Decision Support Systems in Wood Procurement. A Review

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Many kinds of planning systems have been labelled decision support systems (DSS), but few meet the most important features of real DSSs in planning and control of wood procurement. It has been concluded that many reasons exist to develop DSSs for wood procurement. The purchasing of timber seems to be one of the most promising areas for DSS, because there is no formal structure for these operations and decisions deal with human behaviour. Relations between DSSs and different features of the new approaches in wood procurement are also discussed, and hypotheses for future studies suggested.

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1 Introduction

Managers and researchers are facing a multitude of new problems, e.g. increasingly severe competition in the marketplace, increasingly tighter quality requirements, specialised mill production, faster flows of timber, customer-oriented production, and environmental and social or societal expectations. Therefore, there is an urgent need to develop and to study decision-making and planning systems.

Planning may be seen as a decision-making process, and plans are used as the bases for operative decisions. This being the case, the theory of decision making may represent one frame of reference when approaching planning problems. The two main approaches available for studying decision making are as follows: the mathematical-statistical approach and the human behaviour approach. Decision may be defined as the act of using quantitative methods especially if one assumes that the decision maker acts rationally, which is, however, seldom entirely true in practice. We assume that the difficulty in describing decision making mathematically is often true when applying optimisation models in solving planning problems in wood procurement.

In this study, wood procurement is defined, as common in Finland, to include purchase, logging and transport of wood for forest industry as well as the management of these activities. The utilisation of mathematical and other relevant models in the planning of wood procurement has increased at the enterprise level, but it has also brought with it many disappointments as discussed by Robak (1990), for example. Models have often resulted too simplified solutions to the real life problems. At the beginning of 1990s, the woods departments of large forest-industry companies in Finland used optimisation models in their tactical or operational planning, but only linear programming models (LP). None of the small companies used them (Meriläinen et al. 1995).

Decision support systems (DSS), widely discussed in business management literature, imply the idea that decision making is a human task, and that computerised systems only support it. The disappointments referred to in the above, together with the wide interest in DSS in common management science, suggest that the application of DSS also in wood procurement may be one of the most interesting areas of forest operation re search in the near future. Wood procurement operations are geographically decentralized in a wide area. Unpredictable weather conditions affect on the operations, and human behaviour is a key factor in wood trade. The scale of operations is often very big. Therefore, problems may be ill-structured and complicated, and unexpected events may happen. DSSs have been designed to assist decision making in this kinds of situations, as explained below. Some DSS studies already exist in the field of wood procurement.

The main benefits of DSSs can be summarised as follows: DSSs support decision making also in complicated and un-structured situations and assist the user in reacting to unexpected events. Several scenarios or alter native decisions can be created and tested. At the same time, the decisions are analytical (cf. Alter 1980, Keen 1981, Meador et al. 1984) The aim of this review was to critically evaluate and synthesise the research in this field and to introduce and advance hypotheses for future research. Articles dealing with the application of DSSs in wood procurement or planning models for wood procurement having some features of DSS were reviewed. In addition, some common literature was also included to clarify the features of DDSs.

2 Decision Support Systems

For example, Simon (1973) set the following prerequisites for a management information system (MIS) if it is to increase performance: the output must be small when compared to the input; it must include active and passive effective directories; and it must include analytical and synthetical models capable of solving the problems, evaluating the solutions and making decisions. Kallio et al. (1979) stated that only small and frequently repeated decisions can be fully automated. Moreover, big and important decisions require experience, even intuition, on part of the decision maker. DSS joins human thinking and computerised data processing and provides support not only in well-structured decision situations, but in other situations as well.

Keen and Morton (1978) were the first to attach the label "decision support system"(DSS) to systems aimed at dealing with various kinds of ill-structured problems, and at supporting all phases of decision making. Such systems are appropriate for iterative use and they are flexible and adaptive. The features of modern DSSs include ad hoc queries using natural language and interactive graphics. These may also include built-in problem analysis models that render them close to artificial intelligence (AI) (Kaila and Saarenmaa 1990). Bolgar and Wright (1994) concluded that the good performance of DSS will be manifested when both its ecological validity and learnability are high. Ecological validity can be understood as the validity in a decision making environment.

When working with a DSS, the user learns about the problem in more detail and cognitive processes can also be included in the system itself. DSSs can be made part of the enterprise's hierarchical planning system and they can support decision making by individuals and by teams (cf. Alter 1980, Keen 1980, Sprague 1980, Sprague and Carlson 1982, Turban 1993). The characteristics of MIS and DSS listed in this chapter are considered in this study to be characteristic of real DSSs. All of them are very seldom met in a single application in practice, but a real DSS does include several of them.

Some authors have considered that the user must be involved in the design and development of a DSS, which is an iterative and adoptive process improving managerial decision-making effectiveness rather than generating solutions (Alter 1980, Sprague and Carlson 1982, Prasal 1985, Robak 1988). This may make it easier for managers to accept and adapt these systems.

3 Need to Develop DSSs for Planning of Wood Procurement

The analysis of exiting systems gives a basis for an assessment of the need to develop DSSs for planning of wood procurement. Several planning systems for wood procurement are described in literature. Some of these have been labelled as belonging to the DSS category. What features of real DSS are included in these systems, what areas of wood procurement they are covering and what kinds of decision making problems are without any support in the existing systems? At the same time, we may be able to find need for research.

These systems, or research on the subject, utilise GIS and topological models (e.g., Reisinger and Davis 1986, Herrington and Koten 1988, Reisinger 1989, Becker and Jaeger 1992, Shiba 1992, Johansson and Gunnarsson 1994), productivity and cost functions (Ericson and Westerling 1985), mathematical programming (Davis and Reisinger 1985, Mendoza and Bare 1986, Reisinger and Davis 1986, Nuutinen 1992, Williamson and Niewenhuis 1993, Lihai 1994), heuristic algorithms and models (Sessions 1985, Reisinger and Davis 1986, Linnainmaa 1992, Leino 1993), simulation (Shiba 1992), network models (Sessions 1992), the queue theory (Korpilahti 1987), data envelope analysis (Shiba 1995), and artificial intelligence (AI: Expert Systems, Fuzzy Set Theory) (Thieme et al. 1987, Kärenlampi 1988, Leino 1993). The studies referred to are examples of systems utilizing built-in models, a typical feature of DSSs, and most of them utilise more than one method. Some models embody environmental factors as constraints or otherwise. On the other hand, many characteristics, such as ability to deal with ill-structured problems, are lacking in these systems.

Some systems have been designed to work as a part of forest management planning (harvest scheduling) systems, and they have only a very loose relationship with operational wood procurement (e.g., Herrington and Koten 1988, Covington et al. 1991, Sessions and Sessions 1992). Others have been designed for specific tasks such as road design and network design (Thieme et al. 1987, Becker and Jaeger 1992, Shiba 1992). Only a few models deal with timber sales operations and support for purchase decisions (Herrington and Koten 1988, Nuutinen 1992). Planning systems referred to by the acronym DSS may not meet all the characteristics of a real DSS or all the requirements of the present-day decision-making environment. Quality management systems may require new kinds of models in controlling quality. Statistical methods are traditional possibilities, but other means also used in controlling industrial processes are worth studying, and even artificial intelligence (AI) should not be excluded.

Comparisons of models as a part of DSS in dealing with different wood procurement problems and environments are almost lacking as is also the case with real cost:benefit analysis. The question of the extent to which models allow for creativeness and experience-based elements in decision-making process is also worth studying when applying them in DSS.

One reason for managers not applying rationally-based models may be in that human decision-making processes often do not follow rational models (Schweder 1977). Managers may use only a small portion of the information available and necessary for good decision making (Chestnut and Jacoby 1982). On the other hand, in complex decision environments, managerial decision making based on limited information, experience and intuition may yield better results than purely rational models (Mintzberg 1982). Thus, Robak (1988) came to the conclusion that decision processes, which do not follow rational models, may act at such deep levels of human consciousness that they cannot be modelled by contemporary decision analysis methods. He suggests prototyping, where a system is developed through iterative, evolutionary steps, in collaboration with managers, as a partial solution to problems.

Some authors have called for a hierarchy of models from national and strategic level to the tactical and operational level, and for cuts in existing data. They point out that processes are interactive and the balance between planning and control mechanisms means that control information can be used in the reconciliation of plans (Pritchard 1990, Whyte 1990).

Hierarchical systems have already been introduced. Ericson and Westerling (1985) and Ericson (1986) have presented the SKOGSPLAN 84 system as a modern approach to the planning of logging operations. It is a hierarchical system including five levels from strategic to monthly planning. The user makes all the decisions, but the computer is used for computations, collations and reporting of different alternatives, utilising, among other things, functions and correlations. Alongside the goal of achieving maximum contribution profit, the goals may include full employment and optimum inventories of wood. In this system the decision making is an interactive process between man and computer, but other features of real DSSs are lacking.

In Nordic wood procurement, the majority of the wood raw material is purchased from small, non-industrial, private forest estates, and this impairs the data available for planning. Although we live in an era "rich in data", some relevant data is expensive to obtain. In wood procurement, and in the wood-based industry, one prerequisite to "getting the right raw material to the right place at the right time" is the availability of adequate information on marked stands, including the quality class distribution of sawtimber logs. This can be achieved by advance measurement of the stands or from forest management plans developed to include such a data. An interesting new idea is to use data of harvested stands and 'nearest neighbour method' to predict the characteristics of a new stand.

Systems labelled to be of the DSS type deal with harvesting schedules, selection of logging methods, transportation routes, logging and transport plans, pricing of marked stands, planning of roads and road networks, and control and steering of logging and transportation operations. These systems, or separate studies on the subject, often utilise GIS and several kinds of models, including AI, as reviewed above. A few of the systems consider environmental factors, multi-objective decisions or negotiation processes between managers, and non of these is a part of a larger hierarchical system.

GIS involves many kinds of potential applications in DSSs. Most of the aforementioned systems utilise GIS. In addition, GIS has been used in estimating available wood resources and purchase competition (Brinker and Jackson 1991). In operational planning, GIS has been utilised not only in controlling operations, but also in formulating logging compartments according to the present demand for wood raw material by mills (Hämäläinen et al. 1990, Reisinger et al. 1990). Other applications include road network planning, long-distance transportation route planning, and simulation of the impacts of harvesting on forest areas and landscapes (Pulkki 1984, Smart et al. 1990, MacDonald et al. 1991, Dippon and Cadwell 1991, Tan 1992).

Many researchers are of the opinion that full benefit is achieved only if GIS is integrated with a real DDS (Densham and Goodchild 1989). In 1989, only five companies out of eighteen utilising the GIS had fully integrated it with the decision support environment of the operations (Reisinger 1989). Because 20–30 % of GISs' implementing costs are hard ware and software costs and 20–80 % consist of the costs of establishing the necessary databases, the cost:benefit ratio is estimated to be only 1:1, if a GIS is used only for producing maps, but greater than 2:1, if it is used in advanced planning and control activities. If several organisations utilise the same GIS system, the said ratio could be as high as 5–7:1 (Tveitdal and Hesjedal 1989, Kylen 1990, Leggat and Buckley 1991).

The requirements of planning and control systems differ according to the kind of enterprise and decision-making environment applied within the enterprise. This is seldom addressed in studies. The relationships with respect to management policies and systems should also be taken into consideration; e.g. environmental policy, quality policy and systems, management by objectives and decentralised / centralised decision making. Team work is another such factor. A team managed by objectives can, in planning and controlling their activities, make use of simple PC-based systems, as presented by Andersson (1993) and Skutin (1993). No applications able to consider un-structured or complicated situations exist.

4 Recent Approaches and Hypotheses for Further Studies

Robak (1990) calls for new approaches (even cognitive processes), concentrating more on improving the entire decision process than on model development. He sees the following changes influencing the decision environment: organisations become flatter and autonomous team work increases, and therefore more decision making support is needed; operational, regulatory, environmental and societal objectives and constraints become more complex and volatile; there is a tendency towards decentralised decision making; organisations are richer in data; information technology evolves even though companies do not learn enough about turning data into useful information.

These changes require new approaches, including the need to go back to problem solving, while understanding that there may not be the one "right answer". Complex decisions involve multiple objectives and the system specifies how to negotiate a solution through computers. Different models require linking models. Without going into this issue in more depth, it may be necessary to identify the problems which can be easily solved using optimisation models or models related to them, and develop models of appropriate validity for these problems. In the case of more complicated problems, more room should be left for human intelligence in problem solving. Heuristic rules may also be useful parts of real DSSs.

The utilisation of the principles of logistics has been discussed widely in literature. Calculation indicating that benefits can cover the costs of pre-measurement of marked stocks, planning costs and utilisation costs of modern tools (such as telemetric data transfer) in the control of logging have been presented (Imponen 1990, Andersson et al. 1994, Uusitalo 1995). How to utilize these principles in DSSs for wood procurement is unanswered. Some operational planning systems, while being well-structured, include interactive components and alternative suggestions for decision making. These systems include GIS, optimum models and simulation systems enabling formulating of the logging compartments or cross-cutting programme according to the prevailing market situation (Mendoza and Bare 1986, Hämäläinen et al. 1990, Ahonen and Lemmetty 1995).

Decision support should be extended to the purchasing of timber. In Nordic countries, timber is mainly purchased from small private forest estates and one company may annually harvest several thousand separately marked stands. In spite of this, only some commercial pricing systems (no studies available) for marked stands have been developed to support the decision making in purchasing and sales operations. Because there is no formal structure for these operations and decisions deal with human behaviour, the utilisation of DSS could be beneficial.

The new approach in wood procurement often also includes modern, rather flat organisations, decentralised decision making, management by objectives and results, management by quality, and even environmental quality systems, team work, etc. Management by quality and objectives, together with working in independent teams, moves the emphasis from ordinary control of activities to the planning and setting of management and quality politics and systems, to the setting of objectives, and to creating a participatory and innovative atmosphere, as well as follow-up systems.

When practising decentralised decision-making and team work with quality management, the control of operations resembles control of industrial processes, and industrial planning and control methods may be appropriate. The human-centred approach in applying advanced manufacturing technology (AMT) is also emphasised (Corbett 1988). This means that well-trained workers and teams can act independently and creativeness on part of the team is encouraged in order to activate human re sources. The planning process at the upper level of the organisation produces only objectives by a discussive process and the control system is indicative of the progress of the team in rewarding and training purposes. In some cases, the system issue alarms if work productivity or quality are inadequate. Can we develop planning and control systems towards a cognitive process? When people or teams work quite independently, they may gain experience and ideas that may benefit the whole organisation.

One question needing to be answered is: How can we include the experience, knowledge and creativeness (intuition) of managers in the planning process? One means is through negotiation processes between different levels of an organization. The structure of DSSs should be so flexible that this dimension of decision making is easily done and DSSs could include rules to create beneficial compromises. The psycho-social approach to decision-making may also utilise the synergy between individuals (brainstorming, etc.). Team work is one possibility, but other means could also be innovated. Models could include innovative elements.

Cognitive processes can also be included in models and systems. A prediction system of taper curves for bucking in harvesters learning from the former stems of a stand is a simple application of this idea (Ahonen and Lemmetty 1995). This, however, is an example of a highly technical system. Is it possible also to learn about human behaviour in the timber trade, for instance?

Environmental issues are, as a rule, included in the quality requirements of wood procurement. To produce relevant cost data for decision-making, environmental issues must be described in such a way that they can be entered as variables in the cost and benefit functions. The same applies to other objective variables included in multi-objective decision-making. All these tendencies set new requirements for planning and control systems.

When single phases of the process are more and more in control, a need to optimise the total process from the stump to the markets becomes evident. Some attempts have already been made to build a DSS simulating an industrial process and its interaction with raw material and wood procurement (Kärenlampi 1988). Together with the aforementioned aspects, shared development in society stresses the need for integrated DSS at all organisational levels of enterprises.

Decision making processes and the information requirements should be studied at different organisational levels before we are competent in designing real DSSs for wood procurement. Planning and control systems are more and more process-control oriented and they can be described as an information flow and feedback system. Besides those mentioned in the above, research problems also include the following issues: How do the teams really work? How do people internalise the objectives of the company they work for? How can an innovative atmosphere be maintained? How do the teams interact with the other hierarchical levels of their organisation? The main question from the planning point of view is: What kinds of hierarchical DSSs are required?

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