sawmill. The evaluation is described fully in Hillring (1995*a*), and summarised in Appendix 1. This terminal was used between 1986 and 1990. It was not operating at the time of evaluation.

The tree section terminal at Byggelit Lockne AB, Brunflo, is a stationary unit directly connected with the company's particle board mill. It operated between 1986 and 1992 and was in limited use at the time of evaluation (see Hillring, 1995*b*).

At AssiDomän AB's sulphate and cardboard mill (Frövifors Bruk AB), Frövifors, a debarking drum was adapted for processing tree sections. This debarking unit is used for conventional pulpwood debarking; tree sections were decreasingly used between 1985 and 1992 (see Hillring, 1995*c*).

The tree section terminal of Svenska Cellulosa AB (SCA) is directly connected with the heating plant at Älvsbyn. The plant was fully operational at the time of evaluation, and tree sections have been used there since it was completed in 1985 (see Hillring, 1995*d*).

The remaining six terminals which received Government support (Fig. 1*a*) were not fully evaluated by retrospective position analysis. However, the same method was used in principle for data collection and analysis (see Hillring, 1995*a*). Of the six, two utilised tree sections at the time of evaluation (Table 1): these were the terminals at Obbola and Norrsundet, owned by SCA and STORA, respectively. No operation of tree section terminals was indicated for the final four (Billingsfors, Borgstena, Mörlunda and Skärblacka).

The tree section terminals evaluated were operational to different extents between 1985 and 1992. Table 1 shows the total production of forest fuels based on tree sections from these terminals.

Of the terminals studied, five were in operation in 1985 and five in 1992. During this period (1986–1992), production varied considerably at the several plants. One terminal did not use tree sections at all. Over the entire eight-year period, total production of forest fuels corresponded to 2156 GWh (gigawatt hours) or ca. 8 PJ. The highest production for a single year was 382 GWh (1.4 PJ) in 1987. Production has since declined to 252 GWh (0.9 PJ) in 1992. The maximum capacity at the nine plants which used tree sections, amounted to 1.3 million m^3 f of biomass tree sections or 1076 GWh (3.9 PJ) of forest fuels annually.

A comparison with Brunberg (1991), regarding the utilisation of tree sections during the 1989–1990 felling season, suggests that the terminals studied represented about half the production in Sweden. The total production of forest fuels from tree sections was ca. 500 GWh $year^{-1}$ (1.8 PJ $year^{-1}$) during this period.

At the time of evaluation (1992–1993), the tendency was for production of tree sections to decline throughout Sweden. Most of the tree section terminals closed down or suspended operations. In the province of Norrbotten, where the terminal in Älvsbyn is situated, tree sections were still being utilised relatively widely. Tree section felling was also still to be found around the terminal at Norrsundet.

Discussion and conclusions

System evaluation

The number of tree section terminals more than doubled during a brief period in the 1980s. Investments were made at a turning-point in the development of the energy market in Sweden. The price of oil decreased significantly, and large amounts of electricity from nuclear power stations began to be used for heating purposes. This had an adverse effect on conditions for the operation of the terminals. Some players may have perceived the signals from the energy market in time, and perhaps in most cases refrained from investing without Government support. However, those companies which invested

Table 1. *Forest fuel production for 1985–1992, based on tree sections in the terminals which received support in accordance with SFS 1983:1108 (compare Fig. 1a). Units: GWh*

Year	1985	1986	1987	1988	1989	1990	1991	1992	Total
Billingfors	2	4	2	2	3	–	–	–	13
Borgstena	20	20	–	–	–	–	–	–	40
Brunflo	–	14	28	27	7	7	7	6	96
Bygdsiljum	–	16	16	16	16	2	–	–	76
Frövifors	20	28	38	24	16	4	4	2	146
Mörlunda	–	–	–	–	–	–	–	–	0
Norrsundet	–	54	73	58	27	41	38	37	328
Obbola	11	48	106	110	78	86	97	104	640
Skärblacka	–	20	23	30	36	33	9	–	151
Älvsbyn	11	80	96	85	111	87	93	103	666
Total	64	284	382	352	294	280	248	252	2156

in debarking drums for tree sections required new debarking units, and therefore presumably took other considerations into account as well. Other players emphasised competition on the timber market or an increased raw material base as vital criteria for investment. It is therefore likely that some companies would have invested in any case, without Government support.

Below, the results are discussed and conclusions drawn from the case studies and from the reference study (Hillring, 1995*a*). According to the principles for evaluation by means of retrospective position analysis, the conclusions are conditional. Other readers or decision-makers may make other interpretations and assessments, and draw other conclusions from their own perspectives and interests.

Marketing conditions

The biofuels market has undergone major changes, and the predicted shortage of fuel in the early 1980s has become a massive surplus. The amount of forest fuels presently available exceeds the amount actually consumed by a ratio of 10:1. When tree sections were developed, they provided a means of using the wood which was of interest to industry and which was able to augment the forest fuel supply in quantity. Industry was one of the great promoters of the conversion from oil to domestic forest fuel, and in the early 1980s energy-saving activities and the expansion of boiler capacity for biofuels were widespread.

Because of the increased amount of forest fuels on the market – the chip and sawdust markets were deregulated when the Wood Fibre Act ceased to apply in 1993 – heating plants have followed two main routes as regards the purchase of forest fuels. As a result of the increased freedom of choice, they have been able to select preferred assortments. Several heating plants have also built boilers capable of taking lower-quality raw materials (by-products), at lower prices. In a variety of ways, neither of these market developments has favoured tree sections, which are of relatively low quality compared with chipped pulpwood or refined fuels, and which cost more than sawmill by-products.

Tree sections have generally been used as a feedstock for non-bleaching sulphate pulping processes, which are tolerant of quality variations, e.g. a high proportion of bark. The production of unbleached sulphate pulp fell by 14% between 1980 and 1992, while that of bleached sulphate pulp increased by 22% (Skogsstyrelsen, 1993). Requirements concerning the quality of the raw materials have therefore become more stringent with time, where sulphate pulp is concerned (cf. also *Environment*, p. 11). The studied particle-board industry has changed its raw-material base during the same period, from pulpwood to sawmill by-products.

Investment support for tree section terminals contributed to the extensive and long-term learning process which took place during a period of 20 years. This involved a positive reversal of the forest industry's attitude to forest fuels, and the control of large parts of the market for forest fuels. This process (the synergy effect) consisted of showing that there was sufficient raw material for both industry and the fuel sector, and that technical solutions were available for securing raw materials for industry as a first priority.

Forecasts for the future of utilisation of forest fuels are favourable, according to assessors. The use of forest fuels is expected to increase, primarily for heating purposes in the production of district heating, and for electricity generation (combined heat and power generation). A decrease in the use of individual wood fires in self-contained accommodation is, however, forecast. The total increase is uncertain, but is expected to lie between 13 and 28 TWh (47–100 PJ) over the next fifteen years, according to Nutek (Nutek, 1994*a*) and SLU/SIMS (Eriksson, Hektor & Lönner, 1994).

Economics

A number of authors have specified different criteria for profitability in their financial cost estimates for tree section systems. Lönner, Liljeblad, Hjälm, Strand & Lindqvist (1983) gave cost estimates for three types of processing technique: stationary debarking units, separate stationary units and mobile units. Björheden (1986) and Eickhoff (1989) suggested that mobile processing was preferable to transporting the tree sections to a stationary unit. The present study has a different point of departure than the analyses referred to above, which precludes direct comparison. There have also been too many changes in the world around the systems, relative to the factors taken into account by the above-mentioned authors. For instance, the price of fuel has fallen sharply in real terms, whereas the technology for tree section system has not developed significantly since those cost estimates were made.

Harvesting of tree sections is most profitable when there is a relatively large difference in price between the industrial timber section and the energy section, or when the price of energy is relatively high, as it was in the early 1980s. Since the price of energy has fallen, the exploitation of forest fuels in the form of integrated felling has not been profitable. When the price of pulpwood is similar to that of forest fuels, as it was during the recession in the early 1990s, it is most profitable to take whole trees from some types of stand. One factor which could cause tree sections to become profitable once more, would be an increase in oil prices, leading to higher fuel prices, therefore to an increase in the demand for forest fuels. If the fuel price were to increase considerably, thinning would make an extra contribution to the operating net surplus. The situation would then approximate the conditions envisaged by the forestry enterprises in their original cost estimates when applying for government support. A new economic upturn for the forest industry could bring about an increase in the demand for raw materials. Tree sections could then once again become interesting as a marginal raw material.

The costing for forest fuels produced using tree sections is not favourable (1993–1994). If a production cost of SEK 110–120/MWh (Brunberg, 1991) is achieved, the margin is very narrow, since forest fuel costs on average SEK 108/MWh (Nutek, 1994*b*). There are local exceptions to this. One such is in Älvsbyn, where the production costs for 1992 were ca. SEK 120 per tonne of tree sections, or approximately SEK 50/MWh of forest fuel. As things stand at present, the majority of companies require a greater justification for investing in tree sections, than purely monetary considerations can provide.

During the recession of the early 1990s, the exploitation of pulpwood proved to be a competitive alternative to the exploitation of forest fuels. The main reason for the availability of a certain quantity of pulpwood as an energy raw material, lies in the more stringent quality demands of the pulp and paper industry. Apart from the monetary considerations, one advantage in this is that mineral nutrients required by the trees remain in the stand, since delimbing takes place there. The advantage of nutrient recirculation (by leaving limbs and tops) may be reduced if a large-scale recycling system for combustion ash is introduced. A further advantage in using pulpwood is that it is possible to select different options for utilisation further down the transport chain towards final use (Lœstadius, 1993).

Tax increases on fossil fuels have gradually increased the competitiveness of forest fuels after tax, even though the price of oil after tax has not risen sufficiently in compliance with the political discussions which took place in the 1980s (forest fuels are tax-free). Improved competitiveness has led to the development of refined fuels which, owing to their increased density, can be transported to areas with a high demand for forest fuels, such as cities. Cheaper and more homogeneous (as regards quality) forest fuels than those obtained from tree sections – such as sawdust – are also available for this application.

In forest industry, the replacement of oil by forest fuels has been most marked. The major changes in the tax system for manufacturing industry, which have been made in recent years, to the effect that only a quarter of the carbon dioxide tax, sulphur tax and nitric oxide tax is payable, have reduced differences in competitiveness between untaxed, domestically produced forest fuels and imported fossil fuels subject to low taxation. A tendency towards the reduction of the industrial utilisation of forest fuels is not yet apparent (Nutek, 1994*a*), but may be expected to emerge in the longer term now that tax on fossil fuels (oil, coal and gas) has been reduced for the first time in two decades.

The current situation, with highly internationalised markets, and free movement of capital, means that Sweden has difficulty in applying different criteria for industrial production as compared with its neighbours. It may therefore become increasingly difficult for Sweden to retain its high (in an international context) taxes on fossil fuels, which are a very powerful driving force behind the increasing use of biofuels in Sweden.

The significance of support for investment was not specifically studied in the present investigation, but some companies have commented that this support brought forward their investment in tree section terminals. This agrees with the results of Nutek's Energy Report for 1993 (Nutek, 1993), which included an evaluation of investment support for combined heat and power plants.

Technique

Development of the techniques for tree-section working has not kept pace with other technological development in surrounding systems during the past decade. Consequently, there have been difficulties concerning the supply of raw materials from the terminals. Two striking examples are forest industry's demand for raw materials, and the development of the cost and quality of biofuels. In the pulp and paper industry in particular, technological advances and the development of new, environmentally-friendly manufacturing processes have been very evident during the past decade. One reason for this may be that the processing of biofuels is a secondary activity as far as most players in the market are concerned (Hektor, 1990). The driving forces towards R&D are therefore less strong than those for the main activity, such as pulp or paper production. Such factors may, in the long term, also affect plants which currently are operating.

From a technical point of view, the delimbing drum and debarking plants manufactured by KMW in particular have met the original specification. However, the surrounding systems have continued to develop, which has meant that the tree sections in most cases no longer meet their quality requirements, and that their costs are too high vis-à-vis the market price of forest fuels. The pulp and paper industry has made its quality requirements more stringent. The chipboard industry studied here has changed its raw-material base for manufacturing over a period of ten years, with the result that pulpwood has become less important relative to sawmill by-products. The driving force for the future development of tree section systems is thus weak. However, some development of the logging system for tree sections is going on.

Tree sections have been driven out of the market in large areas of Sweden, through the use of single-grip harvesters for thinning. The single-grip harvester system is better suited to the existing logistic structure of forestry. The same reasoning also applies to final felling. If tree sections are to be utilised, the integrated exploitation of normal fellings is preferable. There is also less justification for the further development of the tree section system, since the supply of raw material for forest industry may be assumed to suffice, given conventional exploitation, the utilisation of recycled paper and the importation of wood for industry.

In some areas, tree sections have been driven out of the market by forest fuel systems using logging residues. Where this occurs, integrated exploitation is not possible and existing logistic systems cannot be used. The exploitation of logging residues is most profitable at the final felling, and the method has not been used at the thinning stage to an appreciable extent. The most important reason for exploiting logging residues is of a biological or ecological nature, since most of the nutrients remain in the forest. Monetary reasons are also taken into consider-ation. If combustion ash is returned to the forest on a large scale, this is likely to take place also on land where logging residues are being exploited. If this is so, the advantage compared with the current tree section system will be less pronounced. The logging residue system is most profitable in forests with the largest quantity of logging residues per unit area after felling, i.e. in southern Sweden.

The development of new industrial technology for the integrated exploitation of industrial raw materials and energy raw materials for the future is weak at present in Sweden. However, development and rationalisation are going on in Finland, one example being the 'Massahake method' (Viinikainen & Ahonen, 1993), in which technological development is based on the optical sorting (scanning) of chips when chipping entire trees. Another example is the flail delimber of tree sections (Eeronheimo, 1995), originating in North America, which is a promising technique for integrated harvesting.

Environment

The environmental profile of forest industry is evident nowadays, the green annual balance sheet (e.g. that produced by AssiDomän) being an example. This has resulted in the rapid development of environmental considerations in the pulp and paper industry during the past few years. Environmentally-friendly bleaching methods have replaced chlorine bleaching, which is harmful to the environment. The paper and pulp market also demands a higher degree of specialisation. Special pulps and papers for applications such as photocopiers and telefax machines are new types which have evolved. These are manufactured with a high degree of accuracy, and place great demands on fresh wood materials: this does not suit tree section systems, with their relatively slow flow, the result, in part, of long terminal times.

When tree sections and whole trees are exploited, considerably greater amounts of nutrients are taken from the forest than when stems alone are exploited. The current recommendations of the National Board of Forestry (SKSFS 1986:1) regarding the removal of biomass will not suffice in future. Nutrient recycling (e.g. ash recycling) is necessary to the long-term, sustainable exploitation of biofuels.

Evaluation method

Retrospective position analysis has been used in the present study to evaluate individual projects (case studies) on forest fuel systems which utilise tree sections. The knowledge gained from the case studies formed the starting point for an evaluation of the tree section system as a whole, the interaction between the tree section system and the surrounding world being emphasised. The choice of method for project evaluation has increased our knowledge about the dependence of the tree section system on surrounding systems, and of its effect upon such systems.

The question of perspective, and that concerning interaction between various interests, are important constituents of the tree sections problem area. They must therefore be taken into account when selecting an evaluation method. The results, and the discussion above, show that investments in tree section terminals were part of the wood raw materials game during the period studied. The game is still in progress, even though power positions have changed. The analysis also indicates that power and interest were the driving force behind investments in the terminals, not considerations such as concern for the environment.

The general feature of position analysis can be illustrated by two examples:

(1) The first approach is to illuminate the problem area from different angles, to obtain different views of the same set of facts;
(2) The second approach is to compare position analysis with position sensing, which should provide a basis for any course correction required.

As regards the second situation, Söderbaum (1993) drew an analogy with an aeroplane fitted with a range of advanced instruments for information and control. The pilot uses the instruments to acquire information about his current position or state, and about changes to this state. This information permits the pilot to make decisions and to correct his position to the optimum course. According to Söderbaum, the analogy shows that the multi-dimensional analysis obtained by position analysis, cannot be compared with one-dimensional monetary measurements. The interpretation of this is that the pilot would be unable to fly the aircraft if all the information received from his gauges were combined into a single measurement, such as km h^{-1}. When complex problems are to be analysed, aggregated measures are far too narrow.

Position analysis originates in institutional economy, where it is emphasised that value judgements and conflicts always exist whenever research and investigation are carried out. It is therefore justifiable to recognise the existence of different evaluations and to accept that other observers may draw different conclusions from an evaluation, than those drawn by the investigator. The means of resolving this lies in the conditional nature of all parts of the analysis.

The method is also based on general systems theory, and the procedure used in retrospective position analysis helps the researcher to work 'in the spirit of systems theory'.

Investigations and evaluations carried out using position analysis have the advantage that they force both the investigator and the reader to learn, as opposed to more 'aggregated' methods, in which knowledge is concentrated into one-dimensional variables such as money. However, this causes position analysis work to be more comprehensive, and its results to be more difficult for the decision-maker or reader to assimilate, which may be perceived as a disadvantage. The method also generates knowledge, and the investigator has the freedom to search constantly for new methods of investigation while the work is in progress.

Position analysis reveals a number of areas of particular interest, in which conflicts affect development. In such situations, it may be necessary to supplement the analysis, in order to obtain deeper knowledge. Two examples can be adduced from the present study: the first is that further knowledge might be provided by technical or economic analysis of the forest industry's transition to another raw material base, and to more stringent quality requirements, during the period of the study. The second concerns technical or economic analysis of the structure of the entire biofuels market, and of how the market is affected by factors such as changes in taxation or changes in the price of fuels.

When carrying out evaluations, retrospective position analysis may be an appropriate first step in identifying areas for continued study, e.g. by specific economic and technical analysis.

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Appendix 1

Summary of case study

The evaluation of the project at Martinsons Trävaru KB in Bygdsiljum is summarised here, to illustrate the method used in evaluating case studies. The various stages of the evaluation process, employing retrospective position analysis, are described briefly above.

Identification of problems

The relevant institutions, rules of play, interested parties and players are identified at the first stage. Martinsons and the Swedish government are regarded as the main interested parties and Martinsons alone is the main player.

As both an interested party and a player, Martinsons strongly and actively influenced investment in a tree section terminal. The company already possessed a knowledge of bundle delimbing and the drying of biofuels. The tree section terminal was a strategic investment, to supply the saw mill with saw timber at lower prices than those on the forest market, and to provide access to wood during periods of government regulation of the wood market.

The Swedish government had an interest in replacing imported oil with indigenous fuels and electricity. The government (via the Energy Administration at Nutek) was thus the other interested party.

Project development

In this phase of the study, two different potential developments of an investment in the tree section terminal in Bygdsiljum were identified. The first was the planned project, A_1, described in the application for government support. The second was the actual development (case study), A_2. The frame of reference for both developments was 'business as usual' (A_0), which is a fictitious option, involving no investment in the tree section terminal.

The development of the project is briefly described in Appendix Fig. 1, which highlights the important decisions for the project actually implemented. Times (t_1, t_2, etc.) have been identified as the most crucial points of the project.

Description of systems

The description of systems consists of a list of systems affected by, or significant to, investment in a tree section terminal in Bygdsiljum, in relation to 'business as usual', A_0.

The systems were listed when the problems relating to the project were in the process of being identified (Appendix Table 1).

Determination of positions

In the chronological determination of position, systems are analysed from the viewpoint of when and how they have been affected (changed in relation to 'business as usual') by project A_2 (Appendix Table 2).

The significance of the spatial determination of positions indicates how the project has affected the systems in terms of state. The position determination should be compared with 'business as usual'. Since the analysis is conditional at every step, anyone other than the author may draw their own conclusions.

The greatest significance of the section terminal at Bygdsiljum was clearly on a local level. There are exceptions to this, such as the decrease in carbon dioxide emissions resulting from the burning of biofuels (global significance).

Analysis of effects

The effects of the terminal project at Bygdsiljum were analysed. The effects were assessed by the author for the identified dimensions and systems. The analysis of effects is conditional.

The effects of the project development A_2, and the expected effects of the planned project A_1, are listed in Appendix Table 3. The frame of reference for the two options is 'business as usual' (A_0).

Analysis of activities and goals

The analysis of activities and goals is divided into two parts. The first is an analysis of the interests of the main player (Martinsons, Appendix Table 4). For every identified activity, one or more goal objectives are assumed by the author on the basis of the planned project (A_1). This is a way of defining the interest. Whether

Appendix Fig. 1. Development of the tree-section terminal project at Martinsons Trävaru KB in Bygdsiljum. S = search decisions, T = terminal decisions and t = time.

T	t_1 – 1983	The company invests SEK 14 million in an "ADIAC" drying plant for saving energy when drying wood and biofuels. They have plans for biofuel producion integrated with the sawmill.
S	t_2 – 1984	Martinsons applies for governmental support for investment in a tree-section terminal in Bygdsiljum
T	t_3 – 1984	Planning and building of the tree-section terminal
S	t_4 – 1985	Commercial utilisation of tree sections starts at the terminal
S	t_5 – 1986	Termination report to the Swedish Energy Authority
S	t_6 – 1990	Utilisation of tree sections stops. The terminal is mothballed
S	t_7 – 1993	Evaluation

Appendix Table 1. *Identified systems affected by the investment in a tree-section terminal in Bygdsiljum*

S1 = Forestry
- harvesting operations
- wood market
- biological restrictions

S2 = Forest industry
- supply of primary products
- pulp production

S3 = Energy supply
- the tree section terminal at Bygdsiljum
- internal deliveries
- external deliveries

S4 = Rules of play
- energy taxation
- attitudes and government sponsorship
- environmental regulations

S5 = Monetary systems
- business economics
- biofuel prices
- price competition with other fuels
- production costs
- foreign trade

S6 = Knowledge
- tree section harvesting
- government grants

S7 = Labour market
- employment

S8 = Environment
- air pollution
- nutrient recycling

Appendix Table 2. *Chronological determination of positions for systems (S1-S8) influenced by the project (A_2). Empty cell: no influence on the system at the relevant point in time. O = influence on the system at the relevant time. t_{1-7} = time according to project development*

	t_1 1983	t_2 1984	t_3 1984	t_4 1985	t_5 1986	t_6 1990	t_7 1993
S1 Forestry				O	O	O	
S2 Forest industry				O	O	O	
S3 Energy supply	O	O	O	O	O	O	O
S4 Rules of play	O	O			O	O	
S5 Monetary systems		O	O	O		O	
S6 Knowledge	O	O		O	O	O	
S7 Labour market		O		O	O	O	
S8 Environment				O	O	O	

Appendix Table 3. *Spatial determination of positions for systems (S1–8) influenced by the project (A_2). Global, regional and local significance with spatial influence. X = influence, O = no influence*

Systems	Global significance	Regional significance	Local significance
S1 Forestry	O	O	X
S2 Forest industry	O	O	X
S3 Energy supply	O	O	X
S4 Rules of play	O	O	O
S5 Monetary systems	O	O	X
S6 Knowledge	O	O	O
S7 Labour market	O	O	O
S8 Environment	X	X	X

or not the goals are met is analysed, and is described briefly on the basis of the case study.

In the second part (Appendix Table 5), the interested parties (Martinsons and Nutek) are asked whether, in their opinion, the goals have been satisfied after investment in a tree section terminal (A_2).

According to the analysis above, only the goals of utilising government grants and minimising the loss of nutrients from the forest were satisfied. The other goals were not satisfied. The result indicates that the investment did not meet the expectations of the planned project.

In the second part of the analysis of activities and goals, the main intrested party – Martinsons Trävaru KB – was asked to assess the extent to which various goals had been met: to increase thinning, larger volumes for barter, increased utilisation of primary products, decreased costs for logging operations when thinning is carried out, an increase in the cost of producing biofuels, increased competitiveness on the forest stand

Appendix Table 4. *The effects of the studied project as regards identified systems (S1–8) observed for different dimensions.* + *= positive effects,* – *= negative effects,* O *= no effects,* ? *= uncertain effects.* A_1 *= the planned project with expected effects.* A_2 *= the executed project with estimated real effects*

	Effects for different dimensions							
	Monetary		Knowledge		Biological		Psychological	
Affected systems	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2
– A1 Forestry	+	O	O	+	O	?	O	?
– S2 Forest industry	+	+ –	+	+	O	+	O	?
– S3 Energy supply	+	–	+	+	O	O	O	?
– S4 Rules of play	O	?	?	O	O	O	O	O
– S5 Monetary systems	+	–	+	+	O	?	O	O
– S6 Knowledge	+	O	O	+	O	?	O	+
– S7 Labour market	O	O	?	+	O	?	O	O
– S8 Environment	?	?	?	+	O	+	O	+

Appendix Table 5. *Analysis of activities and goals for Martinsons Trävaru KB as identified by the author*

Activity, a (same division as for the systems)	Assumed goal direction, M	Interest satisfied? Yes/No
Forestry a_1	M_1 Increased profitability of thinning	No. The tree section assortment was never established
	M_2 Advantage on the wood market	No. Not really, but some advantage was achieved with respect to competitiveness on the forest stand market
Forest industry a_2	M_3 Secured supply of primary products	No. In the long term the tree sections were not valid for barter with timber. In the short term pulpwood from tree sections was used for barter
Energy supply a_3	M_4 Use of tree sections for energy supply	No. Fuel from tree sections did not fit the largest burners in the area
Rules of play a_4	M_5 Useful experience in utilisation of government grants	Yes. The company has gained experience in utilising government grants
Monetary systems a_5	M_6 To get government grants for the investment	Yes. Government grants were received
	M_7 Good profit for the investment	No. The investment has not been profitable
Knowledge a_6	–	–
Laboru market a_7	–	–
Environment a_8	M_8 To minimise the loss of nutrients from the forest by selecting appropriate standards for harvesting	Yes. The general restrictions for harvesting of tree sections have been followed

market and better negotiation power for the bartering of pulpwood and saw timber. To summarise, most of the goals were satisfied in the short term. In the long term, almost no goals were satisfied.

The analysis of goal-satisfaction for the other intrested party of importance – the Swedish government – is more general, and is described in Hillring (1995*a*).

Conditional conclusions

The tree section system at Bygdsiljum did not contribute to an increase in the profitability of thinning or final felling. No harvesting of tree sections was carried out in the area at the time of evaluation.

Forest fuel from tree sections from Martinsons is not competitive on the market for the district heating plant in the town nearby

(Umeå), both for economic reasons and for technical reasons relating to the boilers. Tree sections were never profitable at Bygdsiljum. Other forest fuels subsidised the fuel from tree sections for some time. Other forest fuels became available to the company, and it was considered financially advantageous to cease using tree sections at Bygdsiljum.

There were technical restrictions on pulpwood from tree sections at the MoDo pulpmill at the time of the evaluation. Martinsons could use the tree sections to increase the amount of saw timber for a short period, when the market was favourable in the 1980s. This probably applied for that period only. At the time of evaluation, there was sufficient wood on the market, which means that the terminal will not start operating again in the foreseeable future.