Original Research Article||

Performance evaluation of Debre Birhan based plywood manufacturing company, North Shewa Zone, Ethiopia

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Abstract

The demand for building wood material in Ethiopia is increasing at alarming rate, resulting in increases in product prices. To overcome wood shortage, Ethiopian government has opened an opportunity for foreign investors to establish different types of wood product factories in the country. However, efficiency of these enterprises needs to be study to find out any irregularities which needs to be improve in the future for better performance of these companies. So the initiative was started from one of such plywood based factory, Debre Birhan plywood processing company with the objective to assess the operational performance of the company. A multi-stage sampling technique was used to select representative respondents. The data were collected through questionnaire surveys, interviews, observation records, and document review. Non-financial perspectives were explored using key indicators of operational performance associated with resource utilization, quality management, and operational practices. Data collected were analyzed using descriptive statistics of SPSS Version 20. Results show that Debre Birhan Wood Processing Company produces three categories of plywood (5-ply, 7-ply, and 9-ply) but lacks veneer thickness standards. The operational processes are categorized as log storage, debarking, bucking/trimming, peeling, green-clipping, drying, grading, gluing, panel layup, pressing, trimming, sanding, packaging, and processing activities. Performance indicates needs for improvement to quality management standards. The mean value of quality management criteria implementation using variable characteristics of log such as log form, dimension, and defects were 3.26, which shows intermediate achievement. The average performance of the company's production capacity over the four years was 81.53%. It is recommended that the company use the available resources efficiently to grow in a competitive market and keep up with modern information.

Key words: Performance, plywood, quality criteria, veneer, wood processing

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INTRODUCTION

The world's trade in wood is predominantly in primary or secondary products, and their contributions, such as construction materials, electrical poles, paper manufacturing, furniture making, and other building materials, are vital to the economic growth of society (EFAP, 1994; FSR, 2015; Brack, 2018). The sustainable production of wood has the most important to role in fulfilling the diverse outputs and services values (MEFCC, 2018). Forestry-related products are in great demand and increasing actively in Ethiopia (Rawat and Tekleyohannes, 2021). FAO (2016) reports strong growth in the production and consumption of wood-based panels and sawn timber; the global production in 2013 was increased by 8% and 5%, wood-based panel products, and sawn timber, respectively. A very modest growth (<1%/year) was quantified for pulp and paper production. Rawat and Tekleyohannes (2021) found primary and secondary forest products manufacturing is expected to increase from the current 112 million m^3 to 158 million m^3 by 2033. Infrastructural expansion and remarkable building activities are responsible for rapid increase of wood-based products in construction materials (MEFCC, 2018). Expanding the production potential of wood product companies to succeed with rapidly growing construction activities is essential (Bekele, 2011).

Industrial wood products are sawn wood, wood-based panels (plywood, fiberboard, chipboard), and paper (Bekele, 2000). The two types of plywood are structural or non-structural (APA, 2012), where structural plywood is used for construction purposes and non-structural plywood is purchased for aesthetics value and have high-quality face and paint. To supplement the limited supply of plywood products from domestic sources, the country is importing the product from abroad (Lemenih and Kassa, 2014; Alem, 2016; Rawat and Tekleyohannes, 2021). On the contrary, Debre Birhan wood processing company is a top company established for manufacturing structural plywood utilized in the domestic market. Besides, wood processing company has shown growths to process highly demanded wood products in the country, yet gaps exist. Bottlenecks to the expansion of industrial wood processing were not clearly described and the processing limitations and wood processing performances were not well-documented in the wood processing industry (FSR, 2015). Validation should be forwarded as production planning and scheduling and that they are efficiently utilizing the available resource.

Limited research has been conducted on quality standards, productivity, and production capacity of wood processing companies. Additionally, there is a limited identification standard used for log selection in utilization for face, back and interior veneer of plywood work. Therefore, this research has been conducted to respond to the company's veneer and plywood product processing and quality performances. In addition, the finding also focused on log supply efficiency, processing performance, and production success at Debre Birhan wood processing company.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Debre Birhan wood processing company, located in the Amhara regional state, North Shewa zone which is approximately 120 kilometers northeast of Addis Ababa, the capital city of Ethiopia. The study site is located between 9°41' N latitude and 39°32′ E longitude at an elevation of 2,840 meters above sea level. The average annual temperature and rainfall ranges between 20.7ºC and 8.2ºC and 814-1080 mm, respectively. The company is a principal construction plywood manufacturer in Ethiopia. It is a share company between Amhara Forest Enterprise and a Chinese investor with a proportion of 51% and 49% shares, respectively. Now the company is running with fully covered Ethiopian experts after four years of aggressive effort of knowledge transfer from the Chinese experts.

Sampling Procedure and Sample Size

A multi-stage sampling procedure was employed to select representative respondents. In the first stage, as par discussion with human resource department all company staff members were classified as management staff members and production operation staff members. The target populations were the employees of Debre Birhan wood processing, primarily those from management and senior production professionals. As per identification based on their job position 13 permanent employees in management staff and 125 Production operations staff were listed, which 138 of total population was quantified for sampling. Secondly, respondents were selected using random sampling for production operations staff. Sample size was determined according to the formula described by Gill and Johnson (2002). Equation (1) is used to compute the initial sample size. Since the initial sample size (eq-1) is above the population, their equation (2) is used to compute the new sample size.

In the third stage, the sample respondents were selected proportionally. All management staff (13 individuals) and 89 production staff were interviewed.

$$n_0 = \frac{Z^2 \times P(1-P)}{e^2} \qquad \textit{Eq. 1}$$

$$n_f = \frac{n_0}{1+\frac{n_0-1}{N}} \qquad \textit{Eq. 2}$$

Where; n_o = initial sample size, n_f = target sample size, Z= Z-value for Confidence level (i.e., 1.96 for 95% confidence level used in this research), P= percentage picking choice (i.e., 0.5 used for this research), e = confidence interval (i.e., 0.05 used), N = Total population

$$n_0 = \frac{1.96^2 \times 0.5(1-0.5)}{0.05^2} = \underline{384.16}$$

$$n_f = \frac{384.16}{1+\frac{384.16-1}{138}} = \underline{102}$$

Data Source and Methods of Collection

Both primary and secondary data were collected. Primary data included annual volume of material processed, marketed, wood raw material input-output relationship, the operational performance, and challenges affecting the operational performance. Primary data were collected using questionnaire, interviews, and physical/technical observations. Multi-stage interviews were held with unit and middle-level management divisions, and professional employees were also included in a face-to-face interview. Interviewees were purposely selected from department leaders including heads of the production with technical teams and administrative authorities within the company. Respondents for the interview were selected and arranged from departmental management, production workers and machinery technical heads, human resource department, procurement department, and property and logistics case team. Physical/technical observations were used to assess the manufacturing techniques in the production processes as well as the raw material supply quantity, and quality in the company.

Secondary data sources were collected from the company's various reports, production documents and data, and website of Amhara Forest enterprise (AFE) to validate the data collected from primary sources. Secondary data included the annual volume of wood utilized and the output produced, and identification of season for less output produced.

Veneer and Plywood Production System Model

***Log allocation*:** The section is concerned with optimizing the supply of logs needed for the company considering the log length (straight over 2.7 m), diameter (as per sort of machine intake capacity), and defects free as suitability indicators for use. The model is used to outline the appropriate method and type of wood with the company requirement. Veneer and plywood operation represented one of the utilization centers to evaluate the proper allocation strategy of log for the production.

Generally, component manufacturing consists of a series of connected processes that convert the input material into the final product. Thus, the performance of the manufacturing process depends on how well the resource is balanced between the process and within each operation. A generic model for the evaluation of the performance of manufacturing was presented in Figure 1.

Production and Quality Performance

There are four specifications that are used in veneer grading operations. These are represented by A_1, A_2, B, and C grades assigned by the quality management team in the company. In data collection the criteria for each grading were assessed using interview and physical observations. Data collection were based on veneers length and width; quality, full-sized, surface smoothness, knot, surface hole use as the back and face of plywood products. A_2-grade is smaller veneer; veneers having some defect but small size and easily repairable. Quality parameters on plywood products were classified based on their back and face surface sheet quality. Plywood grades are classified into two: A-grade and B-grade type plywood. Data was collected using interview with store managers on time and criteria for plywood grading to be A-grade plywood products or B-grade.

The production capacity of the company was assessed using the trends from four consecutive years, and the performance results were calculated using the following equation.

$$PP\ (\%) = \frac{Actual\ annua\ production}{Planned\ annual\ production} \times 100$$

Where PP = production performance

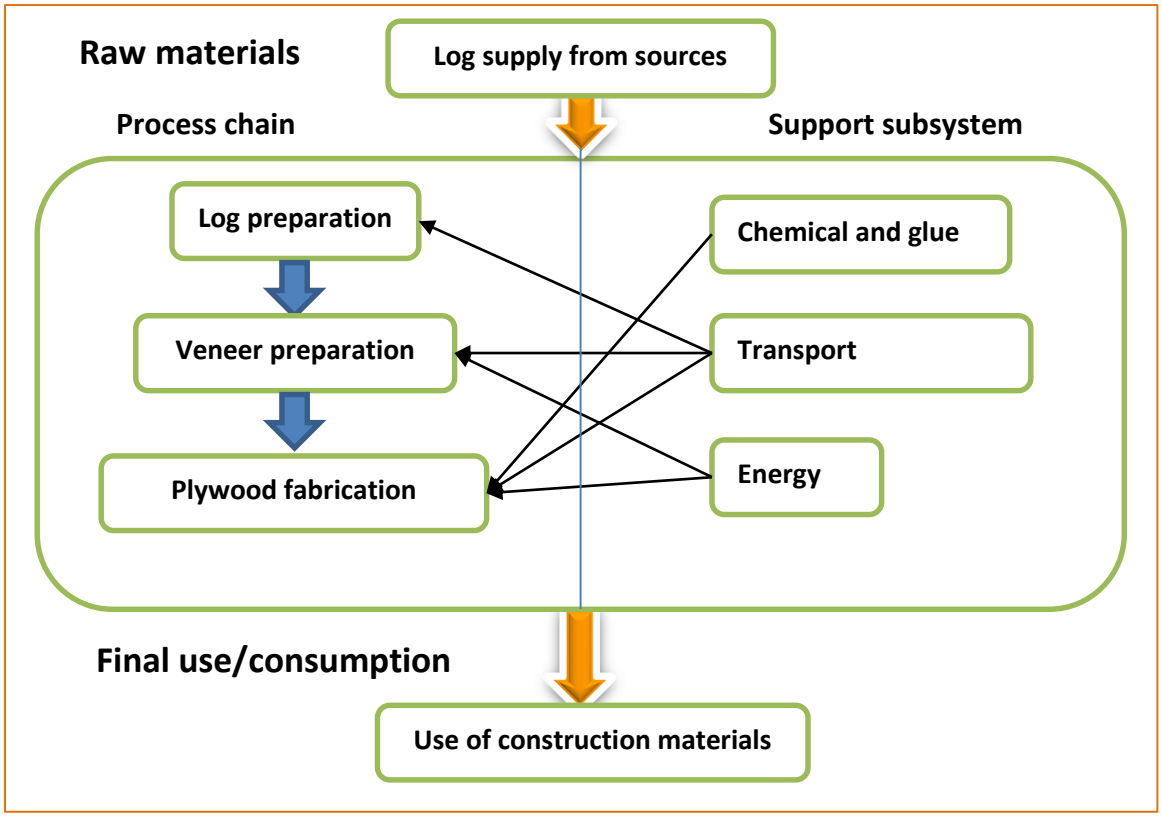

Figure 1. Veneer and plywood processing systems model

Data Analysis

The collected data were analyzed using the qualitative and quantitative data analysis methods. Before analyzing the data, raw data were processed (coded, edited, ordered, and organized) to generate relevant information. Descriptive statistics were used to analyze and understand the issue covered with production performance and current challenges that influence company performance improvement. The collected data were analyzed using each qualitative and quantitative evaluation methods. Qualitative evaluation methods were held with data collected in the form of descriptions while the quantitative analysis method was related to the numerical form of data. The Statistical Package for Social Science (SPSS version-20) and Microsoft Excel were used for analyzing data. Mean, frequencies, and percentiles analysis were used.

RESULTS AND DISCUSSION

Company Product Description

Veneer and plywood are produced at Debre Birhan wood processing company (Table 1). The veneer products were categorized based on the length and width for the two veneer types and the number of laminated veneer sheets for plywood products. Result indicates that the differences in veneer products were the length and width but the same thickness were manufactured. In the manufacturing process at the company the actual thickness desired was 2 mm and the considered value for shrinkage after drying and the machining lathe adjustment error was 0.2 mm. Similarly, Barbara (2014) stated that Australian Standard veneer drying shrinkage and machining distortion from Eucalyptus was +/-0.2 mm. The plywood products fabricated in the company were classified based on their number of plies/sheets and represented as 9-ply, 7-ply, and 5-ply with an estimated thickness (mm) of 18, 14, and 10, respectively. The most quantitatively produced plywood type was 9-ply type due to dominance in the market demand. The other two types (7- and 5-ply) plywood products are manufactured only on order by customers. APA (2012) stated that plywood thickness varied with the variability in exit moisture content, the pressure used for pressing, and a difference in thickness of veneer used for exterior and interior parts of the product than layer quantity.

Table 1. Dimensional description of veneer and plywood product types produced by Debre Birhan Wood Processing Company

Product type		Length (m)	Width (m)	Thickness (mm)
Veneer	Face veneer	2.50	1.45	2.2
	Interior veneer	1.30	0.70	2.2
Plywood	5-ply	2.44	1.22	10
	7-ply	2.44	1.22	14
	9-ply	2.44	1.22	18

Log Thickness Preference

Log thickness preference was measured and assessed using the survey questionnaires. The company's standard log thickness range was 13-45 cm. The discussion with log supply and quality managers indicated that the minimum and maximum thickness of logs were not continuously implemented for the scarcity of log supply at the rainy season. The thickness limitation to the maximum of 45 cm was restricted based on the intake capacity of the peeling machine, where logs thicker than the given ranges in diameters cannot be peeled. In general, with the specified thickness and machining capacity the professionals' preferences were obtained (Table 2).

Table 2. Log preference on the basis of diameter (large as >25 cm and small diameter were 13-25 cm Eucalyptus globulus log)

Log types	Frequency	Percentage (%)
Larger diameter log	81	82.65
Small-diameter log	3	3.06
Both	14	14.29
Total	98	100.0

Implementations of Log Quality Selection

The selection criteria of the company on five-point Likert scale and all these criteria were considered for a face veneer log (Table 3). The result indicated that the highest consideration in log selection was straightness (minimum of 2.7 m) and followed by knot-free, and then log with required diameter measure (13-45 cm) which are highly achieved for acceptance. On the other hand, characteristics of stump-pull/felling split, log handling damage, fungal decayed wood, and large-sized knot were among the criteria with high achievement to reject. Intermediately achieved selection criteria was shape, and growth defects. Finally, the least consideration was given to taper ratio measurement, lengthwise curvature/bend, check/shake, and logs with insect damage. A similar study by Barbara (2014) also indicated that the selection of quality logs used for veneers also needs proper management of logs during transport and supply handling. Furthermore, the overall mean result of the log quality implementation (3.26) indicated that the performance of the company is intermediate. According to Barbour (2001), the three most important criteria in specifications used by buyers and sellers with at least good implementation as criteria to determine the value were log grade, scale, and species. Bennett (2014) also confirmed that there was a strong negative relationship between lumber recovery percentages and log taper. Contrary to the literature, the consideration of log taper ratio as a criterion by Debre Birhan Wood Processing Company was very poor.

Table 3. Extent of implementation of various log quality practices for the company

Group	Variables measures	Min	Max	Mean	Std. Dev.
Criteria to receive	Straightness of log along 2.7 m	2	5	4.22	0.806
	Log diameter require as per machine capacity to peeling processes	1	5	3.93	0.933
	Cylindrical in shape	1	5	3.39	1.232
	Knots free log	1	5	4.19	0.713

	Minimum taper ratio	1	4	2.42	0.884
Criteria to remove	Lengthwise curve/sweep of log	1	5	2.09	0.838
	Log of abnormal/growth stressed	2	5	2.72	0.928
	Stump pull and felling split	2	5	4.00	0.812
	Log handling damage	1	5	4.07	0.828
	Sized holes on a log	1	5	2.96	0.994
	Log with the bumpy surface	1	4	2.98	1.184
	Log with shake/check	3	5	2.11	0.884
	Frequent but small-sized knot	2	5	3.34	0.849
	Large-sized knot	2	5	3.97	0.779
	Insects damaged	1	4	1.79	0.763
	Decayed wood	3	5	4.01	0.711
Average of mean and SD of criteria achievement				**3.26**	**0.88**

Veneer and Plywood Processing

The company's veneer and plywood production operation process with their supportive processes chains under the study is shown in Figure 2. The process includes bucking, debarking, peeling, green clipping, drying, grading followed by gluing, layering, cold pressing, hot pressing, trimming, defect sanding, and plywood grading.

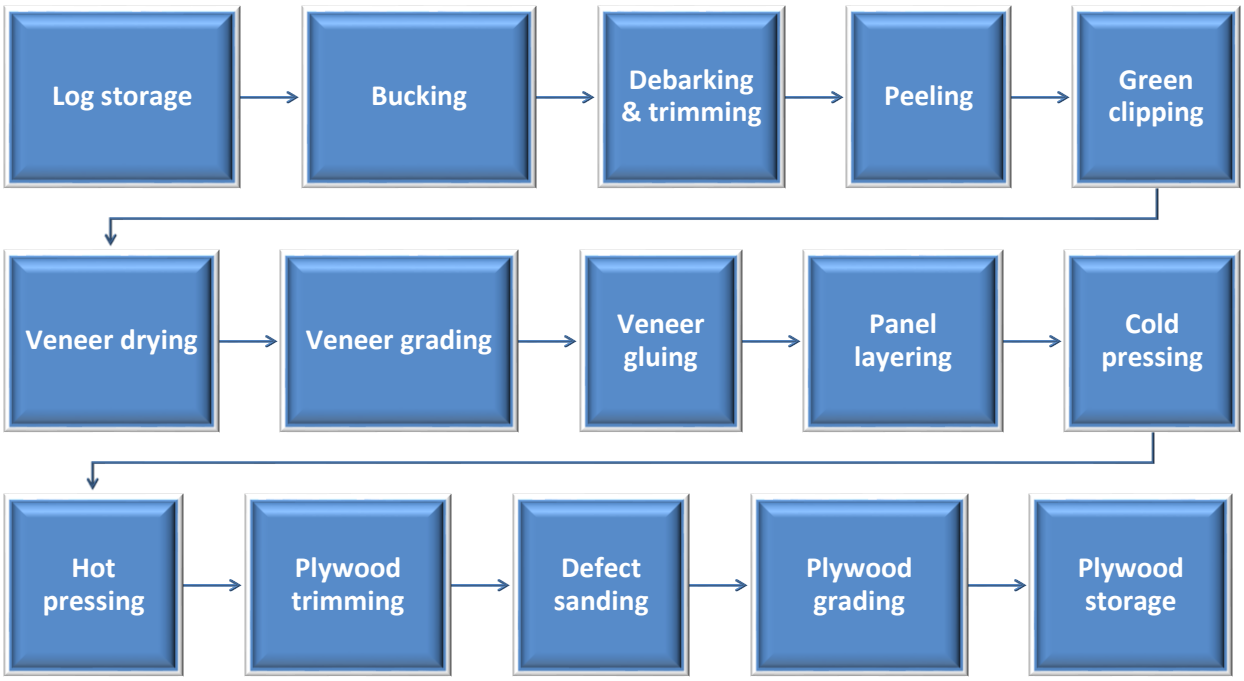

Figure 2. The complete operational activities for plywood fabrications

Log Preparation Processes

The preparation process includes log handling/storage, bucking, debarking, and trimming activities (Figure 2). The company's cut-length were 2.5 m for a face veneer and 1.3 m for interior veneer parts. Similarly, Irle et al. (2010) stated that the common cut lengths used by the majority of veneer manufacturing companies are 2.7 m for face veneer logs and 1.3 m for interior veneer logs, respectively. Bark removal was applied using the log debarking Spindles of Lathe technology through manual mounting which conveys good skinning effect. Similarly, Leggate et al. (2017) stated that using Spindles of Lathe debarking machine is usually with a more basic design, and is well suited to small operations and small-diameter logs. The problem in preparation phases is lack of log conditioning

(heating/soaking) processes due to short time storage of logs. This short time storage date was indicative of high log utilization capacity relative to the supply of logs. Moreover, the company doesn't have log dipping pond. Contrary to this Emmanuel (1993) indicated that logs of especially hardwood species need to be conditioned to soften the wood to facilitate peeling and to produce an acceptable quality of veneer through soaking in hot water, exposed to live steam or hot water sprays. Figure 3 indicate the most basically applied log preparation processes exercised in the Debre Birhan Wood Processing company.

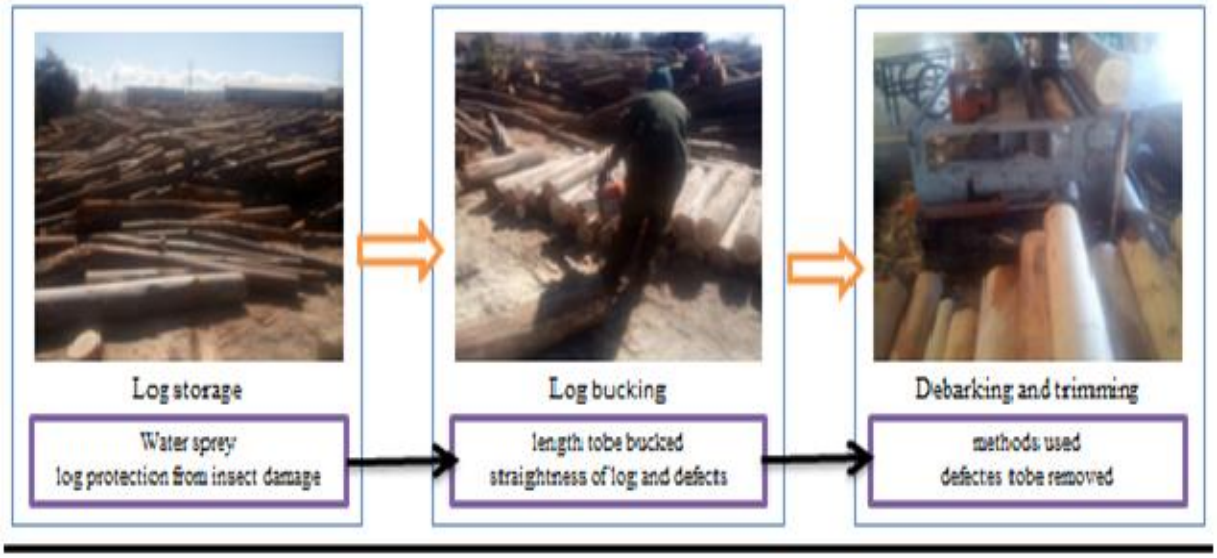

Figure 3. Log preparation activities of the first work-flow for the company

Veneer Preparation Processes

The second comprehensive class of time-intensive operations in the company is the veneer processing class, which starts with log peeling and ends with veneer grading. Figure 4 indicates the peeling operation in the company that is done using rotary peeling methods with a Spindles of Lathe veneer peeling machine. The method is the best for effectively utilizing small-diameter logs to recover more veneer from low-grade logs for manufacturing interior veneer and producing a more uniform cut. The performance report from Debre Birhan Wood Processing company was supported by Leggate et al. (2017) from Australia, where the majority (>90%) of the veneer companies use rotary peeling for a maximum yield. The rotary peeling method is preferable as it results in the widest sheets; with knots cut to show the smallest cross-section, where most small-sized wood and splits are left in the core. As reported by McGavin (2016), rotary veneer processing using Spindles of Lathe methods can efficiently process young fast grown hardwood plantation trees with resulting veneers containing visual grade qualities and mechanical properties suitable for the manufacture of structural veneer-based products. The veneer was conveyed from a peeling machine with a cut-width adjusted to 1.45 m for the face and 0.7 m for interior veneer). The veneers were clipped manually with pressure acting from two sides, applying critical care for quality.

Veneers are dried using solar- and air-drying systems for the summer/dry and winter/rainy periods, respectively. There is difficulty of regulating the standard moisture content due to unavailability of drying machine. The moisture ranges of 10-12% for the face and 7-9% for the interior veneers are tolerated after drying, which is in line with the report of Walker (2006) for plywood manufacturing having 6% to 12% range of moisture for the veneers. Furthermore, Zhang et al. (2006) described the need for veneer sheets to be dry before peeling/clipping to prevent the glue from over penetrating the wood, a phenomenon known as bleed-through. The adequate drying will help to avoid steam-induced blows during the hot-press. The drying temperatures of 90 -160°C may be considered normal with higher temperatures up to 175°C being used on certain tree species to reduce the overall drying time. Contrary to the recommended practices of regulating drying conditions, the Debre Birhan Wood Processing company lacks mechanical-drying machines and does not exercise the regulated drying conditions. In addition, infrastructure (electricity) is a bottleneck to efficient production settings.

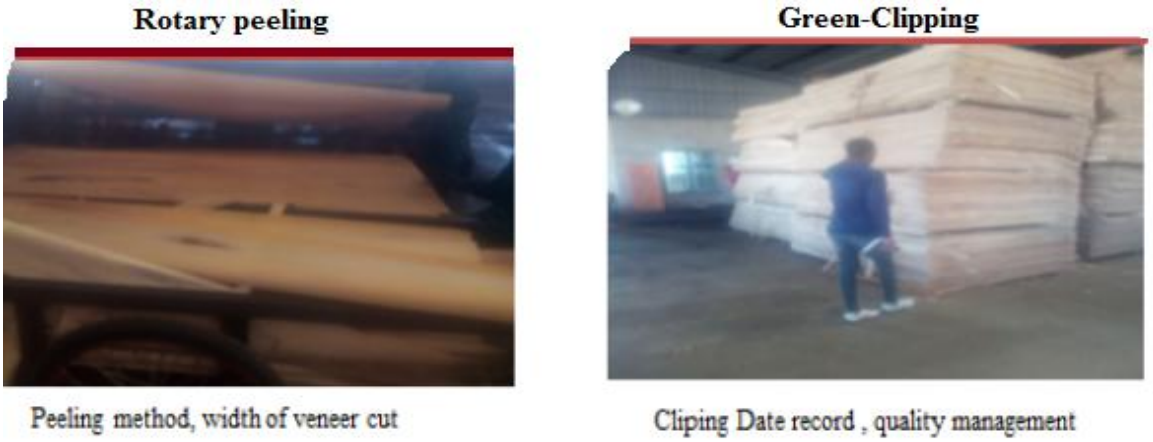

Figure 4. Rotary peeling and green clipping operation and main information flow

Figure 5. Veneer drying system and information

The moisture content of veneers and substrate is a critical factor in manufacturing of high quality and high-performance veneered products. However, the veneer produced in Debre Birhan Wood Processing company has a lot of drying defects like split, cracks shrinkage, waviness, and collapses. These defects were noted to be partly caused by low care during transportation to drying and during drying (manner of veneer set up on a rack), as well as lathe operation during peeling. The poor management results in fairly high veneer waste in the company, with the lack of a veneer jointing machine after drying, further affecting the standard and quality of the final product.

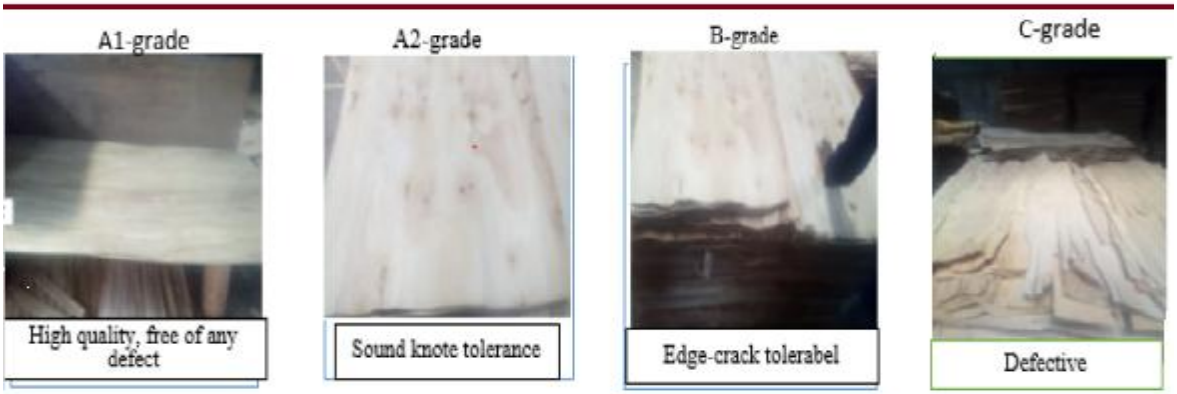

Figure 6. Criteria used for veneer grading in the company

Plywood Fabrication Process

In the fabrication process, the appropriateness of time, layering set-up and orders were assessed (Table 4). The time interval between layering and cold-press was not quantitatively specified. After the lay-up process, the wet laminated material goes into cold-press to flatten veneers. After the cold-press, the product is shifted into hot-press, where it is held for 8-15 minutes under pressure. The pressing time varies depending on the electric power. The minimum time of hot-press was needed for 5-ply type plywood whereas the maximum time requirement was for 9-ply type plywood products. This is in agreement with the reports of Irle et al. (2010) where the length of cycle specification is calculated as 'rule of thumb' is 1.5 min. for each mm of panel thickness.

Table 4. Parameters for veneer layer operations

Layer no.	Layers set-up	Layer part with adhesive coated veneer	Veneer quantity (minimum)
5-layer	**L'**-T-L-T-**L'**	2^{nd}, and 4^{th}	2 face and 12 interior veneer sheets
7-layer	***L'-T-L-T-L-T-L'***	2^{nd}, 4^{th}, and 6^{th}	2 face and 20 interior veneer sheets
9-layer	***L'-T-L-T-*** $(L_{(f)})$ ***-T-L-T-L'***	2^{nd}, 4^{th}, 6^{th}, and 8^{th}	3 face and 24 interior veneer sheets

***L'**= longitudinal,* $L_{(f)}$ *= longitudinal B-grade larger veneer, T = transverse (interior veneer), L= longitudinal (interior veneer)*

Production Capacity of the Company

In the analysis of the production performance of the company, the working hours, shifts per day, and machine availability were stated, and the company has a working time of eight hours and one shift per day. The production capacity was also assessed using intake capacity of plywood into the storehouse using current manufacturing performance and the recorded result indicates quantity was fluctuating over seasons of the year depending also on the input materials. Finally, the planned and the actual capacity of the wood processing company regarding the production capacity of the four years of plywood products were revised from the prevailed. Figure 7 shows the four years (2008-2011 EC) trend of the company's actual versus planned annual production. The average capacity utilization and the actual output of the company potentially increased in consecutive years. The result of the production performance of the company compared to its yearly plan of total production was 81.53%. In addition to the production performance, the trend of four years plan to actual production indicates there was a high improvement in balancing the plan according to their capacity. As seen from the start, the planned capacity was decreased, whereas the actual capacity increased, although there was a limitation on increasing planned production towards the end of the assessment years.

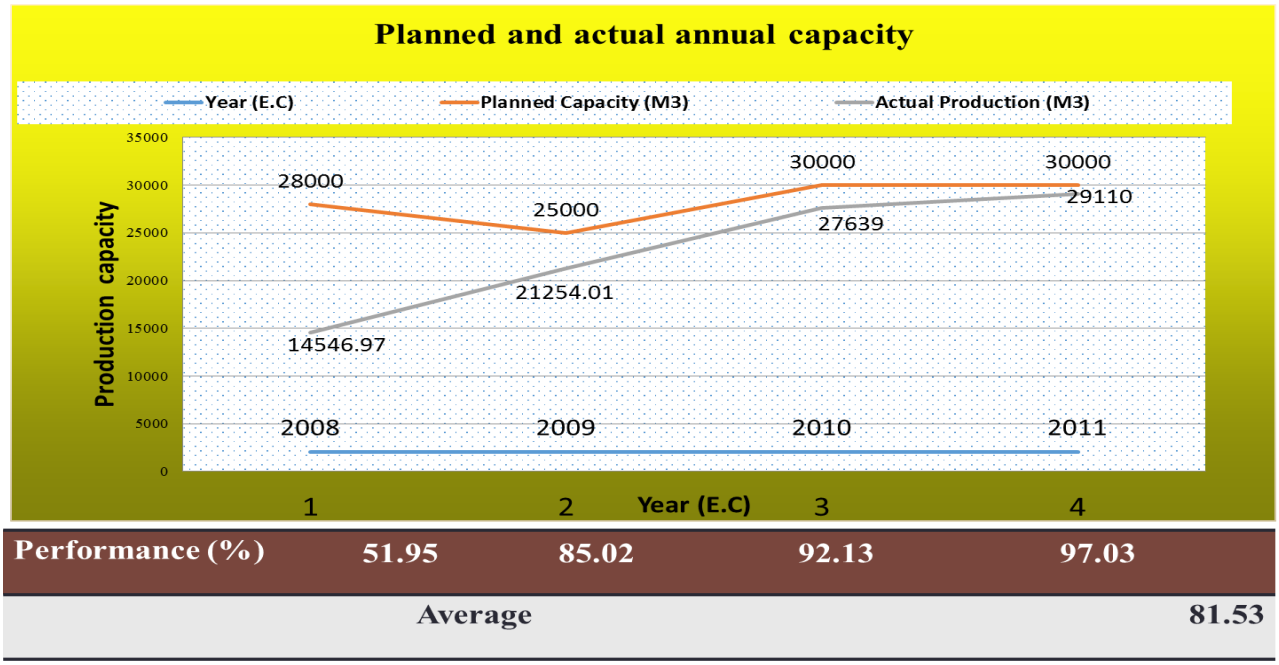

Figure 7. Production capacity of the company (source: document review)

CONCLUSION

The performance of Debre Birhan Wood Processing Company was evaluated in terms of quality management, production processes, capacity utilization, and challenges to performance improvement. The result indicates that log utilization was a function of quality implementation but, the specified quality criteria in log selection depends on log shape, diameter and knot. Regarding the plywood production, the company has three main phases of manufacture: log preparation phase (log storage to log trimming), veneer processing phase (veneer peeling to grading), and plywood manufacturing (veneer gluing to plywood packaging). Moreover, a veneer grading (A1, A2, B, and C) process follows only observable defects with the poorest quality veneer being grade C, in which defects such as cracks, knots, small-sized holes, and edge-scratches were acceptedFinally, the research findings indicate that the operating performance of the company concerning processing and quality standards was achieved at an intermediate level.

CONFLICTS OF INTEREST

Authors declare that there is no conflict of interest in the publication of this article.

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