A Framework for CTL Method-Based Wood Procurement Logistics

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ABSTRACT

Wood procurement logistics has developed dramatically during the last few decades. The adaptation of general logistics theory, increasing customer orientation, product-based bucking, the externalization of work processes, the expansion of international wood trade and the rapid development of management tools and methods have changed the characteristics of wood procurement tremendously. Consequently, there is a growing need to redefine the concept of wood procurement. This paper attempts to lay down a general framework for CTL (cut-to-length) method-based wood procurement management and to highlight the most important research and development objectives in this area.

In wood procurement the main customer service goals are price, dimensional requirements, quality requirements and the ability to react to changes. The price is always important, but the smaller the proportion the wood cost is of the total production costs, the less significant the price becomes. The importance of quality and dimensional requirements increases with the rising value of wood. Due to improved inventory booking systems and transportation optimization systems, wood procurement companies have managed to decrease stock levels, thus decreasing rate costs. The company may aim to decrease the level of stock, but not without possible additional costs. According to logistics theories, an increase in stock levels increases storage costs but, on the other hand, a decrease of stock levels increases transportation costs and the risk of lost profit.

Seasonal variation and the ability to react to changes have great significance to logistics costs in wood procurement. Small stumpage reserves inevitably lead to expensive harvesting and transportation activities. But more research should, in the future, also be directed at improving classifications of harvesting and transportation accessibility.

In the Nordic countries significant progress both in tree bucking control and transportation allocation has been achieved in practice, but they are still considered as separate processes. It is in most cases undesirable to cut many products from the same stand, since it implies too many loading and transportation operations. Therefore, it is necessary to choose which products in what quantities may be cut from each stand. This means that tree bucking control and wood transportation problems should not be considered as separate tasks, but instead be optimized as a whole. If they are considered as separate processes the gains achieved through better product characteristics are lost in increasing transportation costs. Current wood pricing systems make it difficult to fully exploit the advantage that could be gained through this kind of optimization.

Keywords: *Supply chain management, wood procurement, tree bucking.*

INTRODUCTION

Management in the broad sense refers to the manner in which a business is directed, conducted or regulated so that a desired result will be achieved. Wood procurement management has traditionally been seen as a single business function that embraces a rather broad spectrum of activities aiming at providing the many mills and plants of the forest industry with the basic raw material, i.e. wood. One of the most traditional definitions of the main factors in wood procurement includes wood buying, tree logging, transportation and raw material reception at the mill. Another, rather commonly used definition states that wood procurement comprises all technical and commercial activities that need to be carried out in order to provide wood raw material from forest to mill [29] [30].

Wood procurement logistics has however developed drastically during the last few decades. The adaptation of general logistics theory, increasing customer orientation, product-based bucking, the externalization of work processes, the expansion of international wood trade and the rapid development of management tools and methods have changed the characteristics of wood procurement tremendously. Consequently, there is a growing need to re-define the concept of wood procurement.

For many years already the international scientific community has employed the term Supply Chain Management (SCM) in conjunction with wood procurement [10][11]. SCM emphasizes the logistics interactions that take place between marketing, logistics and production [1]. The supply chain (SC) encompasses all activities associated with the flow and transformation of goods from raw material through to end user, as well as the associated information flows. SCM is the integration of these activities, through improved supply chain relationships, to achieve a sus-

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tainable competitive advantage [9].

When using the term SCM in conjunction with wood procurement, at least two things have to be taken into account that separate the wood supply chain from many other supply chains. Firstly, wood procurement represents a divergent product flow, where one raw material produces a number of separate sub-products [10] . This means that the raw material supplier participates in a number of supply chains. Increasing the effectiveness in one chain may decrease effectiveness in another. Secondly, the SCM concept in general includes both raw material supply (so called 'upstream') processing, as well as delivery to the customer ('downstream'). When applying SCM in wood processing, it has to be remembered that the concept also comprises decisions about what raw material sources are exploited, where factories are established and where markets are located. The forest industry has traditionally established factories either around the raw material sources (e.g. Finland, Sweden) or around the main markets (e.g. central Europe). While international wood trade is increasing rapidly, it is no longer certain that the forest industry will continue its investments in the Nordic countries.

In principle, a factory can arrange its wood procurement by itself or buy the service (raw material and delivery to the mill) from other companies [29]. If wood procurement is organized by the company itself, SCM philosophy can at least in principle be employed within the company without organizational constrains. In many circumstances it is however difficult to base wood supply completely on a company's own woodlot buying actions. Because, in most cases, the wood buyer has to buy complete wood lots, it has to decide what to do with those wood assortments that cannot be processed by its own factories. Accordingly, companies having their own wood procurement department or subsidiary companies are also forced, to a certain extent, to trade by barter of certain wood assortments with other companies. This is one reason why the forest industry has recently consolidated into bigger companies almost all over the world. Big forest companies having several different wood processing factories have to master several wood supply chains at the same time. It might lead to the overweighing of one wood supply chain and the under weighting of another. A company may even have a business strategy to do so.

How should wood procurement then be defined today? A new definition might be: Wood procurement is a process that integrates a number of technical, commercial and logistical activities aiming to deliver wood raw material to wood processing mills; and simultaneously taking into account the most important characteristics of the conversion process and end-product. Note that the conversion process can itself be defined in many ways. Bucking the logs according to customers' requirements in the forest can be considered as a primary stage of conversion. Moreover, chip storage at pulp mills are in some companies managed by wood procurement departments since they are also in charge of deliveries of chips from sawmills and plywood factories.

This paper attempts to lay down a general framework for the CTL method-based wood procurement management and to point out the most important research and development objectives in this area. The intention is to activate scientific discussion about the main challenges for future development in this area.

WOOD PROCUREMENT - DEFINITONS AND DESCRIPTIONS

The wood supply chain starts from **timber reconnaissance** (Figure 1). **Timber sale** can be initiated by a wood seller, wood buyer or consultation agencies. Prior to timber sale, forest stands to be sold need to be marked and delineated, and the volume of each wood assortment within the stands to be cut needs to be estimated. Through these activities the stand becomes merchandise, called **stumpage**. In a normal trading situation, there are several potential wood buyers that are competing for it.

The stand can be purchased as a **standing sale** when the wood buyer is in charge of harvesting and delivering wood assortments to the roadside, or as a **delivery sale** when the wood seller is in charge of these activities. Through the timber contract, the stumpage is registered in the company's **stumpage reserve** or **delivery reserve** depending on which one of the sale methods is chosen. These **timber reserves** form a unique method of managing the wood supply chain in the most efficient way. The wood buyer pays a deposit of roughly 20 - 30% of the estimated total amount giving the company permission to decide the exact harvesting time. In the old days, a company's wood reserves may have corresponded to wood usage of 10 to 12 months but are now commonly at the level of 3 to 4 months usage.

Once harvesting, off-road transport and **wood measurement** have been carried out, the final payment to the wood seller can be made. Consequently, cut wood can be registered as **roadside storage**. This process is generally called **timber receiving**. Wood measurement can be done at the roadside or by the harvester's measurement system. Wood is in most cases transported by trucks to the factory. Railway and waterway transportation must in most cases also be preceded by truck transportation. Through this preliminary transportation to railway and waterway stations, wood is registered as **railway storage** or **water-**

way storage. All wood transported to the factory is measured and registered as **factory storage**. This process is called **factory reception**. In addition to deliveries from its own wood procurement organization, factories also generally receive wood from external suppliers. There might be **imported wood** or **exchange trades** with other companies. In pulp factories wood is also received as **chip deliveries** from saw mills and ply wood factories.

inventories and use of less expensive forms of transportation. When service levels are pressed to their upper limits, logistics costs will rise at a rate disproportionate to the service level [3].

The geographic placement of stocking points and their sourcing points form an outline for the logistics plan. The number, location and size of the facilities and assigning market demands on them determine the paths through which products are directed to the marketplace. Finding the lowest cost assignments, or alternatively the maximum profit assignments, is the essence of facility location strategy. Inventory decisions refer to the manner in which inventories are managed. Allocating inventories to the stocking points versus pulling them through inventory replenishment rules represent two different strategies. The particular policy used affects the facility locations decisions and should therefore be considered in the logistics strategy. Transport decisions can involve mode selection, size of shipments, and routing and scheduling. These decisions are influenced by the proximity of warehouses to

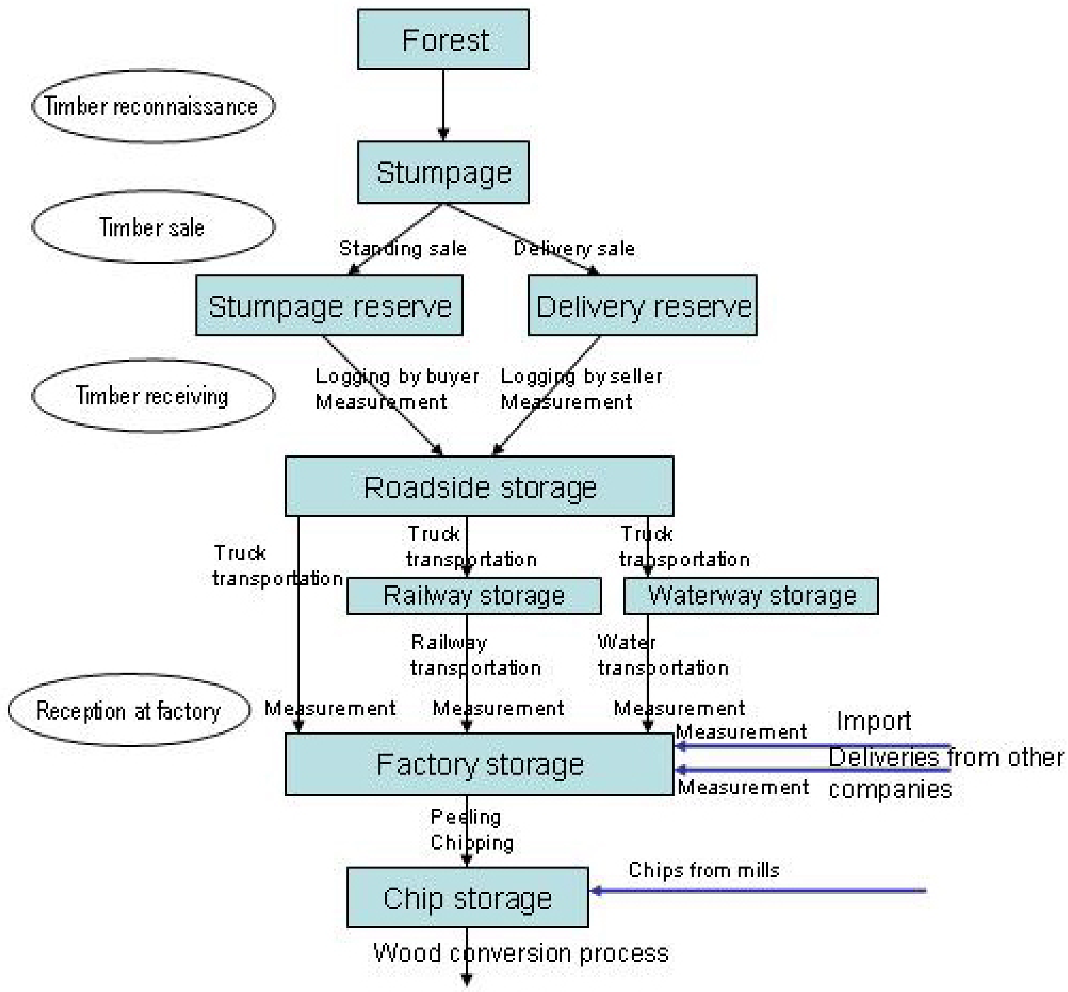

Figure 1. Flow-chart of CTL method-based wood procurement.

CHARACTERISTICS OF WOOD PROCUREMENT LOGISTICS

Logistics Planning in General

Logistics planning tackles four major problem areas: customer service goals, facility location, inventory decisions, and transportation decisions, as shown in Figure 2. These problem areas are interrelated and should be planned as a unit, although they are rather commonly planned separately. More than any other factor, the level of logistics customer service provided dramatically affects systems design. Low levels of service allow centralized

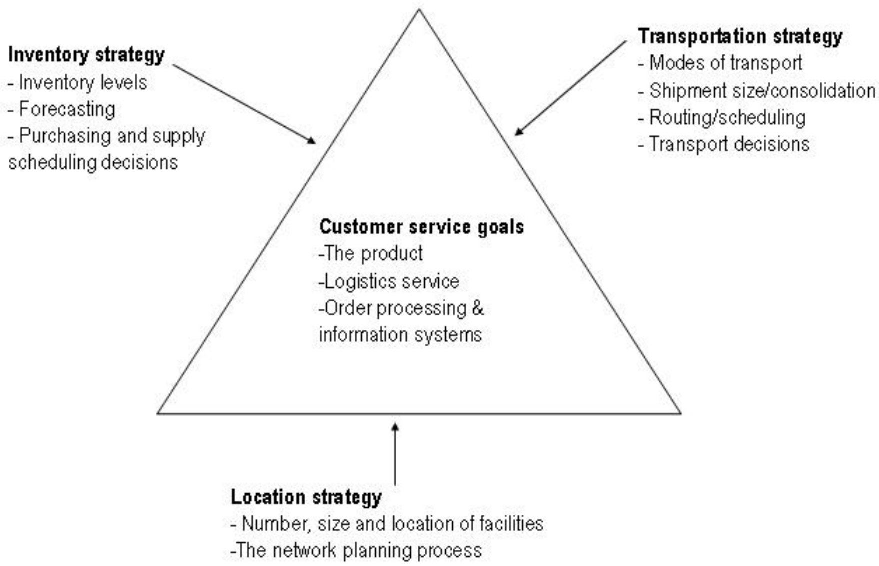

Figure 2. The planning triangle of logistics according to Ballou [3]. The illustration is a summary of several similar figures in the book.

customers and plants that in turn influence warehouse locations. Inventory levels also respond to transport decisions through shipment size [9][3].

Wood Procurement and Logistics Planning

Despite the unique characteristics of wood procurement, general logistics theory offers a good framework to examine the major processes of wood procurement. From many re-engineering approaches wood procurement management has recently been examined mainly within the framework of SCM [5][8][1][12]. Recent management activities in industry, however, indicate that more emphasis has been put out on Lean Management and Time-Based Management (TBM) that put a strong focus on minimizing storage costs and short lead times perhaps at the expense of the increasing cost of transportation and sorting. Much less effort has been put into increasing profits in the wood conversion process or for the final customer.

The planning triangle of wood procurement logistics is shown in fig. 3. In wood procurement it is useful to define the factory that makes the primary conversion as a customer. The needs of the factories are derived from the needs of their customers (secondary conversion plants, end-customers) but the enterprises may have totally different strategies to fulfill their customers' demands. Accordingly, one of the main tasks of strategic planning is to set out customer service goals. In wood procurement the main customer service goals are price, dimensional requirements, quality requirements and the ability to react to changes. The price is always important, but the smaller the proportion the wood cost is of the total production costs, the less significant the price becomes. The importance of quality and dimensional requirements increases with the rising value of wood. The most valuable wood parts are usually separated from butt logs meaning that the butt log quality has the most important role in providing extra income for factories. End-users are now more demanding than before in terms of dimensional requirements. While factories, dealers and users are urgently minimizing the size of their stocks; the ability to react to dimensional, qualitative and quantitative changes is becoming more important. It may be the most important customer service goal, even more important than the price of wood.

In the old days, factories were always established around raw material sources. Later, the development of transportation systems also made it possible to establish factories close to the markets. Since transportation of low value raw material is not cost-effective, close-to-market factories are usually paper or secondary conversion wood factories that do not use basic wood raw materials but raw materials that have already been converted, such as pulp, lumber, etc.

Wood is today increasingly transported between neighboring countries. In order to complement the raw-material demand needed for specific end-products, wood procurement companies have to work in the global wood market. It is, therefore, not only the location that affects the raw material source, but also the factory's need to calculate from which sources raw material should be acquired. There are basically three sources: a company's

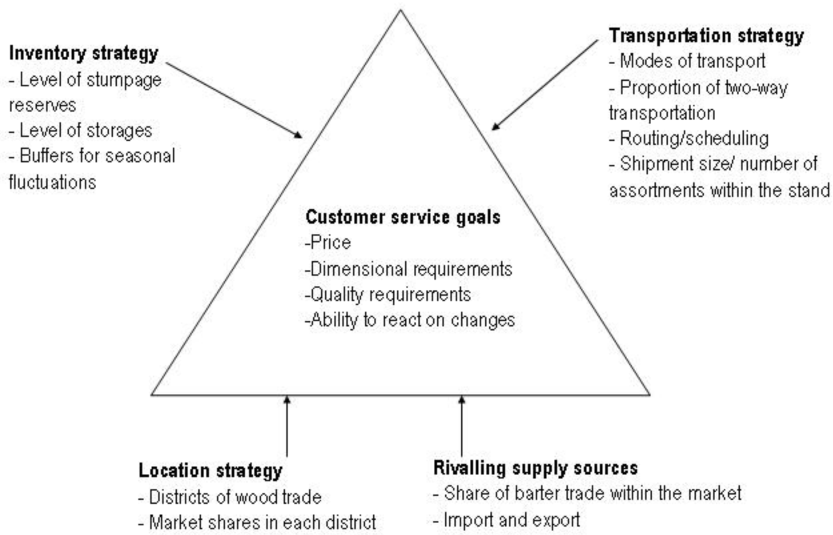

Figure 3. The planning triangle of wood procurement logistics.

own wood buying actions, other companies from the domestic markets and imports.

Organizationally, domestic wood procurement activities are often geographically divided into several wood procurement districts (catchment areas). The borders of districts generally follow natural wood flow directions, i.e. those areas are united into the same districts where the wood is transported to the same factories. Each district may have a different strategy in terms of market share, types of wood lot bought, wood price policy, etc. The borders of these districts and the strategies created for them are the most important strategic decisions made by wood procurement companies. These strategic decisions have crucial importance to the logistic planning and success of each company.

Transportation is more or less adjusted to meet the logistical restrictions provided by the market share policy and pricing policy. The stands bought from private markets need to be cut and transported to the company's own factories at any cost. There has been a tremendous development in transportation optimization systems in recent years that have considerably enhanced transportation and decreased cost [18][4][25]. The further the wood is transported, the less important the speed needed and the more important the price of each cubic meter per kilometer. Long distance transportation is usually carried out by high-volume vehicles such as trains and ships, while easily rerouted timber trucks are mainly used for shorter and middle-distance transportations. Recently, more attention has been directed to avoiding driving unloaded [32][7]. This can be achieved by increasing two-transportation possibilities as well as controlling the number of wood assortments from each stand. Stressing the importance of customer needs tends to increase the number of wood assortments cut from each stand, which inevitably leads to smaller shipment sizes, and thus an increase in driving unloaded and higher fixed costs.

Due to improved inventory booking systems and transportation optimization systems, wood procurement companies have managed to decrease stock levels, thus decreasing rate cost [4]. The company may aim to decrease the stock levels but not without possible additional costs. According to logistics theories, an increase in stock levels increases storage costs but, on the other hand, a decrease in stock levels increases transportation costs and the risk of lost profit [3]. Within the wood supply chain, small inventories may also lead to a loss in the optimal profit of conversion. Since the properties of wood vary markedly according to certain stand and stem properties, the lack of certain kinds of stands may cause value losses, since the wood is not converted most effective way (Figure 4). It is natural that quantity requirements come first and quality requirements are secondary.

The stock level has two different aspects; the number of storage facilities and the average storage size. A high number of storage facilities gives more possibilities to optimize routes of transportation in order to avoid driving unloaded. On the other hand, a small amount of one wood assortment from one storage point increases the share of fixed costs. Logistics is symbolically compared to the analogy of a Japanese lake that is also highly relevant in the case of wood procurement management [10]. This analogy refers to how reducing the water level in a lake (stock levels) brings previously submerged obstacles (production problems) to the attention of navigators. When the water level is high, boats have no problems in navigating on the lake. Lowering the water level makes navigation more difficult and increases the risk of shipwreck.

Seasonal Variation

Wood procurement is disrupted, in almost all parts of the world, by seasonal variation caused by tradition or nature. Variation caused by existing wood selling traditions can, to a certain extent, be influenced by economic incentives. Variation due to weather conditions cannot be directly affected but its effect can, to a certain extend, be controlled by good planning. Rains and high moisture content of terrain is the weather and seasonal factor that affects logging activities and transportation most [28][30][19]. Due to high moisture content, logging is annually shorter or longer periods are impossible. In the same climatic regions there are however differences in different types of stands. In Northern conditions, almost all stands can be logged during winter since soft soils freeze during cold winter times. Drier, sandy soils can be harvested without deep logging ruts even during high moisture seasons [31].

Seasonal restrictions are, to a degree, included in wood procurement planning procedures. Harvesting activities are highest during cold winter times and the level of mill stocks are usually increased before difficult spring times when the moisture content is highest in forests and on forest roads. Stumpage reserves are usually divided into winter stands, summer stands and moisture-resistant stands. The softest soils can be logged only during the frozen winter season, certain rich soils and dry soils also during dry summer seasons and only the driest heaths during the wettest spring and fall seasons. A similar classification can be made for off-road transportation restrictions.

Seasonal variation and the ability to react to changes have great significance on logistics costs in wood procurement. It seems that companies are very seldom in a peaceful, well-prepared situation, but activities are always affected by some seasonal (e.g. unusually high precipitation) or commercial reasons (e.g. a wood selling strike). There are several ways to improve a company's ability to react to seasonal variation. First, the system of harvesting and transportation qualifications during different seasons could be improved. The current system is based on forest officers' competence and rule-of-thumb estimations. Researchers should develop more accurate definitions that are based on geological facts and measurements of terrains and roads' accessibility.

Secondly, small stumpage reserves inevitably lead to expensive harvesting and transportation activities. Accordingly, it can be questioned whether short lead times and low storage levels have been taken too far in certain countries. A decrease in stock and stumpage levels is very important in times of high rates but has that been carried out at the expense of increasing transportation costs and a loss of profit in conversion? To some extent, the determination of the optimal solution is obstructed by the complexity of the calculation.

The Importance of Information Flow

Wood procurement is a part of the wood supply chain. The whole supply chain can be divided into a certain number of core processes (Figure 5). According to logistics theories, the supply chain consists of a material flow that provides profit for the owner of the process and an information flow that controls the material flow. Since certain factors in the wood supply chain are very difficult to measure or predict, information that can be received as a by-product from previous or following processes can have a crucial effect on the efficiency or quality of other processes. Transportation can be taken as one example. The recent enhancement of transportation in the Nordic countries can be explained by improved measurement and inventory systems. While harvesters are able to measure wood while harvesting and register the amount and quality of cut wood into the information systems, the optimization of transportation becomes possible due to exact information about the wood.

Analogously, tree bucking control has improved through more accurate requirements from the sales department aided by more accurate control at timber receiving. Future de-

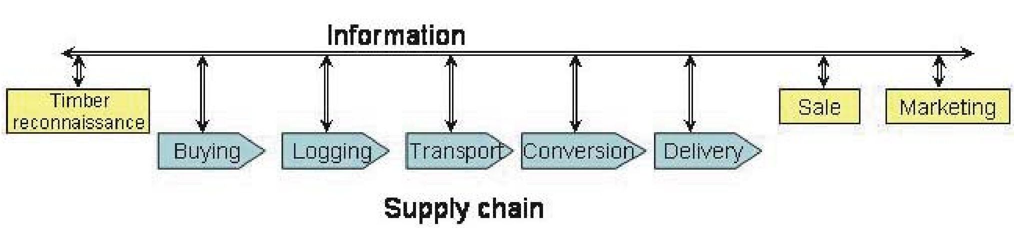

Figure 5. Information about the wood supply chain.

mands would include more accurate information about the composition of the forest stands in connection to wood buying actions. That would improve the planning of tree bucking control and would even make it possible to plan the bucking process and transportation process simultaneously. It is clear that all major technological steps in the future can only be achieved through improved information flow.

Supply Chain Optimization

The adoption of general logistics theories in wood procurement has already reduced logistics costs but it is obvious that further reductions require new thinking and radical changes in traditional wood trade habits. The process of producing logs from tree stems attaining the highest value is a denominated bucking optimization problem [23]. Recently, Laroze [16] has stated that bucking optimization problems occur at stem level, stand level and forest level. At stem level, the bucking pattern that maximizes the stem value should be determined. At stand level, the bucking pattern for each dbh class should be established, maximizing the aggregate production value. At forest level, a bucking program should be determined for each stand, maximizing the global fit.

At stem level, the bucking optimization problem is generally formulated using dynamic programming [24][20] although alternative approaches have been published as well [20][26]. Most stand level models have been formulated as two-level optimization problems in which the upper level of the model consists of the linear programming (LP) formulation and the lower level is a dynamic programming (DP) model which generates the variables of the LP [22][6][20]. Rather similar algorithms have also been presented by Sessions et al. [27], Pickens et al. [23] and Laroze and Greber [17], but they do not utilize the DP-LP connection as strictly. Kivinen and Uusitalo [15] have developed a fuzzy logic based method that can directly calibrate the price list of a harvester to optimize the stand level problem. The first forest level optimization procedures were recently presented by Laroze [17], Arce et al. 2002 [2] and Kivinen [14].

The classic dilemma in tree bucking optimization is that in order to achieve the maximum result at stand level it is to some extent necessary to compromise on the principle of optimizing individual stems. Moreover, a global maximum to the forest level problem requires us to compromise on the principle of optimizing individual stands. Recent works by have proved that it is possible to specify individual targets based on prior information about each forest stand [17][14]. Disregarding whether we consider the tree, stand or forest level problem, bucking control can be divided into two main tasks; which products (wood assortments) in what quantities we cut from each stand (wood allocation problem) and what kind of logs in terms of small-end diameter and log length are cut within one product (a product fine-tuning problem). American researchers have traditionally turned their attention to the first question while the European researchers have mainly focused on the latter question.

In the Nordic countries significant progress both in tree bucking control and transportation allocation has been achieved in practice but they are still considered as separate processes [5]. Due to heavy investments in research and training, harvester operators are today more skilful in controlling the bucking in such a way that the demand distribution of logs for individual sawmills can be satisfied. Although the number of different wood products has been growing rapidly, wood procurement companies do not have any decision-support system for how to react to the wood allocation problem.

It is in most cases undesirable to cut many products from the same stand, since it implies too many loading and transportation operations. Therefore, it would be necessary to choose which products in what quantities may be cut from each stand [2]. This means that the tree bucking control and wood transportation problem should not be considered as separate tasks but they should be optimized as a whole. If they are considered as separate processes the gains that are achieved as better product characteristics are being lost due to increasing transportation costs.

Forest level optimization can be carried out only providing accurate information on stand properties is available. We cannot rely on the optimization if the data is inaccurate. Therefore, the work that has to be done in order to define the correct data for the optimization is as important as the optimization process itself. Much recent effort has been devoted to predicting and modeling the diameter distribution of trees (e.g. [13]). Many researchers have also made excellent progress in modeling the inner knottiness of stems (e.g. [21]). However, this work in its current form cannot be utilized in tree bucking optimization. The future bucking optimization system will need comprehensive estimates of the joint distribution of the most important stem characteristics within each stand.

Providing accurate data on stand composition as well as forest level optimization procedures was available, there is still one obstacle that needs to be overcome before a new kind of logistical optimization is possible. Current wood trade is based on the measurement of single logs (veneer logs, saw logs and pulp logs) cut from each stem. Forest owners are eager to make sure that the valuable log section is always fully maximized. Log lengths can be con-

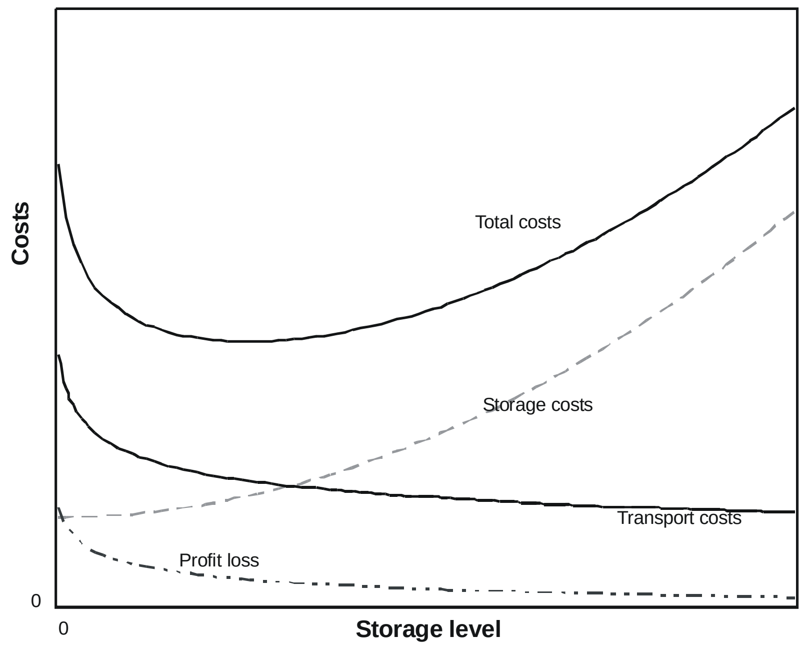

Figure 4. Contrary to general logistics theory, a decrease in stock levels not only increases transportation costs but also causes potential profit loss since wood is not converted in the optimal way.

trolled only within a section that fulfils the requirements of each wood assortment. Efficient forest level optimization requires wood to be cut according to end-users needs. Technically, the measurement and cutting processes can be separated if needed. Modern harvester heads could measure the volume of certain wood sections even if cutting was executed according to users' needs. This kind of stem-based pricing is, to some extend, carried out in Finland and Sweden but not in the context of forest level optimization.

CONCLUSIONS – MOST IMPORTANT RESEARCH AREAS IN THE FUTURE

The most important factors that obstruct the further reduction of logistics costs are seasonal variation, wood trade traditions and a lack of accurate information about the stand composition. The effect of seasonal variation can, to a certain extend, be compensated by better planning. An increase in the level of stumpage reserves enables companies to divide stands into more detailed soil and transportation classes. Before that, better terrain classification systems need to be developed that are not based on descriptive definitions but on geological facts, soil moisture prediction models and accurate soil mechanics measurements.

An increase in stumpage levels requires the adoption of new procedures in wood trade. Stands situated close to main roads and those on hard heaths will, for logistical reasons, be very important in the future. A more accurate cost comparison is needed in the future to calculate the advantage of those stands. On the other hand, stands on soft soils will be even less attractive in the future than today. The increase of stumpage payments from hard soils may in future be compensated by a decrease in stumpage payments from soft soils, but companies need better ways to calculate the advantage and disadvantage of each category.

The need and intensiveness of round wood storage also needs be reconsidered in the future. Providing the proportion of moisture resistant soils decrease in the future, there will be a growing need to increase the proportion of winter time logging and to further develop storage systems. In Finland there has been a growing trend towards covering spruce pulpwood logs under a thick snow layer during wintertime to guarantee the supply of paper mills during the summer season.

The release of current wood trade systems in the Nordic countries would provide lots of new possibilities in the field of logistics. The separation of the measurement and cutting process would at the same time give forest owners full payment for those wood sections exceeding certain dimensional and qualitative constrains, but would also allow the industry to allocate wood in the best possible way. Recent studies by Arce et al. [2] and Kivinen [14] indicate that that kind of optimization could be technically possible in the near future.

Forest level optimization necessitates accurate information about stand properties. Tree-by-tree optimization of cutting (that affects following logistical paths) prior to harvest can be executed only when we have accurate information about dimensional and quality distributions of each tree species within each stand. Although there have recently been several studies that have focused on this subject, there are rather few examples of practical solutions. It might be that researchers have to prove the necessity and the value of improved information in euros or dollars before the forest industry is willing to discuss new solutions.

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