INTRODUCTION TO FOREST OPERATIONS AND TECHNOLOGY

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Literature
In modern cut-to-length harvesters, bucking of stems is controlled by value and demand matrices. Through the automated bucking control, stem partitioning into different timber assortments according to tree species can be adjusted and the log size distribution by assortment controlled to meet the specifications of production plants.

The value and demand matrices controlling bucking optimization are specified in an APT file. A **value matrix** or **price list** is a two-dimensional table, in which the value of each log of given length and diameter is defined relative to logs of differing dimensions within the same timber assortment. An assortment-specific value matrix is designed for each timber assortment. In each value matrix, a **baseline price** is designated by which the value of different timber assortments is proportioned against

*Figure 7-24* The harvester’s bucking optimization system controls the partitioning of the stem into various log assortments as well as the size distribution within each assortment.
others of the same tree species. The size class-specific values of the value matrix commonly vary ± 10–20% from the baseline price. The basic idea, however, is that the matrix values of two different timber assortments do not overlap. For instance, the baseline price of a saw log is generally 200 and ranges from 180–220, while that of a clearly more valuable veneer log is 300 ranging from, for example, 270–330. Thus, this system configuration ensures that the harvester always attempts to make the most valuable timber assortment whenever quality considerations allow (branchiness, crookedness, curviness etc.).

![Log Value Matrix](image)

Figure 7-25 An example of a log value matrix used in harvesters.

A **demand** or **target matrix** is a table, which reveals the relative target amounts of diameter-specific log lengths within a specific timber assortment. Since
stand characteristics primarily determine the diameter class distribution of logs (large logs unattainable from small stems), the most recent trend is towards defining diameter class-specific log length distribution targets. In such case, the relative target amounts of different length classes are specified within each diameter class.

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**Figure 7-26** An example of a log demand matrix used in harvesters.

The prerequisite for stem optimization calculation is that the shape of the stem to be optimized can be determined as accurately as possible. Generally, the tapering of the stem as a function of height is referred to as the stem curve or stem profile. In harvesters, the optimization calculations are founded on measurements made by the harvester head as well as the stem profile prediction based on this measurement. Certainly, the most precise method would be to first measure the stem from the
stump to treetop and only then proceed to cut it into logs. In practice, however, this would prove to be far too slow, and likewise the stem would be exposed to damage during processing.

Figure 7-27 A harvester’s on-board computer system predicts the profile of the stem being handled prior to the first cut.

In order to predict the stem profile reliably, measurements made by the harvester must be accurate. Consequently, the settings and calibrations applied by the machine operator play a significant role. Errors arising from measurements by the harvester are by no means eliminated in the stem profile predictions, but rather, the error tends to be cumulative. Accurate measurements carried out by the harvester combined with a well-selected stem profile prediction model may lead to either a good or poor stem profile prediction, but an inaccurate measurement will undoubtedly result in an inaccurate stem profile prediction. As a consequence of a flawed stem profile prediction, bucking is less than optimal. The bucking results may appear successful at a glance, but monitoring measurements made at the sawmill scaling and inspection station may reveal that the wrong log classes have been prioritized. The most advanced stem profile prediction
models are based either on the so-called mixed stem curve model technique or relative stem shape theory.

When the stem profile and price matrices are known, calculating the optimal bucking alternative is, in principle, a rather straightforward operation. First, all possible bucking alternatives need to be listed. Then, the value of each alternative can be calculated based on the log volume and price list. Finally, the optimal bucking pattern can be selected based on the highest value. In real life, however, this is impractical, for the number of bucking alternatives can easily amount to thousands or even tens of thousands. Therefore, the optimal bucking alternative is actually chosen with the assistance of efficient algorithms. In most harvesters, an algorithm combining dynamic programming and network theory, as presented by Näsberg in his thesis published in 1985, is used as the basic solution. By doing so, the number of bucking alternatives is reduced from tens of thousands to a few hundred, which ensures that optimization calculations progress smoothly when actually processing the stem.

It is wise to delay the optimization calculation until sufficiently reliable, measurement-based information is available on the stem profile. In practice, however, the decision concerning the positioning of the first bucking point needs to be made prior to the first cut, in other words, 3–4 meters from the felling cut. It is not unusual for the first stem profile predictions to be somewhat inaccurate, and the optimization process may have to be repeated for the rest of the stem. Different harvester manufacturers offer various solution models for comparing the actual stem profile and the predicted one. The optimization software in most types of harvesters does nonetheless permit the operator to adjust the tolerance threshold value, which results in re-optimization.
Figure 7-28 The bucking optimization proposal is always recalculated if the difference between the stem curve prediction and the actual measured diameter exceeds the tolerance threshold value.

The central principle of the optimization system is to maximize the value of a single stem. This principle is referred to as bucking-to-value. Bucking-to-value optimization does not consider timber assortment-specific target distributions, but rather proportions of different log sizes are determined in connection with each bucking according to unchanging value tables. In short, the bucking pattern of any given stem is always optimized according to the same relative value ratios. Subsequently, optimizing the value of an individual stem can easily create a situation where the log size class distribution delivered is undesirable from the perspective of the sawmill receiving the logs (for example, short and long logs in excess). Instead of optimizing the value of a single stem, the objective of bucking should be to amass as suitable a log size class distribution as possible on the whole. In order to direct bucking optimization procedures towards the best overall results, it is necessary
to compromise the principle of optimizing single stems to some extent.

Accommodation of the single stem optimization principle in the assortment-specific target distribution set for the entire stand has been implemented in harvesters in a relatively simple manner. The bucking problem is not construed as an optimization model, but rather, the bucking is adjusted as it progresses. When optimizing a new stem, previously accumulated log quantities are taken into account. This so-called bucking-to-demand principle can be applied in two ways. In the adaptive price list method, the software continuously updates the values in individual cells depending on whether too few or too many logs in a specific log size class have already
accumulated. Optimization is still carried out on the basis of the price list alone.

In the **near-optimal method**, the software pinpoints the bucking combination which serves the distribution target most appropriately, but whose value simultaneously differs at most by the maximum tolerance from the stem value achieved via the bucking-to-value optimization. Practical trials have shown that the selected method has little bearing on how well the distribution control works.

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**Figure 7-30** Principle of the adaptive price list method.