

# Transfer System to Adapt Timber Harvesting Operations to Local Conditions

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## Abstract

*Sustainable management requires equal consideration of economic, ecological and social criteria. The science looks back on more than 50 years, in which different multi-criteria decision-making models have been developed and refined. They are well suited for the solution of complex tasks, but are dependent on case studies and limited to them. Due to this high complexity, it is not possible to transfer the results of such case studies into practice. It is, therefore, necessary to prepare a transfer model that gives the opportunity to the practice to translate the scientific findings into their local multi-criteria decisions. Such a transfer model should provide a fixed basic structure, with which the complexity is reliably depicted. However, it should be open for individual additions and adaptations in order to adapt to the locality. In the process of finding the action options, it should support the user to enlarge the search space as far as possible. The criteria and attributes should be largely fostered by scientific if-then rules, in order to meet the transfer task. In this context, uncertainties, risks and side effects must be pointed out. In the selection of the scales, in contrast, it is recommended to dispense with scientific objectivity in favor of simpler applicability in practice. On the basis of these demands, a model is developed for finding optimal wood harvesting methods. In phases Develop – Assess – Evaluate, the user is guided through the decision-making process. Initially, he is commissioned to develop concrete action options for his individual task and to predict their results. After that, he has to check six criteria with attributes and assess the options. Several methodological concepts are offered for the final evaluation. The model has proven its worth in various teaching environments. Therefore, it is recommended to develop it into an online tool for a wider target group as a continuing education module.*

*Keywords: harvesting, decision making, assessment*

## 1. Need for a transfer model in decision-making questions

Since the 1960s, it has become increasingly accepted that, for a sustainable management, several criteria have to be considered at the same time. The consequence is that the decision-maker needs a suitable multi-criteria decision-making methodology.

Jischa (1998) describes the path taken by the debate on sustainable development and identifies as milestones the book *Silent Springs* by Carson in 1962, *Limits of Growth* by Meadows in 1968, *Global 2000* by Barney in 1978, *Brundtland-Report* in 1987 and *Agenda 21* at UNCED in 1992. Parallel to this political process, both in technology development and in science, efforts were made to integrate ecological consequenc-

es and social needs into decision-making and to raise them at the same level as the business objectives. Kangas et al. (2008) and Diaz-Balteiro et al. (2016) give a systematic overview of the development of scientific decision-making methods. A shift in focus is apparent here:

First of all, the focus was on methods which, using the linear algebra, sought to develop classical optimization functions and to calculate the shortest paths, minima or similar optima. As important representatives of this group, the authors name the Goal Programming, TOPSIS (Technique for Order Preferences by Similarity to Ideal Solutions), and the Point Method.

In the 1970s, discrete methods emerged, in which the finest option was selected from a finite set of options. The ELECTRE (Eliminating and Choice Trans-

lating Algorithm) and PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) are mainly concerned with the gradual containment of the decision by exclusion of options.

Saaty uses another approach, the AHP (Analytic Hierarchy Process), to assess all options based on a set of criteria, and it is only in the end that he decides which option is best in the sum of the assessment criteria (Saaty 1977, Corrente et al. 2013). The central problem of these methods is to find as many objective judgments as possible and to exclude subjective influences. AHP solves this problem by looking for the better option in paired comparisons and by calculating the overall value using the eigenvalue method (Vaidya and Kumar 2006). According to Diaz-Balteiro et al. (2016), in addition to AHP, the Development Analysis (DEA) and the MAUT method (Multi Utility Method) belong to this group of methods.

A major disadvantage of these methods is that they originally cannot deal with uncertainties or risks. Therefore, there are many approaches to expand them, including the application of fuzzy methodology (Kangas et al. 2008).

Although the development of these methods has been intensively pursued since then, no standard has been developed. Since, in specific case studies, the basic idea of the AHP method is very suitable for resolving decision-making problems and, for example, considering that it can integrate expert groups into the set-up of pair comparisons to solve the subjectivity problem, this method is most likely to become a scientific standard.

However, all these decision-making methods have a problem: They only work in a specific case study, which defines all, the framework conditions as well as the options for action and their probable impact, and the objectives of the decision. However, when trying to generalize the results, these methods reach insurmountable limits:

- ⇒ A key issue is that the decision-making structures, as well as the selection of the criteria used in the case study, are subject to changing interests and are tailored to the local framework conditions in the case study. As soon as other structures or criteria are important in another case, a new case study has to be carried out, since the results of the given study cannot be transferred
- ⇒ Likewise, the options for action can hardly be generalized. As soon as in another case only one single deviating action option occurs, the pair comparisons of the case study lose their basis.

However, since technical processes are subject to rapid change, results based on case studies lose their relevance with every technical change

- ⇒ To exclude prejudice and to uncover undiscovered connections, scientific investigations are based on extensive data collected in a case study. These data are not limited to the cause-and-effect relationships that can be determined by the natural sciences, but also include the assessments and the objectives of the case study. Thus, their results are only valid for this case study and are not transferable
  - ⇒ As soon as the decision-making method tries to simulate risks and uncertainties and to consider the question of whether the decision-maker is more risk-averse, neutral or risk-tolerant, the results assume such a high complexity that a transfer to real questions falls into the background
  - ⇒ Almost all methods are based on the same principle that the different criteria are scaled with a uniform assessment scale. However, the finding of a common scale that meets the criterion of scientific objectivity presents itself as a challenge. In particular, when »soft facts« are involved, for which there are hardly reliable data, the methods reach their limits.
- If these assessments are combined, it is obvious that the transfer of decisions obtained in case studies cannot be generalized. Without wishing to challenge its scientific value, it should be noted that its value is severely restricted in practice.
- The practice, however, expects the scientists to point out the solution of their problems. It does not want to be fed with singular results, which are no longer transferable with increasing complexity. Because this lack of transferability is system-dependent and cannot be resolved, the scientists are invited to develop a methodology that enables the practitioner to answer his own questions on the basis of findings obtained in scientific case studies:
- ⇒ First, it will be examined what characteristics a suitable transfer model should have
  - ⇒ Subsequently, a model for the application to forestry decisions will be developed and presented
  - ⇒ It will then be discussed whether this particular model meets the requirements of a transfer model
  - ⇒ To conclude, in a short future, the tasks to be undertaken by scientists should be determined.

## 2. Characteristics of a suitable transfer model

Beforehand a note of warning should be sounded: From the requirement to overcome the limited transferability of scientific working methods, it is imperative that any model that arises here must deviate from scientific standards! The one who goes on this path inevitably leaves the quality standards of scientific work. In doing so, he is exposed to the criticism – often violating – by his colleagues. The task, however, of creating a transfer instrument, which can be understood and used in practice, is fatally tied to this disadvantage. If, however, it were possible to build a bridge to practice in this way, it would seem worth all the efforts. Who else, if not the scientists, could build such a bridge?

Further to this basic view, the individual requirements will be discussed:

### 2.1 Specification of a decision-making structure and criteria

The decisions that are made here are usually so complex that they must first be given a structure and the appropriate criteria for making the decision have to be selected. This requires not only a certain methodological knowledge, but also a great deal of time, which the practitioner can hardly muster. This is why it is necessary to offer frequently recurring basic structures and also to specify the most important criteria. Such a skeletal decision-making model should be a middle way between standardization on the one hand and adaptability to individual needs and conditions on the other.

The AHP model can be used here as a sponsor: One important reason for its success is that it offers a very simple, easily adaptable structure, which is limited to three levels. On the lower level, the options of action are to be assessed; on the upper level, the values are to be satisfied, and the criteria for judging the options are in between (Saaty 1977). This structure can easily be captured and transferred to any application.

When it comes to the question of the appropriate criteria, it becomes more difficult. Inexperienced model builders tend to take as many criteria as possible in order not to overlook anything. However, they run the risk of overshooting the model and making the decision impossible.

On the other hand, Saaty pointed out the psychological research results of G. Miller (1956) in the development of AHP, according to which the number of criteria should be no less than 5 and no more than 9 («seven plus or minus two», Saaty in 1990). Given such a limited number of criteria, it is the responsibility of

the model maker to select them very thoroughly, and to ensure that they are independent from one another and that they completely cover the set objectives.

Therefore, it is unpreventable that these criteria remain relatively abstract (e.g. protection of the soil). The user must, therefore, be given the opportunity to search for suitable attributes, which in his case allow a more concrete assessment of the respective criterion. In the example considered, it would be useful to take the specific ground pressure in kilopascal (kPa) as a criterion. However, it often appears necessary to define several explanatory attributes for one single criterion, which can be used either as an alternative or as a complement to one another. In our example, the decision-maker could consider the number of crossings as important in addition to ground pressure. For more than one attribute, he must specify how the assessment of the criterion is made up of the values of the different attributes.

### 2.2 Help in finding options for action

In my experience, many practitioners tend to focus on very few favorites at the beginning of the decision-making process, thus severely restricting the search space. As a result, some options for action, which would be particularly well suited under one criterion, are simply overlooked.

The opposite should, therefore, be the case: first to collect as widely as possible different options for action and to evaluate them in a later step, because it is always better to leave an option after negative assessment fall back than not to take it up from the very start. A transfer model should, therefore, offer a heuristic that helps the user to creatively generate as many different action options as possible.

### 2.3 Intuition where no data are available

Since the practitioner does not have the opportunity to collect extensive data before his decision, he has to resort to the available information. While this sacrifices a fundamental property of scientific work, the transfer model must be able to partially engage with intuitive assessments.

However, in order not to open the floodgates to any subjective assessment, a middle way is required between data-related rules and intuitive application: Wherever there is sufficient evidence, which can be generalized via if-then rules, the scientist should also offer it to the practical user. However, where such a generalization is not possible, it should be up to the decision-maker to follow his own intuition and assessment.

A suitable transfer model should, therefore, have a comprehensive set of decision-making rules that give

the user security. It has similarities to a decision support system, but it should allow him to deviate from those rules, where it is more appropriate for his or her individual decision-making situation due to locally based experience and knowledge, even if it cannot be subjected to any scientific review.

#### 2.4 Dealing with uncertainty and risk

Decision-making models tend to conceal uncertainties and risks behind figures and pretend to assume a higher degree of certainty. To compensate for this disadvantage, various methods have been proposed by scientists that can be used to describe both the factual uncertainties and risks, as well as their individual handling of the decision-makers (Kangas et al. 2008). However, they have further increased the already high complexity of the models. Thus, they are diametrically opposed to the effort to simplify and unify models for practical applicability.

Nevertheless, it would be wrong to ignore uncertainties and risks. Wherever possible, the user should be aware of uncertainties and risks so that he can take them into account when making his decision. Within the framework of the if-then rules, they should be communicated openly so that the user can only choose those options in which he is sufficiently secure. In this way, one leaves the judgment of the decision-maker's intuition: after all, he is the one who has to make the decision and to take responsibility for it.

#### 2.5 Choice of an appropriate assessment scale

As already shown, a central problem of optimization is to compare the scores of different criteria. Therefore, most of the scientific methods mentioned are looking for a uniform scale on which all criteria can be represented (exceptions such as outranking methods, see Kangas et al. 2008).

As such, the economist likes to resort to monetary units because they have indisputable advantages:

- ⇒ Everyone understands them intuitively
  - ⇒ They make an abstract assessment without the user becoming aware of this abstraction
  - ⇒ In addition to the criterion-related assessment, they also meet the balancing between the criteria, so that the sum directly contains a final judgment.
- However, these advantages are counterbalanced:
- ⇒ Money values can be easily found only if the criterion has a real market value
  - ⇒ All scientific attempts to assess non-market criteria with monetary values are critical; the assessment depends, in particular, on the method by which it was calculated

⇒ As soon as attempts are made to present the impairment of any absolute value (e.g. the probability of a fatal accident) with monetary values, errors or even morally questionable statements can hardly be avoided

⇒ The obvious temptation to simply exclude such soft facts from the evaluation leads to ignoring relevant criteria.

Therefore, monetary scales are not recommended here.

We have seen that the AHP method solves this problem by making pair comparisons and thus automatically developing a uniform internal scale. However, this method has considerable disadvantages, too: On the one hand, it only works in a closed system. As soon as another option is added or the viewing space is changed in some way, the pair comparison must begin at least in parts from the beginning. Secondly, the pair comparison grows very quickly to a very time-consuming task, so that the practitioner may be forced to keep the search space as small as possible in the sense of the time economy, which is counterproductive, as shown.

Another solution is to deliberately allow the subjectivity of the decision-maker and leave it to the judgment with a scale that corresponds, for example, to grading in the school, see value analysis by Zangemeister (1973). This seems to be justifiable if the decision-maker only has to justify his decision to himself. However, if he were to justify his decisions to a third party, it would be necessary to disclose and discuss these subjective judgments.

It is, therefore, best to adopt a decision-making rule that does without a uniform scale. Then one could use a suitable scale for each criterion, whose values depend entirely on the question and which can be easily estimated by any expert.

### 3. A decision-making model for forest technology

On the basis of these demands a sketch of a model will be given that fits to the strategic development of harvesting methods in forestry.

#### 3.1 Balance between prebuilt structure and flexibility

In section 2.1, the transfer model was to have balance between the specification of a structure on the one hand and the freedom to adapt this structure to the diversity of technical situations. What is meant by diversity in this case?



- ⇒ These are the framework conditions like geographical attributes of the ground, biological details of the woodland like species, age, dimensions, mixture, climate and the actual weather
- ⇒ These also are socio-economic conditions like wage-level, education of the workers, infrastructure, etc.
- ⇒ Finally, for the decision-maker, the objectives of his company have the status of a framework, too. For him a decision can only be made when he fulfills the priorities and restrictions of his own normative system.

If all of these conditions and limitations were integrated into our model, it would go beyond the scope of a transparent transfer system. Therefore, a model should be developed that presets a skeleton of basic structures that can be filled by the local knowledge of the user.

The model should be a bit more restrictive in terms of handling the assessment of the criteria, which are

represented by if-then rules (Weiss 2007). Here, the complex knowledge of experts should be collected and represented by a strong tool of rules, which are presented to the user. Normally, he will accept these general assessments. However, in some cases, when he has a more precise local knowledge or possesses some insights that differ from the main stream, he seeks for the chance to alter the assessment for his own to familiarize the model. In both cases the advantage is that all relevant criteria can be integrated, while the user may concentrate on those criteria that seem to be the most interesting for him.

Saaty (1977) has predefined a simple structure of options, criteria, and objectives that should be adapted to our transfer model. In case of forest technology, it can be translated to (Fig. 1):

- ⇒ First step »design of technical options«: It is the task of the user to look for technical options that seem to be adaptable under the local conditions. For each option, the functional results of the

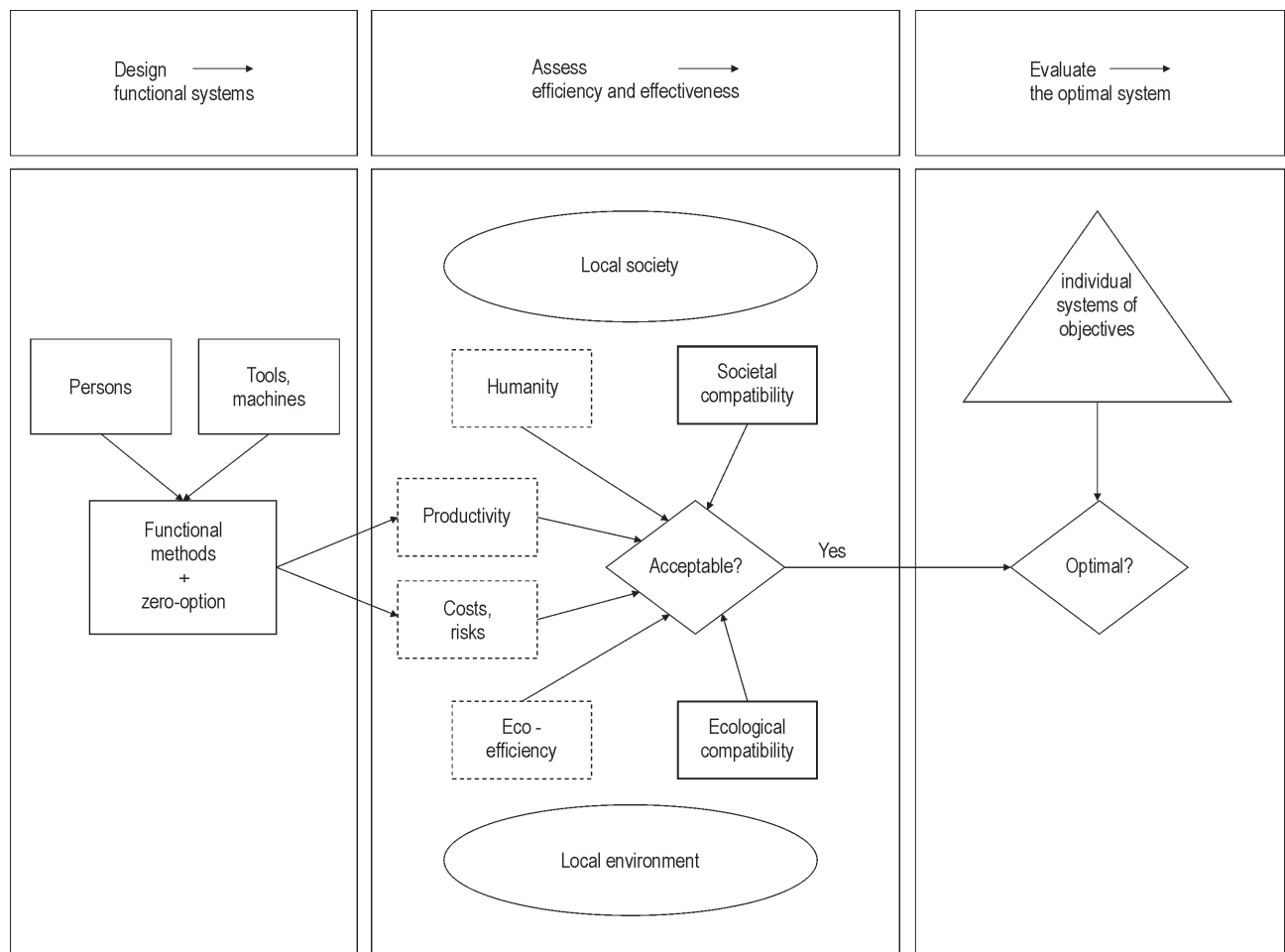


Fig. 1 Basic structure of the decision model for forest technology with the steps design, assessment and evaluation

work, like time consumption, productivity, quality of products etc., have to be forecasted

⇒ Second step »assessment of the options«: The options will be assessed by a set of important criteria. In order to prevent shortcomings, a fixed set of criteria should be proposed. The user will get the chance to underlay these criteria by fitting attributes by himself. If one option fails, it will not reach the third step because it is dropped out of the decision making process

⇒ Third step »final evaluation of the options«: Under those options that reach this third step, the decision-maker is free to elect that option that seems to fulfill the individual needs of his company in a best way. This part of the decision will never be taken over by any anonymous rules, because it is the expression of the responsibility of the decision-maker.

Following up, the steps will be described more intensively. As an example, a simple decision making situation will be carried out in parallel (data and assessments are fictive and have no relevance to real situations, see Fig. 3 and 5).

### 3.2 Design of different options

On the first step, the decision-maker looks for technical options, or in our case: He has to find harvesting methods that could be able to reach the technical goal. Under these options, he will elect the best one. This shows the relevance of this first step. The search-area defines the quality of the decision. If the decision maker is lazy – and in practice this is often the case – and feels happy with one or two alternatives, the likelihood to find a really better solution is limited.

Experienced decision-makers suggest to look for more than 5 options, which should be as diverse as possible. Among them, there may also be some options, that seem to be unproductive, too expensive, old fashioned and so on. Though it seems to be inefficient to deal with options that will never have a chance to be the best, the advantage is that they enlarge the field of vision. A good method to enlarge the number of options is to look for different levels of mechanization.

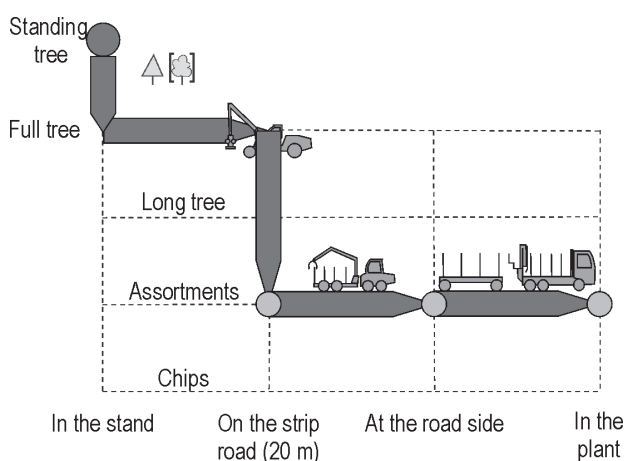
And there is also a special option that is called the zero-option: i.e. to do nothing. More often than expected, the zero-option had the best assessment because it saved money where the positive effects of any activity never justified the negative side effects or risks.

Talking about options concerning the harvesting operations, the following should be specified: harvesting operations are all operational steps from the living tree to the storage place alongside the forest road. This includes the processing steps like felling, delimiting, topping, bucking and in some cases chipping. However, it also includes the transportation steps like hauling and skidding or forwarding. In most cases, the sequence of the processing steps is fixed. So is, of course, the sequence of hauling from the original stand of the tree to the skid road and the skidding to the forest road. However, the combination of processing steps and transport steps can be altered in several ways:

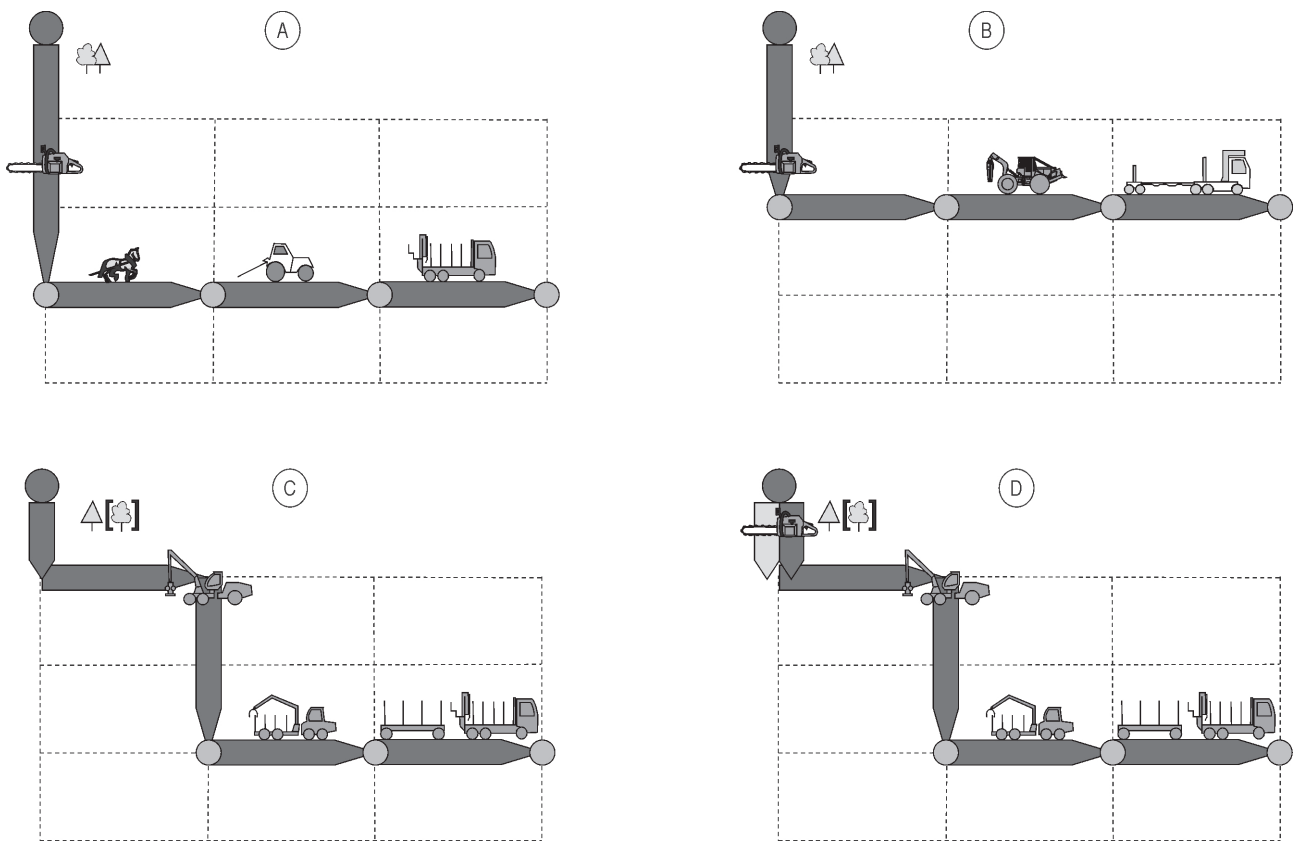
⇒ For example, in traditional forestry the tree is felled, delimited and topped by a chain saw. Then the tree length can be hauled by cable to the skid road and skidded to the forest road; in this case the first processing is finished at the stump site, followed by the extraction as second sub process. In a third sub process, the tree length is crosscut into pieces at the landing.

⇒ A harvester, however, first fells the tree, then moves this full tree to the skid road, where it starts delimiting and crosscutting and finally topping. In a second sub process, a forwarder loads the logs and forwards them to the forest road.

Normally, the decision-maker is creative enough to develop some functional alternatives. This task can be supported by a functiogram that has been developed by Dög and Erler (2009). On a two-dimensional table, the most important functions of harvesting operations



**Fig. 2** Functiogram of a harvesting method; here a fully mechanized cut-to-length method is presented with harvester and forwarder on assessable ground and permanent skid roads



**Fig. 3** Functiograms of four harvesting options: a) Semi-mechanized cut-to-length method with horse and tractor; b) highly mechanized tree length method with skidder; c) fully mechanized cut-to-length method with harvester and forwarder (see also Fig. 2); d) highly mechanized cut-to-length method with motor-manual pre-cutting outside the crane zone, harvester and forwarder; not illustrated here: e) the zero-option, which means no harvesting at all

are specified, the processing functions top to down and the transport functions from left to right, building together a net with sides (functions) and nodes (states). Each sub process can be depicted as a combination of procedural steps from the starting node to the end node. Between two sub processes, which can operate independently, a bubble marks a buffer. As soon as the decision maker decides to use a specific machine, he can define the sub process that this machine is able to run. While barely the total harvesting needs are covered by only one process (except the use of a harwarder or biomass harvester), the fixation of one sub process limits the choice of the other sub processes. This can be shown graphically by means of the functiogram (Fig. 2). Filling up the functiogram, other options can be generated that the decision-maker probably had not in mind before.

**3.3 Assessment of options by a set of criteria**

To understand the assessment process, it is important to recognize that the options are not assessed as

	Efficiency	Effectiveness
Economy	Efficiency	Productivity
	Costs, risks	Quantity, quality, timeliness
Ecology	Eco-efficiency	Ecological compatibility
	Energy, soil degradation	Stand vitality, damage, impact to soil, water, stand productivity
Social aspect	Humanity	Societal compatibility
	Strain, stress, safety, personal development	Recreation, culture, employment

**Fig. 4** Complete system of six partial objectives with typical criteria

such but rather their effects that are likely to be reached, as well as the expected efficiency of work. In some cases, if we are lucky, this information can be

taken from our own experience. However, in all other cases, a forecast that is based on fictional assumptions must be made:

- ⇒ Adaption: In a case that this harvesting method can be observed at a fair or anywhere else, we can try to assess whether the foreign results can be transferred to our own conditions and – if not – what will be the difference
- ⇒ Prolongation: In a case that the unknown method is very near to a known method and only small elements are different, the effect can be estimated on the basis of the effects of the old method
- ⇒ Analytical approach: If both possibilities fail, we can try to estimate some effects in analogy to other methods, where similar tools or machine elements (type of wheels and axles, harvesting head, etc.) are used.

In case of harvesting operations, the decision-maker will first forecast the quantity, quality, and value of the products (effectiveness). On the other hand, he will try to estimate the costs and procedural risks (efficiency). In the skeleton, these assessments of effectiveness and efficiency are foreseen as two independent criteria that have to be assessed in any case. The transfer system can offer some basic estimation for productivity and the costs depending on technical details (volume per tree, skidding distance, etc.), but they should be proved and altered by the decision maker, if needed.

However, according to the idea of sustainable development, the ecological and social aspects have to be regarded at the same hierarchical rank. The suggestion at this point sounds a bit schematic, but helps to find a systematic one that can be easily understood and communicated: To make the same difference for ecology and social aspects like in economy. This means as follows:

- ⇒ Ecological effectiveness asks for risks and side effects on soil, water, stand, biodiversity, and productivity. To forecast these effects, there are a lot of well-known correlations. The problem is normally to condense them to a common assessment of the partial objective of ecological effectiveness that should be called »ecological compatibility«
- ⇒ Ecological efficiency asks for the sparing use of natural resources like energy. In our case, the most important resource that we disturb for a long time and, therefore, »use« for our harvesting operations is the soil under the driving machines. An important attribute to measure ecological efficiency can, therefore, be the percentage

of forest soil that is covered by skid roads; with 20 m distance, it can reach 20% of the productive soil, in case of no driving restrictions it can easily reach 40% and more

- ⇒ Social effectiveness is reflected in the effects towards the society and answers to their societal needs. They involve recreation, cultural demands and the hope of employment. In parallel to the ecological partial objective, it can be called »social compatibility«
- ⇒ Social efficiency asks for the sparing use of social resources – a strange concept. Social resources involve all human beings who are working in the process. Sparing does not mean to rationalize them in order to lower the costs (that would be economy), but to lower the damage and danger for them. In other words: Social efficiency asks for the standard demands of ergonomics and can be condensed in a partial objective called »humanity«.

In most countries, there are some legal restrictions that have to be regarded in the decision making process. In Germany, for example, clear cuts are normally not allowed, machines have to stay only on skid roads and special hydraulic liquids have to be used.

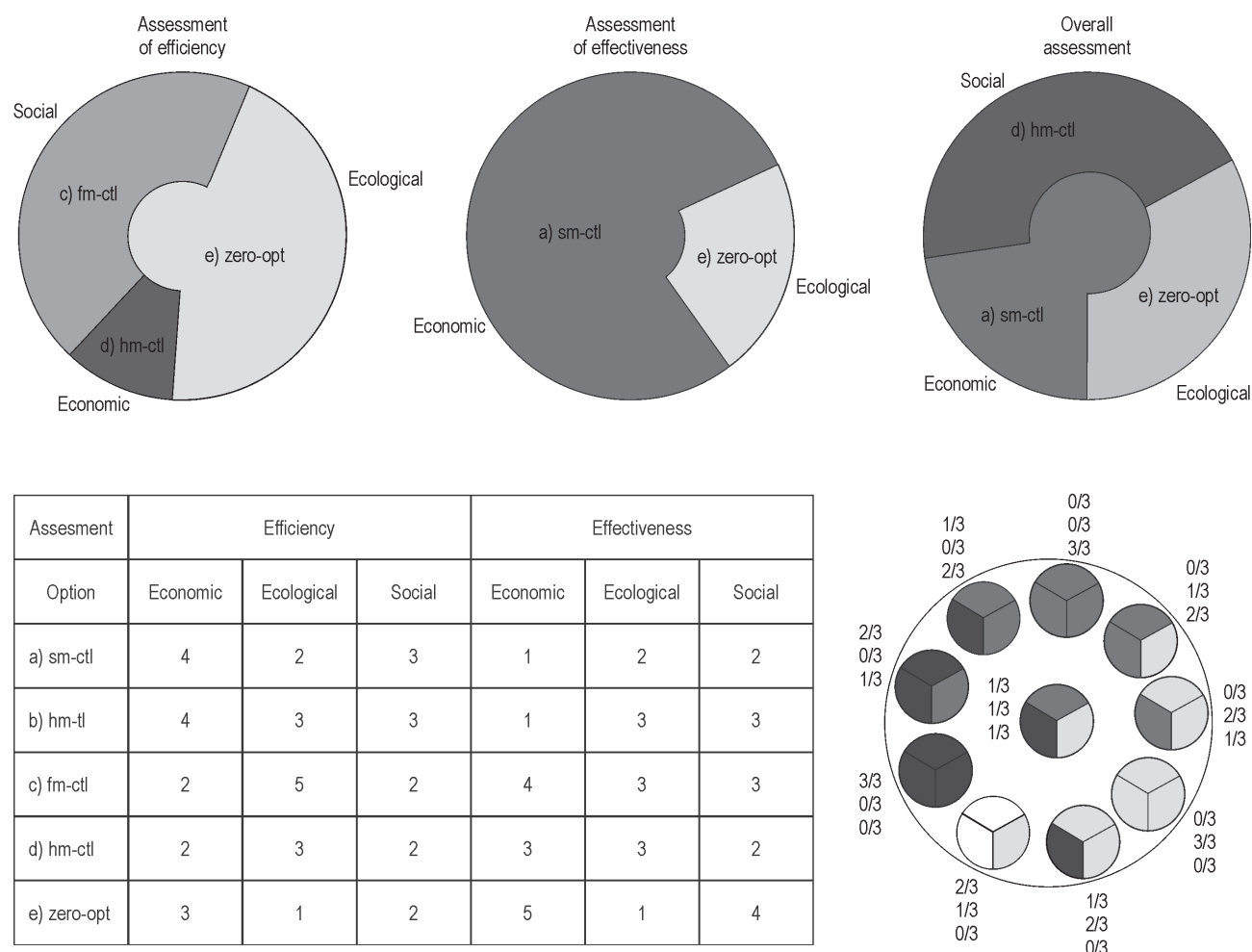
In addition to these restrictions, the forest owner can decide to respect specific restrictions, which is called a voluntary self-limitation (Faber 2008). Well known are the forest certification systems like PEFC and FSC, which – depending on national rules – set standards for a specific behavior. In Germany, for example, they provide certain distances of skid roads and for wheel ruts after harvesting operations. If the decision-maker fears that the risk is high to exceed such a limit, he is well advised to drop the option completely.

### 3.4 Uncertainty and risk

Many of these assessments contain open questions and risks, which must be considered by the decision-maker. This is particularly true of the risks and side-effects of forestry actions on the environment. The transfer system should, therefore, take particular account of the environmental risks and provide the user with as much information as possible.

A well-fitting tool, developed by Gröll, is in use in the North East of Germany (see Erler and Gröll 2008). It assesses the sensitivity of the forest soil as well as the productivity of the forest site and condenses this information to a 5×5 diagram that is called technogram. Each field of the diagram represents the sensitivity against the traffic of forest machines (as indicator





**Fig. 5** Optimal option depending on the preference pattern of the company, shown for efficiency, effectiveness and overall assessment (sm: semi-mechanized; hm: highly mechanized; fm: fully mechanized; ctl: cut-to-length method; tl: tree length method; zero-opt: no harvesting at all)

of ecological compatibility) and the productivity value of the stand (as indirect indicator for eco-efficiency). In a comparable scheme, the impact of each technical option can be expressed by a 5×5 diagram called ecomgram, by which the compatibility for this very site is assessed. A comparable tool would support the user of the transfer model in assessing the ecological compatibility and efficiency and herewith in lowering the risk of decision-making.

### 3.5 Scales and evaluation

Up to this point, we have not made any determination regarding the scales. In Chapter 2.5, we have spoken only against the use of monetary values and pair comparisons.

As long as a relative evaluation of all criteria is attempted, however, a uniform scale is irreplaceable.

Despite all the doubts, it has proved useful in this case to use a scale, which is based on evaluation in school teaching because the associated values and their relations are commonly known and balanced. In some cases, it is necessary to provide an explanatory guidance, if the assessments are not logically accessible.

As soon as all options are assessed under all criteria, the evaluation can follow. It seems to be obvious to follow a hierarchical structure that brings the partial objectives to a ranking order. First, all options are assessed under the focus of the most important criterion. When different assessments are found for all options, the best option will be selected and the decision process is finished. Only when two or more options are similar under this first criterion, they (and only they) are assessed by the next important criterion. The advantage of this lexicographical way of decision-mak-

ing is that it easily leads to a decision. However, the disadvantage is obvious: it is only acceptable when all options are in principle elective near to each other.

Another solution to be applied in scientific research is to weight the criteria. However, this requires a very intensive focus on target systems and is, therefore, not suitable for practical applications.

Therefore, we suggest to use the decision making process: different decision structures are calculated to show which options were the best under which structure. A basic structure, in which the relationships between economy, ecology and social needs are altered in steps of one third, has proven very good. Between 1–0–0 and 0–1–0 and 0–0–1, there are intermediates like 0.66–0.33–0 and 0.33–0.33–0.33 and so on with 10 combinations in all. For each combination, the best option is shown with the effect that the decision-maker can see which consequence a certain preference concept would have (Fig. 5). This helps him to get a feeling for the technical consequences of his preferences.

Here is an example:

- ⇒ Concerning the efficiency: Under given assessments, highly and fully mechanized cut-to-length methods (c and d) are best, when ecology has a lower value, otherwise the zero-option e) is the best
- ⇒ Concerning effectiveness: With the presetting, the semi-mechanized cut-to-length method a) is optimal; only under maximum ecological focus, it will be lapped by the zero-option e)
- ⇒ Concerning efficiency and effectiveness together with balanced weighting, three options are competing: Under social focus the highly mechanized cut to length method d) is optimal, while under ecological focus, the zero-option wins; with economic focus or balanced weights, the semi-mechanized cut-to-length method a) is the best.

In chapter 2.5, the scales based on the natural assumptions of the criterion to be assessed have been described as optimal. They can thus be understood by any professional user and applied without contradiction. In the above example, the specific ground pressure would be in kPa, or an ordinal scale derived from it (light – moderate – heavy). With this type of scale, it is possible to provide decision-making, which is specialized in the exclusion of inappropriate options and reduces step by step the set of options.

In our transfer model, this could look like this:

- ⇒ Firstly, as many options as possible are required, all of which fulfill the functional objective

- ⇒ For each criterion, one or more attributes are selected for which natural scales are created
- ⇒ For each scale, a minimum condition is defined that must be met by each option
- ⇒ If an option in one attribute does not meet this minimum condition, you can try to improve it and re-evaluate it under all criteria; if this is not successful, the option must be excluded from further selection
- ⇒ As soon as all options have met all the minimum conditions, they can be regarded as usable without exception
- ⇒ Now, there is nothing to select a single criterion as decisive. This is usually the economic efficiency.

This method has the advantage of being very similar to the intuitive approach of many decision-makers. It is, therefore, subjectively perceived as meaningful and accepted.

## 4. Discussion

The presented model is not seen to be an alternative to the scientific model approaches that are used to evaluate multi-criteria decision-making situations. It was made clear that this model, in contrast, should be a transfer model that should bridge the gap between scientific knowledge and practical decision-making needs.

As this model is neither right nor wrong, it can only prove that it stands the test in reality:

- ⇒ It should be teachable between people so that they can understand and use it
- ⇒ It needs to be open for participation in a way that is open for the individual knowledge of the user and ready to be integrated into rules
- ⇒ It has to be adaptable to local conditions and variability over time
- ⇒ It must be operational in a sense that it can be controlled with clear results.

### 4.1 Readiness for teaching

In study situations at university, this model has been taught numerous times. It could be proved that students are able to adapt it to specific problems after a short time with high transparency and quality. The same model could also be used with success in international context. In doctorate theses, it has been adapted to conditions in Greece (Dimou 2002), Brazil (Saraiva da Rocha 2011), and Iran (Badraghi 2013). For

students of tropical forestry, it serves as a basic pattern to explain the diversity and different technical solutions in global forestry with different regions and cultures.

#### 4.2 Readiness for participation

This model gives to the user the chance to introduce its own experiences and local knowledge. The combination of easy and fixed skeleton structure on one hand, and complex assessment on the other hand allows individual adaptations without lacking the complexity that is necessary for an overall assessment.

However, this flexibility has its shadows, too. In contrast to any standardized models, a comparison between different users and different companies is not possible. In each case, it is essential to look at all adjustments at all levels. So, this model is not a tool to normalize the decision results, it is rather a tool to ease the decision making process in a complex surrounding.

#### 4.3 Readiness for communication

Though the model is very complex, its structure is simple and near to reality. This helps people to adapt it to local conditions and needs without profound knowledge of decision-making structures. By its transparency, it is a valuable tool in the leadership process and may even help to find the legal liability.

#### 4.4 Readiness for operational control

A public forest service in Germany took this model to modify the forms for working advices with the consequence that finally the character of the advices changed to a real contract with clear objectives and competences (Erler 2009). The experiences of the last 10 years have shown that this tool is in practical use and gets positive feedback.

### 5. Future outlook

The model has been in use for several years and has proven its benefits. It is mature enough to be made available to a larger group of users. It has been available as an online tool, which can be used for the training of forestry staff, service entrepreneurs and forest owners.

To this end, however, considerable efforts still need to be made:

- ⇒ The tool itself has to be prepared and adapted to the possibilities and limits of E-learning
- ⇒ Criteria and attributes must be filled with up-to-date scientific findings and must be stored with appropriate scales

- ⇒ All the calculations required for the entire decision-making process must be carried out and made transparent by the online system, without limiting the intuitive use.

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Received: November 8, 2016.  
Accepted: February 17, 2017.

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