The Box Assignment Problem in Log Yards

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Abstract

This paper presents an optimization approach to minimize log yard round wood transportation time for a medium sized hardwood sawmill. The log yard is the first processing step in a mill and it has to ensure a smooth raw material supply to the entire production process. The log yard also serves as an internal storage and provides sorting capacity for the mill. Thus, an optimal assignment of ejection boxes, storage boxes and feeding carriages is required to minimize transportation time at a log yard. The main contribution of this paper is to present an integrated approach which considers log transportation time, storage capacity and yard crane deployment, simultaneously. Therefore, the optimization was performed in these three steps: definition of storage spaces per assortment, calculation of distances and finally the calculation of the optimum material flow by means of an heuristic model and a binary integer problem.

Introduction

Round wood is sorted and stored before processing at the log yard. According to the different log diameters and qualities, different storage boxes are used. This paper deals with the arising box assignment problem at log yards in order to minimize overall transportation distance from ejection boxes to storage boxes and further on to the saw line. Although the box assignment problem in log yards is daily routine and not new we are not aware of a paper which presents the formal problem and proposes a solution approach. Data used throughout the paper are provided by a hardwood sawmill with an annual production capacity of 30,000 cubic meters.

Research for improving sawmill's productivity mainly centers around cutting pattern generation (see Todoroki and Rönnqvist (2002) and Yanasse and Limeira (2006)). But in order to improve operating efficiency additional material flow consideration are required. Mendoza et al. (1991) present one of the earliest papers dealing with the topic of hardwood sawmill optimization and Randhawa et al. (1994) show the topic of object orientation for sawmill simulation.

Greigeritsch et al. (2007) focus on the short term production planning and discrete event material flow simulation using simulation for finding the system bottleneck and planning tasks for scheduling an optimized production whereas Gronalt and Greigeritsch (2008) present an analyzing tool for supporting sawmilling industries by using a detailed material flow evaluation and modern computer simulation techniques. Hence, no direct applicable solution for the log yard planning and optimization could be found in literature.

The objective of this paper is to show how an easy to handle logistic optimization approach, concerning the log yard of an European middle size hardwood sawmill can be performed. Considering that the software of choice has to be easy to handle and unproblematic applicable with a commercial available computer system, Excel is used for the optimization of the model. It is assumed that Excel will not provide the optimal solution, so Xpress is used for comparison.

Material and Method

In a sawmill logs are sawn into several board dimensions during the initial production process. During the production, the characteristics of a log impact processing times, quality and yield of the produced boards. In general these log parameters can be defined by specie, grade and scale. Grade is the determination of the log quality which reflects the estimated yield of the lumber, while scale means the volume of a log which is measured in cubic meters. The log yard serves as a storage where logs are stored according to their diameters.

Process description

The analyzed sawmill produces three main hardwood species: beech (Fagus sylvatica), European oak (Querqus robur/Querqus patrea), European Ash (Fraxinus excelsior) and a small amount of softwood. As beech production accounts for app. 75% of the total annual production, the log yard will be optimized for this raw material segment. Therefore, the assortment arrangement changes 3 to 8 times per year while the changes mainly depend on species and length changes. Before the sawing process logs are measured, cut to length, sorted and stored on the log yard.

Clearly, the production rate at the sawmill must cope with the feeding rate of the logs and the yard crane productivity. Fig. 2 shows a typical log yard layout and the log's flow. The layout is used as a starting point for our calculations. Before being placed on the conveyor system {1} the logs are sorted by species and pre stored. In the system the logs are at first two dimensional measured by means of an opto-electronic measurement device. The combination of log shape and human quality grading identifies the optimum cut in length {2} which ranges in this case from 3.5 to 6 m in 0.5 m steps.

The metal detector {3} analyzes metallic enclosures when the log passes through its electric field. If metal is enclosed the field shifts, what can be measured. The position of the metal is marked by color and the log is ejected. Having passed the metal detector, the log is on the sorting line were the logs are ejected according to diameter and length {4}. The sorting line consists of a chain conveyor with mechanic ejectors, putting the logs into one of eighteen ejection boxes.

If a certain box {5} is full, a gantry crane {6} transports the logs into one of the assortment storing boxes. The crane moves with a speed of 80 m/min (crane) and 100 m/min (diagonal) respectively. The ultimate load of the crane is according to machinery data at 8 tonnes. As the claw has a weight of 0.7 tonnes, the effective bearing load is at 7.3 tonnes. The capacity of transportation depends on the relative density of the beech logs, yielding about 1.0 tonnes per cubic meters in moist condition. Assuming this the log diameter and the log weight restrict the transportation capacity. In contrast to that the storing box capacity depends mainly on the log diameter. In current status, storage boxes are designed to cover a high variability of assortments. When one assortment is finished the logs are transported to the sawmill charging {7}. Straight before the sawing process logs are debarked. The debarking process directly before the sawing process offers a natural protection layer. Even more this process chain permits the distribution of clean logs to the saw as all contamination is removed in combination with the bark {8}. The level of a finished assortment is determined first visually depending on the filling degree of the storage box and second in correspondence with the gained measurement data of the volume determination. In this case the sawing process is done by means of a frame saw. The limiting factors of this saw milling technology are the maximum width which can pass the frame, meaning the maximum log diameter. Other effects are the downtime if the sawing pattern has to be changed and the consumed energy which depends on the number of saws clamped in the frame.

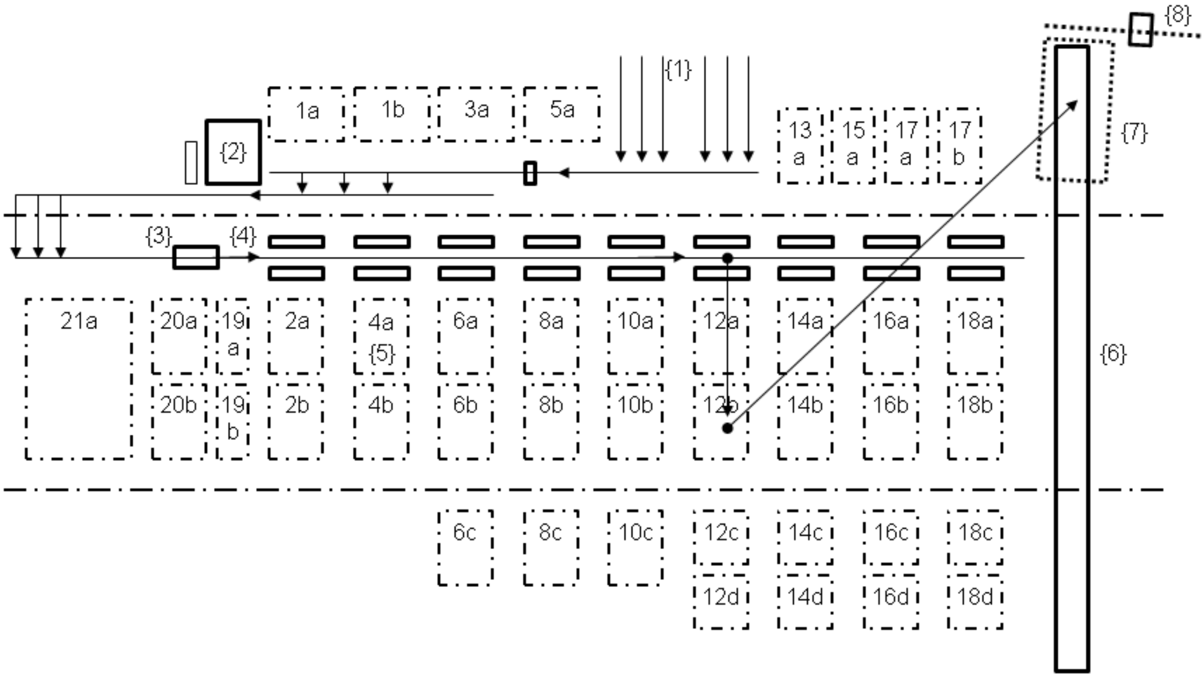

Fig. 1: Original shaped log yard with 42 storage boxes

The objective of this study was to optimize the log yard performance by reducing the overall average transportation distances. To achieve this, at first the feeding amount per hour and shift was calculated. Following on this the assortment size per shift (8h) is determined. Subject on this value the storage volume and the needed space are calculated and optimized respectively. To generate a comprehensive optimization model, the crane transportation time from eject box to storage box and finally to the sawmill feeding are measured and calculated using the construction planes of the yard. As a simplification the number of storage boxes have been reduced in the first place to ensure an assignment without distribution of the assortments to several storage boxes.

Model formulation

The box assignment problem is a special application of the capacitated facility location problem (CFLP) and formulated below as a binary integer problem. It is assumed that the company operates a mill with a log demand D per shift leading to a required storing capacity of CAP_s per box s. This creates a number of transportation moves N_a for each assortment a. A comparison of the original box width with the assortment volume, which is needed to operate the mill for one shift shows, that only fifty percent of the batches can be stored in one single box. The other assortments would have been needed to be stored in two boxes. This leaded to a reorganization of the log yard with a reduction of storage boxes.

Double-stage model

First the double-stage method is analyzed, where the assignments are solved sequentially. The first stage is to assign the assortment a to the storage boxes s considering the available storage volume and the logical assignment constraints. With the result of stage 1 the next instance is going to be solved. Therefore, the best assignment of assortment a to ejection box e is calculated. Hence, the transportation time is minimized in both steps.

Partition model

For simplification the number of boxes has been reduced and in addition the fragmentation of an assortment is not allowed in the previous described double-stage model. As an expansion the solution of a model where the assortment can be divided into several storage boxes was investigated. Furthermore the assignment of ejection and storage box is conducted simultaneously in this model.

Real world decision rules

The aim of this work was to generate a system which offers an industry applicable solution of the log yard box assignment problem. This leads to an algorithm based on simple iterative Excel spreadsheet calculation models. A series of inter connected spreadsheets containing transportation time, transportation distance, manual blocking, box width and further exclusion criteria as for instance minimum and maximum values for box width and single usage criterion were generated. This approach provides the application of the model directly at the control panel of the operator, making the interaction very user friendly.

The double-stage approach was also implemented as an heuristic in Excel. The restrictions of the volume of assortment a excluded certain combinations from the beginning on. From these combinations the minimum transportation time was chosen and ejector, storage box and assortment were blocked for the following selection process. The used algorithm is shown in Fig. 2.

$A_0 = A$
while $A_0 \neq \{\ \}$ **do**
    for $i \in A_0$ **do**
        find minimal TT_s
        move (pick $s \in S$) is **forbidden**
        assign corresponding assortment i to box s
        remove i from A_0
    end for
end while

Fig. 2: Heuristic Algorithm for box assignment problem

Conclusion

The Log Yard and Box Assignment Problem has been modeled in a new way which guarantees a production optimized and time transparent solution. The model is flexible enough to deal with variations of the production volume and intermittent blocked boxes. The solution methods of the problem are adapted to the variations, corresponding to the changes.

Future work should be performed analyzing the gained data in comparison with real data. In practical application it is possible to confirm the exact generation of the optimization models. In this paper the model is based on feeding data and log storage yard spacing regulations meeting direct production data in contrast to theoretical approaches, which do not take advantage of structures in the problem data. Nevertheless, the model presented in this paper shows a valuable way of solving logistic problems in wood products industry.

Furthermore, different wood types in the same planning period and changing demands of diverse diameters should be considered.

Further work should be done on the optimization of the lumber yard. The lumber yard shows a high variety of different species, grades and even more important, a high variation in turnover frequency.

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