FORESTRY PLANNING

PREFACE

Erik Johan Ljungberg’s Education Fund has generously funded the compendium. It has been part of a larger effort to introduce more technical expertise to SLU's forest programs. The authors of the compendium come from the Department of Forest Resource Management at SLU in Umeå. The Compendium consists of three main parts: forest inventory, remote sensing and forest planning. It is intended to be used as literature in the department's courses, mainly at the basic level, but is also freely available on the Internet and can be used by others interested in the subjects

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Updates and selection for the course Forest planning with PlanWise as decision support. Translated by Tomas Lämås, Karin Öhman, Jeannette Eggers, Patrik Ulvdal, Pär Wilhelmsson and Johanna Lundström, January 24, 2020

Content

2. BASIC PLANNING CONCEPTS

A plan consists of a number of interconnected decisions that have been documented and relate to future actions.

Planning ludes a number of activities; mapping of prerequisites, elaboration of relevant alternatives, and choice of the best alternative. The goal of the business permeates all three steps.

Decision-making is sometimes described as three phases: Intelligence - Design - Choice, which is similar to - but not identical to - the steps in a planning process.

This chapter intends to go over some general concepts of planning. There is extensive international literature on planning concepts and the presentation makes no claim to cover all interpretations of the concepts. The intention is to give a brief introduction in order to make the reader interested in moving on, if possible, to create an insight that planning is a complicated business that requires different approaches depending on context and purpose.

2.1 Planning - what and why?

Planning seems to be a trait that, in combination with our social talents, forms the basis of our species' dominance on the planet. The purposes, forms and methods of planning vary with the context. Individuals, families, relatives, friends, district councils and the multinational corporation do so in very different ways. In this publication, the focus is on planning in a professional context. We primarily think of forest companies, but other types of organizations are also possible. The greatest applicability of the review of different concepts is for organizations with a certain structure, often a hierarchy, where planning needs to be organized in a systematic way. It is thus well suited to analyze the large forest company.

As mentioned, planning takes place in other contexts than in complex organizations. Other planning situations dealt with in this publication are the private forest owner's planning, the community's need for planning and planning when a number of stakeholders are involved in forming a plan. Some of what is discussed here can of course be useful in those situations too, but other concepts may work better.

The upcoming pages on planning are a brief introduction with no claim to completeness. Other easily accessible sources exist, e.g. Wikipedia / Planning which can be a start for anyone who wants to move on. What is included here has focus on and examples from forestry and will hopefully provide a basis for working in this complex area.

The content of this chapter is structured as follows. As we focus on the professional use of planning, we need to provide a definition of planning that separates it from other more general meanings of the concepts of planning and a plan; we must know what we are talking about. It is the first section of this chapter. Next, we present how planning proceeds according to the standard template for companies and other organisations. With a better understanding of what planning is and how it basically works, we can go into why you are planning, that is, its purposes.

This chapter is dedicated to presenting the basic elements of what is planning, what here is called the planning process. In the next chapter (Chapter 3), we begin to differentiate between different planning processes. Different types of planning processes can then be built together into planning systems for all or parts of the organization. A, in some sense, complete planning system is then described in section 3.1 Planning of the large forest company.

2.1.1 What is planning?

In order to be able to define the concept in a more formal sense, and as a concept that is useful for describing the process of planning, we first need to specify the requirements we place on a business for it to be called planning, and to place the concept in relation to other concepts, mainly decision-making and implementation.

Like most concepts with some complexity, "planning" is filled with different meanings. We use the term on a daily basis to express our intentions or thoughts about the future: “What should you do after work / tonight / during the weekend; What do you have plans for?” We all ask these kinds of questions - and it's about planning. Institutions - authorities, companies, NGOs, etc. - are involved in planning and in making plans. One question we also ask is whether there is any difference between the individual's personal planning and an organization's planning? This text assumes that an organization's planning is qualitatively of a different nature compared to the everyday planning we all do. Here, three criteria will be set up to qualify an activity as planning and which results in a plan (the criteria are essentially based on Mintzberg 2000).

Planning concerns the future

Let's start with what should be common to all planning regardless of where, when and by whom. Planning is an activity reserved for thoughts and communication about the future. The future can then be of a different nature. It may be a probable, potential or desirable future. What we are looking for in the first case is a forecast (or projection) of what will happen, and the planning work is to try to capture it. Another future is the potential. It may not be the most likely but, nevertheless, a future that may have significance for us. The planning work here is mainly about trying to capture and describe different potential futures, which are reasonable and at the same time relevant to us. Here you typically talk about developing scenarios. Another type of future is the desired future, the future that we want to shape.

Often the terms descriptive of the probable future, explorative of the possible, and normative of the desired future are used (Börjesson et al. 2006). If planning in general and here in particular is associated with normative planning, what’s the role of descriptive and explorative planning? Of course, a descriptive plan, a forecast, can be used to underpin a decision. Once you have the forecast there you may be able to make a decision without further planning or it will form the basis for a more complex planning process where the forecast goes in. It is more difficult to see how explorative scenarios could be used for decision-making without considering how to proceed given the development of the scenarios. It is the last type of future we primarily associate with planning; the desired future. We make a plan that aims to meet requirements, wishes and needs. It is also the type of planning that we will focus on.

One argument for focusing on the desired future is that it relates to decisions. It connects to the other two criteria for planning; criteria that concerns complexity and formal status of planning processes. In practice it means that we limit ourselves to normative plans and normative planning. A descriptive plan, a forecast, does not require any decision from us.

Making a forecast can of course make it necessary to make a series of decisions, for example, what data we are going to use, what forecasting method to be used, and how to present the results. But the forecast does not really contain any decision on future action alternatives. On the same basis, exploratory scenarios contain descriptions of the future, not of our choices.

A system with linked decisions

To move forward, we need to clarify the relationship between a plan and a decision, planning and decision making. A decision is a choice between two or more options. So (normative) planning is ultimately about making choices, making decisions. But planning is not the same as decision making. Planning comes with complexity. Suppose you are at a forest fair and are thinking about which quad bike to buy for your family forest holding. If the choice is just about choosing the what quad bike and really nothing more it concerns decision making but (in the sense we use the term here) not planning. Imagine, on the other hand, that your decision requires you to check your liquidity, combining it with a plan for how to manage your forest, what implications may be imminent in the future, what it provides for both financial factors and the need for the quad bike. The work of developing a decision basis may require consultation with related parties. Then it concerns planning.

We will return to this example later, but now we focus on what the plan itself contains for decision elements. The final decision on the plan consists of whether or not to buy the quad bike. To get there you need to consider a number of other decisions concerning which stands you want to harvest, which silviculture is needed (requires terrain transport of seedling, etc.), and how you handle other parts of your economy. Thus, you make a number of decisions that are interconnected and that represent the plan that also includes your final decision. It also means that there is consistency in the plan, that is, the different decisions in the plan are logically related. If your plan includes a quad bike purchase, it may be necessary that the plan also includes activities that generate the funds needed for the purchase.

Planning is thus not about making a decision. Planning is an activity or process that leads to a system of linked decisions. The plan includes a number of different activities that connect to each other. The distinction between decision making and planning (which thus integrates decision making) is not clear. However, there is a certain complexity that takes you from a single decision to a plan with a number of linked decisions.

One way of looking at planning is to consider it as a "repetition of the real process at the macro level " (Eliasson 1976). This means that planning is regarded as a general rehearsal of what’s going to happen; what is in the plan is not the actual actions but an intended course of actions. When planning, you can say that you go through what is going to happen, see that it makes sense, but you do not do it in "reality" but overriding it at the macro level. The actual process is about implementation, something that is not touched upon in this publication.

Documentation

The third requirement when talking about planning (in addition to aspects of the future and complexity), is that the plan is documented in some way. This concern work in organizations and the fact that many people are involved. If a plan is to function as a plan in such a context, it must in some way be available. A documented plan can be communicated. (This normally means, though not generally, that it must be written down on a physical or digital medium.) At the same time, this means ensuring a certain degree of integrity of the plan. It makes it possible to follow up the plan, it can not be changed arbitrarily, while it is possible to change the plan if conditions make it necessary without having to redo the entire planning process.

Definition of a plan

That is, a plan consists of a number of interlinked decisions that have been documented and relates to the future.

After the planning process

What remains when you have your plan in hand is to implement the decision, to implement it. That means in the example of the quad bike that the purchase is done along with other related activities. Implementation is not included in planning processes as described here. Often it is good to make a distinction between them. When studying implementation key concepts are rather steering and control. Then it is central to be able to follow the course of actions and make corrections based on what is actually happening in the process.

2.1.2 How is planning done?

What does planning mean in terms of activities? Of course, there are many ways to build a planning process. It depends on the purpose and context of the planning. On a very general level, it can be said that it depends on what point of departure you have when it comes to how decisions are made. It is also crucial for how a planning process is described; Planning is often complex, and the same planning process can be described in many ways.

Classic model for a planning process

The classic model for planning, or the rational planning model, has been described in a variety of ways but is basically a three-step process (Kimble 2016 or Planning 2016). Based on Figure 2.1, it can be described as follows. The starting point is a mapping of the conditions and prerequisites, e.g. that you find out external threats and opportunities (external analysis) and internal strengths and weaknesses (internal analysis). This means that you do a so-called SWOT analysis where external and internal refer to the organization's surroundings and internal capabilities. The next phase consists of developing relevant alternatives. The last step means that a choice is made of the best alternative, that is, the best plan among the options available.

The overall goal of your activity (business) has to be considered in all stages. It influences what one draws attention to when mapping, it controls which alternatives are interesting and it is of course (and must be in rational decision-making) decisive for which plan is determined. In figure 2.1, the goals lie in a loop, i.e. to indicate that they can be modified based on the experience gained during the planning process. New opportunities or limitations can emerge or be identified that you did not initially think of and that may change both your target, your analysis and your options. (Implementation is included as a dashed box to mark its relation to planning, but without being part of what is called planning.)

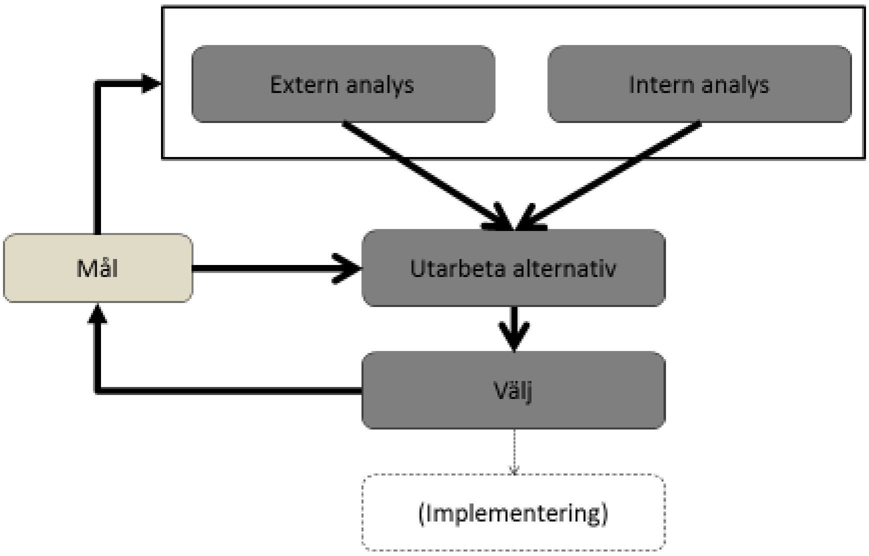

Figure 2.1. The classic model for a planning process.

Planning vs. decision making

The description of the planning process above is closely linked to a generally (though not generally accepted) theory of rational decision making (note the difference between decision making and planning as above). The rational model of planning in its original form (and as a recipe for how you ought to do rather than a description of how you really do it) presupposed that, in principle, one gained complete knowledge of the prerequisites and that all relevant alternatives were developed. In that way you would find the absolute best plan. As you realize, it is not always possible. In some, well-known, situations it may be possible. But often neither resources nor imagination are sufficient to be able to make a comprehensive description of the starting position (mapping) or the development of all plan alternatives. The criticism of the rational model was given its concrete form by Simon (1960) who introduced the concept of " bounded rationality ". The concept simply means that there are limitations to how much information can be collected and processed, and how much analysis you can do to set up different alternatives. Our ability to evaluate and make decisions in the third stage of planning can also be limited. It may simply be that one should not try to cover everything when planning; perhaps the plan must be in place before everything is mapped and before the funding for planning ends. Simon believed that practical planning is governed by rules of thumb that limit planning activities.

The term "*bounded rationality"* has been applied here to the planning process. Originally, it was about decision making (not planning in our sense) and was the result of a general analysis of structured decision making (or rational decision making that took into account limitations in force at that time). It may be a good idea to briefly mention the analysis as it often appears in the planning literature and is a powerful tool for structuring, not only decision-making, but also an analysis of planning processes (more detailed references can be found on wikipedia, Computer notes (2016) and on other sites). Rational decision-making was described by Simon as consisting of three phases: Intelligence - Design - Choice (IDC in the following).

Intelligence is the phase in which one tries to understand where one's problems exist and collects data on conditions that can explain it, ie. provides a diagnosis of the problem that must be solved. In the design phase you develop different alternatives and then in the choice phase you choose the best option. It is on the basis of an analysis of how practical decision-making takes place that Simon finds that thumb rules are crucial to being able to handle the complexity and diversity that you generally find yourself in. Then, of course, the rules of thumb can be more or less good.

The connection of the IDC structure to the three phases of the classical planning model is striking. But they are not identical, one involves a formalized planning process, the other a way of understanding how decision-making goes. However, there are some details that make IDC interesting for a planner (especially as planning for us is about decisions). In some cases, especially for smaller organisations such as the non-industrial private forest owner, it may be more fruitful to use IDC instead of relying on the entire planning terminology that we will go through here. Another feature is that the feedback between the different planning steps can be seen more clearly or become more obvious (see Figure 2.2).

Another feature is that a planning process can be analyzed in its various parts with IDC. Simon spoke of "Wheels within wheels". Let's start with planning as a process with many activities. At each stage of the planning process, a number of decisions must be made. We can study them according to the IDC model. Take the part of the planning where alternatives are elaborated. This is in itself a part-problem that must be solved. What does the problem look like in terms of time we have, resources we can spend, the quality of the result demanded, what to focus on? These are typical intelligence issues. Once we have straightened out, questions remain as to what methods we should use to elaborate alternatives. This represents the design phase of the sub planning problem to develop alternatives. Thereafter you have to choose method based on one or some criteria, i.e. you are in the choice phase. In this way, you can analyze and perhaps create greater clarity in what you do in your planning and also see opportunities to improve it in its various parts.

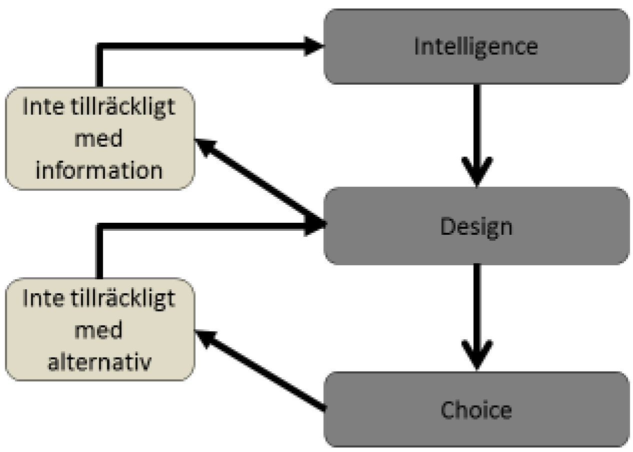

Figure 2.2 The decision-making process according to Simon (1960) (after Computer notes 2016)

2.1.3 Why planning?

In this paper planning concerns a formal process to develop a plan - a coherent set of interlinked decisions - which promotes future purposes. Equipped with this definition, planning is an activity that we associate with organizations rather than individuals. Planning is something that permeates modern organizations, whether governments, voluntary organizations and companies. Why do they do it, why put resources into something that actually is necessary? We can discern several purposes and some of them are described below.

Planning is not an obvious matte. Several studies have shown advantages of performing planning. But it can also have drawbacks, so a positive net effect has been difficult to verify. Among the planning cases, for example, find the small indie music publisher, successful and with increasing sales. In the end, you take in external skills to organize your business and start planning your business in a more conventional way. The result was better order at the expense of the business losing its soul and being shut down. Planning is not a *Panacea* to success; it is important to be aware of why you are planning and how to set up the planning based on the goals you have.

Here we will go through a number of purposes focusing on an organization with a certain complexity and with a formal planning process. It is the purposes, one or more, that one can find e.g. at family forestry, but it is no such a situation we primarily base our reasoning on. We also do not devote ourselves to the purposes linked to issues of a very general, strategic nature. The report is to a large extent, if not solely, based on a review by Eliasson (1976).

At the overall level, one could talk about planning that shapes the character of the organization and that relates to questions about how to manage the environment within which you are operating. One question concerns how the company or organization should position itself in the market (should we invest in pulp or diapers?). Another question is how to manage central resources, e.g. should you keep operations within the organization, or should you outsource them? These are examples of goals that are intended to create, what in the literature is called "*sustainable competitive advantage* ". These are questions of a general nature, we talk about strategies, a concept we will return to but as planning problems we will not deal with them.

Optimize a business

Another group of purposes are of more central concern for us as forest planners, namely those aimed at optimizing an activity. We describe it on the basis of two concepts: resource allocation and risk management.

<u>Goal fulfilment and resource allocation</u>

The most obvious reason for planning, or the one you usually find first in a textbook, is to be effective in terms of goal fulfilment. By planning, where you find out what is important (analyzing your goals), making careful studies of various options, and spend time evaluating the options whether or not they suit your goals, you could be more effective. This means that you have an opportunity to use your resources more effectively than you would otherwise.

The focus is precisely on getting a plan with the right thing (or person) in the right place at the right time. There are of course other purposes of planning, but what is emphasized here is precisely the allocation of resources.

Risk management

A further aim is to create plans that allow you to efficiently manage the uncertainty that lies ahead. A better word is perhaps foresight, ie to create a readiness to meet various event developments. (Of course, you are predictive when making a plan focusing on resource allocation as above, but focus is not the uncertain future, which is emphasized if we use foresight.) Your plan may be based on a certain price picture, but certainly it would be good to be able to take into account that it can be changed? Or that it will be a very severe winter when you can harvest stands having poor bearing capacity? By planning, you have the opportunity to be better prepared for the future. This may mean that you have a built-in alarm clock that tells you when to switch to another action plan. E.g. this may mean that when you have had a sufficiently long period of low temperature, you include a number of stands with poor bearing capacity in your operational plan. It can also mean that you already now make decisions and implement measures designed to ensure you get into a better position than you would otherwise do. An example of the latter is when the roads are upgraded to cope with long thawing periods; most often you may delivery with the existing roads, but to be confident you plan on a specific extra quantity of upgraded and good roads.

What is being addressed here about the uncertain future may be associated with the concept of robustness. It is not a very clear concept, but if you are referring to a plan that gives robustness, you generally mean a plan that contains measures that work well regardless of the future scenario. The above example of road upgrading can be seen as such a plan; Regardless of the length of the thawing period, you can fulfill the contracted deliveries.

A related term is *contingency planning*. Such planning means that you make a plan for each scenario. E.g. you make a plan for each of a few different price levels. Or a plan for normal winter and a plan for severe winter. You can then observe what is happening and act according to the circumstances that are the according to the most suitable plan. In theory, it should be a good way to manage an uncertain future. In practice, it is rarely applied. In practice, making a plan is often so demanding that you do not have the resources to do yet another (or how many are needed to keep track of all relevant but unforeseen). There are other reasons why *contingency planning is* generally not a practical tool, something we will return to below. If organization manages risk and uncertainty, it is rather in terms of robustness.

Management of a business

Naturally, any organization aims to be effective. Another group of goals is also about efficiency but more with a focus on how to manage an organization and the people in it. An organization is a complex organization, with members having different roles, competencies, values, and ambitions. Getting such organization to work is not an easy thing. A starting point for planning is that it can function as a communication and control instrument.

One purpose working on planning processes is to create a common idea of what to achieve. The forest company shall deliver 100,000 m^3 per year over the next few years. Or the costs per harvested m^3 have to decrease by 20% over the next 5 years. This could be an expression of goals that emerge as a result of planning, where the implementation may need other and more detailed plans. The important thing is that you have communicated what has been stated and what is to be achieved. For it to work well, all involved preferably agree on it.

In this context you sometimes talk about goal management. It is a way to avoid detailed planning and management, or an alternative to it. However, there are other ways to get employees to realize a plan besides directing in detail (or at least providing directives on what to do) and goal management, for example, by building common values. (But that's another part of organizational theory that we won't go into here.)

Another purpose of planning that is less related to efficient resource utilization, but more related to getting the business working, is coordination. But making a plan where different activities link into each other in an appropriate way - are coordinated - isn’t it all about efficiency? When we use the term coordination in this particular context, it is not about optimizing. It is about communication, learning, getting people to understand each other's tasks so that their work is coordinated. It is planning as communication. The coordinated plan may not be the most effective, but it is possible to realize.

Follow-up

Another purpose of planning is to have as a yardstick for control and follow-up. If you have a plan, you can identify deviations. If the plan says that at the end of the month you should have delivered 10,000 m^3 but only 7,000 are actually delivered, you have a signal that motivates you to follow up and investigate what could be the reason. There is another aspect of the plan as a follow-up instrument that links to the plan as an instrument for communicating goals. If the employee has been involved in drawing up a plan that expresses what is to be achieved, it also constitutes a control instrument. Not only is the employee having a set goal, it is also something they know they will be judged against. The plan can act as both whip and carrot.

The fact that the plan is an instrument of control is not entirely unproblematic. Let's just indicate what the problems is. As a goal, you might want the plan to be set so that you are stimulated to do something little extra. At the same time, it is not good to have a plan that you too often fail to finish, ie. the whip function dominates. Another aspect is the possibilities of *contingency planning*. A plan containing different variants becomes unclear as a follow-up instrument. Let's say the plan takes into account whether it is a severe or mild winter where the mild winter requires smaller volumes and allows for higher costs. When you follow up the outcome, you might ask the question: Was it a cold or warm winter? As a basis for follow-up, a plan is a plan - do not blame the circumstances (especially if you use goal management).

Note on forest planning

What is most common when studying commercial organizations is to study planning as a communication and control instrument (Eliasson 1976). If it was the case in the 70s, it certainly holds true even today. Planning as a teaching topic is to a large extent based on planning as a rational process where it is important to utilize forest resources as efficiently as possible. The methods that a student mainly gain insight into when it comes to forest planning concern the disposition of the material (and personnel) resources to optimize the outcome. At the same time, it is important to know how it actually works to understand why planning is done the way it is done and the potential to develop it further. It is otherwise easy to have a naive belief that it is just about implementing effective methods to optimize operations when so much other matters are clearly influencing.

2.2 Different types of planning processes

The previous section introduced planning as a process. That process can be described in IDC terms (or equivalent). We now think that a planning process according to IDC is its own limited box. A planning system, unlike a planning process, is made up of a number of IDC boxes connected to each other[1] . One terminology commonly used to describe different parts of a planning system is to characterize the different parts as being strategic, tactical or operational, each part consisting of one or more IDCs. The strategic planning processes in the system are those which generally constitute the start of the planning work, while the operational ones constitute the final step before implementation; the tactical forms a link between them.

There are, of course, other ways of describing a planning system. E.g. the time dimension is used in this publication to characterize the various parts of the large forest company's planning system. It is also not uncommon to use the organizational level to designate different parts of the system. While using other dimensions to describe their system, it may be good to go back to the strategic-tactical-operational triple to get the character of the planning that takes place in a certain part of the planning system. We return to that question at the end of this section.

Another issue that is briefly touched upon has to do with why you divide planning into different parts and not just have one well-coordinated and complex planning process.

In conclusion: The terms used below can be perceived as abstract and the context unclear. Something that can facilitate understanding is to first read the section of The Large Forest Company's Planning. It describes the application of a system.

2.2.1 Strategic planning

Strategic planning has many and varying meanings. That ambiguity is reflected in the concept of strategy. Strategy is used on everything from superpower's long-term planning to chess player 3's closest moves. This ambiguity is also found in forest planning; even in such a relatively limited area, importance varies between authors. Even in practical forestry, you find this ambiguity among organizations.

Let's assume that strategic planning is the highest level in an integrated planning system. It is the planning that is most comprehensive, has the longest time horizon and is the least bound by other planning. It is also reasonable to assume that it is made at the top of an organizational pyramid.

When we talk about strategic planning, we can go back to the strategic objectives mentioned in the previous section. They basically relate to what kind of organization you want to be. Anthony (1965), one of the first to structure planning in a modern way, expressed the purpose of strategic planning as "… to determine the future posture of the firm in the market…". Another area for development of strategies concerns central resources, e.g. issues regarding outsourcing, location of production and development, etc. Strategic planning in this sense concerns a gigantic area of business economics that is not dealt with here. You can get a start by turning to Wikipedia (strategic planning).

It is generally not strategic planning in that sense that is meant when using the term in forest planning. Strategic planning then aims at planning the forest resource in the very long term, usually at least one rotation period. It is the most overall type of planning and is generally done by forest experts or supported by them. We will return to the issues raised during the review of the planning of the large forest company as “Long-term planning”. There, the term long-term is used instead of strategic partly so as not to be confused by the different meanings that the word strategy has, and partly because that type of planning is not always called strategic outside of the large forest companies.

2.2.2 Tactical planning

The concept of tactical planning lives an uncertain life. In the general, business economics literature, you don’t of find the term used. But in forest planning, it is well established and is found as the intermediary level between strategic and operational planning. Among the large forest companies, tactical planning is established as a (fairly) well-defined routine. It is characterized in section 3.1.4 “Medium-term planning” at the large forest company.

2.2.3 Operational Planning

Operational planning is well established at almost all companies with some kind of complex business. This applies as well to all forest companies. This planning directly precedes the practical implementation of forest operations. What follows is implementation of operations, i.e.. directives, control and follow-up. This planning directs harvesting teams to objects, harvesting takes place, logistics takes over. And in order for it to work, other planning must have been implemented. Among others, contracts with the customer must be established and there have to be roads for timber transports. What operational planning represents, at least on the forest side, can be found in the section on the large forest company.

2.2.4 Comparison of the types of planning

In Anglo-Saxon literature, three W are found to characterize strategic-tactical-operational planning: what, where and who? It suggests something of what sets them apart. If strategic planning specifies what is to be done, the tactical refers to where it should happen (or perhaps rather how) and the operative who will do it. With the same meaning one could express it as: what orientation (within what frames), what resources, and who should carry it out?

Figure 2.3 summarizes many of the characteristics that are usually attributed to the different types of planning. Strategic planning is placed at the top and operational at the bottom. It is not totally clear but reflects, if nothing else, the organizational structure to which the planning system is linked.

Figure 2.3.

Strategic planning is done less frequently than the other parts of the planning system. The fact that it is ad hoc also means that it is done as needed and is designed based on the questions that emerge for the moment. At the time of writing (autumn 2016), the telephone company Ericsson has profitability problems in a market with very rapid technological development. The need for strategic planning is known, not as a recurring routine, but as a need for a review of the entire business (which has resulted in a plan with major reductions in Sweden). The information you have, collect, and process is often incomplete. This is not only because the problem has a wide scope or covers many aspects, but also because the situation is not really well defined. The planning problem is unstructured.

That strategic planning is unstructured has been described by various authors as *"... problem stimulus is often ambiguous and poorly understood, and the manager cannot exclusively utilize predetermined processes for solving the problem ...* " Brightman (1978, p.2) and Mitroff & Mason notes that " *... ill-structured decision problems are ill-structured and problematic because they rest on a base of critical and tenuous assumptions ...* " (Mitroff & Mason 1980, p . 331). According to this approach, the outcome is the result of a debate about the benefits of different strategies. There is no well-structured problem there, but a complex set of related issues. In terms of the IDC model would lead to emphasis is on problem identification or problem construction rather than problem solving (Eden et al. 1981). (Other references with brief and simple descriptions of " messy " or " wicked " problems can be found in, for example, Allen & Gould (1986) and Conklin (2005), where the former also deals with and relates to forestry.)

The prerequisites for operational planning is actually the opposite of the strategic planning 's. You know the planning situation well and precisely. Thereby, you have detailed information. It is also frequently applied and thereby there are established routines within the organization. In summary, it is a well-structured problem where, with limited efforts, it is necessary to produce a good solution based on having all (or almost all) relevant information.

We will then return to this description of the different types of planning processes when we discuss the concept of decision support system (see Chapter 5). To indicate what the research stands for in this regard: A decision <u>support</u> system is best suited for semi-structured planning situations, while decision-<u>making</u> systems are something that occurs primarily for operational planning. It can be interpreted that strategic planning can not be served by a decision support system as it occurs seldom and has an elusive character making it not motivated to construct a system for planning and decision support. Rather, it means that the strategic planning itself, as described here, is not in its entirety covered by a decision support system. However, various issues that may be raised in strategic planning, e.g. a long-term harvest calculation, benefit greatly from more or less advanced decision support systems.

2.2.5 Why a planning system?

In principle, if the harvester goes to one stand or the other, it will affect which forest you have in the future. Everything you do has long-term effects, and this is especially true in forestry. So why don't you have a single process that makes you plan everything one step; even the production manager's choice of one of two stand has long-term significance. The reasons for not doing so are several. The most obvious is that the planning problem would be too large, too comprehensive and you would not find any solutions to all the problems linked to each other, or you will find no good solutions. We will briefly touch on some of the reasons for creating more or less complex planning systems.

One reason has to do with the distinction between different types of planning that we have just gone through. Some planning problems are of a strategic nature, others are tactical and again others operational. The different types of issues can be inappropriate to mix because the focus is so different. It is, for example, possible to see a link between this cause (the nature of the planning problem) and the different roles that exist within the organization. Some decide what others should do. For example, it is natural for company management to set the framework for other parts of the organization. It can also mean that some types of planning are such that one does not want to involve some people for some planning. For example, it may be that strategic planning touches on such sensitive issues that it should stay within a smaller circle. It also links to the resource issue (should everyone be involved in all planning) and the skills issue (why participate in a planning where you have no skills).

Another reason to divide the problem is what we mentioned first, ie. that the problem as a whole is too large; it is complex and needs to be divided in order to be manageable. One way to do this is to first do the planning with an aggregated description of all or part of the company's operations. When you have a plan based on that description, you can then proceed to make a more detailed planning within those limits. It is really the basic recipe for forest planning. There is long-term planning often with very aggregated data and multi-year planning periods, while operational planning is done with detailed data and planning periods that can go down to individual days.

Yet another reason why planning is done in different stages has to do with making decisions. Let's say that a senior department makes a multi-year budget. Within the framework of that budget, the underlying department makes plans for each year, ie. one goes into a planning process every year within the framework of the multi-annual budget. A planning activity at one point thus forms the basis for planning at a number of later time points. This is also a basic principle found in forest planning (shown in the section on the planning of the large forest company). In the long-term plan, decisions are made as a result of planning that is made every five or ten years. The decisions taken in the long-term plan govern the planning activities at (geographical) management units for each of the years that the long-term plan covers.

There are thus both practical and organizational reasons for splitting the planning into different parts and forming a planning system. There are further aspects of how to design a planning system that we do not elaborate on here. One question is what role different parts of the organization play in the planning system. The point of departure for the above reasoning is that a parent level specifies the framework for the underlying, a so-called top-down model. The opposite is to allow different parts of the organization to make their plans, and then to summarize the results on an overall level, a so-called bottom-up planning. There are a number of intermediate forms between top-down and bottom-up. Another aspect has to do with how to integrate actors who are in the same value chain (forest to industry) but are independent entities, e.g. forest machine contractors and transport companies. It is only to be noted that forestry in a wider sense constitutes a fantastic rich field for research and development - and improvement.

Self-Study Questions

1. Is the traditional forest management plan (skogsbruksplan) a plan? If it is, is it descriptive, explorative or normative?
2. If you do not implement your plan, has the planning been useful or was it just a waste of resources?
3. Can a decision or planning process be non-rational? How would decision / planning be done in such cases?
4. What does the term "bounded rationality" stand for? Exemplify what can make the long-term forest planning in the large forest company "bounded"?
5. Let the long-term planning of the large forest company be the starting point.
    a. Can it be considered as strategic planning or not?
    b. Evaluate long-term planning based on other aspects illustrated in Figure 2.3.
6. The medium-term planning at a large forest company, are there operational elements in that planning or is it merely tactical in nature?
7. What is the purpose of the operational planning in the large forest company?
8. As a standard for forest management planning, the large forestry company has a planning system divided into three levels. What benefits and potential disadvantages can it have?

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3 APPLIED PLANNING AREAS

The planning of the big forest company. They have large forest areas spread over large areas, employed staff and contracted entrepreneurs in a geographically dispersed organization, as well as often own industries or supply agreements with different industries. Thus, they have the need and opportunity for planning routines and a clear plan.

Long-term, medium-term and operational planning. Planning is done in steps where the long-term planning is comprehensive, and the underlying steps are taken to fulfil the results of higher-level planning.

3.1 Planning of the large forest company

Half of the total forest land area of 28 million ha has been owned by what might be called institutional owners. These are privately owned PLCs 25% (mainly the large companies SCA, Holmen, Bergvik, public owners 19% (the state, state-owned PLCs and other public owners) and other private owners 6% (including the Swedish Church, foundations and commons) (Skogssverige 2016) It is primarily among the institutional ones that we find forest owners who have such large holdings that they require a formalized and structured holding, and this section deals with them.

3.1.1 Background

All forest owners who in this context could be called large use basically the same principles in their forest planning. In the 1960s, in connection with the mechanization, the transition from log driving to road transport and year-round operation, the basic elements of a forest planning system were developed. Forestry companies, together with researchers, defined the steps in a hierarchical planning process that would encompass everything from long-term planning to operational activities. Although the methods and tools have been technically developed since the 1960s, the same elements still form the basis of how the planning process is structured. This section aims to present this structure in its basic features. Forest planning is constantly evolving with new data collection methods, new methods and systems (including software) and more powerful computers to meet new challenges. However, there is no ambition here to cover this development; the focus is on describing the structure so that more detailed studies can find their place in it. For those who are interested in more details about the companies' forest planning processes, consult theses (Söderholm 2002, Eriksson 2008) and a few scientific articles (Nilsson et al. 2012, Nilsson et al. 2013, Eriksson et al. 2014, Nilsson et al. 2016).

3.1 .2 Planning Hierarchy

The structure of the planning process can be described as consisting of three phases: Long-term planning, medium-term planning and operational planning (Figure 3.1)[1]. The process can be interpreted as a system. A system consists of different elements that are linked to each other with specific relationships. The supporting elements here are the three phases. Each phase is defined by the occurrence of certain activities and a plan is drawn up. The relationship between them essentially consists of passing information from one phase to the next. That information consists of the plan and the decisions contained in that plan. In that it is a hierarchy, ie one plan is higher ranked next, and provides a framework for planning in the next phase.

Description here does not exclude the possibility of other planning steps occurring before, simultaneously with or after forest planning. But what is presented here is the planning process that is directly related to forest measures and is regular in the sense that planning is done more or less regularly.

In principle, long-term planning has an endless time horizon, but for practical reasons it is often limited to about a hundred years or a forest generation. It lays the basis for sustainable forest management (" *Sustainable Forest Management* ", SFM). It includes the establishment of a general framework for felling and nature conservation. The purpose of the medium-term planning is to identify, within the boundaries set by the long-term plan, which areas are suitable for harvesting within the next few years. The tracts will then be inventoried to provide better data for operational planning. Operational planning is about scheduling individual harvesting teams for the next few weeks or months. It is coordinated with the planning of deliveries and storage with the ultimate aim of meeting industry demand.

[1] The descriptions of individual companies are often more detailed and, for example, may have two steps for planning in the medium term. The terms strategic, tactical and operational planning are not used here as they refer to the purposes of planning rather than stages of a planning system. Long-term planning could potentially qualify as strategic planning, while medium-term planning may correspond to tactical planning and operational planning may be considered operational planning, but this is not an obvious division.

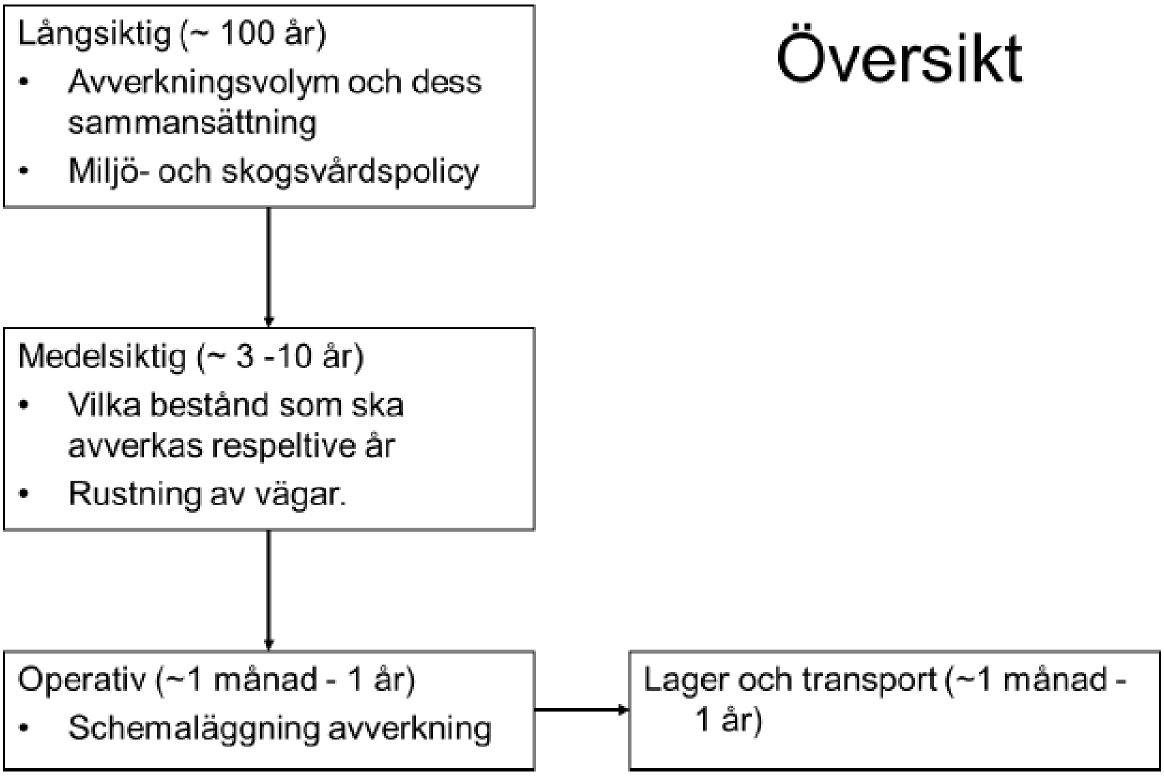

Figure 3.1. General description of the planning system.
To understand the planning system and how it works, you need some insight into who is responsible for what in this process. A generic picture of an integrated forest company can be described as consisting of two parts; a forestry part and an industrial part (Figure 3.2)[2]. The forest has a delivery function *vis-à-vis the* industry that acts as a customer. The forest organization typically consists of a head office (HQ) and a handful of geographically organized districts or administrations. Districts can be further subdivided into sub-districts.

[2] This is a functional description. The formal organization may look different, for example with sawmills belonging to the forest organization. Integrated forest companies today are exceptions rather a rule. In 2004, Stora Enso and Korsnäs companies merged their forests and sold it in a separate PLC, Bergvik; a contract arrangement secures deliveries from Bergvik to the industries in StoraEnso and Korsnäs. At the time of writing (November 2016), only SCA is formally an integrated company, but is undergoing reconstruction. However, this should not prevent forest planning from being seen in the context of industry needs.

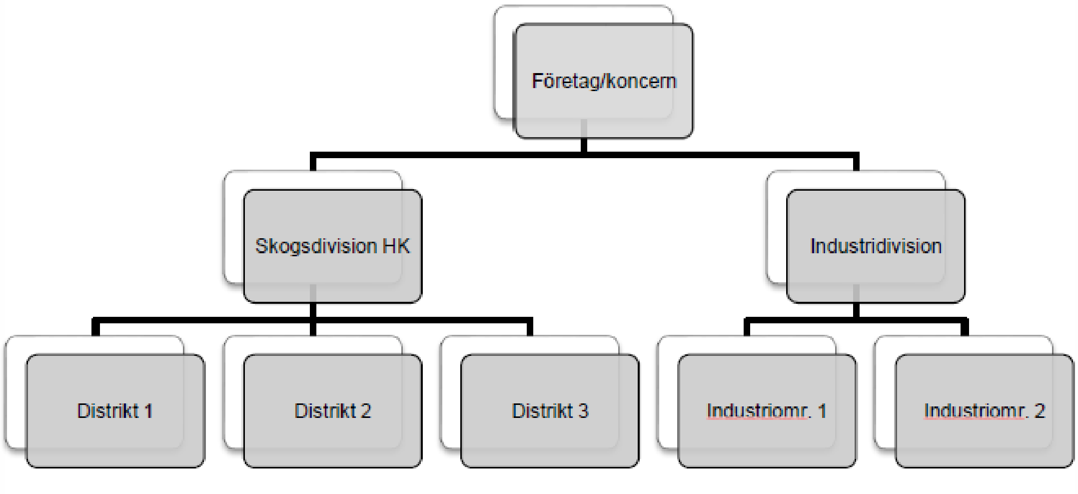

Figure 3.2. A general description of the integrated forest company's organization, which has a forest ownership and industry.

HQ has personnel responsible for the forest planning system. HQ also has the main responsibility for long-term planning. It includes developing policies for silviculture and nature conservation. Decisions that affect individual districts are made in collaboration between HQ and the district staff. When the long-term goals established, the initiative belongs to the district. Thus, the district is responsible for decisions relating to medium-term planning. HQ only monitors compliance with the company's policy and set goals. The operational planning is often at sub district level, e.g. by logging managers or within work areas. Here are major differences between companies, on whom to make plans and how often they are updated. Furthermore, how the collaboration between the delivery and logistics organization is designed differs and thus how the connections between harvesting, storage, transport and industrial consumption work.

3.1 .3 Long-term planning

Long-term planning can be said to lay the foundation for the implementation of SFM. Long-term planning is usually carried out at 5-10-year intervals. Historically, the planning process has almost always been preceded by a random inventory of the entire forest holdings as a basis for the planning, a so-called "företagstaxering". As the term long-term planning is used, it is possible to distinguish between two different types of decisions. The first type concerns the establishment of different policies that govern all subsequent operations in the forest. One of these concerns rules and recommendations for forest management, sometimes summarized in a forest management manual. Here, for example, suitable silvicultural methods and prioritization rules for thinning and final felling are specified. Another important policy concerns environmental protection. Since the beginning of the 1990s, all major companies have developed elaborate routines that now form part of the Forest Stewardship Council (FSC) certification system.

The second type of decision in the context of long-term planning concerns a quantitative analysis of future harvesting and forest management, including the effects of nature conservation commitments. Here, analysis of logging volumes over time is a key part. With the present forest state as a starting point, projections are made of the state where different management strategies and objectives are tested. The aspects that are assessed are, of course, economic and production-related, but also those that affect environmental status and, where such considerations need to be considered, social aspects. The option that seems to be the best is then the starting point for continued planning in the medium term.

The decisions that emerge in the long-term plan and which guide the future planning are partly about harvesting and partly instructions for forest management and the environment (Figure 3.3). The most important data regarding logging are related to the total logging volume that corresponds to sustainable management. In connection with this, the distribution of final felling and thinning and different types of thinning are determined. The environmental plan is registered in the Ecological Landscaping Plan (ELP), which contains provisions for the treatment of areas of special consideration. This requires data on the state of the forest, descriptions of provisions and their management, as well as various software for managing data and performing analyses.

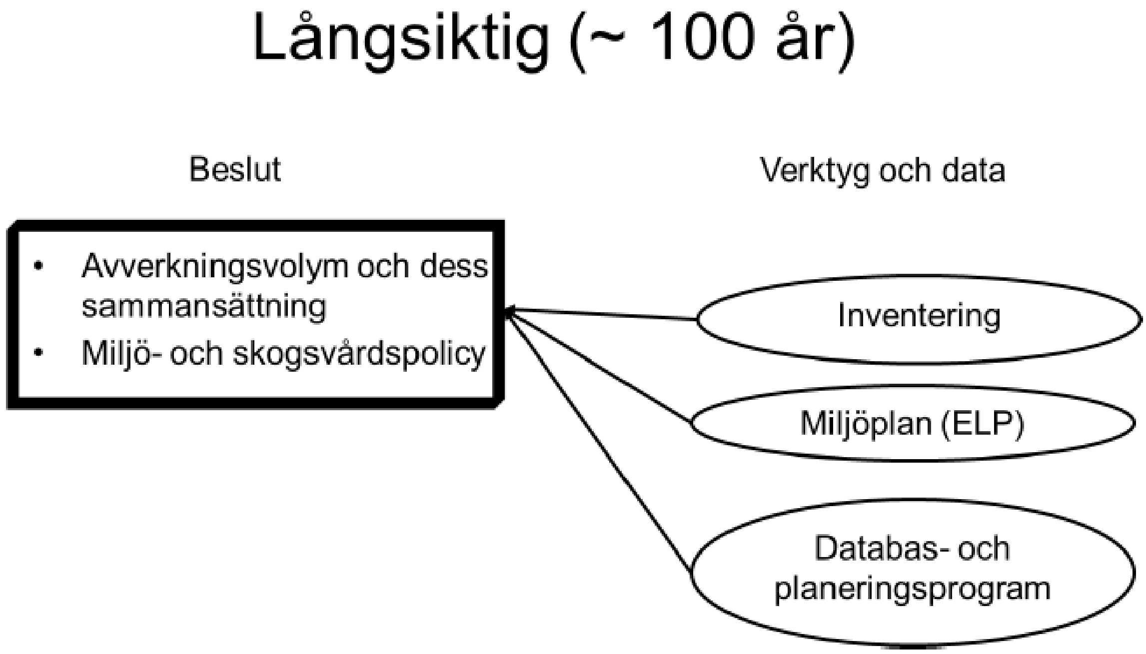

Figure 3.3. Decisions and tools for the long-term plan.

Several activities need to be coordinated to prepare the plan. This is a summary of the procedure that has been followed, in whole or in part, by most companies over the past few decades:

<u>Subjective Inventory</u>: The planning in this as well as in the later stages is dependent on a forest map and a stand register. In principle, a forestry plan is made in which the entire forest holdings are reviewed, stands are delimited, and inventory is made. The work is based primarily on a subjective inventory of stands in combination with aerial image analysis. However, this is a rapid development, mainly with methods linked to airborne laser scanning (ALS). This means that you can expect this part to have a more dynamic character, where registers and maps are constantly updated.

<u>Objective Sampling Inventory</u>: Since the stand register is made using subjective methods and may contain systematic deviations (bias) and large random errors, an objectively collected material from sample surfaces is preferred. If the content is sufficiently large, test surfaces from the National Forest Inventory (RT) can be used as a supplement. The disadvantage of a sample is, of course, that you cannot do analyses that take into account the location of the stands (see section 4.1 Linear programming for more on working with strata.)

<u>ELP</u>: During the work with ELP, additional information is collected on key habitats, other management-requiring biotopes, rare species etc. The result of the ecological analysis is entered on maps and is registered as areas that should leave for free development or that need special managmetn. Different principles can guide the design of the ELP, but common is that some form of landscape perspective is required. To identify sensitive and worthwhile objects, high competence is required; the work is often done by hired staff with specialist expertise.

<u>ANALYSIS</u>: On the basis of (a) the sample (inventory), (b) the limitations constricted by the ELP and (c) the rules (policies), a long-term analysis is performed. The analysis concerns felling and associated measures. Today, the Heureka system (Heureka 2016) is largely the only system used by major forest owners. The system includes models for growth, mortality, growth and reafforestation as well as financial valuation. The system allows the analysis to be done either by optimizing or simulating. Business applications usually mean that you develop plans by optimizing. The planning horizon typically covers about 100 years. The solutions derive the total felling level together with information on the amount of thinning, the distribution of different types and the extent of forest management. These tasks, together with forestry instructions (including priority rules for selecting felling objects) ELP and other instructions, are now moving on to medium-term planning.

Figure 3.4 illustrates the different types of activities. A stand register is created or updated, and a sample is made where a few stocks are carefully inventoried. An ELP is made where different parts of the holding are classified either for leaving or for special treatments. With this as a basis, the long-term analysis is made. In the figure, two alternatives are analysed, one of which initially gives higher volumes, which may be good for the company, but which may not be considered sustainable when forced to lower volumes in the long term. The second option may be what you decide on. This means locking in the withdrawal volume and its composition for the first 5-10 years (highlighted in the figure), depending on how often long-term planning is done. The arrow between the map and the logging calculation below illustrates the fact that registers etc. must be completed in order for a meaningful long-term analysis to be made.

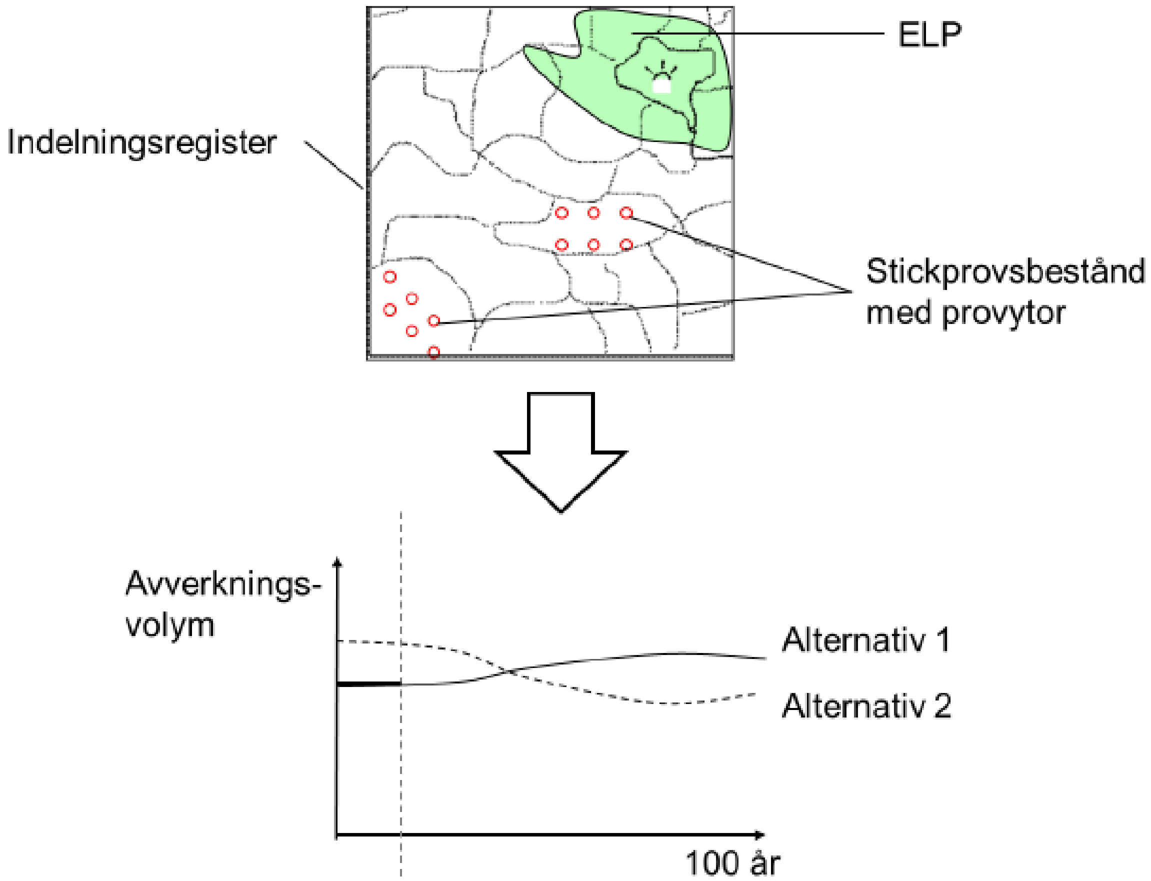

Figure 3.4. Analysis of two long-term harvesting plans based on sample data and the ecological landscape plan.

Often, the quantitative analysis for each district is done separately and then the plans are consolidated into a plan for the entire company, unless the company's holdings aren't that big which in that case enable the analysis for the entire holding in one go[3]. Although planning is done per district, it is with staff from HQ and under its supervision.

[3] The district or administration does not always constitute the area of calculation for the long-term plan; it may in some cases include two or more or parts of districts.

3.1.4 Medium term planning

The most important result of the medium-term planning is a register of well-invented areas, i.e. a tract register. A tract consists of one or more stands that are intended to be harvested at approximately the same time. The area can contain both thinning and final felling. The tract register corresponds to normally include 1.5-2 years of harvesting. During planning, the need for improvements to the road network is identified (Figure 3.5).

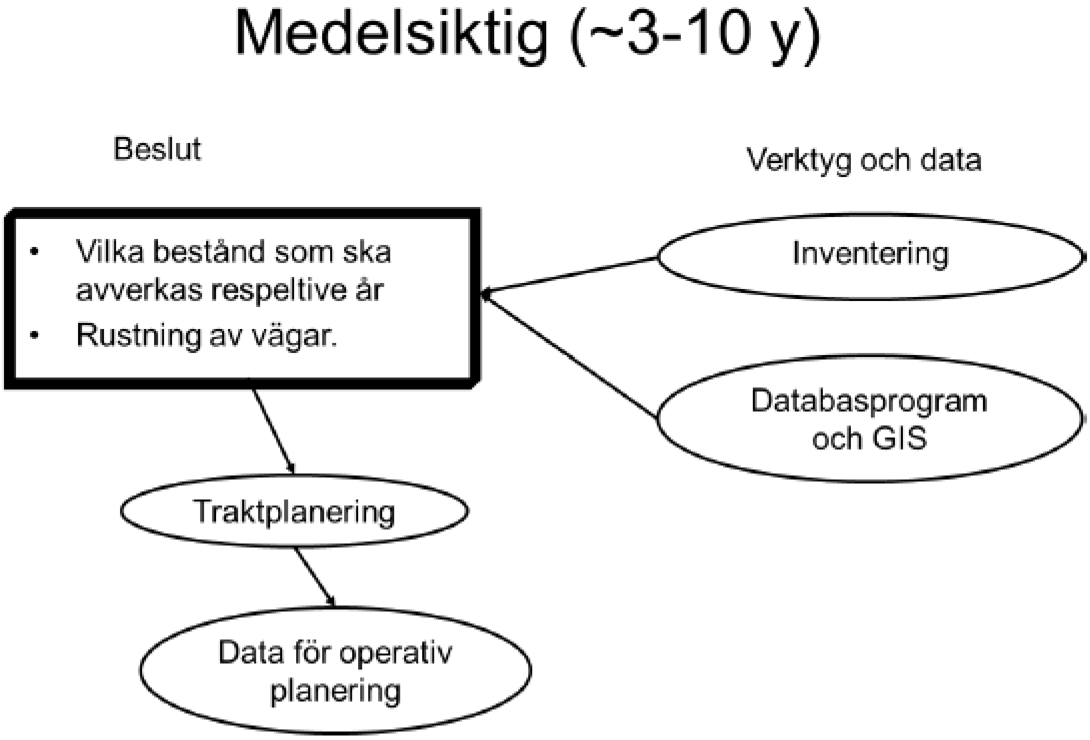

Figure 3.5. Medium term planning.

The planning starts with an analysis of the stand register and the forest map in a GIS. A selection of stands is made covering the harvesting for a period of three to ten years (the range indicates that the companies' approaches differ quite a bit). The stands are then planned for felling in a certain year, sometimes even in a certain season (e.g. winter, spring, summer, autumn). One has to make sure that the composition of the selection to the tract register for each year is such that it provides a reasonable basis for the business.

The basic requirements for the selection are, firstly, that it complies with the long-term plan. This means that the composition of logging volumes with regard to tree type and logging (thinning and final felling) should be in total harmony for the entire planning period. However, deviations for individual years may be justified. For example, one can take more first-time thinnings in a given year in order to have access to such a system. Another basic requirement is concentration to a limited number of roads, year and season (to the extent that the latter subdivision is used). Thus, it is only here that felling localization comes into the planning and it is the need for concentration that is the reason for it.

Bearing capacity is another problem that must be addressed. By bearing capacity here is meant both the bearing capacity for forwarding and road transport. It is necessary to make sure that the harvesting volume from stocks with different carrying capacity stays within certain limits each year. If you have too much volume a certain year from stands with poor bearing capacity, you may have problems during autumn and spring; if you have too little it means you will have problems in other years. In the same way, stands must be rationed with good sustainability so that one can always cope with the “rainy and wet” seasons.

For those stands that are considered to be relevant for harvesting in the next 1.5-2 years, a field inventory is made. The objectives of the inventory are several. First, the area is delimitated on the map. The suitability of the delimitation specified in the previous inventory for the inventory register is assessed; if necessary, they are adjusted and stands adjacent to the area can also be included. Another purpose is to identify elements that require attention (eg wet areas, zones adjacent to water and ancient monuments) and to delimit them. Unintentional felling of these can thus be prevented when, for example, felling takes place in winter or in the dark. Third, the area is invented to obtain better data on the timber that can be expected to come from harvesting. The accuracy of the stock register is normally too low, or the register may be too old, to give a satisfactory forecast of the exchange of different assortments, ie data needed in the operational planning. The most ambitious inventory is done with circle sample plots where the trees are calipered. Normally, subjective assessments are made where the stand register data is used as support. Systems for this purpose are in use and integrate GPS and GIS. Another task that is usually entrusted to the planner is to assess the quality of the road, ie. what road class it holds.

Note that the tract register covers a shorter period of time than the first sample. The reason that the first covers a longer period of time than the tract register is to try to avoid "greedy" solutions, ie. that you pick up the well-placed stands in the first years and then have a much more difficult harvesting in the following years.

The medium-term planning is an extremely complicated planning problem where many requirements must be satisfied simultaneously. One of the most difficult is to meet the requirements for concentration on roads and at the same time adaptation of the quality of the roads. The planning is therefore still largely done manually, where the planner takes the help of database search and reporting of samples via GIS. Optimizing systems are being introduced and are being used to some extent. One example is VägRust (Frisk et al. 2011) developed by Skogforsk. The Heureka system also provides some opportunities for medium-term planning.

The effort put into the planning that is done in the medium term varies between companies. An influencing factor is the situation in the market, that is, the extent to which correct deliveries are of central importance. However, some form of field inventory is always done, or should be done, if the company is to follow the certification rules.

3.1 .5 Operational Planning

The most important result of this planning activity is a schedule for the areas to be harvested when and with which harvesting team. The plan is detailed and generally indicates the date when harvesting should start and end on a specific tract (Figure 3.6). The plan is made on the basis of what is available in the tract register, often by a logging manager or sometimes by the individual logging team.

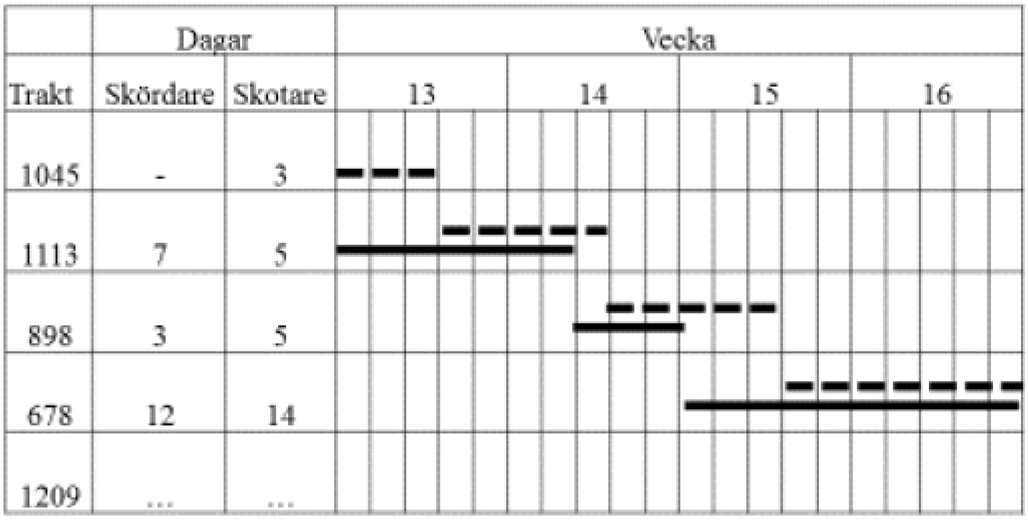

Figure 3.6. A Gant scheme describing the activities of a logging team day by day for a few weeks.

The procedures for this planning stage vary greatly among companies. Nevertheless, the following basic properties can be identified (Figure 3.7). The planning horizon is never longer than one year. A routine with a rolling three-month planning horizon is not uncommon. This means that a schedule is made for the next three months but only the decisions that lie in the first month are implemented. After the current month has expired, the next month comes in as the "hot" month, possibly after adjustment, and a third month is scheduled. A longer planning horizon would of course facilitate management, but the limiting factor here is the reliability of the market forecasts. It is important to be able to adapt to changing market conditions at short notice.

Schedule, ie the sequence of tracts that the teams is to cut must meet the delivery plan to the industry. It is only in this planning step that forestry and industry coordinate their operations seriously. Deliveries are stated for the current month (shorter periods may occur) and a forecast is made for the next two months. At the same time, it is good if the tracts for a logging team can be taken in such an order that the time and cost of moving between the tracts can be limited. One limitation that often conflicts with the requirements for deliveries during certain seasons is the availability of areas with high bearing capacity. During spring and autumn, soil conditions and road standards prevent logging and road transport on many objects.

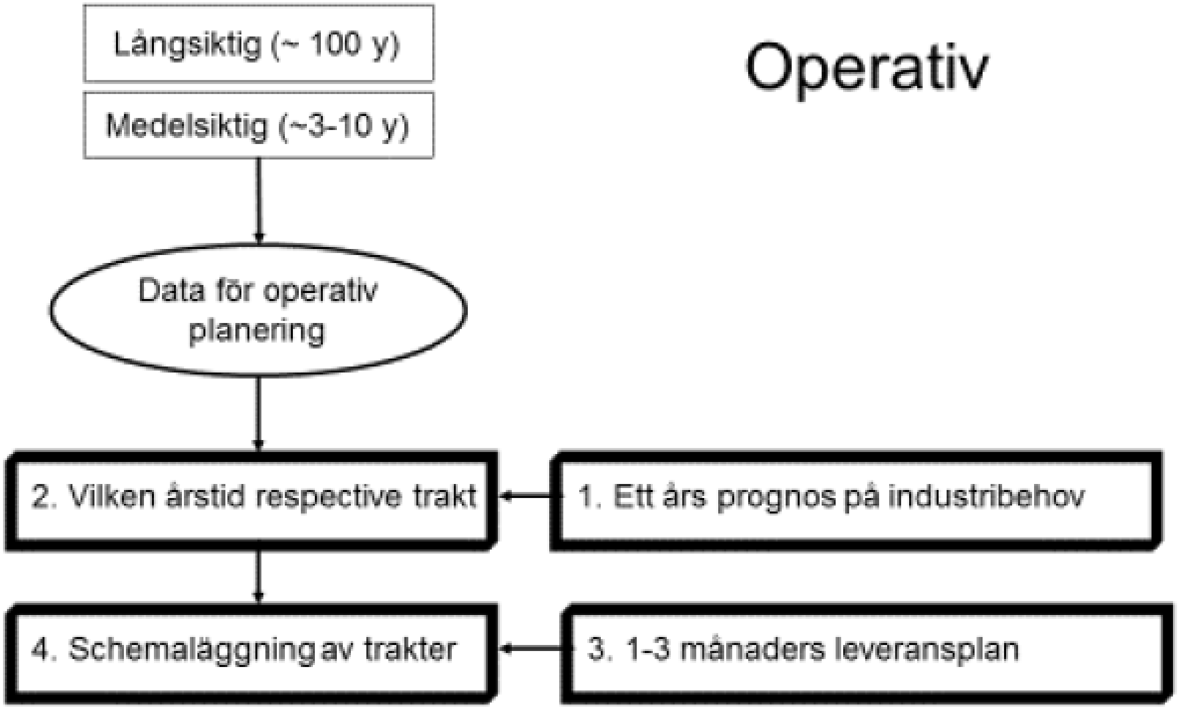

Figure 3.7. The parts of the operational planning.

The operational plan specifies the use of the actual harvesting resources and when and where the timber is made available at harvesting. It is obvious that if the information in the tract register is not correct, the operational plan will be incorrect. Too little of an assortment will be delivered too late or too much too soon. Such deviations from the plan, in combination with low stock levels and requirements for fresh wood, may require costly adjustments.

It is often up to the individual logging team to do the detailed planning of the tract. The tract description includes planned retention such as leaving buffers around streams and defining other protected environments. A classification of the road standard is also usually included to ensure that it can be felled at the scheduled time.

Unlike the earlier planning steps which occurs at roughly the same organizational level in most companies, operational planning is associated with different organizational arrangements. In some companies, operational planning is a task for the forest organization and follows the district organization. In other companies the operational planning it is instead part of the marketing organization. Differences also exist as to who carries out the planning. In some organizations, a planner does the scheduling before handing out the plan to the felling teams, in others the teams themselves are responsible for planning the tracts assigned to them.

3.1 .6 Some Reflections

The purpose of this section is to highlight what you do in the various stages of forest planning in Swedish companies and the relationships between these steps. Something to emphasize is the nature of forest planning as a system. This means that what is done is rarely the result of single, independent activities. Instead, each activity has an impact on following activities, and is impacted by previous activities.

Planning for nature conservation is one example. Considerations on large areas are summarized in the ELP and are part of the long-term plan. Identification of retention patches and nature conservation areas of the neighbourhoods is done in connection with medium-term planning. Finally, everyday retentions and considerations towards the environment are made in connection with the actual harvesting. The intent behind this design is basically to minimize costs and utilize knowledge in an efficient way. ELP requires experts. It does not make sense to use them to identify small, retention patches scattered throughout the forest. This can be delegated to regular staff at the district, also given that they receive training in species recognition and related subjects. Everyday considerations are best taken by the harvesting team.

What can you say about the future development of this system design; how long will it survive the 21st century? With improved methods for obtaining data on forests and faster computers, a development path is that the planning steps tend to merge and become more integrated. It is possible, for example, that planning in the medium term will be done with a model that incorporates aspects that exist in long-term planning today. And perhaps the long-term planning focuses on other and more comprehensive aspects than today, such as strategies in its true sense for the utilization of forest resources. A complementary line of development could be that more of the initiatives in the planning work come from the district and local level, since there is more expertise and more developed software. When it comes to operational planning, an increasingly intimate link between harvesting operations and industry can be identified. The driving force here is increased demands on quality of end products combined with the need to reduce costs. The steps in the supply chains are increasingly linked. Or will we see a whole new paradigm where forest resources are viewed from a completely different perspective? As a dynamic layer for carbon and not yet finished products? Or as a collection of ecosystem services whose management forms the central part of planning?

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3. 2 Planning for individual forest owners

3.2.1 Introduction

In Sweden, the size of forest properties varies widely between different individual forest owners, but for most people the holding is not so large from a forest planning perspective, which means that there are both fewer decisions to make and fewer choices to choose from. However, in most cases, forest owners have poorer knowledge of forest management (eg forest planning, forest management, wood science, technology, economics) and thus clearly need support for their decisions.

An individual forest owner and his/her forest ownership may not be so important to the country's inhabitants, the forest industry, nature conservation and other interest groups, but all in all, they are very important as just over half of the productive forest land in Sweden is owned by individual forest owners. In total, they account for 60% of the harvested volume in the country as they have a larger area of land in southern Sweden with more fertile locations than in the north.

Most of the forest properties have a significant economic value for the individual owner, and in most cases, additional value on a more personal level such as a family farm, a growing environment, a living environment, traditional carriers, and the forest has value for recreation, mushroom and berry harvesting, hunting. , etc.

The total value of the privately owned forest land is very large, hundreds of billions, so it is important for both the individual forest owners overall and the community that these forests are used effectively. All of this combined make planning for individual forest owners important.

Also, for this ownership type, planning and decision making requires a holistic approach to the entire forest holdings, information on forest condition, proposals on possible actions and their consequences, as well as selecting the best action based on the owner's goals. By definition, a plan should include silvicultural activities and refer to the future (the nearest and some time ahead). It is through various activities that you control the business.

3.2.2 Traditional forest planning for individual owners

For several hundred years, the traditional planning horizon for individual forest owners has been to establish a ten-year plan. The ten-year plan horizon is chosen so that a forest educated person then can make a reasonably good forecast of how the forest grows and develops (subjectively, i.e. without counting in detail), and what measures are appropriate. The starting point is to divide the forest in reasonably homogenous areas (stands) and draw their borders on a map. Aerial photos (orthophotos) are usually used for good overview and drawing background. This is followed by a field inventory, where the characteristics of each stand are described and appropriate silvicultural measures are proposed, based on conventional forest management. The advice is adapted to the current forest policy and spirit of the time and is usually given without consideration to the owner's goals. The results are compiled in a written report with a map, departmental description in tabular form, and summaries of the entire property. Such a plan is called a forest management plan.

3.2.3 Some terms

There are several terms for the owner group of individual forest owners. A few common terms are family forest owners and small forest owners. In English, “family forest owners”, “small-scale forest owners” or “non-industrial private forest owners” are often abbreviated to NIPF. Sometimes only "private" owners are used, which is misleading as the term also includes privately owned limited companies. The Swedish Forest Agency now uses the term private individual forest owners in their statistics.

Forest management plan actually means "plan for forestry" and is thus equally useful for planning for other owner categories. To say that a forest management plan as a concept applies only to individual forest owners is a narrow interpretation.

Up until the beginning of the 1980s, forest management plans for individual forest owners were prepared mainly solely with a focus on timber production. Later there are examples of plans where the planning has been adapted to also take great account - more than the law requires - of various interests, e.g. nature conservation-oriented forest management plans (NISP), recreation- adapted forest management plans and reindeer husbandry-adapted forest management plan.

The changing forest policy from 1993 and a market adjustment has led to the concept of green forest management plan, which was launched by the Southern forest owner association (Södra skogsägarna) in collaboration with the Forest Agency. A green forest management plan refers to a plan where 5% of the productive forest land is left for free development (no management) or management with the aim of developing nature values, and where an additional 5% of the area is reserved for nature considerations in addition to what is required by the Forest Act.

Some organizations and companies have put other names on their plans; Forest owner's plan (Northern forest owners), forest management plan (Middle forest), Plus forest management plan (SCA), while others are content with forest management plan (Norrskog, Holmen, Stora Enso, BillerudKorsnäs, Sydved) .

The forestry legislation's advice and instructions mention "green forest management plan" once, "planning" about ten times and just as many times any other type of plan is mentioned.

In FSC's certification rules, which are mainly applied to large forestry companies' land, the term "forest management plan" is used eleven times. "Forest management plan" or "management plan" is also used eleven times, "planning" 21 times, "plan document" 39 times and "ecological landscape planning" once.

Another concept that is sometimes used is an action plan, which then means a proposal on what measures should be taken, without the forest state in each department being described.

3.2.4 An average forest owner - example of calculus

Individual forest owners have an average of 51 hectares of productive forest land. The following calculation example shows the conditions for the owner (can be one or more persons) of an area average forest property.

The average harvest is 4.32 m^3sk a year (Table 1.2), which gives about 4.10 m^3f pb of timber per year. We further assume that the gross value is SEK 350 per m^3f pb, that the felling cost is

SEK 100 per m^3 f pb and other costs SEK 50 per m^3 f pb, then the net will be SEK 200 per m^3 f pb (Figure 3.8). This means an economic return of SEK 820 per hectare corresponding to SEK 39 600 per year, which corresponds to SEK 27 700 kr per individual owner and year given an average of 1.43 owners per property. Since an average annual salary is about SEK 300 000, it is evident that most forest owners cannot be said to be economically dependent on timber income for their livelihood, even if the contribution can make a difference at the margin when necessary expenses are paid. The self-employed forest owner can reduce the cost and thereby increase the return, or at least receive some compensation for his/her work.

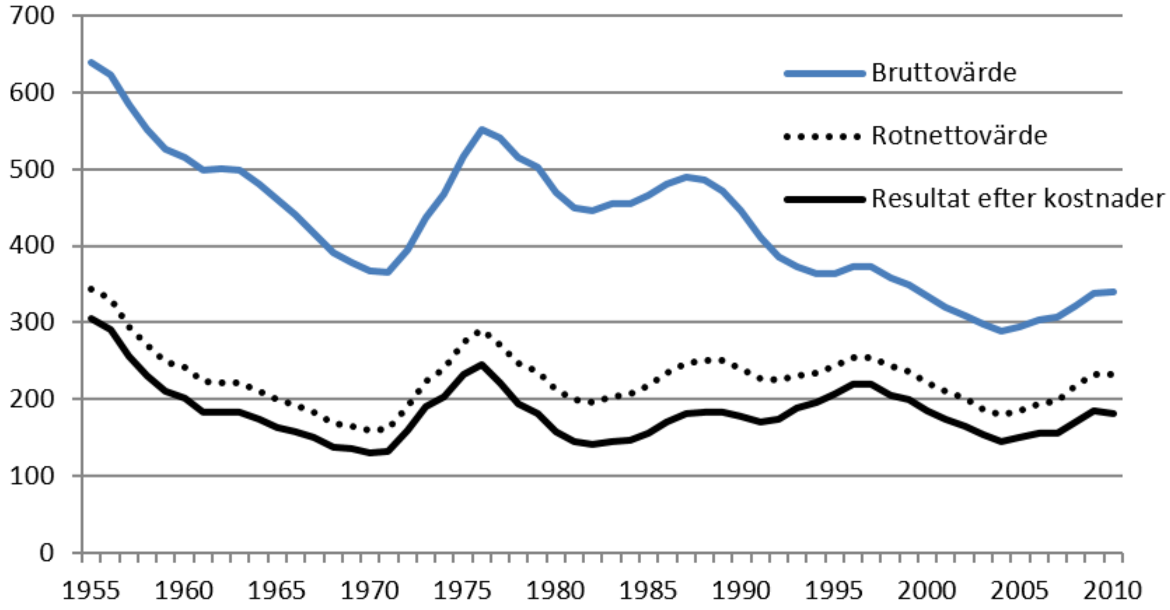

Figure 3.8. Gross value (bruttovärde), net worth (rotnettovärde) and profit after costs (resultat efter kostnader) in SEK per m^3 f pb in 2010's monetary value (CPI). Ongoing five-year averages calculated on the basis of the forest board's statistics in forest statistics yearbook 2014.

The average property in Sweden has a sales value of SEK 400 per m^3 ob (LRF consultant, price statistics 2015), which for the calculation example above where the average growing stock is 152 m^3 per hectare (Forest Data 2016, Department of Forest Resource Management) and a property size of 51 hectares, gives a sales value of 3.1 million SEK. If we divide with 1.43 partners per farming unit, the wealth value per partner will be 2.17 million. The direct return on restricted capital will then be 1.28% (27,700 divided by 2,170,000). Although the annual financial return is not so great, the farming unit has a great economic value even for an average forest owner. For two thirds of forest owners, properties are not mortgaged, and in many cases the mortgage ratio is low (Forest Barometer 2017, LRF consultant and Swedbank). These conditions, of course, vary with the size and forest characteristics of individual properties, and the situation of the individual owners.

In addition to the direct financial return and any increase in value over time, the forest property provides financial security, an opportunity for self-employment or a hobby where the costs can be paid with untaxed money. In addition, the feeling of being a forest owner can be a value in itself, to decide for yourself and to continue a project over several generations. The forest can also provide firewood, hunting rights and connection to the countryside and to other forest owners. Many also see forest ownership as a positive part of their identity.

How many decisions need to be made? We assume that the production forest can be divided into 14 departments of each 3.5 hectares after 5% of the area has been set aside for free development to benefit nature conservation. If the rotation time is 70 years, there will be a final harvest and one or two thinnings per five-year period. Additionally, one regeneration and one or two clearings per five years. If the holding period is thirty years, there will be about 15 final felling decisions and about 15 forestry decisions during the holding period.

3.2.5 Description of individual forest owners

Remains to be written, so the interested person is now referred to statistics on the Swedish Forest Agency's website, Lidestav and others (2015), Westin and others (2017), and the Forest Barometer LRF consultant and Swedbank (2017 or later) : Statistics on the distribution of properties by size, distribution in regions, bonities. The distribution of owners among those who live on or near the property (residents) or not (residents), age according to the entire population, sole owner compared to multi-owners, self-employment, change processes. Comparison with Europe or some countries.

3.2.6 Need for decision basis

The individual forest owner needs a basis for his/her decisions. Knowledge about forest and forestry, interest in learning more, the opportunities to spend time on decision planning including monitoring and follow-up, self-activity, and so on, vary considerably between different forest owners. The considerations and calculations of individual forest owners make and the need for information, advice and support therefore varies greatly. In principle, the individual forest owner's planning is also about finding the best way to manage his/her forest based on what the owner wants to get out of his/her forest ownership.

The challenges for those who draw up plans for individual forest owners are partly different from working with large forest owners' holdings, since the latter have professional managers who usually have better insight into the issues. The conditions for individual forest owners vary considerably. Many may not even know for sure where their property is located, while others have great knowledge and local knowledge, and a great interest in learning more.

Many forest owners hand over supervision and decisions about measures, and perhaps even the execution of the management, to another person. Many properties are owned by more than one owner. These can have different purposes with their forest ownership, which can lead to increased need for support for planning and decision-making. By law, properties with three or more co-owners are required to appoint a manager (ref!), who can be an unbiased person or one of the co-owners.

Some forest owners have management agreements with a forest owners' association, the Forest Society or some forest company. In this case, the owners do not have to ensure that plans are drawn up, but the managing organization usually draws up a forest management plan.

The forest owner can get advice on measures in individual departments from timber buyers before or in connection with timber transactions, or from other forest owners, through associations, forest contractors and consultants. The Forest Board can also advise, but they charge if the advice is to be given in the forest. At present, however, they can make exceptions if the questions concern alternative management methods such as continuous cover forestry or deciduous forest management. Such advice can suffice in many situations, but as a planner, you want to have a grasp on the whole, the forest condition on the entire property and the owner's goals and views on the future, in order to be able to give advice.

Some forest owners do not have timber production and financial returns as targets at all. Then they may not need a traditional forest management plan either. However, they may benefit from a plan drawn up with the aim of nurturing and improving natural values, cultural values, recreational values, hunting values or any of the other functions of the forest.

What data is needed is primarily governed by the owner's goals, but the Forestry Act applies to all forest owners, so everyone needs sufficient information to stay within the framework of the law.

A description of the state of the forest is the basis. But in order to make decisions, descriptions of possible or at least reasonable measures and their consequences are needed now and in the future. The alternatives should be ranked with regard to the forest owner's goal fulfilment. For the forest owner who wants help with decision-making, one single proposal for action is sufficient, i.e. the highest ranked proposal.

Most individual forest owners choose to do harvests in their forests, and after harvesting they also sell the timber to industry, through the forest owners' association or the forest industry companies. Many people chop firewood for their own heating. Some process some wood themselves via saw and craft. But no one puts up any large quantities of wood piles for final storage. For those who harvest and sell their forest, part of the target should therefore be net income and present value.

Production possibilities in the long term is an important point, at least for those who see the owning and management of forest in a generational perspective. At the same time, the current state of the forest is decisive for what can be done in the short and medium term, which reflects the ownership period of a two or three decades that an owner usually has. Generation thinking can be about using and managing resources effectively and then transfer resources in some form - but not necessarily forest - to the next generation. If the next generation is not interested and motivated to acquire knowledge of forestry, it may be better to have another investment of capital.

The planner's task becomes different if the landowner is an individual or a large forest company; it is important to help the small forest owner find out both what he/she wants, what the forest can give, and how the forest should be managed. A further complication for planning may be that the goal changes during the holding period as life changes.

Thus, what information, what data, what decision-making basis and planning support a forest owner needs depends on many different conditions. Ownership conditions, goals, interests, knowledge, willingness to learn more, willingness to take advice and buy services, ways of making decisions, ability and opportunity to be self-employed as well as forest conditions can affect.

3.2.7 Views and demands from the outside world

Many people have views on how the forest can, should and may be used. Society sets the framework through forest and environmental legislation. Tax legislation also has an impact. In addition, the forest is such an obvious part of Sweden that the public often has views. Various interest groups (conservationists, hunters, ornithologists, reindeer herders, etc.) try to influence the decisions. The end consumers of the products that the forest is converted to also have views, as well as the fiber-based industry (sawmills, etc.) that stands between the forest and the consumers. This applies both to land use and management methods and partly to the timber requirements for the industries. This means that the individual forest owner needs to be reasonably open to and aware of the various requirements, but above all have his/her own picture of what he/she wants to achieve and insights about what the forest can provide.

3.2.8 What should be included in a forest management plan

How a plan should look like depends on the forest owner. The plan should include proposals for the measures over a certain period of time that will lead to the best goal achievement over time. A plan can include all elements as a plan for a forest company, with a strategic (long-term, overall), a tactical (medium-term) and an operational (short-term) level. In any case, the plan should be so concrete and clear that the forest owner can understand the content of the plan, and how it was produced.

The plan should also be possible to keep up to date as actions are carried out, it should be interesting and motivating. The consequences of different measures should be described and quantified so that the forest owner can understand what happens if a proposed action is carried out, but also if it is not carried out, if the action is carried out in another way, or if another action is carried out. The effects should be described for the ecosystem services and benefits that are included in the owner's goals. If you want and have the opportunity, it is desirable to include even the ecosystem services that the owner may be interested in in the future, as well as those that are demanded by society.

The plan should be designed to attract the forest owner to learning about his/her forest and forestry, but also how other stakeholders can be affected. The plan should also be designed so that the next generation becomes interested in reading and learning. Interactivity is desirable, that the reader can test to perform various actions and get a consequence description is positive. The plan should also be easily accessible.

The forest owner should be able to supplement his/her plan with additional information afterwards, e.g. photographs from the forest, notes on trails, windfalls, dry trees, unusual plants, fungal sites, moose paths, other cultural values, etc. and forestry measures implemented. Previous actions and historical images can also be interesting. Did Grandfather fell in any part of the forest, where did Granny pick berries, etc.

The plan may also contain up-to-date information, e.g. how much has the forest grown recently, how much CO2 has been sequestered, how big is the risk of windfall (both before a storm based on wind forecast, and after a storm with better data), snow break, insect attack.

The information in the plan should also be easily updated with information that comes from public inventories or based on the owner's own inventory or forest management. Updating of the consequences of proposed measures against changes in forest conditions and price lists should be kept up to date.

3.2.9 Development opportunities

Technological developments with smart phones and tablets provide fantastic opportunities, which could be utilized significantly more than today. Imagine one or more mobile apps. One who guides the forest owner around the property, reads a description of the forest state and shows where the planner has gone and measured. The app would then be able to read a planner's comments when he/she walked around the property. In addition, the app could guide to all mapped natural and cultural values as well as present and argue for and against various measures in the department in which the forest owner stands and their consequences in the short and longer term. The app could also provide information on which contractors are nearby and who carry out assignments in the area.

The other app might illustrate how forests grow and change. What if you could keep the phone in photo mode over a department or a landscape section and get a visualization of how characteristics change over time for a given management type.

Another app could be used to more or less automatically record working hours and performance, as well as update the forest management plan. The information on own performance can then be used to advise on what measures and in which departments self-employment provides the best profitability or goal fulfilment.

Or an app that provides support for easy programming of a drone for aerial photography and then takes care of and matches the images so that the image serving as basis of the forest map can be updated.

Something that would help the forest owner's is an app that could provide guidance on in which departments higher quality data of forest condition are most useful, and where data collection with methods that provide high-quality data can or should be done. That app might also be able to draw up an inventory plan, either by drawing out a dotted grid (pattern) for an objective inventory, or possibly by proposing appropriate locations (some kind of stratification) to perform subjective measurements or and estimation of nature value. The app could then guide the measurement points, instruct how to measure and work on a sample surface, receive measurement values from measuring instruments and calculate objective estimates of the forest state including sampling errors for the department. The data can then be sent to a powerful server for analysis with some really advanced forest sustainability analysis system. The results of the analyzes are then retrieved and presented appropriately according to the forest owner's wishes.

Today's forest owners would probably ask for many more features if the opportunity existed, and tomorrow's forest owners can be expected to have more and perhaps completely different wishes for today's forest owners. A plan for an individual forest owner in the future will most likely look different and be designed in a completely different way than today. The needs of the future are not the same as yesterday's. Tomorrow's opportunities and conditions are not known today.

This approach means that the forest owner values more than timber production, that the owner wants to operate an efficient forestry from an economic perspective, that the forest owner has local knowledge and wants to contribute with data collection and have views on operational planning. The view also means that the forest owner wants to learn more - and has more to learn and can be motivated to learn more - about forest planning and forest management, etc., The forest owner - or his/her agent - becomes an actor in the planning process.

The method of producing the forest management plan in the broad sense must be cost-effective, i.e. the utility of the plan must be greater than the cost. The benefit of better planning should have diminishing marginal utility, while the cost of improved planning should be growing. The difference between the benefit and the cost is optimized when an extra krona in planning expenses only returns the corresponding benefit in better decisions.

One basis for planning is the forest state in the starting position. If we completely disregard the cost, one would want information about every tree, every square meter of land, every body of water, etc. However, measures in the forest can never be decided and implemented for each individual tree, since costs must be taken into account for moving around machines and for labour. At present, we also cannot collect information on individual trees on a practical scale. We are likely to describe forests divided by or collected within departments in the future as well. The first planning step when planning for the individual forest owner is therefore to delimit divisions (description units, stands, action units, departments or what you now choose to call these delimited areas).

3.2.10 Does a forest management plan lead to effective forest management?

Is it effective for an individual forest owner to devote resources to planning? Is it effective to draw up a forest management plan? In either case, the correct answer is that the plan is profitable if it leads to a greater increase in goal fulfilment than the plan costs to produce.

A forestry completely without planning means completely random decisions e.g. about where in the forest to harvest, and it becomes obvious that some kind of planning is appropriate. How much to spend on planning is a more difficult question. Any kind of current state description and division into stands or description units is needed anyway and can be said to be a basis for decision.

In addition, it is reasonable to do measures that are relevant to the forest condition of each unit. The most common way to decide on measures is to follow a forest management norm (forest management recommendation) with regeneration, clearing, thinning and final harvesting at appropriate times with regard to the forest condition with respect to tree height and stock density (base area) in relation to location, tree, location. Such general management recommendations are not adapted to the owner and the forest state on the property and are usually made without direct connection to the financial result.

An appropriate plan requires property-specific and owner-adapted analyses, but also good data on the forest state and a precise target formulation. In the forestry master's program, students in a first step are asked to draw up forest management plans mainly using traditional subjective methods (supplemented by some constituent analyses for some stocks), and in the second stage to do real estate analyses with the best analysis system we have available today, namely Heureka PlanWise . In the latter analysis, students can choose to compare the economic net present value between their first forest management plan and the one that results from PlanWise analyses. The results can differ by SEK 100,000 or more, which can be seen as a measure of a hidden cost for establishing a traditional plan. (The visible cost is what the forest owner must pay for the service to draw up a plan).

This means that the measures proposed in a traditional forest management plan are not the best. The conclusion assumes that the target formulation in the PlanWise analysis corresponds to the forest owner's goals. It also assumes that the data on the forest matches the reality well enough, and that all parts (models) of the PlanWise system are able to describe reality well enough.

One should not think that a person with a forestry education with a subjective judgment based on his or her knowledge can decide what is optimal management because issues are so complex.

The Heureka system is built by researchers based on current knowledge of how the forest grows and responds to measures given the forest state, but the reality is of course complicated and varied. Therefore, despite its level of detail and complexity, Heureka PlanWise certainly does not provide a correct answer to the question of how the forest should be managed. Forestry also involves risks (storms, snowfall, fungal infestations, etc.) that are difficult to model and manage in the system.

There is room for humility from both the traditional forestry planner and from the planner using Heureka. It can be said that the analytical planner should familiarize themselves with, understand and explain the solution provided by the planning system before it is implemented. It is extenuating that you can follow up on the results and do new planning and analyses after 5-10 years, which in a forestry perspective is a short period of time, and that there is a small difference in goal fulfillment between the treatment options near optimum. Some treatment options are roughly equivalent, as illustrated in Figure 3.9.

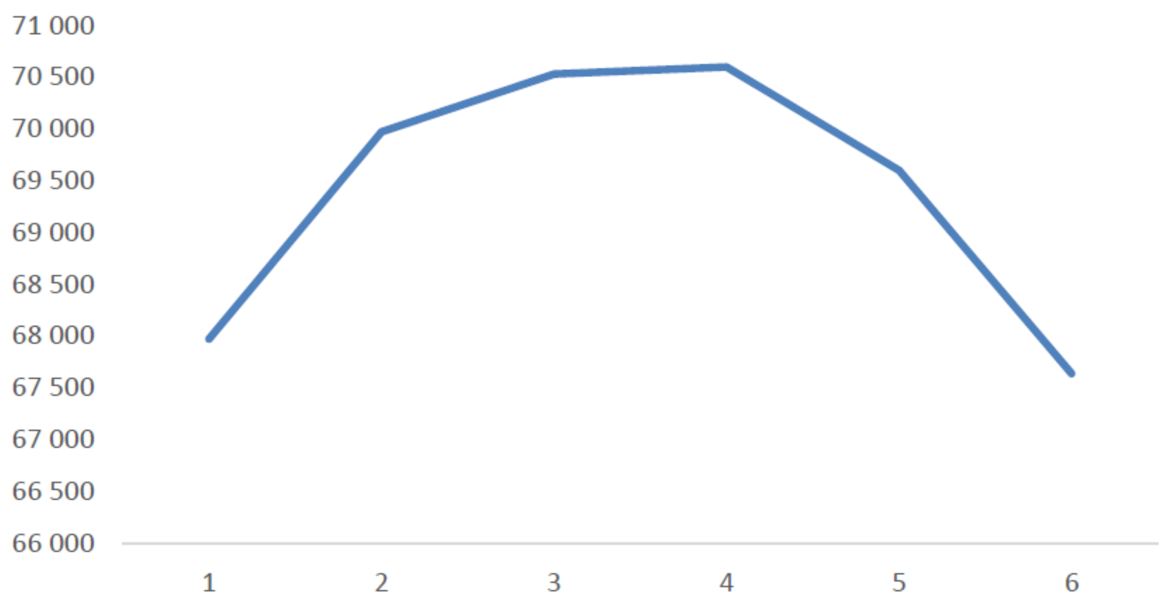

Figure 3.9. Theoretical example of how the net present value (SEK / ha) for a department changes over the stand’s age at final harvest (five-year periods).

3.2.11 How is the forest management plan used?

The forest management plan is primarily intended to help the forest owner make the decisions that lead to the highest goal achievement, i.e. for deciding what measures to take, how these should be carried out and when. Perhaps a simpler way of formulating this is to select and rank (prioritize) objects / priorities for actions leading to the highest goal achievement. But the plan can be used in several ways (which ultimately also aim for maximum goal fulfillment).

Alm (2012) investigated the level of activity of 138 forest owners in northern Sweden with a forest management plan compared to 100 without a plan. He found significantly higher activity in those with plans (6.7% of the forest area under some activity per year against 3.5%). The activity rate after the plan has been acquired is significantly higher than before (6.5% versus 3.1%). Of the proposed actions, two out of three are performed (upper and lower quartiles is 44 and 90%). Whether the forest management plans also led to higher goal fulfillment for the owners was not investigated.

A study in 1981 (SOU 1981: 81) based on interviews with 2,500 individual forest owners showed that more harvests were done in forests with a forest management plan than in those without a plan. This led to legal requirements in the 1980s for everyone to have a forest management plan. The underlying purpose was to secure the timber supply of the forest industry after a few years around 1980 with low harvesting. The conclusion was later criticized because the connection could have been the opposite, i.e. that the forest owners who harvest for some reason have a need for a forest management plan, while those who do not want to harvest do not consider themselves needing a plan.

Svensson (2002) sent out a questionnaire to forest owners in Älvdalen that had a forest management plan and received replies from 125 owners (63%). The results showed a significantly increased activity rate for both felling and forest management. Cleaning increased by 320%, thinning by 115% and final felling by 145%. A quarter of the forest owners considered changing ownership.

Harrysson (2009) interviewed timber buyers and concluded that a forest management plan facilitated dialogue with the forest owner, reduced the time for forest assessments and facilitated timber purchases for the company that prepared the plan.

According to Carlén (1990), a forest management plan had a significant positive impact on both the probability of felling and harvested volume, but the owner's age had a greater impact.

The plan is often used as a means of communication within the family, with partners and with authorities, for example, when applying for a grant. The plan can also serve as information when registering for final harvesting or applying for grants, in real estate appraisal, in discussions with neighbours, timber buyers and inspectors and with forestry contractors. Furthermore, it is a good basis when communicating with neighbouring residents, with other stakeholders, with banks and advisory consultants for transfer planning.

The plan provides the basis for the lender's decision on loans. It is the basis for the owners monitoring and follow-up, for certification and compliance with the law, grant documentation, and as a basis for speculators in a sale. In addition, it can be used as a basis for calculating the basis for the sale of felling rights or forest management assignments. It is not least an excellent basis and source of inspiration for own and family's learning about everything that has to do with forest and forestry.

3.2.12 Content

The basic principle is that the plan must contain the information needed for the owner to be able to make the decisions that lead to the highest goal achievement. A forest owner who wants to produce biodiversity throughout the forest - property obviously needs information other than that completely focuses on timber production. A forest owner who want to have some income does not need the same information as those who want maximum income. But information gathering requires resources, which means that you cannot collect more information and devote more resources to analyses than you can gain from improved decisions.

There is no official standard for what a forest management plan needs to contain. On the other hand, there is a tradition about which variables are fundamental, and that tradition assumes that timber production is at the centre but that environmental considerations are included. The certification rules put, however, demands on what should be included in the forest management plan, which the forest owner needs to take into account if he/she wants to become certified. You can make a very long wish list with things that many consider necessary but also things that may be interesting in a forest management plan.

- A description of what goal the plan is based on
- Overview map showing the property's parcels, roads, terrain at large with mountains, marshes, lakes, and possibly agglomerations
- Forest map with demarcation of all departments, with aerial image as background or as a theme map
- Description of the forest state per department, in terms of ID, area, age, productivity, harvesting class, volume and tree species may be said to be the traditional characteristics. Basal area, stem density, average diameter, average height, saw log quality, (all of these sometimes per tree type), other comments, damage, nature and cultural values, social values, soil conditions, site conditions, terrain conditions, terrain transport distance, diameter spread are other properties that also have a value in analyses before decision-making and thus should be included in the forest management plan
- Nature value assessment, primarily of areas with high values
- Target class division is reported in the department description, but also in a separate table overview and in the theme map
- Description of inventory method, per a department if the method varied, quality labelling, as well as the information that has been gathered from public records
- Summary of forest condition of the property, area, stem volume, species distribution, mean productivity or site index, age distribution (area, volume), these tables and figures are presented both for the target class PG and PF, respectively NS and NE (these are management classes in the green forest management plan and refer to different levels of consideration to nature values)
- Proposed measures for the period of time the plan relates to, harvesting measures, forest management measures, current forest state and state following proposed and possible harvesting measures
- Action Points can advantageously be presented in one or more theme maps

- Description of how the proposed measures were produced. Analyses with Heureka PlanWise combined with any subjective field control is the best we have today, but easier and cheaper analysis may be sufficient for some forest owners' situation and goals
- Impact description of the measures proposed, volumes, areas, age class distribution, tree species distribution
- Target achievement. E.g. net present value, income, quantities and areas for other things included in the target, value of indicators
- Alternative proposals for action and their consequences
- Detailed advice to forest owners regarding management measures, monitoring of forest stands and up-keeping of the plan
- Essential summary on one page.

The absolute minimum level of information is a forest map with department - boundaries and identities and the corresponding department registers with the key variables including proposed measures for the planning period.

3.2.13 Some views on the time horizon of the plan

A very common time horizon for a forest management plan for a privately owned property is 10 years. The planning period is then divided into three periods, and the proposed measures are stated to be made "immediately", "in the first" or " in the second five-year period". Ten-year horizons are common in many other countries in Europe, but longer time horizons also exist, even in Sweden. The "third five-year period" is sometimes used for action proposals.

These time horizons have sprung from history when making forecasts of forest growth and development completely subjective or possibly using growth lines in some thinning template. Now that we have access to advanced analytical tools, the time horizon should be longer to show the production-potential, sustainability and the common generational thinking. A rotation period may be appropriate given the time it takes for the forest to develop.

An individual forest owner should spend some time pondering what they want to get out of forestry during their tenure, and then maybe 30 years is a reasonable horizon.

On the other hand, it can be argued that the world is changing, that both the owner and the outside world change over time and that both the plan and the planning should be adapted to it. The owner’s experience, abilities and values change over time, and thus the goal, the society is also changing and thus also all the political regulations affecting forest use. The climate is changing, the state of knowledge about forestry, forestry technology, production opportunities, demand for market prices, the benefits of the market are changing, i.e. prices and price relationships are changing. In the long term, we do not know which of the benefits the forest can provide that forest owners and society need and with what priority. In this case, the forest management plan is primarily a medium-term plan based on the conditions that currently apply. The plan may be what a knowledgeable and experienced person suggests after a more or less comprehensive "inspection" and for a low cost, with the aim at least to avoid making unnecessary forestry mistakes, and not to take too big risks. One does not want to miss out on obvious forest management measures including thinning or miss putting away forest areas with high nature values. In these cases, it is very important that the person preparing the plan is well educated and has sufficient depth of knowledge to avoid "excessive tree management" that does not sufficiently take into account economic, technical, biological etc. realities, and proposes measures that cost more than they taste. .

3.2.14 Is the plan public?

The Forestry Act does not require that information in the plan be made public. The Swedish Forest Agency provides some information about the state of the forest based on laser scanning, but it is not a plan for how the forest should be managed in the way included in a forest management plan. The plan may be considered confidential information and it is the forest owner who decides how the information should be disclosed to others. However, the certification rules require that parts of the plan be public.

Facts. FSC's claim to the plan.

PRINCIPLE 7: MAINTENANCE PLAN

A written management plan, adapted to the scope and intensity of the business, must be drawn up, implemented and kept up to date. The long-term goals of forestry use and the means by which they are to be achieved must be clearly stated in the plan.

CRITERION 7.1

7.1 The management plan with supporting documents must contain:

a) Forestry goals.

b) Description of the forest assets to be used, environmental constraints, land use and ownership, socio-economic conditions and a clear description of neighbouring areas.

c) description of forestry systems / other management systems based on the current forest ecosystem - the system's ecology and on information obtained through the inventory of assets.

(d) Justification for calculating annual harvest level and tree species selection.

e) Methods for monitoring forest growth and dynamics.

(f) environmental protection measures based on environmental assessments;

(g) systems for the identification and protection of rare and endangered species;

(h) maps describing the forest resource, including protected areas, planned forestry measures and ownership rights;

(i) description of the harvesting methods and equipment to be used and justification for the use of these methods and equipment, respectively;

Comment: Under principle 7, references are made to appendices 3A and 3B, which are part of this standard. The purpose is to create a more technically manageable standard by clearly presenting requirements regarding plans and documentation. The purpose is also to enable forest users to verify that the standard is complied with.

7.1. A BS. Forestry users must meet the requirements for planning documentation in accordance with Annexes 3A and 3B.

7.1. fS. In the case of forest measures in or in connection with areas with particularly high cultural and natural values, there must be a treaty directive / job description that describes these areas and how they should be treated.

7.1. GSA. Same as 6.1.7SA.

7.1.a-bSA, 7.1.fSA, 7.1.gSA VER: Plan documentation, interviews, field visits.

CRITERION 7.2

7.2 The management plan shall be revised at regular intervals, to include results from own follow-ups and from new scientific and technical information and to be adapted to changing environmental, social and economic conditions.

7.2.1SA. Forest users' planning documentation must be updated in relation to the scope and intensity of the business. In the case of comprehensive planning audits, results of follow-ups and relevant new knowledge should be used.

Comment: Plan older than 10 years is revised when required for follow-up and control.

7.2.1SA VER: Planning documentation.

CRITERION 7.3

7.3 Forestry employees shall receive the training and guidance required to ensure compliance with the management plan.

7.3.1S. Forest managers must ensure that hired workers or contractors have the necessary skills 31 and, if necessary, provide guidance to ensure compliance with the management plan.

7.3.1SA VER: Proof of knowledge. Proof of employment. Interviews. Entrepreneurship agreements, relevant trade unions.

CRITERION 7.4

7.4 Except for information of a confidential nature, forest users shall keep a summary of the main points of the management plan public, including what is stated in 7.1.

7.4.1SA. Forest management plan documents, with the exception of confidential parts, must be able to be displayed upon request 32. Confidential elements may apply, for example, to the protection of species susceptible to disturbance or crime.

7.4.1SA VER: Availability of documentation.

Appendix 3A: Planning documentation; information available to the public

The table shows what information should be made available to the public for SLIMF, that is, what information that smaller landowners should make available to the public. The certifier must be able to access all documentation that requires different standard points (see Appendix 3B).

Indicator SLIMF 20-1000 ha

5.1.1 Targets for forest management

7.1 Description of the starting position, goals, management and map and register with map of:

- Key biotopes etc. (6.2.1S a and b)

- Areas designated for nature conservation purposes (6.4.1-6.4.3S)

- Forests with a high conservation value (9.1.1SA, 9.1.2S, 9.3.1S, 9.3.3SA)

SLIM <20 ha

Aim for forest management

Written or oral information on:

- Key biotopes (6.2.1S b)

- Areas with high nature values according to 6.1.7SA.

- Forests with a high conservation value (9.1.1SA, 9.1.2S, 9.3.1S, 9.3.3SA)

Examples of documentation

Map of areas designated for conservation purposes and forests with high conservation value and summary key points in the management plan

3.2.15 Plan program, updating and format

In most cases, the plan is drawn up with a computer. There are special applications for this purpose (ForestMan, pcSKOG , Splan) which include GIS functionality and which provide support for updating. The forest owner can obtain the program and use it for additions, extensions and updating, or have the organization that made the plan updated it. These programs have their strengths (primarily to keep track of and maintain departmental records and forest maps), but they are not designed for the kind of analysis and planning that can be done with Heureka PlanWise. They are not planning programs in that sense.

Keeping up to date is important. The forest state should be adjusted annually on the basis of estimates of the stock's growth in each department (projection), based on public data sources such as the Swedish Forest Agency's Basic Data, or that the forest owner himself/herself or his/her contractor or manager keeps the permit on the basis of the forest management or harvesting work. We may think that the forest is growing slowly and that most departments are being left without action, but it is important that the state description is sufficiently accurate to be used as a basis for decision-making and when revising the plan for a new time period. Even after five years, the plan can be quite outdated. If the plan is to serve as a basis for communication, it is also important that it is up to date.

The usual thing is that the plan is printed on A4-size paper and inserted into a cover. The maps are printed in A3 or larger format and can be embedded so that they can be taken out into the field. In addition, there are computer programs so that you can have your plan in your PC, and in advanced mobile phones or in field computers. The latter assumes that one has his or her plan in cloud service or accessible via the Internet at any company or planning program provider. Digital plans are easier to keep up to date. While the paper version can of course be kept up to date, a regular pen is reasonably sufficient to up-date the department registry and forest map with actions performed, but it will soon get messy when up-dating state descriptions. It is better to keep the plan up to date in a computer and then make a new printout of a current plan every year.

3.2.16 Who prepares the plan

The usual thing is to hire someone trained for the work to establish the forest management plan. It can be in direct contact with the person doing the job, or through the wood-buying organizations. The latter can let employees make plans, but more often they hire sub-consultants (entrepreneurs, students, seasonal employees). For the organization, it is an opportunity to get an overview of the forest state on the property and a trusting relationship with the forest owner and be able to give advice on harvesting, which can provide improved opportunities to buy more wood. If the organization has the plan in its computer system, the forest owner becomes dependent on contacts with the company for updating.

The organizations often have one or several planning officers who handle orders, arrange documentation for the planning work, hire, educate and administer field personnel. They will also receive data and examine the finished plans and arrange printing. The field season for the planners usually starts with some introduction to the job. Those who are brand new need a thorough introduction, the experienced need to learn what has changed since before, and both need to train and calibrate their measurements and assessments.

Even the State Forest Agency (Skogsstyrelsen) can undertake to establish forest management plans. During the 1980s, they implemented the ÖSI project (ÖSI stands for “overview forest inventory”) and was then also the organization that prepared the most plans. The government invested considerable money in drawing up plans for all privately owned forest land. The aim was to increase the level of activity and logging volumes among the individual forest owners, as a study showed that more harvesting occurred on properties with a forest management plan than on those without a plan (SOU 1981: 81).

The forest owner can draw up a forest management plan for his/her property himself, but according to the certification rules, the planner must have relevant training. One option for the owner is to update and use an existing plan on their own, for example by doing their own inventory and planning.

3.2.17 How to make forest management plans

Forest management plans for individual forest owners are currently (2016) still based mainly on subjective methods. The forest owners' goal is not described at all or very vague, data about the forest, the nature and cultural values, etc. on the property is collected through subjective assessment and support measurements of subjectively selected locations, and the proposed measures are provided based on what planners assess in the field , and after some adjustment with respect to the state of the forest and the growth of the entire property. Proposals for logging for the entire property are adapted to what is deemed appropriate.

Data collection begins with image interpretation. Aerial image interpretation can be performed by professional image interpreters or by the businessperson based on available images and data. This may be data from laser scanning 2009-2015 or from aerial images taken later. Departments and different types of ownership are defined (divided) based on what can be seen and interpreted in the picture and based on experience of what are reasonable sizes and shapes of departments. In addition, some variables can be interpreted for the departments, such as land cover, mean tree height and volume. Alternatively, a classification can be made based on the height of the trees based on airborne laser measurement. Estimates based on the same data (e.g. the Swedish Forest Agency's Basic Data) can provide estimates of the departments' timber volume and amount of biomass, as well as the average height, basal area and average diameter. A preliminary assessment is made of which areas should be given target class NO or NS (nature conservation without (NO) and with (NS) management).

Thereafter, or first of all, the forest owner is contacted with questions about special conditions and if the forest owner has any goal that he has considered and formulated and is willing to report to the planner.

Then the field inventory is made. The departmental boundaries are checked and adjusted if deemed appropriate, and the forest state is checked via support measurements. If the interpreted data is misleading, the values are adjusted, especially if preliminary departmental boundaries are moved. Major errors can occur in the preliminary interpretations. Assessments are made of all variables that will be included in the plan, and alternative measures are considered and noted. Furthermore, the occurrence of nature values is assessed, and it is noted whether there are areas with potential for high nature values as well as cultural values and social values.

The field work and at least parts of the preparation are usually done by subcontractors to forest owners' associations or forest companies, but it is not uncommon for forest students to be employed seasonally for the task.

In retrospect (day by day and when the entire property is inventoried), final adjustments of the map are made; values and comments are entered into the planning program together with action proposals. The forest management and harvesting proposals are submitted based on guidelines from the organization or company. An overview and easy-to-read description of and motives for different forest management measures are usually attached. In addition, a brief description can be attached to the work behind the plan.

Some of the organizations that are making plans complement them with objective measurements (like those done in the national forest inventory) in a small sample of departments to give planners feedback and opportunities to correct their measurements and estimates. This is also done to reduce the risk of carelessness and to motivate the people who work in the field, as well as a quality argument to clients and in marketing.

Companies and forest owners' associations usually have plan managers who do some review of the plans. Complete plans including the maps are then printed on paper.

When the plans are completed, they are handed over to the respective forest owners. Often the handover is made by someone with whom the forest owner can have contact for forestry and logging assignments (i.e. timber deals) and who therefore want good contact with the forest owner. Then you can go through the forest state on the property and the measures proposed in the plan, maybe find out more about the forest owner's goals, and the management proposals (or alternatives) can focus on the owner's goals and opportunities. The handover can lead to agreements on forest management or harvesting.

Study questions

1. Which content you would like to include in a plan of your property (especially if you can arrange it cheaply)?

2. Do you know any forest owners? Do they have a forest management plan? Would you like to read their plans, and would they let you read their plans if you asked kindly? What use do you think they have of their forest management plans? If they ask you for advice, how could you use the forest management plan? Would you blindly rely on the state description in the plan, or the proposed actions?

3. A friend wants to buy a forest property that is for sale and asks you for help in assessing the value of the property. You have a few days off and want to help because you have received help earlier and hope to learn something from this. There is a newly made plan as a basis. How would you do?

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3.3 Society's need for planning

3.3.1 Planning at different levels

The need for planning documentation exists at different levels in society, from the individual landowner to authorities and ministries. The individual landowner and forestry company are described in previous chapters in this compendium. Municipalities need a basis for e.g. overview plans and for handling cases linked to the Planning and Building Act, at the national level there is a need for strategic considerations and decisions on forest resources and their use, such as monitoring environmental goals. Recently, various international commitments and issues have also increased the need for national planning documentation, such as accounting linked to GHG reporting and the Kyoto Protocol and Natura 2000. Sustainable development is an overall goal within the EU and an overall goal for the Swedish government's policy, enrolled in the form of government since 2003. That means that all policy decisions should be designed in a balanced way, taking into account the economic, environmental and social consequences in a longer time perspective.

In the forest sector, there is a long tradition of studying sustainability by means of forest impact assessments (SKA) and timber balances (VB). Forest impact assessments are conducted to strategically study the consequences of different scenarios in the trade-off between production and the environment and other interests. In the timber balances, actual felling, timber supply, timber use and potential felling are analyzed and compared. In recent years, the forests' possible contribution to energy and climate policy has also become increasingly relevant.

Forest policy decisions should be based on strategic, reliable facts. This is the main motive for Sweden's long tradition of national forest assessments and forest impact assessments (SKA). The issue of secure timber supply has later been extended to sustainable use from both economic, ecological and social dimensions. This has meant that SKA has also been expanded, mainly through the introduction of various environmental aspects.

3.3.2 History

Forest impact assessments, or logging calculations, have at least for 150 years been an important basis for decisions relating to the use and management of forests and supporting the development of the forest industry. Decisions are made both in the public and in the private sector. Prior to major changes in forest policy, such impact assessments are usually carried out. In the private sector, the analyses are of great importance in e.g. investments in the forestry and energy sectors, but also in the selection of forest management strategies.

The first known national impact assessment was done by af Ström in the mid-19th century and is reproduced by Agardh & Ljungberg (1857). It covered the entire country with the exception of "inaccessible" forests in the "northern provinces" and " fields without forests " in Skåne, Halland and Småland. The forest area amounted to 12.8 million hectares, and the potential annual supply of wood was estimated at 5.7 million fathoms, which corresponds to 15 million cubic meters. Consumption was estimated to be 19 million cubic meters. Thus, the timber balance was clearly negative, and a future catastrophic shortage of forests predicted, especially as population growth had begun to pick up.

Tor Jonsson, 1880–1949, forest researcher, professor of forest inventory and division of forestry at the University of Forestry 1915–44, principal of the university 1927–36.

The next milestone was Jonson & Modin's (Anon 1933) felling calculation. It calculated the harvesting quantity that should be available for the next 20 years. To describe the starting position, the first objective estimate of Sweden's forest assets was used, the National Forest Assessment 1923-1929 (Anon 1932). After that, all subsequent calculations at national and regional level have used the National Forest Assessment data for a description of the current forest state. Jonson & Modin concluded that it was possible to cut about 58 million forest cubic meters annually, provided that forest management was good, and the harvesting policy was largely unchanged.

Jonson & Modin continued to work with felling calculations and presented a more long-term calculation in 1938 (Anon 1938). The term "better half" was used for the first time, the forest with a density belonging to the top fifty percentiles. The calculation answered the question "What will be the harvesting opportunities in the future if all forest has a density that corresponds to the better half?" They concluded that around 1970 it would be possible to cut 70 million forest cubic meters.

Of great importance to the forest industry in southern Sweden became the "Forest Research Institute's calculation for Southern Sweden's Forest Industry Investigation" (Anon 1956). It was based on the new National Forest Inventory, which began in 1953. The data collected from 1953 were better adapted to the needs of conducting impact assessments. Results showed that there was a large untapped harvest potential in southern Sweden. As a result, they dared to invest in a strong industrial expansion.

Starting from the 1973 forest investigation (Anon 1978), a completely new computer-based model for logging calculations was introduced. With this model. it was possible to analyze the harvesting opportunities and forest development in the long term (100 years). It was also possible to study the consequences of various alternative forest production programs that differed with regard to e.g. the intensity of forest management and thinning strategy. Alternative 1 of the study, which describes the forestry carried out during the 1950-1970s, provides a possible future harvest of about 75 million forest cubic meters. Actual harvesting in the 1970s was at about the same level. It therefore became natural that the forest policy adopted in 1979 involved a strong investment in production-enhancing measures. Without increased production, there would be no future expansion opportunities for the forest industry and timber prices would be high.

Even before the report of the forest investigation was published, work began on developing a complete system for forest impact assessments, the HUGI N system (Lundström & Söderberg 1992, Hägglund 1981). The future development of the forest could now be determined on the basis of the growth of individual trees. Thus, it was possible, for example, to produce more detailed figures on both the logging and the forest's dimensional composition. The new forest after regeneration harvesting and the forest management measures could be more varied than before. The new system was "tested" in the nationwide analysis "Felling Calculation 1985" (Bengtsson et al. 1989). The calculation showed that the logging in the option "Today's forest policy" in comparison with the forest investigation's alternative 1 could be increased somewhat in the short term and quite a bit in the long term. The Swedish Forest Agency based a timber balance study "Wood Balances 1985" (The Swedish Forest Agency 1988) on, among other things, this analysis. A main result of the study was that by the mid-1990s there would be a balance between the need for wood and the potential harvesting, which corresponded to a logging level of about 74 million m3 o.b.

When the government decided in 1990 to appoint a forest policy committee (Anon 1992a), it was natural to carry out, in conjunction with its work, a new nationwide forest impact assessment (AVB 92) (Lundström et al. 1993). The Hugin system could again be used. It turned out that it was reasonably well-adapted to determine the consequences of an increased set-aside of forest land as well as the leaving of retention trees during final fellings. On the other hand, it was not possible to study the effects of a forestry with a more diversified forest management in a sufficiently good way, in which, for example, shelterwood and continuous cover forestry are used. AVB 92 provided a significantly higher potential harvest in the coming decades than the previous forecast, AVB 85. The Forest Policy Committee therefore did not have to be particularly worried that Swedish forest would not suffice for both harvesting and strengthening of nature conservation. In the longer term, the difference became smaller. Again, a nationwide impact assessment was followed by a timber balance study conducted by the Swedish Forest Agency. It was named "Timber Balances 1992" (Forest Agency 1993).

In 1993, the Riksdag (parliament) decided on a new forest policy, which included a pronounced balance between production and the environment. Around this time, the forest industry's production and thus the use of wood and harvesting had started to rise sharply. There was therefore an increasing need to investigate the links between the future harvesting potential for different forest management alternatives and different environmental ambitions. The broad impact assessment "Forest Impact Assessments 1999" (Thuresson et al. 2000) was conducted during the years 1998-1999 (SKA 99). The Hugin system was also used this time and was further developed, not least to improve the models for the effects of environmental measures on timber production.

For various reasons, no timber balance study was conducted directly after SKA 99. However, it was already a few years after SKA 99 that the environmental ambitions became somewhat larger than assumed in the scenarios in this impact assessment. The Forestry Board therefore made a simple follow-up to SKA 99, which was named "Forest Impact Assessments 2003" (Gustafsson & Hägg 2004). The work covered only one scenario in which the conditions regarding provisions followed the environmental objectives decided by the Riksdag 2001 and the forestry ambitions at this time. The conditions for timber production were the same as in the scenario "90s forestry" in SKA 99.

The continued increase in harvesting during the first years of the 2000s led to the actual harvesting approaching the potential, or as it is now called the highest sustainable harvesting volume. Therefore, it became increasingly important to carry out a new timber balance study. It was called "Timber Balances for 2004" but could not be completed until 2007 (Bäcke et al. 2007) because of the Forestry Board's analysis work on the storm Gudrun.

As a result of the high logging levels and a number of important ongoing political processes around climate and environmental policy, in the 2007 Regulations, the Swedish Forest Agency was commissioned to "analyze the current and expected future timber balance in different parts of the country ...". As a result of the government assignment, the Swedish Forest Agency started the project SKA-VB 08, which was reported in December 2008. Within SKA-VB 08, scenario analyses were carried out where 4 national scenarios and 6 impact analyses were calculated (Claesson et al. 2008). In the scenarios that were calculated within SKA-VB 08, for the first time, future effects of a changed climate were taken into account. The project also carried out a roundwood and forest fuel balance (Forest Agency 2008). One of the conclusions of the timber balance study was that the Swedish Forest Board estimated that the highest sustainable felling level for the period 2010–2019 is 95–100 million m3o.b.

Since the oil crisis in the 1970s, many potential calculations and balances for forest fuel have been carried out both in research and by authorities. One of the first was the investigation “Increased firing (heating) with forest raw material” (The Swedish Forest Agency & Swedish National Board of Industry 1980). About ten years later, the state investigation commissioned the Biofuels Commission report "Biofuels for the future" (Anon 1992b). Commissioned by the Energy Commission, SLU (Hektor et al. 1995) calculated tree fuel potentials in the 21st century. In recent years, the Commission against oil dependency (Anon 2006) has presented an assessment of the future biofuel potential including forest fuel.

In addition to the aforementioned investigations, potential calculations and balances for forest fuel have been included in several previous forest impact assessments and on the wood balance studies based on them. This applies to, for example, "Felling Calculation 1985" (Bengtsson et al. 1989) and "Timber Balances 1985" (Forest Board 1988), AVB 92 (Anon 1992, Lundström et al. 1993) and "Timber Balances 1992" (Forest Board 1993) and "Forest impact assessments in 2003" (Gustafsson & Hägg 2004), "Forest balances for the year 2004" (Bäcke et al. 2007) and SKA-VB 08 (Forest Agency 2008).

Figure 3.10 shows the outcome of some different forest impact assessments and the development of growth and harvesting in the Swedish forests. The figure shows that logging has historically usually been lower than both the growth and the harvest potential calculations.

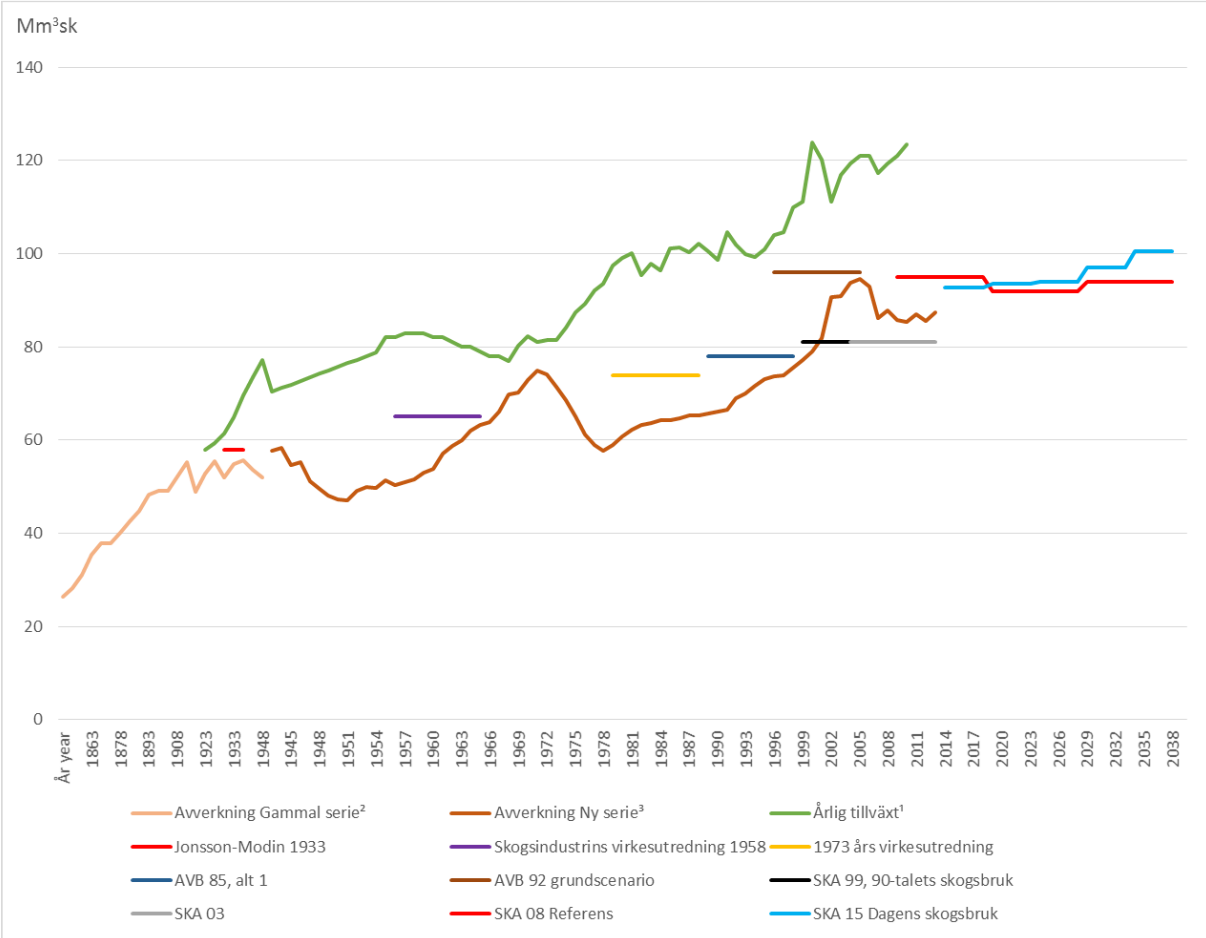

Figure 3.10. Growth and harvesting as well as potential harvesting in some different forest impact assessments. All land-use classes. (green – annual increment, brown – harvest, other colours: results from different forest impact assessments)

3. 3 .3 SKA 15

The most recent nationwide impact assessment was presented in the autumn of 2015, Forest Impact Assessments 2015 - SKA 15 (Claesson et al. 2015, Eriksson et al. 2015, The Swedish Forest Agency 2015). In it, the Heureka's RegWise application was used for the first time to carry out the analyzes (Figure 3.11). The National Forest Inventory plots from the years 2008-2012 were used to describe the initial state of the forest.

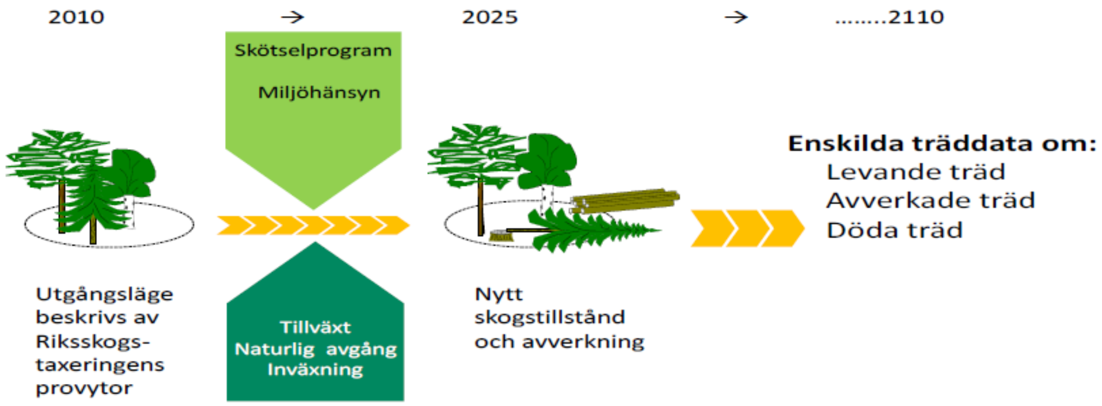

Figure 3.11. Schematic illustration of RegWise's functionality.

The various scenarios analysed were designed after consultation with the relevant authorities, the forest industry, the energy sector and other stakeholders. The results enabled subsequent in-depth analyses of economic, ecological and social consequences and evaluation of the sustainability of various scenarios including vulnerability, and result in a basis for the forestry's strategic considerations and decisions on management and utilization of forest resources.

Scenarios

In SKA 15, 6 national scenarios are calculated and analysed (Figure 3.12) . One scenario, Today's forestry, aims to reflect a development in which the forest is used and managed as it has been done in recent years. Other scenarios reflect alternative developments where some or some conditions have changed in relation to Today's forestry.

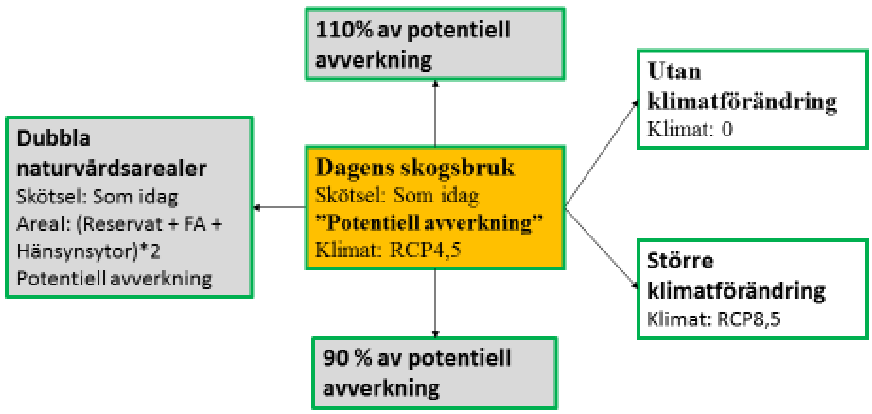

Figure 3.12. Scenarios in SKA 15.

Today's forestry

The scenario describes the development assuming the current (approx. 2008–2013) focus and level of ambition in forest management as well as observed logging behaviour. Land allocation in land use classes is made based on the latest observed actual situation. The calculations assume a change in the climate corresponding to the emission scenario RCP4.5.

Climate change in turn affects the growth of trees. No impact of climate change on the risk of damage is included in the scenarios. Harvesting is referred to as potential harvesting and is as high as possible without significantly reducing subsequent harvesting, which means that it is as high as the net growth in the forest on wood production land.

Today's forestry - harvesting 90 percent of net growth

Management, subdivision into land use classes and other general conditions are the same as in the scenario Today's forestry. In the scenario, harvesting is 90 per cent of the net growth in the forest on wood production land.

Today's forestry - harvesting 110 per cent of net growth

Management, subdivision into land use classes and other general conditions are the same as in the scenario Today's forestry. In the scenario, harvesting is 110 per cent of the net growth in the forest on wood production land.

Double conservation areas

In this scenario, the forest's development is simulated given that the areas of reserves, voluntary set-asides and retention patches left at harvesting are doubled. The additional area is allocated so that the conservation areas' share of the total productive forest land becomes equal throughout the country. The selection of the extra area to set-asied is made by summing the occurrence of a number of variables as indicators of biodiversity, where areas of highest value are selected until the intended area is reached.

Without climate change

Management, subdivision into land use classes and other general conditions are the same as in the scenario Today's forestry. In the scenario, however, there is no effect on tree growth due to a changing climate. The scenario aims to enable, together with the scenarios of Today's forestry and Climate Change RCP8.5, to study the significance of climate change for the results of the scenarios.

Climate change RCP8.5

Management, subdivision into land use classes and other general conditions are the same as in the scenario Today's forestry. However, the scenario assumes a change in the climate corresponding to the emission scenario RCP8.5. The scenario aims to be able, together with the scenarios of Today's forestry and Without Climate Change, to study the significance of climate change for the results of the scenarios.

Main Results

The greatest uncertainty in the scenario calculations is the size of the growth-enhancing effect of a changed climate that is included in the scenarios. The growth effect is based on emission scenarios, which in a number of steps have been converted into an impact on forest growth through several models. According to the meteorological calculations on average, the emission scenario underlying the growth-enhancing effect in Today's forestry, RCP4.5, leads to an increase in the global average temperature of 2 degrees. In the Today’s forestry scenario, this climate scenario leads to an increase in growth of 21 percent compared to the scenario without climate change (Figure 3.13).

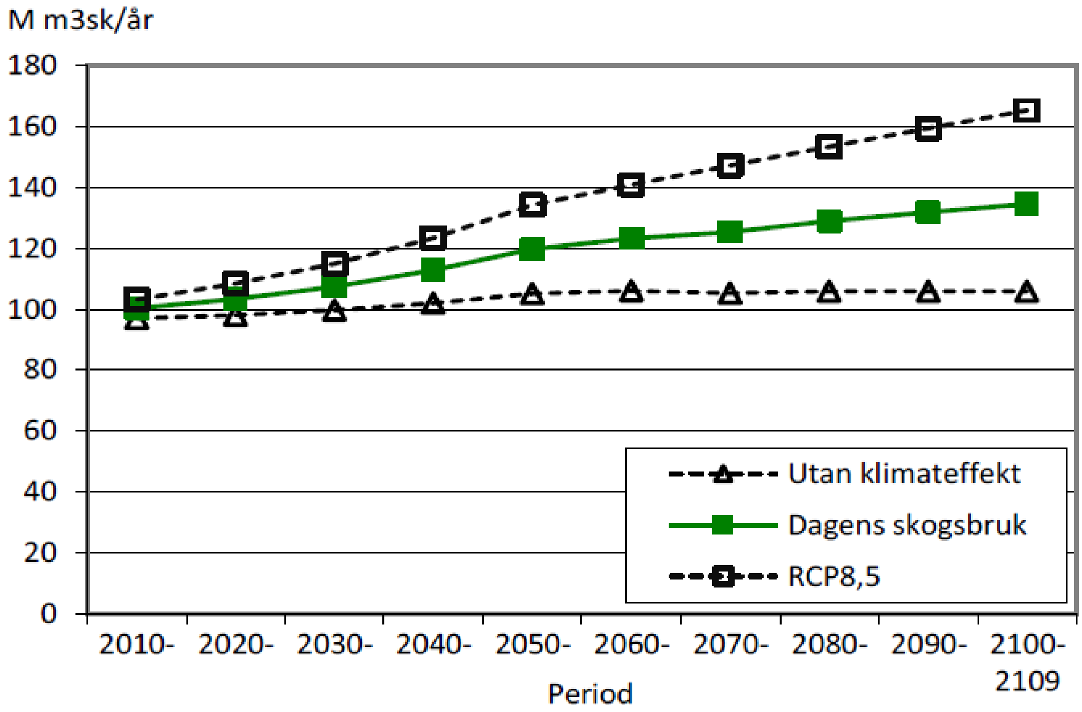

Figure 3.13. Growth (mill m3sk / year) in the scenarios without climate effect (black with triangle), today's forestry (RCP4.5, green) and RCP8.5, the whole country, timber production land and all owners.

Gross increment in all productive forest land in the Today's forestry scenario is 113 million m3 / year in the period 2010-2019. 90 percent or 100 million m3sk / year is growth that occurs in forests on wood production land, while natural mortality is 9 million m3sk / year, which gives a net growth in forest on wood production land of approximately 91 million m3sk / year. Growth increases successively during the 100 years that the calculations refer to, mainly due to climate change, to 150 million m3sk / year on all productive forest land.

In the scenarios of Today's forestry and Double conservation areas, harvesting is determined to be as large as the net growth in forest on wood production land, we call this harvesting level for potential harvesting. It follows that the potential harvest in Today's forestry during the period 2010–2019 is 91 million m3sk / year and that it will increase successively as net growth increases, to 120 million m3sk / year during the period 2100-2110.

In the Double conservation area scenario, 3.7 million hectares were further exempted from forestry. Gross growth in all productive forest land is in the same order of magnitude as in Today's forestry during 2010–2019, but only 82 million m3sk / year takes place in forest on wood production land. This means that the potential harvest is considerably lower than in Today's forestry, 78 million m3sk / year.

In the scenario of 110 per cent harvesting, the ambition is to cut 110 per cent of the net growth in forest on wood production land. This means that harvesting in the first ten-year period is significantly higher than in Today's forestry, 99 million m3sk / year. However, the high felling level means that forests of felling ages are rapidly declining, which limits the felling level successively. After 50 years, harvesting in 110 per cent harvest is at the same level as in Today's forestry.

In the scenario of 90 per cent harvesting, the ambition is to cut 90 per cent of the net growth in forest on wood production land, which during the period 2010–2019 corresponds to 82 million m3sk / year. Successively, net growth increases more than in Today's forestry, due to the lower logging level, which means that the harvesting approaches that of Today’s forestry.

In forests on land set-aside from forestry, growth in all scenarios increases successively during the first 50 years and then gradually decreases during the remainder of the 100-year period. During the first 50 years, most of the growth leads to an increase in the growing stock of living trees. However, during the second half of the 100-year period, growth is almost in balance with natural mortality, which will result in very large amounts of dead wood. Overall, this means that the growing stock of live trees increases from about 150 m3sk / ha to 300-440 m3sk / ha during the 100-year period.

The high level of harvesting in the scenarios, between 90 to 110 percent of the net growth of the forest for timber production land, decreases the average age at final felling of 100-120 years to 60-80 years over the 100 years of the simulation, depending on the scenario. This lowers the age of the forest available for wood supply in all scenarios, so that 97 percent in the scenario Today's forestry is below 80 years after 100 years. At the same time, forest land set-aside from forestry is getting progressively older in all scenarios. In today's forestry scenario, 83 percent of land exempted from forestry is more than 100 years old at the end of the calculation period. That not all set-aside forest is over 100 years is due to storms.

Today's choice of regeneration methods and choice of tree species during regeneration leads to changes in the distribution of different forest types. Most notable is the increase in the proportion of spruce forests in Götaland, which increases from 30 per cent of all productive forest land to 40 per cent of all productive forest land, in the scenario Today's forestry (Figure 3.14).

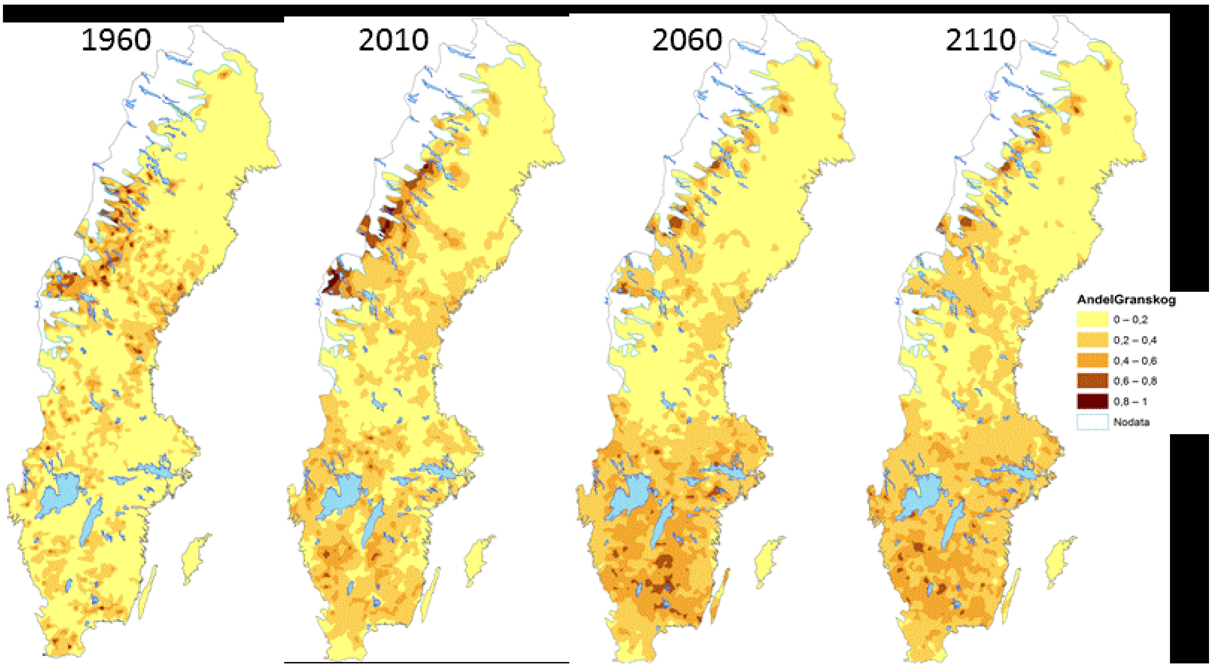

Figure 3.14. Percentage of spruce forests for the years 1960, 2010, 2060 and 2110. The map for the year 1960 is based on data from the National Forest Assessment, averages for the years 1958-1962. The maps for the years 2010, 2060 and 2110 are based on the scenario Today’s Forestry.

The area of old forest is increasing in all scenarios, the increase is moderate in the scenarios Today's forestry, 90 percent harvest and 110 percent harvest. From 8 percent to 12-15 percent of all productive forest land, depending on the scenario. In the Double nature conservation scenario, however, the proportion of old forest increases more markedly, from 8 to 25 percent. The increase takes place exclusively in forests on set-aside forest land.

The area of mature forest rich in broadleaves also increases in all scenarios, from 9 percent to 12-14 percent of all productive forest land. The scenario of double nature conservation does not stand out in the same way as for old forest. The area of mature forest rich in broadleaves is increasing in retention patches and within timber production land, while decreasing in reserves and voluntary set-asides. Most of the increase is in timber production land.

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3.4 Spatial considerations in forest planning

Sustainable forestry means taking into account both ecological, economic and social values. For many of the aspects behind these values, it is not enough to know that you do something in the landscape, you also need to know where in the landscape an action is performed and how the action affects the surrounding areas. Forest planning must therefore also include spatial considerations.

Forestry that strives to meet other goals, in addition to production of timber, such as the conservation of biodiversity, partly needs other planning approaches. In order to preserve biodiversity, it is not enough to know that you are doing something in the landscape, but you must also know where in the landscape you are doing something and consideration must be given to how the action affects areas around. A stand can thus not be managed as an individual unit but must be treated as part of a larger landscape. When planning of e.g. felling we needs to take into account both the geographical location, size and shape of the stand so that desirable spatial (spatial) patterns are obtained.

3.4.1 Why should spatial considerations be taken into account?

An example of an aspect that affects biodiversity and has a spatial dimension is fragmentation of older forest, i.e. the older forest is split up and replaced with young forest, see Figure 3.15. The fragmentation leads to that areas of mature forest becomes less aggregated (the scientific term is reduced connectivity), that the degree of isolation increases and that of each fragment size decreases. Species that are in need of larger areas of contiguous older forest, can therefore be adversely affected. In principle, there are two possible ways to deal with fragmentation and its effects, the first of which is to reduce the cutting rate. The second possibility is to plan the felling in terms of their geographical location and how they affect the condition of the surrounding stands. If you want to avoid fragmentation, you have to plan the logging so that the older forest does not split up over time but remains aggregated.

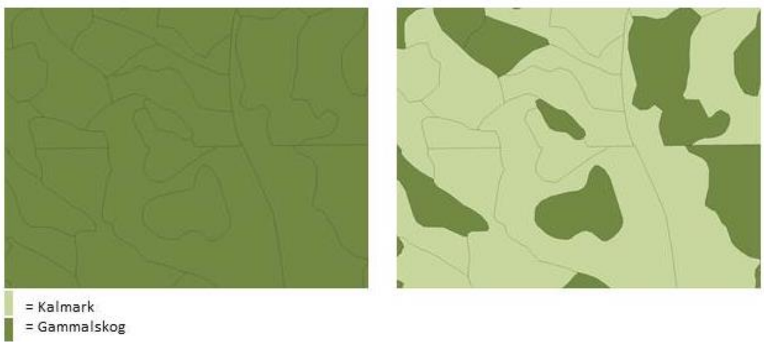

Figure 3.15 Example of how contiguous area of old forest shrinks and is fragmented by felling.

The example above, with old forest, can be further developed into a more general problem where one wants to ensure access to habitat for different species. Habitat models can show how suitable an area is for different species based on the specific requirements of the species. The likelihood that a species is present in an area increases with the amount of suitable habitat, the amount of suitable habitat can therefore serve as a biodiversity indicator. Habitat modelling has been used to illustrate how the amount and distribution of habitat changes over time with a certain forest management. In this way, bottlenecks in access to suitable habitat at the landscape level can be detected, thus avoiding situations that lead to different species not having continuous access to the necessary habitats. A wider range of data describing biotopes and their role as habitats, together with increased use of geographical information systems (GIS), have increased the possibilities to include habitat models in forest planning.

For some species, the amount of habitat can be studied at the stand level. In these cases, no special spatial consideration is needed, but it is sufficient to have knowledge of the state in the stand e.g. tree volume, stem number to determine if the department is a suitable habitat or not. However, for species that have area requirements that exceed the size of a typical forest stand, habitat modelling must be done at the landscape level. In these cases, it is not possible to determine whether a stand constitutes of suitable habitat by looking solely at the condition of the relevant stand, but one must also look at the condition of surrounding stands. This means that spatial consideration must be taken to ensure the availability of habitat for these species. An example of such a species is hazel grouse. For a stand to be classified as habitat, it must contain at least 25% spruce and 10% -40% deciduous trees and be at least 20 years old. In addition, there must be at least 20 hectares that meet these requirements within an area of 100 hectares (see Figure 3.16).

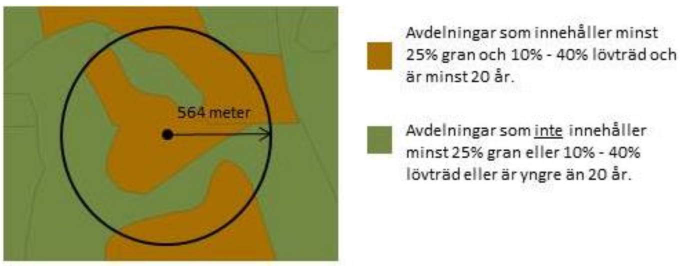

Figure 3.16. For a department to be classified as habitat, it must contain at least 25 % spruce and 10% -40% deciduous trees and be at least 20 years old. In addition, there must be at least 20 hectares that meet these requirements within an area of 100 hectares. An area of 100 hectares corresponds to a circle with a radius of 564 meters.

Another example that means that spatial considerations must be taken into account by planning the size, location and shape of the harvesting is if you want to limit the contiguous area of young forest. An example where this may be relevant is in the mountainous forest, as it is not legally allowed with contiguous areas of clear-felled areas of more than 20 hectares. The motives for this can be both aesthetic and ecological. Large clear-felled areas in the reindeer industry's winter grazing areas can, for example, lead to decreased possibilities for the reindeer to find food, and in addition, movements of the reindeer herd can be made more difficult. But even outside the mountainous forest nice there are reasons to reduce the contiguous areas of clear-felled forest. Among other things, large contiguous areas of clear-felled forest are considered negative from a recreation point of view, especially in urban areas.
A further example that may seem to be contrary to the above is if one wants to concentrate the clear felling into larger felling areas. The reason for this may be to reduce moving and road costs or to create larger contiguous areas of undisturbed forest in other parts of the landscape. Aggregation of units also becomes relevant in forestry where pixels of size 25 * 25 meters constitute the description unit because it is not realistic to let such small description units also constitute action units.

Facts: Reasons for spatial considerations

Spatial consideration means that you are not only interested in knowing the total amount of felling or habitat in the landscape, but you also need to know the shape and geographical location of the felling or habitat in the landscape and how they affect and are affected by surrounding areas. Examples of aspects that require spatial consideration in the forest planning process are limitation of old forest fragmentation, habitat modelling, limitation of large contiguous clear-felled areas and concentration of logging areas.

3.4.2 Spatial relationships

Common to all examples in the previous chapter is that it is not enough to know where actions are being performed. Consideration must also be given to how any felling or other measures affect the surrounding areas. Thus, spatial considerations must be taken into account because there are spatial relationships between stands. If there are spatial relationships between stands, this means that the outcome variable (that is, for example, timber volume or amount of suitable habitat) or choice of treatment schedules in a stand depends on the condition or choice of treatment schedule in the surrounding area. This can be compared to when there are no spatial relationships between stands. Then the outcome variable is independent of the condition and choice of treatment schedules in surrounding areas.

Let's take the example where the result variables are the core area consisting of old forest and harvest volume. Core area consisting of old forest can be defined as the part of an area (stand) that meets the old forest criteria and is not affected by effects from surrounding areas, see Figure 3 .17. The amount of core area consisting of old forest is a function of the stands size, shape and condition in the stand and in the surrounding stands. The amount of core area consisting of old forest, in an area at a given time is dependent on the selected management of the stand and the selected management in neighboring stands. Therefore, the proportion of core area in a stand cannot be calculated only with information about the stand itself but information is required also about its neighbours. Core area is a typical example of a variable that depends on spatial relationships between stands.

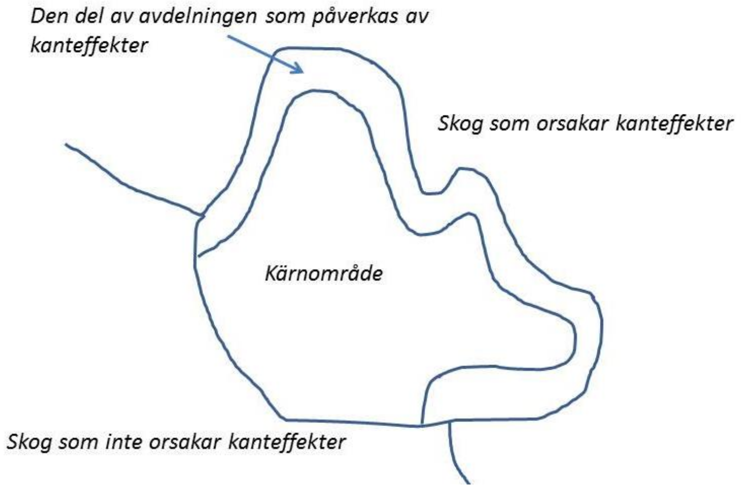

Figure 1 .17. Core area is the part of a stand that is not affected by surrounding areas.

The area of core area is therefore by its nature completely separate from, e.g. harvesting volume. The harvesting volume in a stand is independent of the management in surrounding stands. To describe how much volume can be cut in a stand, you just need to know how the current stand is managed. You do not need to know the condition or how much volume is being cut in surrounding stand. Harvest is therefore an example of a variable that is not affected by spatial relationships between stands.

Different variants of spatial relationships

Spatial relationships can be divided into whether they are primary or secondary depending on whether it is the actual projection of the forest state or the evaluation of the forest state that is affected by the spatial relationships. An important step in the forestry planning process is to develop treatment schedules that simulate the future development of the forest. In Heureka (and many other planning systems), projections are first generated by a number of different treatment schedules for each stand. For each treatment schedule, the outcome is then calculated in each planning period for a set of parameters, e.g. age, standing volume, and amount of dead wood. Thereafter, the optimal treatment schedule for each stand is selected based on given objectives and restrictions with the system's built-in optimization program. When done this way, it is assumed that spatial relationships between departments can be ignored in the projection of the individual treatment schedules and instead managed in the optimization. In other words, only secondary spatial relationships are handled. A secondary spatial relationship means that it is the evaluation of forest conditions and not the projection itself that depends on the choice of management in the surroundings. An example of a secondary spatial relationship is the amount of core area that depends on the state of the forest in a particular department and the state in surrounding departments. This can be compared to primary spatial relationships, which means that the projection of the condition for a particular stand is also dependent on the condition in the environment. An example of a primary spatial relationship is that the amount of deciduous plants that is established after harvesting depends on the amount of deciduous trees in surrounding areas.

Spatial relationships can also be divided into dynamic and static relationships. If there are dynamic relationships, the evaluation or condition in the departments changes over time, while static relationships are constant over time. An example that leads to a dynamic relationship is whether a stand should be classified as habitat or not. The amount of habitat depends on how the condition is in surrounding areas and will therefore change over time as the stand and surrounding stand change as the forest grows and is managed in different ways. While the distance from a stand to a watercourse is an example of a static spatial relationship since the distance to the watercourse is constant over time.

Facts: Spatial relationship

If there are spatial relationships between stands, this means that the outcome or choice of treatment schedule in a stand depends on the condition or choice of treatment schedule in surrounding departments. The spatial relationships can be divided into primary or secondary based on whether or not the actual forest state projection is affected by surrounding stands, and static or dynamic based on whether the impact is constant over time or not.

3.4.3 How can spatial considerations be included into the forest planning process?

Traditionally, spatial considerations are not handled in the strategic planning. Instead, the spatial location of harvest has been handled in tactical planning and / or in ecological landscape planning. Spatial aspects such as considerations to fragmentation have been addressed at the strategic level by introducing requirements in the planning model for a certain minimum area of old forest. It has not been taken into account that the size, shape and distance between areas of old forest determine how well they function as suitable habitat. However, by not taking spatial considerations at strategic level, there is a risk that, you will reach, for example, harvest levels that will be impossible to meet in tactical planning or that you overestimate the amount of available habitat.

In general, there are two ways of introducing spatial considerations into the forest planning process: 1) the exogenous or two-stage approach 2) the endogenous or integrated approach. These two approaches differ in how they handle the spatial aspects in the optimization process normally used to find solutions to the formulated planning problem (see Figure 3.18). The approach chosen to deal with spatial considerations in the forest planning therefore affects which optimization technique can be used.

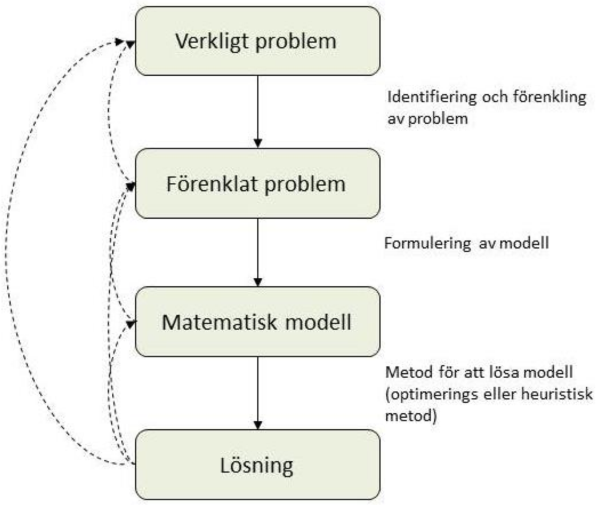

Figure 3.18. Schematic illustration of the optimization process. The dashed arrows mean that you have to take a step back in the process when the desired result was not obtained.

The exogenous approach

In the exogenous approach, no spatial information is handled in the optimization algorithm. Instead, the planning problem is solved in two steps. In step one, the spatial considerations are determined before the optimization by e.g. some areas are excluded from harvesting and set aside for free development or that the stands closest to a watercourse must not be final felled. This can be done in the Heureka by creating a zone (i.e. a domain) that includes the stands that should not be harvested. For that domain, only treatment schedules are generated without harvesting. Then, in step two, the rest of the planning problem is solved through traditional optimization.

If the exogenous approach is chosen, different variants of optimization methods can be used. For example, linear programming (LP), which is the method traditionally used to solve forest planning problems, can be used because no spatial information is handled in the optimization. LP assumes that all functions are linear and that the variables are continuous. This means that the decision variable (x_{ij}), can take any value between 0 and 1. This means that a stand in one period can be managed with different treatments and one cannot know where in the stand something is happening. It is therefore not possible to control spatial relationships in the optimization if we use LP.

The exogenous approach does not in principle take into account the dynamics over time, therefore it is suitable when you have static relationships. By allocating areas for free development "in the future", you meet the spatial requirements today, but no consideration is given to the development of the landscape over time. Another disadvantage with the exogenous approach is that limited consideration is given to how valuable e.g. the excluded areas are to other goals and restrictions. Perhaps other areas of equal value can be allocated for biodiversity, but where the consideration leads to a smaller loss in eg. economic terms.

The endogenous approach

In the endogenous approach, spatial considerations are integrated into the optimization, and the resulting spatial pattern is therefore a result of the optimization. To be able to handle spatial aspects in the optimization each decision unit, e.g. stand, must be managed as a separate unit, unlike non-spatial optimization where stands can in many cases be managed in groups (strata). Secondly, variables or restrictions that in some way describe the spatial relationships needs to be included in the optimization model. Thirdly, the entire stand must be managed with one and only one treatment schedule, since it is necessary to know exactly where in the landscape management are being carried out. Fourth, one must know the geographical location of the stand and what is happening in surrounding stands. These four mentioned aspects affect the methods that can be used to solve the planning problem. Examples of possible methods are different algorithms for integer programming or different heuristic methods. Among the latter, simulated annealing, tabu search and gentic algorithms have often been used to find solutions to spatial problems.

Although the endogenous approach can give rise to complicated optimization problems, the endogenous approach offers the opportunity to evaluate a very large number of management alternatives. This increases the possibilities, to both investigate the consequences of many spatial alternatives and to find the most cost-effective solutions. The endogenous approach is suitable to use when the spatial structure of the landscape is not constant over time, ie when we have dynamic spatial relationships.

How does the optimization in the endogenous approach change?

A traditional forest strategic planning problem is to maximize the net present value of future management with the requirement that the harvesting volume may not vary too much from period to period and that a certain amount of old forest should be available in each period.

This can be described by the following mathematical model:

$$\text{Maximize} \quad Z_1 = \sum_{i=1}^{I} \sum_{j=1}^{J_i} D_{ij} x_{ij} \qquad (1)$$

Subject to:

$$(1-\alpha) \sum_{i=1}^{I} \sum_{j=1}^{J_i} V_{ijp} x_{ij} \leq \sum_{i=1}^{I} \sum_{j=1}^{J_i} V_{ij(p+1)} x_{ij} \qquad p = 1, \ldots, P-1 \qquad (2)$$

$$(1+\beta) \sum_{i=1}^{I} \sum_{j=1}^{J_i} V_{ijp} x_{ij} \geq \sum_{i=1}^{I} \sum_{j=1}^{J_i} V_{ij(p+1)} x_{ij} \qquad p = 1, \ldots, P-1 \qquad (3)$$

$$\sum_{j=1}^{J_i} G_{ijp} x_{ij} \geq \overline{G}_p \qquad p = 1, \ldots, P \qquad (4)$$

$$\sum_{j=1}^{J_i} x_{ij} = 1 \qquad i = 1..I \qquad (5)$$

$$x_{ij} \geq 0 \qquad i = 1...I,\ j = 1...J_i \qquad (6)$$

x_{ij} = decision variable, the percentage of stand*i which* is managed by the treatment schedule *j*
P = number of planning periods
I = number of stands
J_i = number of treatment schedules for stand *i*
D_{ij} = net present value for stand i and treatment schedule *j*
G_{ijp} = hectares of old forest for stand *i* , treatment schedule *j* in period *p*
V_{ijp} = harvested volume for department *i,* treatment schedule *j* in period *p*
$\overline{G}_p$ = hectares of old forest required in period *p*
α = the highest accepted decrease in harvested volume between two periods
β = the highest accepted increase in harvested volume between two periods

Equation 1 is the objective function and expresses the total net present value from future management. Equations 2 and 3 mean that the harvested volume does not vary too much from period to period. Equation 4 specifies the demand for old forest in each period. Equation 5 expresses that a department must be assigned at least one treatment schedule. Finally, in Equation 6, it is specified that the decision variables cannot be assigned negative values.

The model (Equations 1 - 6) contains no spatial considerations. The management that is selected in a stand has no effect on the condition of the surrounding stands. The result does not depend on the spatial structure or the geographical location of the stands. If one wishes to take spatial consideration and use the endogenous approach, the model must be changed in at least two ways.

First, many forest planning problems have traditionally been formulated with continuous variables, i.e. the decision variable x_{ij} can take any value between 0 and 1. This has been possible since the main focus has been on the total volume of timber that are harvested during the planning period. If continuous variables are used, parts of the stand can be managed with a certain treatment schedule and other parts with another schedule. This means that you do not know where in the stand the management is done and it is not possible to control the spatial relationships. If you should be sure where all actions are done, one cannot have a continuous decision variable, therefore restriction number 6 must be reformulated to express an integer restriction (a stand can then only be assigned to one treatment schedule):

$$x_{ij} \in \{0,1\} \qquad i = 1...I,\ j = 1...J_i \qquad (7)$$

The second change in the model is that variables or restrictions must be added, which in some way express the spatial relationships. Many spatial relationships can be expressed by using so-called decision restrictions. An example of problems where they are often used is to limit the contiguous clear-cut area. This problem can be addressed with two different approaches. In the first approach, which is usually called the unit restriction model (URM), two adjacent stands, regardless of the size of the stand, are prevented from being felled during the same period. This can be accomplished by introducing an additional restriction in the above model, for example:

$$\sum_{j=1}^{J_i} H_{ijp} x_{ij} + \sum_{j=1}^{J_l} H_{ljp} x_{lj} \leq 1 \quad \forall il \in Y, p = 1..P \qquad (8)$$

Y = The set of stands that are neighbours
H_p = This parameter indicates if a treatment schedule for a particular stand and a certain period means final harvesting, ie H_{ijp} takes the value 1 if the treatment schedule j for stand i and period p means final harvest and 0 otherwise.

This approach is based on the assumption that the size of each individual stand is below the largest permissible contiguous clear-felled area. Another approach, usually called the ARM (area restriction model), is based on allowing contiguous stands to be felled during the same period as long as the contiguous clearfelled area does not exceed the maximum allowed clear felled area:

$$f_{ip}(X) \leq S \qquad \forall i, p = 1..P \qquad (9)$$

S = The largest permissible contiguous clear-felled area

$f_{ip}(X)$ = A recursive function that summarizes all contiguous stands with final felling in one period.

However, with this approach, stands larger than S will never be cut.

Another way of dealing with spatial relationships in the endogenous approach is to link the spatial variable to the decision variables by using so-called indicator variables. A new variable is included which is linked to the other decision variables and thus indicates whether a certain condition is achieved or if a stand meets certain conditions. An example is that a stand may only be counted as suitable habitat for a period if the stand and all surrounding stands are managed with treatment schedule that give rise to e.g. old forest in the current period. This can be achieved by adding the restrictions below:

$$R_{ip} \leq \sum_{j \in M_{ljp}} x_{lj} \qquad \forall p, \forall l \in N^i \qquad (10)$$

$$R_{ip} \in \{0,1\} \qquad i = 1..I \qquad (11)$$

$$\sum_{i}^{I} R_{ip} A_i \geq \overline{A}_p \qquad \forall p \qquad (12)$$

N^i = The set of stands consisting of stand *i* and all of its neighbours.
M_{ljp} = The set of treatment schedule that for stand *i* cause old forest in period *p*.

R_{ip} = The variable that indicates whether stand *i* consists of suitable habitat in period *p* (old forest). R_{ip} can only assume the value 1 if the stand and all its neighbours are managed with treatment schedules that give rise to old forest. In other cases, R_{ip} assumes a value of 0.
A_i = Area of stand *i* .

$\bar{A}_p$ = The area of habitat required in period *p*.

Self-Study Questions.

1. Describe what spatial considerations mean?

2. Name some reasons why spatial considerations should be taken into account?

3. Describe how the traditional forest planning problem changes when, instead of only taking into account the amount of old forest, one also wants to take into account the spatial location of the old forest in the landscape?

Literature

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4 TECHNOLOGY AREAS

A long-term forest planning problem usually consists in finding for each stand the best action options based on the objective one for the entire forest holding.
An action option for a stand consists of a sequence of treatments - forest management and harvesting - during the stand's turnaround time.
Linear programming is an optimization method that is often used to search for the best course of action for all stands within a forest holding given the objective.
An optimization problem to be solved with linear programming consists of a target function and a number of restrictions.

4.1 Linear programming

4.1.1 Long-term planning and linear programming

Planning in forestry is a little special because it has such a long time horizon. Up to 100 years is not unusual. It's not that everyone who engages in forest planning does so with such a long time horizon; there is also planning around tactical and operational problems where the planning horizon is considerably shorter. Other kinds of planning that also have a long time horizon are e.g. urban planning, infrastructure projects and construction of large industries. All of these require decisions that extend far into the future. This planning is usually done in project form; you plan once and then it's done. The forestry long-term planning is different. The same questions are asked over and over: What should we do with our forest resource, taking into account the long-term effects of what we do today? The fact that forest planners revisit a similar problem time and time again makes it both urgent and cost-effective to have a methodology for modelling the problem. That's what this compendium is all about.

The contexts in which long-term planning can be found may vary considerably. The most typical situation is probably when a forest owner, big or small, wants to analyze their holdings and find the management which leads to the highest utilisation of the forest resource. Sometimes the management problem can occur in a context where you, as a forest owner, have to take into account different interests, e.g. where recreational areas or sensitive natural environments are located. It can be important to develop a number of planning proposals that may be assessed on the basis of the interests that are represented. This issue arises from time to time in our parliament. Here it is the political position that determines how you want the forest to develop in the long term. The models presented here will in principle be applicable in any of these contexts; the decisive factor is that they require suggestions on maintenance methods that satisfy one or more objectives. We cannot claim that the approach we formulate here is the best in all situations.

Facts: Something about terminology
What is dealt with in this compendium is sometimes called strategic planning. Although some people involved with planning would call it strategic planning, the term long-term planning is used here. Long-term forest planning can mean both strategic and operational planning. In the former case, the aim of the planning is to lead to management goals for the company's own forests. Planning results can be regarded as a series of strategic decisions regarding levels of set-aside forests, forest management programs, etc. In the latter case, i.e. if planning has a more operational nature, it is about making a suitable stand selection within the framework of

an overall strategic plan. The result can, for example, be a set of stands selected for harvest which in turn may form the framework for following, more short-term planning.

The model we will build (or formulate) here to find a solution to the management problem uses the most common and most established optimization method in decision theory - linear programming (LP). It has been used since the second half of the 1960s, i.e. as long as it has been possible for non-IT specialists to use a computer. Three things contributed to the adoption of this model to formulate and solve long-term planning problems, and to retain its popularity: 1) it can be combined with virtually any type of model that describes the individual stand's development during different treatments 2) the model can handle big problems and 3) there are ready-made solutions.

The model was well documented by Johnson & Scheurman (1977) in two different forms, called Model I and Model II. We will focus on Model I partly because it is simpler and partly because it is the most used in forest decision support systems, e.g. in Heureka / PlanWise.

To make a long-term analysis according to this recipe you need:

- A description of the forest treatment units
- A stand simulator that can describe the development of individual stands during different treatments
- A description (formulation) of the LP problem
- A solver that solves the LP problem
- A report generator that describes the solution

We will now go through the analysis for a long-term planning problem for a small, simulated forest holding.

4.1.2 The planning problem

Assume a forest company having a forest holding comprising 8 stands. Company management requires harvesting of at least 1,000 m3 per 10-year period over the next 40 years. At the same time, the harvesting must be carried out in such a way that the standing stock is as large as possible at the end of the planning horizon, in order to guarantee, as far as possible, development in the very long term. (This wording facilitates the formulation because we must only handle volumes and not calculate, for example, financial values.)

In this example, we use 10-year planning periods because we have a growth model with 10-year projections. In order to simplify the handling of figures, and to be able to more easily follow the calculation process, we let the measures take place at the beginning of the planning period (see the box "When do the calculations start when formulating a model I?" below). This means that the planning problem can be formulated as follows in terms of 10-year planning periods:

- Harvest at least 10,000 m3 during each of 4 periods.
- Maximize the standing stock at the beginning of the 5th planning period, i.e. the volume that is standing in the forest after projecting 10 years after the measures at the beginning of the 4th 10-year period.

Facts: When do the calculations start when formulating a model 1?
Usually planning periods comprise 5- or 10-year periods rather than individual years. As a rule, it is the growth model's projection stage that determines the length of the period (for example, it is in Heureka). Another benefit when using longer periods is that the models are smaller and easier to solve. One consequence of working with multi-annual periods is that one has to decide when actions are taken during the planning period; in the beginning, at the end or somewhere in between? It is common to set the action date to the middle of the planning period. Doing so gives a fairly reasonable representation of what happens if activity is spread over the entire period, which is realistic. Suppose you want to get a certain harvested volume for a certain period. If the volume at the beginning of the period is used, we will disregard the fact that the stands on average have a higher volume during the period (and vice versa if you use the end of the period as the decision date). One disadvantage of using the period mid is that growth must be interpolated for the first planning period, i.e. the state of the stands must be adjusted down before starting to make calculations for the model (interpolation is therefore not necessary if using the beginning or end of the period since the growth model is already in sync with the treatment model).

Classification Register

Most forest owners are equipped with a stand register. For the smaller individual forest owner, this register is often referred to as a forest management plan. The register for our company can be found below (Table 4.1).

Table 4. 1. Inventory register

Holding Record				
Stock (No.)	Area (ha)	Growth	Age (years)	Volume (m3 / ha)
1	30	Low	0	0
2	10	Low	10	20
3	40	Low	30	80
4	20	Low	50	150
5	10	High	0	0
6	10	High	10	40
7	15	High	30	120
8	25	High	50	200

Growth model and stand simulator

A forest consists of a set of stands (departments, calculating units and strata are other terms used in the context; see box "Something about the calculation unit in Model I"). Therefore, we need to be able to generate data on what happens when we manage the stands in different ways. The single most important part of a long-term analysis is undoubtedly the part that describes the forest's dynamics. This is the engine in the stand simulator used to analyse forest management.

The growth model below is very simple and is based only on the stock's quality class and age (Table 4.2).

Table 4. 2. Growth model

Year (≤)	Growth (m3 / 10 years)	
	Low	High
9	20	40
19	50	80
29	45	75
39	40	70
49	35	65
51	30	60

Usually, the growth model is included as part of a larger stand projection apparatus. There are also models for describing costs and revenues, sometimes models for describing individual phenomena, such as carbon stock. The growth model is enough for the sake of our example, since the planning problem only requires data on volumes. The simple growth model can show harvesting volumes given harvesting at different times.

4.1.3 LP Models

We will now develop an LP model that represent the company's planning problems. The principle of the LP model is simple and is based on something called a treatment program. For each stand, a set of treatment programs are developed. The optimal combination of maintenance programs is the solution of the problem.

Facts: Something about the calculation unit in model 1
Here are some brief facts on the basic calculation unit used in Model I. The box explains, among other things, why the unit we use to describe the holding is not referred to as a stand but a treatment unit (sometimes a calculation unit).
A forest holding is generally described in terms of stands or compartments. It is not uncommon for stands or compartments to be the computational unit used to create data for a Model I. However, there are (at least) two reasons why sometimes other, aggregated, calculation units are used as the starting point for calculations. One reason is that if the holding is large then the model will also be large. It is then possible to aggregate data, ie. let a smaller number of “type stands” represent the entire holding. This is what is known as strata. For example, a stratum may consist of all stands that are 80-100 years old, tree mix spruce> 70%, SI 22-25 etc. The properties of this stratum can e.g. be the average of the included stands, or by a "typical stand". The area of the stratum corresponds to the total area of the included stands.

Another reason for using strata is that the stand register data is not reliable. Instead, a sample of stands is carefully sampled, and these stands represent the entire holding. Assume that the total holding is 300,000 ha and that 150 samples are sampled (which is very much realistic). Each calculation unit will then receive an area of 2,000 ha (there are more efficient ways of sampling but that will not be discussed here). This is referred to as sample stands, even though their function is exactly the same as the strata described above.

Both of these solutions, i.e. to represent the entire holding with either a limited number of sample departments or strata has an important consequence. It means that we do not know where different treatments are planned to take place. Suppose, for example, you do not want harvest to occur closer than 200 m to buildings. If a stratum contains stands of that type (or a sample stand represents stands that exist there), there is a risk that the model will create a solution where harvest occur near buildings. A solution can be to divide the strata by whether it is close to buildings or not. Here, the model is becoming complicated, especially if several requirements of this type are to be introduced. It gets even worse if there are requirements that are linked to what happens in the landscape as a function of where action is taken. A typical example of this is habitat. We do not know from the beginning where habitat can be optimally established. This would require wall-to-wall data (as opposed to strata) of the holding where it is possible to calculate locally whether there is a habitat or not. If we want to be able to deal with aspects that have to do with where actions are taken, we are in most cases in need of a complete stand register. (More on this can be studied in the section on spatial problems in this compendium).

What is a treatment program? A treatment program is a sequence of actions, e.g. planting, thinning and final felling, for a treatment unit from the current time to the end of the planning period. In our example, this is the result of treatments in each stand during the 40 years of the planning horizon.

To create our Model I, we begin by generating a series of forecasts for each treatment unit under different treatment programs. For each option, the data needed for the LP model is registered. For our model, we only need to log harvest volumes during period 1-4 and incoming volume period 5. In the example, the only active measure is final felling that is immediately accompanied by regeneration. Furthermore, assume that the forest must have an age of at least 30 years in order to be harvested. Stand 1 then has two possible treatment programs with final felling period 4 and no harvest at all. This gives the following harvest volumes and input volume period 5 per hectare: (0, 0, 0.115, 20) and (0, 0, 0, 0.155) respectively (Table 4.3).

Table 4.3 Calculation of 2 treatment programs for stand 1

		Age (years)		Standing volume (m3 / ha)		
Period	Treatment	Period start	Period end	Period start	After growth	Harvested volume
		Treatment program 1				
1	-	0	10	0	20	0
2	-	10	20	20	70	0
3	-	20	30	70	115	0
4	Final felling	30	10	115	20	115
5		10	20	20	70	-
		Treatment program 2				
1	-	0	10	0	20	0
2	-	10	20	20	70	0
3	-	20	30	70	115	0
4	-	30	40	115	155	0
5		40	50	155	190	-

Table 4.4 show two of the possible treatment programs for stand 8. The figures are corresponding to those for stand 1, with a treatment program with final felling period 1 and period 4 (200, 0, 0, 195, 40) and with a treatment programs with final felling period 2 (0, 260, 0, 0, 195). Note that it is possible to specify multiple activities in the same program (e.g. 2 final fellings as in program 1 for stand 8).

Table 4.4. Calculation of 2 treatment programs for stand 8

		Age (years)		Standing volume (m3 / ha)		
Period	Treatment	Period start	Period end	Period start	After growth	Harvested volume
		Treatment program 1				
1	Final felling	50	10	200	40	200
2	-	10	20	40	120	0
3	-	20	30	120	195	0
4	Final felling	30	10	195	40	195
5		10	20	40	120	-
		Treatment program 2				
1	-	50	60	200	260	0
2	Final felling	60	10	260	40	260
3	-	10	20	40	120	0
4	-	20	30	120	195	0
5		30	40	195	265	-

Note that the treatment programs extend over the entire planning horizon. A solution to the planning problem entails assigning a treatment program to each stand. This means that when 1 hectare of a stand is assigned a program, it has been decided what will happen to that hectare over the entire planning horizon (see Box Whole or divided stands? About dividing stands). For example, if you assign stand 8 2 ha of treatment program 1 we can harvest 400 m3 period 1 and 390 m3 period 4 and have a standing volume of these 2 ha of 80 m3 after growth in period 4 (this applies to these 2 ha; the remaining 23 ha in stock 8 must also be assigned treatment programs).

Suppose we have generated several treatment programs for each of the stands in the holding. This can include all allowed treatment programs or just the ones we think are the most interesting. In order to maximize the timber supply at the beginning of period 5 and at the same time be able to harvest 10,000 m3 per 10-year period, we need to find how many hectares of each stand is to be assigned each treatment program. We now use the LP model to find which treatment programs we will use on the different stands.

Facts: Whole or divided stands?

A question that must be considered in this context is: Can a stand be assigned to only one treatment program or can it be assigned to several? In the former case, the stand is a cohesive unit. In the latter case, one opens up the possibility of a stand being split. Suppose, for example, that stock 8, which has 25 ha, is allocated 10 ha by program 1 and 15 ha by program 2. This means that 10 ha will be harvested in the first period and 15 ha will be left standing. It is something of a logical change of mind if you consider that a treatment unit is just a unit for

treatment during a treatment program. However, there are reasons in the analysis to allow stands to be divided.
One reason is that the model can be much more difficult to solve if you require that one and only one treatment program can be assigned to each stand. The mathematical problem then turns from a nice, continuous optimization problem to a difficult combinatorial problem.
The consequences of allowing stands to be divided are different depending on whether the holding is large or small. If the holding is large, very few stands will still be split in the solution (this is a mathematical necessity in all reasonable problem formulations). In addition, if the holdings of type stands (strata) are represented, there is already no direct connection to individual stands at the starting position (see Box Something about the calculation unit in Model I).
If the holding is small, each stand will normally be included in the model, and a not negligible number of stands may be split. The optimization problem can be difficult if you require integer solutions, even if the holding is small. There is a considerable risk that a solution will not be found at all because each stand is large compared to the size of the requirements you set for an allowed solution.
When dealing with spatial problems one may still have assign one and only one treatment program to each stand. For example, if we require that two stands next to each other may not be harvested at the same time, we cannot have a share of one stand assigned to one treatment program and another share assigned to another; the solution must be unambiguous in that regard (more on this in Chapter 3.5 on spatial problems).

It is the treatment programs that are the model's variables. Let X11 be the first treatment program for stand 1. X11 is the unknown area of stand 1 that we manage with program 1. Similarly, we can denote the unknown area of stand 1 that we manage with treatment program 2 with X12 and so on for all other stands and treatment programs. A model I formulation of the company's planning problems will then look like this (note that only coefficients different from 0 are included and that only the maintenance programs developed above are printed; Figure 4.1):

Max	20	*X11 +	155	*X12 +	…	40	*X81 +	195	*X82 +	…	
Avv per 1					…	200	*X81 +			…	≥ 10000
Avv per 2					…			260	*X82 +	…	≥ 10000
Avv per 3					…					…	≥ 10000
Avv per 4	115	*X11 +			…	195	*X81 +			…	≥ 10000
Areal best 1	1	*X11 +	1	*X12 +	…					…	= 30
Areal best 2					…					…	= 10
Areal best 3					…					…	= 40
Areal best 4					…					…	= 20
Areal best 5					…					…	= 10
Areal best 6					…					…	= 10
Areal best 7					…					…	= 15
Areal best 8					…	1	*X81 +	1	*X82 +	…	= 25

Figure 4.1. A representation of the problem of 8 stands with a selection of the treatment programs represented.

Let's go through the lines of the model. The first line is the object function which corresponds to the standing volume at the beginning of period 5. For stand 1, assume (completely arbitrarily) that the solution specifies that 10 hectares should be allocated by treatment program 1 and 20 ha to program 2. The contribution from the first program is then 20 m3 / ha * 10 = 200 m3 and 155 * 20 = 3100 m3, thus a total of 3300 m3. Of course, there is the contribution from other stands.

The following rows (Avg per 2 - 4) represent the harvested volumes for different periods. In the same way as for the object function, the sum of m3 / ha * amount of hectares assigned will be the harvested volume for the respective periods. For example, see Avv per 4. Assume that the solution states that X11 = 10 and X81 = 20. The contribution from these two treatment programs total 5050 m3 (115 * 10 + 195 * 20). Also, remember that assigning a treatment program decides what happens throughout the planning horizon. Assigning e.g. stand 8 1 ha of program 2 (X82 = 1), will give a contribution of 200 m3 in period 1 and 195 m3 period 4 (and 40 m3 standing volume at the beginning of period 5).

Above we assumed (quite arbitrarily) that the solution could mean allocating 10 ha of stand 1 to treatment program 1 and 20 ha of program 2. This corresponds exactly to the size of stand 1. How do we ensure that treatment programs are assigned to each stand corresponding to the size of the stand? This is done by introducing the area restrictions on the rows Area best 1 through Area best 8. If we look at the restriction Area best 1, we see that 1 * 10 + 1 * 20 = 30. Each program must therefore be linked to the area restriction that belongs to that stand, and the restriction shall correspond to the size of that stand.

The model is thus complete. The pattern in the model above generally applies to type I models. There is an object function, a set of restrictions that in some sense apply to requirements for the entire forest holding and a set of area restrictions.

Facts: Concerning treatment programs
Final felling is not usually the only treatment option of interest. However, other types of treatments, such as thinning and fertilizing, are easy to add to the model. Let's assume that we want a program # 3 for treatment unit 1 with thinning period 3 and final felling period 4. If we thin with 30 percent thinning grade, and thinning have no effect on growth, we get the following harvests and stock entering period 5: (0, 0, 21, 94, 20). We then put these coefficients into the model just like the other treatment programs. In principle, a treatment program can be built up by any treatments, the only requirement is that the treatments in some way affect the quantities the model consists of (volumes, costs, etc.).

4.1.4 Using Excel for Model I

There are various programs to solve Model I problems. If you use, for example, Lingo or Lindo or some other general program to formulate and solve your planning problem, all you need to do is enter the formulation as it looks above (some intervention may be needed to make it work). The problem can also be solved in Excel.

If you want to solve the problem in Excel, the first step is to build up the calculations you need. It’s probably easiest to construct the calculations as if you were to produce a solution yourself manually, i.e. you by assigning hectares of treatment programs to the stands yourself. In order to conduct an optimization, it is necessary to collect sums in individual cells and then set requirements for the values in those cells, i.e. put restrictions. The value of the object function also needs to be collected in a cell and set to be optimized. Once the model is created, you call the program that solves the problem, i.e. the add-in called the Problem Solver. You can find it under the Data menu (you may need to pick it up; see Options / add-ins). When you click on the Problem Solver, a window opens where you specify which cell to optimize, what the variables are etc. When it comes to restrictions, it may be good to know that there are a number of cells that have the same restriction, they can be handled in bundles by selecting them and put the same restriction on them (see for example $ B $ 4: $ G $ 4> = 0 below).

Below are examples of how the problem can be solved (Figure 4.2). The assumptions here are that (i) the holding consists of stands 3 and 8 only, (ii) there is a requirement for harvesting 900 m3 during each of the first two 10-year periods, and (iii) the standing volume at the beginning of the 3rd 10-year period should be maximized. (Note: the arrangement is presented with the optimal solution in cells B4: G4.) The instructions for Excel's solution are given in Figure 4.3.

	A	B	C	D	E	F	G	H	I
1	Bestånd	3	3	3	8	8	8		
2	Program	1	2	3	1	2	3		
3			-- Lösning --						
4	Allokerad areal	40.0	0.0	0.0	17.0	4.5	3.5		
5			-- Utfall per ha --						
6	Avv per 1	0	80	0	0	200	0		
7	Avv per 2	0	0	120	0	0	260		
8	St volym per 3	155	70	20	320	120	40		
9			-- Utfall av program som funk av lösning --					Summa	Krav
10	Avv per 1	0	0	0	0	900	0	900	900
11	Avv per 2	0	0	0	0	0	900	900	900
12	Allok areal best 3	40.0	0.0	0.0				40	40
13	Allok areal best 8				17.0	4.5	3.5	25	25
14	St volym per 3	6200	0	0	5452	540	138	12331	<== Objektf

Figure 4.2. An inventory in Excel of a maintenance problem with 2 stocks.

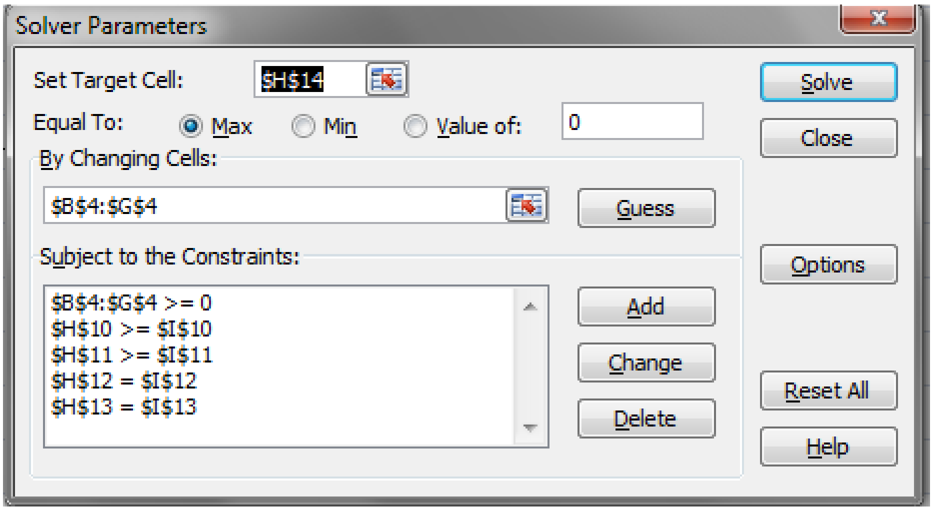

Figure 4.3. The settings for the optimization problem in Excel for the problem with 2 stands.

Some explanations:

- The cells whose values are searched (assignment of areas of treatment program) are the cells B4:G4. These must have values greater than or equal to 0 (the first restriction).
- The values in cells B10: G14 provide the contribution in the form of harvesting volumes and standing volume of different treatment programs. So, for example, the formula in cell B14 " = B $ 4 * B8 ".
- The values in cells H10: H14 provide the harvesting volumes in periods 1-2 as well as standing volume at the beginning of period 3.
- The values in cells I10: I13 can of course also be entered in the Solver Parameters panel directly. However, it may be more convenient to change the numbers in the sheet if you want to do sensitivity analysis.

4.1.5 Model II

If there is a Model I, there should be a Model II. Although the model I is more common and easier to handle, it may be justified to mention something about Model II.

In a Model I, we create treatment programs that span the entire planning horizon (see description of treatment programs above), ie. we make forecasts for the stands under different treatment programs that range from the current situation to the end of the planning horizon. When we create a Type II model, we do not need to forecast the development of the treatment unit beyond the time of final felling. In formulating such a model, we take advantage of the fact that the development of all forests established on the same type of bare land during a given period can be described by a separate set of variables. We therefore bring together all areas that are final felled during a given period and which are of the same bare land type, for example, have the same site index, and treat it without distinguishing from which treatment unit it comes. Successive forest generations are linked together in the LP model by a condition that the regenerated area should be as large as the final felled area for the current period and the land type. This means that you do not need to create treatment programs for each individual stand after final felling.

Model I and Model II are equivalent in the sense that a problem formulated as Model I can always be transformed into a Model II formulation and vice versa. The difference is mainly in the computational aspect. With a Model II, the number of variables can be reduced. This means that we can save calculation time in the LP program and, perhaps even more so, in the stand simulation program where we generate the activities. In Model I, there is a "multiplicative relationship" between successive forest generations. Let's say that for a certain treatment unit we have fixed the final felling period and that we have 5 kinds of treatments before final felling and 4 after. This gives 20 variables with Model I. A Model II requires no more than 9 variables to express the same thing. In addition, the 4 activities that express the development after final felling in the current period can be used jointly by several treatment units. The price that you get to pay for the reduced number of activities is an increased amount of restrictions, equalling the number of periods multiplied by the number of bare land types. Thus, the comparative advantage of Model II increases with increased length of the planning horizon, increased number of treatment programs (as per Model II definition), increased number of treatment units and reduced number of bare land types. Another feature of Model II is that the value of the dual variable equals the land expectation value (LEV). If you want this value in a Model I formulation, this must be calculated based on the activities that are included in the optimal base.

4.1.6 Maintenance program - ha or share of treatment unit

In the models formulated above, the number of hectares has been assigned to different treatment programs for each treatment unit. Heureka instead uses proportions of the total area of the treatment unit. It does not matter to the result; we get exactly the same assignment of treatment programs and thus the same net present values, harvest volumes, habitat etc.

How, then, does the numerical solution itself change? Suppose we have a stand of 10 ha. In a solution using hectares one treatment program is given 4 hectares, another 6 and the others 0 ha. This means that the solution in the model where we allocate shares of the area will receive the treatment programs 0.4, 0.6 and the other 0 shares of the 10 hectares.

When we allocate ha to treatment programs, we multiply coefficients per ha by the number of ha in the solution. A harvest volume of 150 m^3/ ha becomes 600 m^3 when we multiply by 4 ha. When we have shares of the entire treatment unit, the calculation must be based on the total. In the example of harvest volume, the coefficient becomes 1500 m 3 if we assume that the treatment unit is 10 ha. Multiply the 1500 m 3 by the treatment program’s share of 0.4 and we get 600 m3. The problem above for stands 3 and 8 then looks as follows (Figure 4.4)

	A	B	C	D	E	F	G	H	I
1	Bestånd	3	3	3	8	8	8		
2	Program	1	2	3	1	2	3		
3			-- Lösning --						
4	Allokerad andel	1.0	0.0	0.0	0.7	0.2	0.1		
5			-- Utfall totalt --						
6	Avv per 1	0	3200	0	0	5000	0		
7	Avv per 2	0	0	4800	0	0	6500		
8	St volym per 3	6200	2800	800	8000	3000	1000		
9		-- Utfall av program som funk av lösning --						Summa	Krav
10	Avv per 1	0	0	0	0	900	0	900	900
11	Avv per 2	0	0	0	0	0	900	900	900
12	Allok andel för best 3	1.0	0.0	0.0				1	1
13	Allok andel för best 8				0.7	0.2	0.1	1	1
14	St volym per 3	6200	0	0	5452	540	138	12331	<== Objektf

Figure 4.4. Presentation of the planning problem with 2 stands using variables as share of the stands.

Note how all coefficients for harvesting volumes and standing volume per ha in the previous arrangement are multiplied by the stand area (rows 6-8). Furthermore, the solution with respect to the treatment programs become numbers between 0 and 1 (B12: G13). A further difference is that the sum of all shares of a stand should sum to 1.

What, then, are the gains of using a formulation in which shares are allocated instead of hectares? One of the most important ones is that it becomes much easier to formulate and solve spatial problems (see the box Whole or divided stands? and the section on spatial problems in the compendium.) If we then have a stand of, say, 10 hectares we must for the treatment programs require that they assume the values 0 or 10 and nothing else in the case we allocate to have (the sum for allocated programs should still be 10). If shares are used, the variables must assume the values 0 or 1 and nothing else. It makes such problems both easier to formulate, manage and solve.

4.1.7 Calculation system

Finally, something about the system we must dispose of in order to do our analyzes (Fig. 4.5). In principle, all systems based on Model I are designed in this way. There are variations with regards to the connection between program parts, for example, if GIS is integrated with the system, if the solver is assembled automatically by the application or started separately etc.

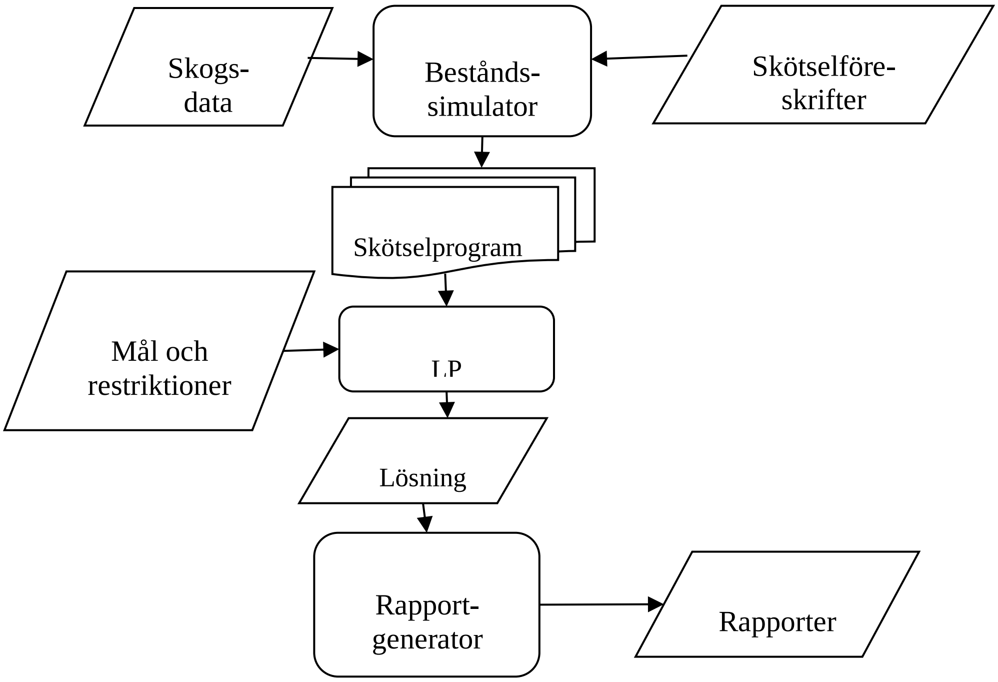

Figure 4.5. Elements in a calculation system for long-term planning

The analyzes are based on a description of forest holdings, comprised of treatment units. For these we generate forecasts in a stand simulation model. The core of this model consists of the growth models needed to be able to forecast forest development under different treatments. Depending on the problem we are analyzing, we may also need cost and yield models for various treatments, the carbon stock in the ground or the availability of biomass. It is generally necessary to have some automated process with which various treatment programs are formulated - even a patient person easily underestimates the number of relevant alternatives that may be considered. In order to exclude certain alternatives, for example only those that violate the Forestry Act or those we know that the growth models have a hard time making a reasonable forecast for, some management rules need to be introduced. Relevant data on each forecast (based on a treatment program), which corresponds to an activity in the model, is collected in a database of some kind. All data is sent to the solver in the format it requires, the problem is solved, and a report is created.

literature

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4.2 Problem with integers

If we have a problem where one or all of the decision variables need to assume integer values, an integer problem arises. These problems are more difficult than common linear programming problems and lack general and reliable solution methods.

A problem is an integer problem (MIP) if at least one of the input variables is defined as discrete variables. For example, they can be such that the variables can only assume integer values $x_j \in \{0,1,2,3,\ldots\}$or be binary $x_j \in \{0,1,2,3,\ldots\}$. If all input functions are linear, it is a linear integer problem. Compared to common linear programming problems (LPs) that can be solved with efficient algorithms without requiring too much data capacity (within reasonable limits as to the complexity of the problem) (see Chapter 4.1 for detailed description of LPs), integer problems leads to completely different requirements on solution methods.

4.2.1 Classic example The traveller problem

One of the most well-known integer problems is the traveller problem. It is easy to describe but quickly becomes complicated to solve. The problem is as follows:

A traveller should visit a certain number of cities. What is the shortest route where they visit all cities exactly once and then come back home again?

The problem can be formulated as a linear integer problem:

$$\text{minimera } z = \sum_{i=0}^{n} \sum_{j \neq i, j=1}^{n} c_{ij} x_{ij} \qquad (1)$$

$$0 \leq x_{ij} \leq 1 \qquad i,j = 1,\ldots,n \qquad (2)$$

$$u_i \in Z \qquad i = 1,\ldots,n \qquad (3)$$

$$\sum_{i=0, i \neq j}^{n} x_{ij} = 1 \qquad j = 1,\ldots,n \qquad (4)$$

$$\sum_{j=0, j \neq i}^{n} x_{ij} = 1 \qquad i = 1,\ldots,n \qquad (5)$$

$$u_i - u_j + n x_{ij} \leq n - 1 \qquad 1 \leq i \neq j \leq n \qquad (6)$$

Where:

x_{ij} {
1, if the road from city *i* to city *j* is included in the tour,
i = 1,…, n, j = 1,…, n (n is the number of cities),
0 , otherwise.

u_i	A dummy variable for $i = 1, ..., n$ (which we use in the model to make sure that a continuous path is selected)
c_{ij}	the distance between city i and city j

The objective function (Equation 1) expresses the total distance we want to minimize. A path may only be selected once, which is regulated in Equation 2. Equation 3 specifies the dummy variable. Equations 4 and 5 regulate that the trip goes to and from each city exactly once. The sixth equation ensures that there is only one continuous tour that covers all cities (and not two or more tours that do not sit together).

The reason why this problem is often used as an example is mainly because many problems can be formulated as a traveller problem, which makes it an important type of integer problem. However, there is also an educational aspect, since it is a problem that is easy to describe, but difficult to solve.

4.2.2 Example road planning

An example of an integer problem in forest planning is when a road network construction and maintenance is to be planned, which has a large influence on when and where to manage the forest. To avoid unnecessary expenses, one should manage road and logging planning together (for further examples of integer problems in forest planning see chapter spatial planning). By concentrating activities during different years, and thus reducing the total road needs in each year, maintenance can be reduced and new constructions can be moved further into the future. The time aspect is also important when considering the cost of the capital tied up in the road network. Concentration also facilitates subsequent annual planning.

If we take an example where we want to plan decisions on road construction and felling. What we want to find out is during which sub-period different road sections are to be built and operating areas (the area from which wood is transported to the same section on the transport route) are driven.

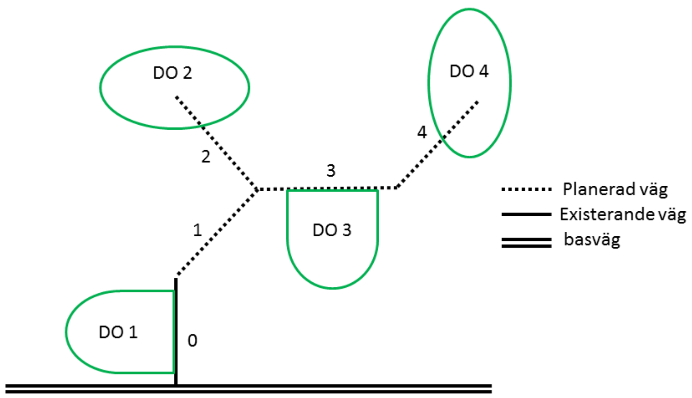

Figure x . Operating areas and road sections.

The model we use to describe the problem is one of many possible approaches to tackle the same problem. Of course, the definitions of different phenomena can be varied in many ways. What is of a more general nature is that the problem contains integer conditions linked to road developments. A road section must be expanded in its entirety or not at all. But the felling in a driving range is possible for several periods, and can thus be described with a continuous variable, which means that it becomes a mixed integer problem.

The model maximizes the total net present value of the activities. Let the margin for the operation of the driving range *j* during period *t* be denoted b_{tj} The margin is calculated as income minus the costs of harvesting and off-road transport, summed over the areas included in the operating area, discounted to the present. The proportion of operating area *j* driven during period *t* is denoted by the variable x_{tji}. Index *i* denotes the section of the road in which the operating area is served and is a dummy variable that has been introduced here only to more easily describe the model. The cost of building the road (discounted) for road sections *i* the period *t* is denoted by c_{it}. If section *i* is built in period *t* variable y_{bitch} is 1, otherwise 0. index *k* represents the road section that section *i* is connecting to, and therefore must be built before or simultaneously as section *i* built. This index has been introduced solely to facilitate the description of the model. All existing roads today have index 0. From this, it follows that variable $y_{100 \text{ is}}$ always 1 and the coefficient c_{10} is 0. If we have *T* sub-periods, *J* operating areas and *I* road sections the model can be described as follows:

$$\max z = \sum_{t=1}^{T} \left(\sum_{j=1}^{J} b_{tj} x_{tji} - \sum_{i=1}^{I} c_{ti} y_{tik} \right) \qquad (1)$$

$$x_{tji} \leq \sum_{p=1}^{t} y_{pik} \qquad \forall t, j \qquad (2)$$

$$y_{tik} \leq \sum_{p=1}^{t} y_{pkk\prime} \qquad \forall t, i \qquad (3)$$

$$L_{tl} \leq \sum_{j} a_{tjl} x_{tji} \leq U_{tl} \qquad \forall t, l \qquad (4)$$

$$\sum_{t} x_{tji} = 1 \qquad \forall t, l \qquad (5)$$

$$y = 0,1 \qquad (6)$$

$$x \geq 0 \qquad (7)$$

The first constraint (Equation 2) ensures that before a operating area can be felled, the road section that the area utilizes must be built. With this formulation of the condition, the road can be built the same period as the driving occurs. If we wanted the road to be completed the year before, instead of summing *p* from 1 to *t*, we must sum over *p* from 1 to *t* -1. If we build a section *i* during period *t* obviously the sections between the main road network and the current section must be built. This is run by Equation 3, where *k '* denotes the road section to which road *k* connects.

In addition to the road problem, a number of other problems must be considered when determining the timing of the driving. There may be requirements arising from the long-term planning for a certain maximum total volume in felling, a certain amounts of thinnings, etc. The industry's requirements for wood supply must also be taken into account. There are also requirements that have to do with efficient resource utilization, e.g., how much volume can be taken out per labour area and period, and the proportion of winter harvesting.

To take into account the minimum and maximum requirements regarding access or production of a resource *l* during period *t* in operating area *j*, we use *atj* . The minimum and maximum amount of this resource that is accepted during a certain period we define as L_{tl} and U_{tl} respectively, and this is regulated in Equation 4. Equation 5 ensures that the overall percentage of the area *j* that is driven during all periods is summed to 1.

Finally, we must define that the *y* variables only assume the values 1 or 0 (Equation 6) while the *x* variables are continuous (Equation 6 and 7).

4.2.3 Solutions of integer problems

Integer problems are much more difficult to solve than LP problems. This is despite the fact that integer problems have a finite number of solutions compared to LP problems, where the amount of possible solutions is infinite. Thus, in theory, one could calculate the target function value of all possible solutions to an integer problem and choose the best one. However, that option quickly becomes unrealistic. The difficulty of solving integer problems depends on the number of integer variables and the structure of the problem, but there is no easy way to define which structures make an integer problem easy or difficult, you have to test yourself. For this reason, there is also no general solution strategy for all integer problems (compared to, for example, the simplex method for LP problems), instead several different specific solution strategies have been developed adapted to different types of integer problems.

Enumeration methods

The simplest variant is to list all possible solutions, but as previously pointed out, this quickly becomes unrealistic. There are ways to get around the problem by excluding solution alternatives if you realize that they cannot lead to a better solution with different types of tests. This technique is called implicit enumeration. The most common class of solution modes that use implicit enumeration are tree search methods

Branch and bound

Branch and bound is a tree search method that is based on implicit enumeration where a decision tree is searched. The tree is based on the original problem where the integer terms are removed. Each branch in the tree corresponds to restrictions placed on any integer variable; this is called bounds, and aims to force the solution away from a non-integer solution. The branches in the tree run out of solutions that are integer with respect to all integer variables. The tree quickly becomes very large as the number of integer variables grows. Branch and bound is therefore based on implicit enumeration because the tree is searched in such a way that you do not have to count through all the branches.

For an example of how to solve an integer problem with branch and bound, we go back to our example with road planning, and assume that the roads and driving areas that we see in figure x are our entire problem. We assume that we have two time periods (T = 2) and that road construction costs and logging volumes can be taken from Table x, and in addition that the coverage premiums for driving is consistently 0, and that at least 1800 m^3 is cut per period.

Table x . Road construction costs and logging volumes .

Weigh the respective area numbers	**path cost**		**felling Volume**	
	Period 1	**Period 2**	**Period 1**	**Period 2**
1	100	90	1000	1000
2	140	126	1000	1000
3	100	90	800	800
4	20	18	1000	1000

The problem can then be formulated:

Max:

$$-100y_{110}-90y_{210}-140y_{121}-126y_{221}-100y_{131}-90y_{231}-20y_{143}-18y_{243}$$

When:

$$x_{122} \leq y_{121}$$
$$x_{222} \leq y_{121} + y_{221}$$
$$x_{133} \leq y_{131}$$
$$x_{233} \leq y_{131} + y_{231}$$
$$x_{144} \leq y_{143}$$
$$x_{244} \leq y_{143} + y_{243}$$
$$y_{121} \leq y_{110}$$
$$y_{221} \leq y_{110} + y_{210}$$
$$y_{131} \leq y_{110}$$
$$y_{231} \leq y_{110} + y_{210}$$
$$y_{143} \leq y_{131}$$
$$y_{243} \leq y_{131} + y_{231}$$

$$1000x_{110} + 1000x_{122} + 800x_{133} + 1000x_{144} \geq 1800$$
$$1000x_{210} + 1000x_{222} + 800x_{233} + 1000x_{244} \geq 1800$$
$$x_{110} + x_{210} = 1$$
$$x_{122} + x_{222} = 1$$
$$x_{133} + x_{233} = 1$$
$$x_{144} + x_{244} = 1$$
$$y = 0,1$$
$$x \geq 0$$

We start by solving the problem as a regular LP problem without integer terms. The object function value will then be -180 (follow solutions in the different steps in Table x2). With regard to the original problem, the solution is not allowed since the y variables are not integers. It can be natural for us to build our decision tree by examining the roads from the main road and out to the outer branches. We create a first branch where one branch corresponds to a requirement that road section 1 should be built in period 1 (y_{110}= 1) and the other that it should not be built in period 1 (y_{110}= 0) (see Figure x2 to follow the decision tree). We add the restrictions to the LP problem we solved in the first step and solve these two LP problems. The problem with y_{110}= 0 does not give rise to any permissible solution and therefore we can exclude all problems with this integer variable set to this value. We continue the scan from node 3. We put "bounds" on the variable that has to do with the extension of route 2 during period 1 and come to nodes 4 and 5. None of these solutions are integer. Since the problem in node 4 has the largest object function value, we can continue the search from there. If we can find an integer solution that is based on node 4 and which has a higher object function value than that in node 5, we do not need to investigate the solutions starting from node 5. The solutions based on node 5 can never have a higher value than the one in node 5 because we are gradually adding more and more "bounds" (and adding restrictions can never increase the value of a solution). At node 4 we try to build and not build road 3 and get nodes 6 and 7. Since the value in node 5 is higher than in node 7 we continue from node 5. We also investigate here to build and not build road 3 under period 1. Both solutions, in nodes 8 and 9, are lower than in node 7. We go back to node 7 and put "bounds" on the variable y_{143} as this is the only non-integer *y* variable in node 7. The solution in node 10 is integer for all y variables and is thus a possible solution to the original problem. In addition, the value is higher than in any other node. We can therefore conclude that the solution in node 11 is the optimal solution to the original problem. We have thus found an optimal solution without having to count all combinations of values for the integer variables.

Table x2. Solution with respect to γ variables.

No	**value**	**y variables**							
		110	**210**	**121**	**221**	**131**	**231**	**143**	**243**
1	-180	0.5	0	0.5	0	0.5	0	0.5	0
2	-	-	-	-	-	-	-	-	-
3	-230	1	0	0.5	0	0.5	0	0.5	0
4	-286	1	0	0	1	0.5	0	0.5	0
5	-300	1	0	1	0	0.5	0	0.5	0
6	-	-	-	-	-	-	-	-	-
7	-336	1	0	1	1	1	0	0.5	0
8	-348	1	0	0	0	0	1	0	1
9	-350	1	0	0	0	1	0	0.5	0
10	-344	1	0	1	1	1	0	0	1
11	-346	1	0	1	1	1	0	1	0

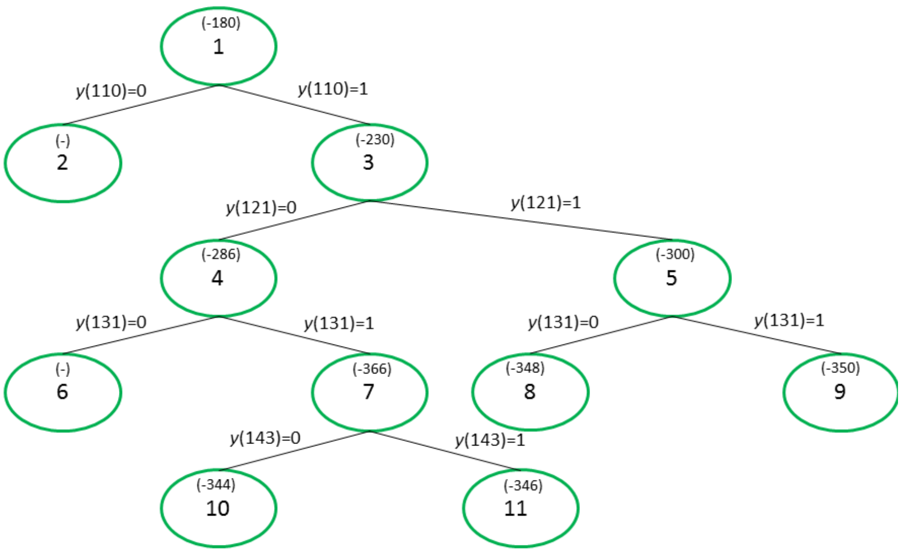

Figure x2: decision tree.

Branch and bound is not always the most effective technology. However, it has some educational advantages and can also be administered independently in cases where only one ordinary LP algorithm is available and has a problem with a limited number of integer variables.

Heurestiker

In many cases, integer problems become unrealistic to solve with classical optimization, so you have to rely on different types of heuristic solution methods instead. In a heuristic method, one usually starts with a more or less arbitrary solution to the defined planning problem. Then this solution changes iteratively in one way or another and the new solutions are evaluated by calculating the value of the target function. Eventually, the search process is interrupted and the best or most recently obtained solution is reported. The search process usually ends, for example, when no better solution is found within a certain number of iterations, when the latest solution is good enough, when some internal parameter in the method is reached, when the limit of the allowed CPU time has been reached or when all possible solutions have been tested. For a more detailed description of heuristic methods, see section 4.4.

literature

Lundgren, J, M Rönnqvist, and P Värbrand. *Optimization* . Lund, Sweden: Student Literature, 2010.

4.4 Heuristic methods

What do you do when you can't solve a problem with a classic optimization method? When the problem is so complex that it is not possible to formulate an optimization model that can be solved with e.g. integer programming based on "Branch and bound".

In the early 1980s, classic optimization methods such as linear programming (LP) increase in popularity in forest planning. A contributing reason for this was access to better and more efficient computers. But despite more powerful computers, they were still limited when solving planning problems linked to spatial considerations, e.g. minimizing transport costs and costs associated with road construction. Therefore, the complexity of these problems led to the use of heuristic methods (HM) as an alternative to LP and other exact optimization techniques.

4.4.1 What Are Heuristic Methods?

Strictly defined, an HM is not really an optimization method, although sometimes it is called that. Instead it is more similar to a structured search process or a “rule of thumb”. The reason why it cannot be defined as an optimization method is that with an HM you cannot guarantee that you will find the optimal solution to a specified optimization problem. However, in a heuristic method there is some form of method built in which improves the chances of finding a good solution.

Since most HMs differ considerably, it is difficult to give an accurate classification of different HMs, but the central component of most HM’s is to start with a more or less arbitrary solution to the planning problem. By solution here is meant that you have given specific values for all decision variables included in the problem. Then this solution changes iteratively in one way or another and the new solutions are evaluated by calculating the value of the objective function. Eventually, the search process is interrupted and the best or most recently obtained solution is reported. The search process usually ends, for example, when no better solution is found within a certain number of iterations, when the latest solution is good enough, when some internal parameter in the method is reached, when the limit of the allowed CPU time has been reached or when all possible solutions have been tested. However, the number of possible solutions is usually so large that this is almost never achieved.

Simulated Annealing

Today, there are a number of HMs available, such as "Tabu Search" and "Genetic Algorithms". In 1993, one of the simplest and most general HMs was also presented, which proved to be one of the most effective: "Simulated Annealing" (SA). The main idea in SA is that some decrease in the objective function in the evaluation of a new solution may be required to prevent optimization system from getting stuck in a local optima. Changes that improve the objective function 's value is always accepted, while changes that decrease the value of the objective function is only sometimes accepted, depending on the value of an acceptance function. At the beginning of the solution process, the acceptance function leads to the acceptance of almost all solutions, but gradually the probability of accepting solutions with lesser value on the objective function is reduced and in the end, worse solutions are not accepted at all and the process ends. The behaviour of the acceptance function is determined by the value of a control parameter which is often referred to as "temperature".

4.4.2 Why should Heuristic methods be used?

The reason for choosing a heuristic to solve a forest planning problem, i.e. finding the combination of treatment schedules that maximize (or minimize) the value of the target function, can be several. There are problems that cannot be formulated so that you can solve it with integer programming and a branch and bound algorithm (see the chapter on integer methods), then an HM is the only possible alternative for finding a solution. Another reason may be that the problem is so large that, although it would be theoretically possible to find the optimal solution through, for example, LP, it would take too long. Then it may instead be better to find an acceptable solution within a reasonable time. However, there are disadvantages to HM's. First, you do not know if you get the optimal solution. A major disadvantage is that how well the method works for a specific problem depends on the parameter values that need to be defined to find good solutions. These parameter values are difficult to know without proper tests, but these tests can often not be carried out in practical forestry planning due to lack of time and experience. Another disadvantage that makes the use of HM in practical forestry more difficult is the lack of decision support systems based on HM. Many forest decision support systems such as Heureka, are designed for problems that can be solved by an exact solution method.

Self-Study Questions.

4. What differentiates Heuristic methods from traditional optimization methods such as Linear Programming?

Literature

Reeves, C. 1993. Modern heuristic techniques for combinatorial problems. John Wiley & Sons, Inc. New York, NY, USA. ISBN: 0-470-22079-1

5. PLANNING SYSTEM

Decision-supporting systems are computer-based systems that have a number of components for communicating between the user and the system, for storing knowledge and for solving user-formulated problems.
The Heureky system is often called an analysis and planning system, but also has the components required to be referred to as a decision support system. The Heureka system consists of a number of software programs intended for different users and problem areas whereof three software deals with forest dynamics (StandWise, PlanWise and RegWise), and one software with multi-criteria analysis (PlanEval).

5.1 Decision support system - what is it?

Forest planning is one of the more demanding industries in terms of planning. It concerns a complicated ecosystem covering a large area that delivers different types of benefits to many different stakeholders, at the same time; an action can have major effects in the long term. Therefore, it is not surprising that much research and major investment has been devoted to developing programs to analyse problems and develop plans. One such system is the Heureka system that was developed in the beginning of the 21st century (Wikström et al. 2011).

A theoretical starting-point for what a planning situation requires of a computer-based decision support can be found in the literature on Decision Support Systems (DSS)[4]. DSS is one of the more unclear terms in the planning area. It is often used about virtually all software (and sometimes other things) that can in any way support, or even replace, a decision maker. The temptation to use the term in that way is of course great considering that the term is something of a fashion word. At the same time, the concept of DSS becomes virtually useless with such a broad meaning. Consequently, the term will hereafter be used in a narrower, and more scientific sense. Namely a software that meets certain requirements in terms of structure and usability.

5.2 The parts of a model based DSS

A DSS should enable a user to access data and models for analysing complex problems. A DSS has a certain structure. In a computer science context, a DSS is often defined as a model-based software system containing four components: (i) a system for giving instructions to the system (language system; LS), (ii) a presentation system (PS), (iii) a knowledge system (KS), and (iv) a system for linking the various components and process and process the problem (problem processing system; PPS) (Holsapple 2008). The relationship between them is illustrated in Figure 1.

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[4] In the future, the acronym DSS will be used instead of the term decision support system because it is such an established abbreviation in international literature.

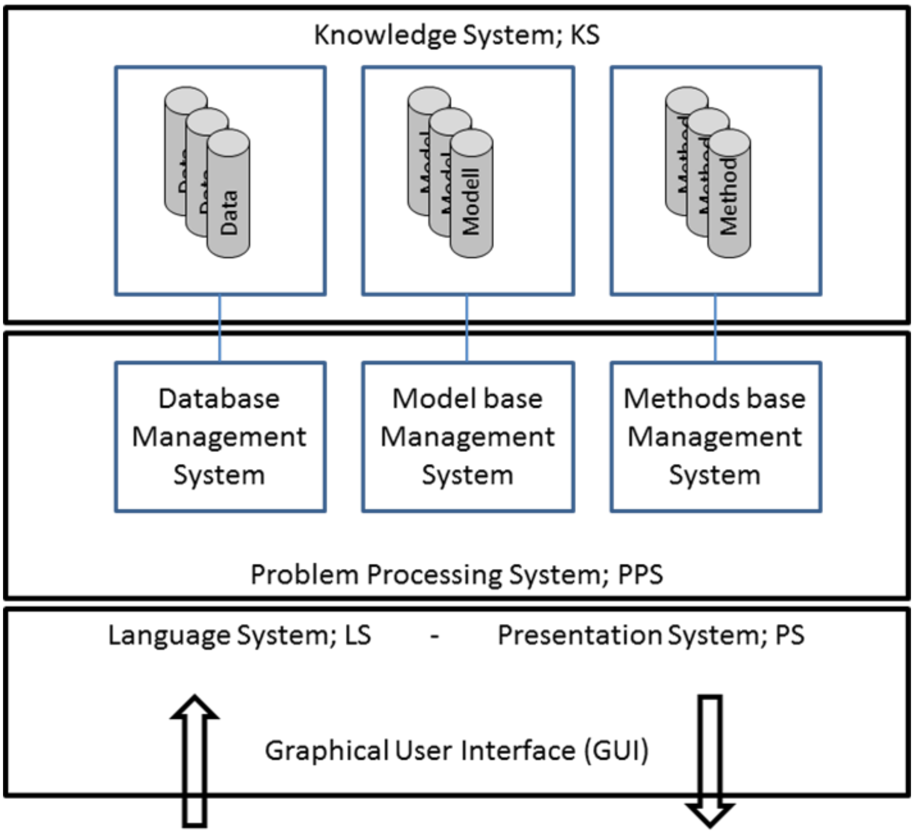

Figure 1. Schematic diagram of the main parts of a DSS (decision support system).

The first three systems are representative systems, where the "communicative" system (LS) consists of all messages to the DSS from the user, the presentation system (PS) of all messages from the DSS to the user and the knowledge system (KS) of all knowledge gathered in the form of data or models. Knowledge is used here as a very general term to describe a representation of something that the system can use to solve the task. The active, function of a DSS is the problem processing system (PPS).

The PPS's task is, simply put, to solve the problem specified by the user. To do this, the PPS need to be able to support the user: to introduce knowledge into the system (e.g. a new model, new parameters to describe the stands), to select relevant knowledge for the problem (e.g. select geographical area and associated stand data), to generate new knowledge (e.g. the consequences of certain demands) and to report the result (e.g. via tables and maps). In addition, the PPS has the task of coordinating and controlling these the more basic knowledge managing functions. There can be a database management system and a database management system integrated in a PPS.

There are different types of DSS. One taxonomy is based on what dominates in KS and the capabilities of the PPS. Here one can distinguish e.g. text-based, database-oriented, rule-controlled, spreadsheet-based, model-oriented and multi-objective-oriented systems. The two latter types are of special interest here. The problems encountered in forest planning often require that data on the state of the forest to be combined with complicated models for forest development and response to various measures. A DSS as support for forest planning is thus often focused on being able to support the analysis using more or less sophisticated simulation or optimization models. The multi-objective oriented systems provide methodological support to handle multi-criteria problems with e.g. outranking methods, analytical hierarchy process (AHP) or multiattribute utility theories (Olson 2008). Given that forest planning often need to weight different values against each other, multi-objective systems based on model-oriented DSS have particular relevance. One could use the model-oriented system's capacity to make forecasts, calculate impact and optimize with the multi-objective system's handling of various criteria.

Another dimension for distinguishing different DSS is whether one or more actors are involved. In the latter case, there is talk of multi-participant DSS, MDSS. MDSS place special demands on the PPS since it has to coordinate the activities of the different actors involved and being able to gather knowledge from different participants, integrate it in the KS and disseminate relevant parts of the content of KS back to the participants (Holsapple 2008). MDSS also includes systems that are designed for negotiation and are aimed at finding consensus among participants. A variant of MDSS is group DSS, GDSS. It refers to systems oriented towards enabling a team to work together. This is not about different stakeholders or a negotiation; rather, it is for a group of employees with a common task. (In terms of terminology, GDSS is seen as a variant alongside MDSS and also as a sub-type among MDSS).

The structure described for a DSS has an important implication: A DSS must have a domain[5]. This means that a DSS is intended to provide support within a specific area, a specific domain. The area we work with has to be limited to find suitable models and methods, and the capacity to handle the data. When it comes to long-term forest planning, there must be models for growth etc. and methods for analysing this type of problem. A GIS will likely be present to handle map material. However, a domain need not belong to a particular subject area. The domain of a DSS may, as mentioned above, e.g. refer to multilingual problems and should help the decision maker no matter what the problem is about. How wide or narrow a domain should be is hardly something that can be determined in general but has to do with the context in which DSS should work. a company is probably narrower in its domain than a system that can work within different companies. The question of the scope of the domain relates to another aspect, namely the flexibility of the system.

Obviously, linking a DSS to a domain means reducing the flexibility of the system in some sense. A spreadsheet like EXCEL is extremely flexible, but hardly a DSS. It is possible to build a DSS in EXCEL and utilize the functionality that EXCEL has, for example a PPS to integrate different models and methods. EXCEL works more like an empty sheet that a user has to fill with their own content. The other extreme consists of systems that are too bound, i.e. that do not allow the flexibility required to support a decision; the system is instead created to give one decision. Typical examples can be obtained from the logistics industry where e.g. the positions of the cars are given as well as the customers' delivery volume and delivery time, and the system delivers driving orders to the drivers. The airlines' scheduling system is of the same nature. Those examples can be called decision systems. Thus, a DSS must have a reasonable degree of flexibility to be effective in the sense of providing support for decisions. That flexibility, in turn, is related to what kind of decision situation a DSS works best in.

[5] The use of the word domain here should not be confused with the domain concept when classifying different types of forest in the Heureka PlanWise treatment programme generator.

Obviously, problems that are well known in terms of data, alternatives and what decision criteria that are to be used are such that you do not need a DSS for, but instead you can rely on a decision system. So, when does a DSS best fit? It may be a good idea to look at what a decision or planning situation contains to see what the consequences are for the design of a DSS. Decision situations can be structured in a variety of ways. Some dimensions that have proven fruitful for characterizing the role a DSS can play are derived from Simon (1957), who focus on the degree of structure, and Simon (1960), based on the different phases of decision making (see also Chapter 2 Basic Planning Concepts).

Simon (1957) distinguishes how well structured a decision problem is. He groups the situations into those that are unstructured, semi-structured and structured. In the unstructured cases, the problem itself, its underlying causes and possible actions, are unknown. The problem is unique and the primary goal is to try to diagnose what it is all about and create a structure. The structured problems are in many cases the ones that have been dealt with before, the data needs are known and methods for solving them are at hand. Between those are the semi-structured problems whose character is partly known but which are nevertheless unique in nature.

Simon (1960) proceeds on the steps that rational decision-making goes through. According to Simon, these are (i) analysis of the actual problem situation and structuring of it (intelligence), (ii) development and design of various possible solutions (design) and (iii) evaluation and choice among the alternatives (choice). The theory is often summarized by the acronym IDC. These phases have different weights in different types of problems. In a well-structured, operational problem, the emphasis may be on generating alternatives, while in an unstructured problem, the focus may be on problem structuring. The phases are of a general nature, i.e. they are not limited to any particular type of decision situation. This means that at a certain stage, e.g. design phase, a new decision problem arises, namely how the design phase should be designed. The decision problem can be structured in the same way, i.e. as an IDC. Simon (1977) talks about "wheels within wheels", i.e. any part of an IDC leads to a new IDC which in turn can update another IDC etc.

Gorry and Scott Morton (1989) proceeds from Simon's degrees of structuring and believe that a DSS best fulfils a function in semi-structured problems. Structured problems have greater benefits from transaction management, management information systems (MIS) and structured optimization systems, i.e. a decision system that is based on a given problem definition, given data, and given methods for developing alternatives and selecting among them. On the other hand, an unstructured problem requires methods for problem structuring. A DSS fits the semi-structured situation through the degree of flexibility the system allows, while certain data and structural elements can be predicted and included in the system's model- or database. However, Gorry and Scott Morton (1989) do not see any limitations for a DSS based on decision level in terms of strategic, tactical or operational planning.

At the same time, Keen and Scott Morton (1978) believe that a DSS is suitable for both semi-structured and unstructured problems. Decisions in an unstructured problem situation can be facilitated by gathering data and information, synthesizing methods, gathering and analysing brainstorming output, helping out by giving different perspectives on a phenomenon and otherwise stimulating the decision maker's creativity. The same applies to semi-structured problems where, in addition, pre-programmed procedures can be used.

Gorry and Scott Morton (1989) also argue that there is a natural link between a DSS and the phases of decision-making in terms of IDC. A DSS provides limited support for problem structuring in the intelligence phase. A DSS hardly has the flexibility required for this; here there are better methods such as executive support systems and problem structuring methods. On the other hand, a DSS is well suited for developing alternatives and evaluating their consequences as a basis for decisions through the data and models that a DSS contains.

It seems that a DSS is primarily intended to support decision making in the design and choice phases. It also seems that the DSS concept has comparative advantages over other concepts, e.g. expert system[6], in the case of semi-structured problems. If the problem is of a strategic, tactical or operational nature does not seem to be of decisive importance. Rather, it is the properties we associate with different types of planning processes (see Chapter 3, Applied Planning Areas).

5.3 What a forestry DSS can do - problem dimensions

To be able to characterize the capacity of a model-based forest DSS, it facilitates if you have a terminology for a DSS characteristics. Within the framework of the COST project FORSYS, a description of various dimensions was developed, and based on this different planning problem can be classified (Borges et al. 2014, www.forestdss.org). The description of the dimensions is the basis for a list of properties (Table 5.1) used here to describe a DSS.

There are, of course, different ways to characterize a planning problem. The dimensions should be partly all- encompassing, i.e. include all forest DSS of interest regardless of regional context or category of forest owner / manager, and understandable i.e. easy to identify from terms that are well established in the literature to describe planning situations for which a DSS can be used. A consequence of these principles is that the dimensions can be experienced as abstract (e.g. they are not defined in terms of the species they can handle or purpose e.g. storm sensitivity, biodiversity or promoting social values). Another motivation for this level of abstraction is the potential flexibility of a DSS.

[6] From Expert system on Wikipedia: "In artificial intelligence, an expert system is a computer system that emulates the decision-making ability of a human expert. [1] Expert systems are designed to solve complex problems by reasoning about knowledge, represented mainly as if – then rules rather than by conventional procedural code. ” Https://en.wikipedia.org/wiki/Expert_system [2016-12-14]

Table 1. Definition of dimensions for describing a DSS

Temporal scale

- **Long-term (strategic) planning.** The planning horizon extends over more than 10 years.
- **Medium-term (tactical) planning.** The planning horizon extends between 2 and 10 years.
- **Short-term (operational) planning.** The planning horizon normally covers less than 1 year, often divided into months or shorter periods.

Spatial relationship

- **Spatial with neighbourhood relationships**. The interactions of decisions made for naighbouring stands (or other areal units) are of importance, I.e. a decision made for one stand may i) constrain decisions for neighbouring stands or ii) influence the outcome of decisions made for neighbouring stands.
- **Spatial without neighbourhood relations**. The location is important, but it is assumed that a decision made for one stand does not constrain decisions for neighbouring stands or influence the outcome of decisions made for neighbouring stands.
- **Non spatial**. The spatial location of the stands has no effect on the formulation of the problem.

Spatial scale

- **Stand level** . Focus on one stand
- **Property level.** Focus on forest landscapes with several stands managed for a common purpose.
- **Regional / national level.** Focus on a region with several landscapes, each managed from its own objective.

Decision-making dimension

- **A single decision maker.** A single decision maker is assumed to be the only one involved in the decisions.
- **One or more decision-makers**. It may be one or more decision makers who have the formal power to make decisions, but other parties (stakeholders) can be involved without having formal decision-making power.

Objective dimension

- **Single**. The managemet planning problem addresses one and only one objective.
- **Multiple**. The management planning problem addresses two or more objectives, any pairs of which could be conflicting, complementary or neutral with respect to each other.

Risk and uncertainty

- **Can't handle risk and uncertainty**.
- **Can handle risk and uncertainty** .

Temporal scale: The division of the planning process into a hierarchy consisting of what are often called strategic, tactical and operational planning levels is well established in most forestry communities. However, the term "strategic" (in particular) may have other connotations than those intended here. Therefore, the more neutral time terms long, medium, and short are used. The use of time scales rather than the strategic, tactical and operational trio could also facilitate the classification of planning problems for smaller private forest owners since the trio has developed in corporate settings. A description if planning based on stratagic - tactical –operational can be found in Gunn (2007), Church (2007) and Epstein (2007), respectively.

Spatial context: Spatial aspects are frequently addressed in forest planning. Spatial phenomena can be characterized in diverse ways regarding the distribution of the objects concerned, their shape, connectivity, and their geometry (eg line or polygon). The classification here is based on having as few categories as possible (three). One indicates that the spatial is not relevant. A typical problem of this type is the determination of the long-term logging level based on strata, i.e. a description of the forest with a limited number of units, each representing several stands with similar characteristics. In that case, you have no idea where in the landscape a certain action is being performed. Another is the calculation of the NPV (net present value); there is generally no reason to keep track of where the NPV is generated. The other two categories indicate spatial significance: one indicating that neighbouring stands are in some way affected by actions in another stand. The other indicating no such connection, i.e. when considering actions in a given stand there is no need to know what is done in neighbouring stands. Examples of the former type of problem concerns such as storm problems, which measures a stock affect the risk of storm damage in neighbouring stands. Examples of the former type of problem relate for instance to wind-throw problems, where actions in one stand affect the risk of wind-throw in neighbouring stands (Meilby et al. 2001; Forsell et al. 2011). An example of the latter type of problem is the typical zoning problem, where constraints are set for stand treatments within zones or for the zones per se but where actions in one stand do not affect the behaviour of other stands (Nalli et al. 1996; Nordstrom et al. 2011). (Compare endogenous and exogenous approaches according to Chapter 3 of the compendium.)

Spatial Scale: Many forestry DSSs focus on supporting forest owners to manage their property. For some forest owners the holding is so small that the owner assesses the appropriateness of measures on a stand-by-stand basis. This makes DSS for individual stands an important category. The regional / national level doesn't need to differ from the property level in purely technical terms; the only difference may be that the region is larger than the property. The purpose of the regional / national scale is to cover problems and systems connected to forest policy. For this reason, a DSS for this scale is equipped with tools for impact assessments of e.g. various regulatory systems, the development of ecosystem services in a societal perspective and the possibility for increased timber utilization on a national scale.

Decision makers: Forest planning can involve a large number of participants, but their level of participation can vary greatly (see section 3.6 on participatory planning). What this dimension concerns is whether a DSS has the capacity or is intended to handle multiple participants. The difference between a system that is for one decision maker and one that can handle several decision makers can be attributed to where on the level of participation we draw the line. There is not any clear definition of when there is a problem of one decision maker and when it becomes a problem for more. Is it for example enough to obtain stakeholder information or does this dimension require a group that jointly make the decision? A variant of DSS that can be unambiguously attributed as systems for multiple decision makers is those designed as GDSS, i.e. group DSS.

Objective dimension: The most common objective cited in the forest economics literature is to maximise the net present value of the forest, as generally operationalised by the Faustman formula. For some owners, this can also be the essential goal. However, many forest holdings several different values need to be balanced. The decisive factor for this classification is whether the DSS can calculate and manage more than one objective (criterion or attribute). The most important requirement should be to be able to express different quantities, e.g. various ecosystem services. The other characteristic of this dimension is whether the DSS is equipped with some methodology that facilitates the analysis of several objectives. However, it is not obvious that a requirement for a formal multi-objective methodology is required to say that it is a multi-objective DSS when e.g. an objective function can be formulated that contains multiple objectives (or you can define restrictions for different desired outcomes) without a methodology for creating it. (See section 4.5 on multi-objective methodology in the compendium.)

Risk and uncertainty: In reality, no problems in forestry are completely free from uncertainty. This would lead to a situation where all DSS also have the capacity to analyse such characteristics of the planning problems. However, it can be noted that there are very few forest planning systems that have a methodology that focuses on such analyses. The closest you come, with a few exceptions, is the opportunity to do sensitivity analyses. (See also Pasalodos-Tato et al. (2013) for an overview of risk problems and forest DSS.)

5.4 Something about forest DSS and their history

Several reviews of forest DSS have been made during the 2000s. For example, seven DSSs were presented in Computers and Electronics in Agriculture (1(49), 2005) and four have been reviewed by Reynolds and Schmoldt (2006). A more extensive analysis of forest DSS were made by Johnson and Gordon (2007), who characterizes 32 systems by several decision factors (biological indicators, interference forest, forest, etc.) and includes 15 in-depth studies of successes and failures of DSS applications. Johnson and Gordon (2007) also cite studies with forest DSS concerning National Forest Plans (Schuster et al. 1993), ecosystem management (Mowrer 1997, Rauscher 1999), biodiversity at regional level (Johnson and Lachman 2001). Reynolds et al. (2008) review 10 systems. The largest description of forest DSS by far is found in the country report from the EU project FORSYS where systems from 25 countries are reported (Borges et al. 2014).

Several general conclusions can be drawn from the literature on forest DSS development and use. Firstly, they are likely to become increasingly important because they can provide tailor-made solutions to specific problems; Standard forest management is often not the best because it has negative effects on biodiversity, and it is difficult to adapt to changing needs. Managing forests that can fulfil several objectives demands sophisticated systems with the possibility to make large scale analyses and can offer functions for iterative communication on-demand and ad hoc analyses together with stakeholders. Second, the social aspect is also increasing in importance (Edwards et al. 2012; Nordström et al. 2013). This will encourage the application of MCDA, decision-making in groups, participation and more internet-based applications (Reynolds and Schmoldt 2006). Third, it can be expected that the need for sophisticated DSS will increase to meet the requirements for a systematic and transparent analysis due to increases in both social complexity (number of stakeholders, more conflicting relationships) and information complexity (degree of the need of structuring and organising available data and relationships) (Johnson and Gordon 2007). Fourth, as a response to these needs, one can see a trend that more comprehensive, general systems are displacing more specialized systems, something that could be seen already in the early 2000s (Rauscher et al. 2005, Reynolds et 2008). Fifth, as a result of the increased scope, it may be appropriate that they serve as hosts for modular programs that can run either separately or interactively, rather than as a single integrated application (Reynolds and Schmoldt 2006). This line of development points to the importance of model- and algorithm libraries as well as the ability to transfer metadata. Sixth, despite the increasing complexity of the systems, they must be adapted to the needs and skills of your various target groups. They must be transparent to avoid the "black box"-syndrome (Johnson and Gordon in 2007, Reynolds et al. 2008). Therefore, adaptive design cycles can be valuable, where systems are used, evaluated and adjusted in successive iterations (Rauscher et al. 2005).

5.5 The Heureka system

As mentioned in the section Sustainable Forestry (Chapter 1.2), methods and planning approaches to achieve a sustainable logging level have a long history. As in so many other areas, computer technology led to a rapid development in the second half of the 20th century. In Sweden, several computerized systems were developed, among the more well-known are Hugin and Indelningspaketet. Hugin was used for regional and national analyses - or avverkningsberäkningar as they were called - based on data from the National Forest Inventory. Indelningspaketet was intended for long-term forestry planning for large forest companies and was unique in several ways, including a thoughtful flow of data from a sample inventory, calculation of the forest state in the initial state, forecasts and finally optimization to find good solutions. Both systems were developed at SLU and both were mainly designed to handle timber production.

Conditions and opportunities for forest-based decision support systems changed around the turn of the millennium. This included changes in forestry objectives, increased knowledge in a number of areas such as forest production and ecology, and generally better opportunities for building computerized systems. To meet these needs, SLU in collaboration with Skogforsk developed the Heureka system (www.slu.se/heureka, Wikström et al. 2011), which is an analysis and planning system developed for a multi-purpose forestry. The first version of the software was released in 2009. Thereafter, the system is managed and further developed by Forestry Sustainability Analyzes (SHa , www.slu.se/sha) at SLU. The system consists of a number of software for different problem areas and users. It currently has a wide use in research, teaching and in practical forestry.

The system is flexible in terms of which data to use. Data from forest plans, the National Forest Inventory, larger inventories made by the large forestry industries (so-called företagstaxering) and from various special inventories can be used as a basis for analysis and planning. The system uses both simulation approaches (answering questions of the type "what if?") And optimizing methods (answering questions of the type "how to?").

The system has three software that all three deals with the long-term development of the forest. They have a common core of models that describe, among other things, tree growth and mortality.

- StandWise for analysis of stand development and management through interactive simulation.
- PlanWise for landscape analysis and planning. Contains an optimizing feature.
- RegWise for country, property or regional analysis. Based on a simulation approach that is run by a regulatory framework for forest actions.

In StandWise, the user can simulate the forest's development in five-year steps and decides if and what actions to take in each period (it is also possible to reverse). The forest's development and results of measures – e.g. volumes, costs and revenues - are shown in tables and charts. The stand in question is also visualized in two- and three-dimensional images, in the first case as a map with the location of each tree, in the second case as a computer-drawn image of the stand. Like the other software, StandWise is flexible in terms of input. In StandWise, it is also possible to interactively enter data, both in the form of stand averages and tree lists (tree species and diameter).

PlanWise handles each stand within a specific area, such as a landscape or a property. The stands can be divided into categories, or domains as they are called in the program, based on the information available on the stand. A typical case is to place the stands in different domains according to the target classes PG, PF, NO and NS. There are three management systems; even aged, uneven aged (CCF) and unmanaged (free development). For each domain, users specify forestry practices and the frameworks for how the forest is managed, such as whether fertilizing is a potential action or not. Based on the frameworks set by users, PlanWise creates a variety of potential management alternative for each stand. An exception is if free development has specified s for a stand or domain, in those cases only one alternative with just no management for the stand in question is generated. The number of rings, times for rings, etc. varies between the different potential action options that are generated. Then, the system's built-in optimization routine is used to select the best option for each stock. This is done based on the target formulation and any restrictions specified by the user. A traditional goal formulation is to maximize the present value of forestry given restrictions on environmental and nature conservation. For large forest holdings where uniformity of income and timber flows are desirable, a typical restriction is also that the revenue or volume of harvested timber may not vary too much between periods.

PlanVis has been used in a number of scientific studies and is used by all the large forest companies for their long-term planning. With PlanVis, far more advanced forestry plans can be produced compared to the traditional forestry plan. The planning horizon can be made considerably longer than 10 years, which is the traditional horizon in the forestry field, the economy is fully integrated and other objects than just timber production can be handled. PlanWise also has a module for tactical planning. Compared to other parts of the system, this module is still relatively simple.

In RegWise, the development of all stands (or sample plots if, for example, data from the National Forest Inventory) is increased five years at a time. In each period, measures such as thinning, rejuvenation felling and forest management are carried out in accordance with a regulatory framework. The regulations regulate felling and forest management in different types of forest, e.g. on the basis of different quality and tree species classes. The total level of rejuvenation logging is controlled via the total growth in the analysis area and aims to achieve a sustainable and even logging level over time. But there is also the possibility to "hard-control" the logging level by specifying specific logging volumes in each period.

The Heureky system also has a software for multi-target analysis, PlanEval, where weights can be made in a structured way for various objectives, such as wood production, nature conservation and recreation goals. The software is also available in a web version, PlanEvalWeb, then a variety of stakeholders can remotely balance different objectives. Various alternative plans developed with PlanWise can then be ranked based on how the decision-makers or a stakeholder weigh.

The results of Heureka analyses are presented in tables, charts and maps. In the latter case, the future state of the forest is presented as thematic maps of e.g. age, tree type composition and stocking (m^3/ ha). One can also easily see where different actions will be taken in each period by e.g. theme maps of thinning and rejuvenation felling.

From the beginning, the goal of Heureka has been for the system to handle a multi- purpose-oriented forestry. Today, timber and biofuel production, habitat for species, forest's suitability for recreation and coal storage are handled. The development of the living biomass - including the amount of carbon - in the trees are calculated. Also, the amount of carbon in the soil itself is handled, partly by decay, and partly by degradation to the atmosphere. Thus, Heureka can be used for analysis of how much carbon is stored in the forest. Also, the amount of forest fuel in the form of GROT or stumps collected is calculated and this data - outside Heureka - can be used to analyse the substitution of fossil fuels. Distribution from logs on forest fuel, pulpwood and timber is calculated and this data can - even in this case outside Heureka - be used for life cycle analyses for products and substitution of energy-consuming materials, such as aluminium and concrete.

Heureka specifies a recreation index for each stock, i.e.. how well a stock is suitable for recreation. The index is based on preference studies where people based on photos of different types of populations have been told how good they seem to be for recreation. Not surprisingly, older, sparse populations, "pillars", are preferred, while young, rich populations rank low.

In PlanWise a habitat model is included where the forest's suitability as habitat for a number of species evaluated. The model is based on characteristics of the stands, such as age and tree species, but for some species also has a spatial component. In addition to the stand properties themselves, a stand can not be too small or too isolated (no other suitable stands are nearby) for the stand to constitute a suitable habitat.

Study questions

1. The travel robot at Länsstyrelsen (https://www.tabussen.nu/lanstrafiken/planera-resa/) allows you to search for departure times etc. for bus journeys. Can the travel robot be referred to as a DSS?
2. Where on the scale from structured to unstructured problems is it said that DSS is the best use?
3. This section describes how to classify different DSS according to certain characteristics or "dimensions". What are the dimensions?

4. Risk and uncertainty are something that is largely related to forestry. Is it common for forest DSS to manage risk and uncertainty?
5. The Heureka system has several software that handles forest dynamics. However, is there any software in the system that specifically handles multi-objective analysis?

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[1] Here, continuous planning process is used to refer to an individual planning activity while planning system refers to the organization's entire set of planning processes. The terminology is not obvious and not widely covered. One argument for using it is the definition of system, ie. a set of interacting or interdependent components forming a whole.

The concept of planning system used here should also not be confused with the same term for the programs used as support for planning. Heureka is often called (and without objection to it) planning systems. Here, such programs are referred to as decision support systems (or DSS after decision support systems).

[2] The descriptions of individual companies are often more detailed and, for example, may have two steps for medium-term planning. The terms strategic, tactical and operational planning are not used here as they refer to the purposes of planning rather than stages of a planning system. Long-term planning would potentially qualify as strategic planning, while medium-term planning may correspond to tactical planning and operational planning may be considered operational planning, but this is not an obvious division.

[3] This is a functional description. The formal organization may look different, for example with sawmills belonging to the forest organization. Integrated forest companies today are exceptions rather a rule. In 2004, Stora Enso and Korsnäs companies merged their forests and sold it in a separate limited company, Bergvik; a

contract arrangement secures deliveries from Bergvik to the industries in StoraEnso and Korsnäs. At the time of writing (November 2016), only SCA is formally an integrated company, but under restructuring. However, this does not prevent forest planning from being seen in the context of industry needs.

[4] The district or administration does not always constitute the area of calculation for the long-term plan; it may in some cases include two or more or parts of districts.