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SYSTEM BALANCE IN MULTI-STAGE TIMBER TRANSPORTATION: A CASE OF MKUMBARA SKYLINE, TANZANIA

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ABSTRACT

Timber transportation is known to be the most important and expensive single component in timber harvesting. It is a crucial part in harvesting planning especially where difficulty terrain and long distances are involved. This paper presents a study of a skyline logging system, Mkumbara, Northeast Tanzania, where difficult terrain and distances cause concern for system balance in a multistage transport system. The stages were forest to upper landing by trucks and tractor, upper to lower landing by skyline, and eventually lower landing to the mill by other log hauling units. This study identified the situation and workplace factors influencing productivity and costs; assessed the coordination of the different harvesting activities, and determined the presence of "system balancing" required for efficiency. The study involved assessment of productivity and costs of timber harvesting for the skyline system from gross and detailed work-studies. The operations assessed include: timber cutting, log transport to the skyline upper landing, terminal operations, skyline operation, and log hauling to the processing mills.

The study revealed that although the potential of the skyline stage was not achieved, log hauling by tractors from the forest to the upper landing was the major bottleneck. Log transportation from the lower landing to the mill need to be improved. The mill demanded 60m^3 of logs per day while log hauling to the upper landing was 38.8m^3 per day. Unit cost at the mill amounted to Tanzania Shillings 6,550/-, with the hauling from forest to the upper landing being the highest, contributing 30% of the unit cost. The daily productivity and costs were imbalanced between all subsequent stages, however, it is recommended that improvement of the forest to upper landing stage could greatly increase productivity, and decrease unit cost, even without large capital investment.

INTRODUCTION

Timber harvesting operations

Logging which is the process of felling, extracting and transporting logs from the forests (Abeli & Nsolomo 1998), involves an aggregation of man-machine components. These components function together to achieve log transportation objectives. Log transportation is the most important and generally the largest single expense associated with log production. The production system is concerned with assembly of raw materials, power, machines and operating supplies. There are a number of sub-operations which interrelate in such a way that an earlier operation influences the subsequent one, and similarly, a later operation may be preceded by some tasks in a particular sequence. The existence of large number of possible combinations within a logging system means that planning of these operations is important if they are to be carried out effectively and economically to ensure a system balance (Shemwetta 1997).

System balancing in logging focuses on the combination of machines and personnel with approximation of quantity of units of the different single activities required for a smooth organization in-spite of different technical labour productivities for each of the stages involved. A system is balanced when the units are harmonized in such a way that they are sufficiently utilized. For instance, if there are too many felling crews or if the equipment used is such that production rates in primary transportation exceed loading capability or hauling capacity, then the entire system is thrown out of balance (Conway 1979).

Wood harvesting is usually divided into three main interrelated phases (each with a number of sub-operations); cutting, terrain transport (short distance) and long distance log transport. According to Abeli and Ole-Meiludie (1990), log transport from the forest roadside to the processing facilities is carried out mostly by logging company trucks. The scope of logging is to deliver the wood in the desired form at the lowest possible cost. In selecting a suitable harvesting system to use over a given area besides costs, it is important also to consider whether the system is technically feasible, as well as being environmentally, silviculturally and socially acceptable (Brink *et al*. 1995). The case of interest is Shume/Mkumbara harvesting system in North Eastern Tanzania where logging is being done on a plantation forest at about 10km straight-line distance from the factory, but the two points have a 1,500m difference in altitude. A permanent skyline was put in place in 1985 and completely replaced a former truck route of 200km round trip (Abeli and Shemwetta, 1988).

Shume/Mkumbara Harvesting System

The installation of the skyline between Shume and Mkumbara resulted into a multistage transport system involving road-skyline-road modes. The system comprises of Shume plantation forest as the source and Tembo chipboard factory as the destination.

The plantation forest lies at 38° 14′ E and 4° 42′ S at an altitude of about 1,920m above sea level, covering a total area of about 3,390 hectares. The area has a binomial rain pattern (a short rainy season between October and December and a long rainy season between February and May) the mean annual rainfall being about 1,200mm. The mean monthly temperatures range between 10 °C and 23 °C.

The plantation is comprised of softwood; *Pinus radiata*, *Pinus patula* and *Cupressus lusitanica* species, with an annual allowable cut of about 20,000m^3. Tembo chipboard factory is the main customer with an annual allocation of 15,000m^3 while about 5,000m^3 was being sold to other nearby small-scale forest industries. Timber harvesting activities are undertaken by the customers themselves.

Tembo chipboard factory is situated at 38° 10′ E 4° 45′ S at an altitude of about 470m above sea level. The factory has a combined saw-mill-chipboard plants with a targeted input of 15,000m^3 of logs annually; 80% of these being saw logs and 20% chiplogs. The main source of its raw material is Shume plantation forest. In the early 1970s, logs were transported from the forest to the factory by trucks, going around the cliff for a distances of about 100km (one way). In 1974 the factory started to experience problems in the log hauling system due to high operating costs. As an alternative, a skyline transport was constructed over the cliff face, making up three operational stages: hauling logs from the forest to the upper landing by tractors; air lifting logs from the upper to lower landing by cableway; and eventually hauling logs by trucks from the lower landing to the factory. This is hereafter referred to as the Mkumbara timber transport system (Figure 1). With these stages the need for system balance becomes more important.

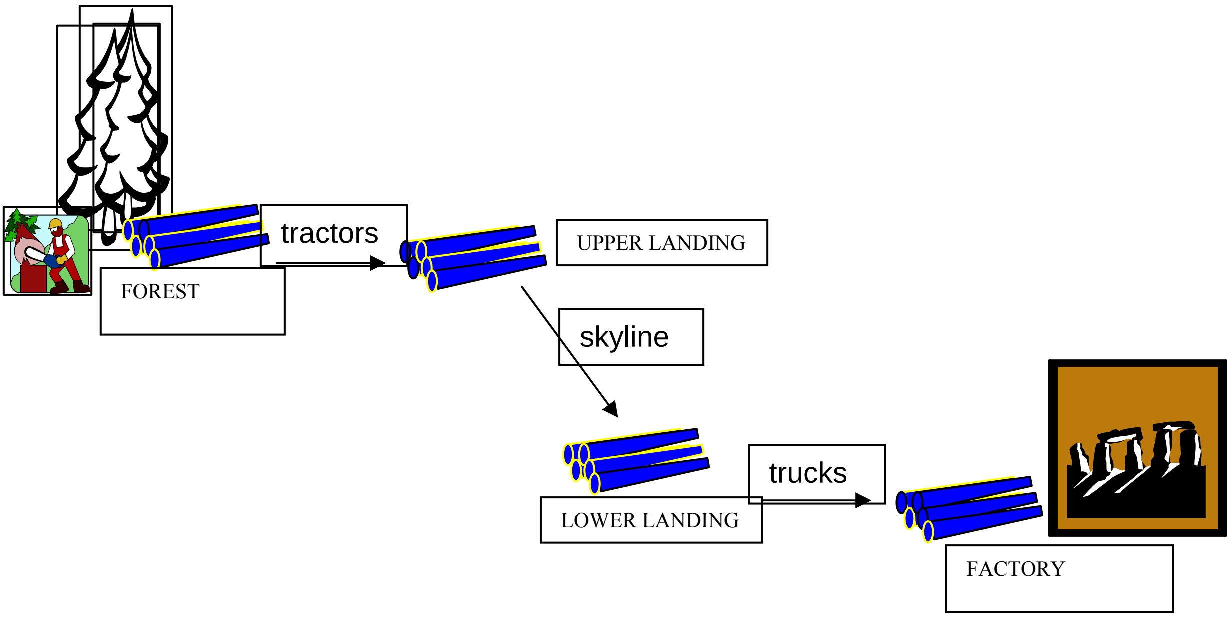

Figure 1. Mkumbara multi-stage timber transportation system

The setup complicates transportation due to repeated handling requiring elaborated planning and execution to ensure a balanced system. Logs harvested from the forest plantation have to be hauled by means of a skyline to the factory. Since the skyline does not start in the forest, neither does it end at the factory, it means that logs have to be hauled by tractors and trucks to the upper landing, and also by other trucks from the lower landing to the factory. This study sought to establish the existence of the "balance" either in physical form (productivity) or the economic form (costs).

METHODOLOGY

Data was collected over a period between 1998 and 2001, covering different harvesting seasons. Both field and office data were obtained. Productivity in terms of volume produced was obtained through work study methods. This was performed on every stage of the system; i.e., felling in the forest, hauling to upper landing, hauling to the lower landing, loading at the lower landing, and eventually hauling to the mill.

A yardstick for balance comparison was daily production (m^3/day) for each stage. Production cost in (Tshs/m^3) was computed for each stage to compliment the 'balance'. Many of the logging and log hauling machines at the factory were beyond the 20,000 hours which is taken as the maximum machine operating life (FAO 1977). Since it was difficult to obtain reliable machine cost data, the cost estimates *C* were computed according to FAO (1977), which is obtained by a factorized ratio of acquisition cost *A* to life expectancy *LE* in productive machine hours, excluding labour cost, as given by the equation:

$$C = \frac{2.4A}{LE}$$

Comparison for balance was made on productivity between adjacent stages. The overall limiting stage was also identified.

RESULTS AND DISCUSSION

The results of productivity and cost for each stage are given followed by an overall discussion on the system balance.

Stage productivity and cost

Tree felling

Ten middle-aged two-man crews, working on a contract basis, performed felling operations using chainsaws and axes. Chain saws were used in felling and bucking while limbing was mainly done by axes. Each crew was required to produce an average of 6m^3/day which involved felling, limbing, bucking and log piling.

The average log length was 4.5m while the average diameter was 26cm. Limbing was the most time-consuming activity, constituting about 49% of the total productive time. This was mainly attributed to accumulated mass of branches, which obstructed the crews from working on the tree. In this operation, an average of 53m^3 was produced per day (Table 1). This production was lower than that of the mill demand, which was about 65m^3 per day. A crew was paid 900TZS/m^3, excluding supervisory costs.

Log hauling to the upper landing

Two old boom-and-winch tractor-trailer units, each with an average carrying capacity of 10m^3, were used in log hauling from the forest to the upper landing. Each unit had a driver and two helpers. The average one-way hauling distance was about 15km. The average total productivity was 38.8m^3 per day, achieved by two trips per unit (Table 1). This rate was lower by 14.2m^3 compared to the daily felling target, meaning that at least 2 more trips were required for the tractors to balance with the daily felling target. This is also lower compared to the daily mill demand of 65m^3. Significant delays were observed at the roadside loading, either due to poor log arrangement or piling of logs beyond the maximum reach of the winch. The hauling tractors operated in less than the expected three trips per day. This was contributed by frequent breakdowns due to their old age, which consequently resulted into high operational delays and costs.

The total production cost in this stage was 2,050Tshs/m^3.

Skyline hauling

Log sorting, scaling, manual loading and pushing of the rail wagon as well as loading the skyline carriage at the upper landing was performed by two crews working on contract basis; each crew was paid 700Tshs/m^3. After loading, the timber was hauled to the lower landing by the skyline (Figure 2). Loaded properly, the skyline carriage could haul 2m^3 per load. The carriage takes 7 minutes to descend, including the terminal operations, one trip takes 12 to 15 minutes. This setting should interpret into at least 4 trips per hour. With an allowance of 5% for delays, the skyline has a least production capacity of 60 m^3 per 8-hour day. Studies by Abeli and Shemwetta (1988), showed that under hot logging the skyline operated at 34 trips/day being loaded at the rated capacity of 2m^3 per load.

However, the observed production by this study averaged 45 m^3/day made up of 25 trips of 1.8m^3/load (Table 1). In other words, one trip averaged 19 minutes. Considering the 38.8m^3/day brought in from the forest, there is a daily deficit of about 8m^3. Yet this production is short of 20m^3 compared to the daily mill requirement. Insufficient logs at the upper landing from the forest affects the "hot logging" and consequently the skyline round trips. Another reason is the manual log sorting and loading into the rail wagons and the skyline carriage, thus contributing to longer loading time and therefore fewer skyline trips/day.

The operating costs for the skyline were found to be 945Tshs/m^3, which accounts for labour wages for two technicians, two

Table 1. The average daily potential and actual productivity capacities and respective unit cost per stage.

Stage	capacity/unit	Observed avg performance	Units/Loads per day	Output m^3/day	Unit Cost Tshs/m^3
Felling	6m^3/crew/8hr -day	5.3 m^3/crew	10 Crews	53	900
Log hauling to upper landing	10m^3/load x 2 trips/day	9.7m^3/load	2 trips/unit x 2 units	38.8	2,050
1 Skyline hauling	2m^3/load x 4 loads/hour	1.8m^3/load	25 trips	45	945
2 Loading at lower landing (by a front-end loader)	116m^3 per 8 hour day	50.2m^3/day		50.22m	656
3 Log hauling to the mill	10m^3/load	9.3m^3/load	5.4 trips	50.22m^3	1,995

1Skyline hauling include loading the trailer, pushing trailer to platform, loading carriage at the upper landing; and unloading carriage at the lower landing.

2Loading time for the unit depended on availability of logs and trucks to load

3The 5.4 is an average number of trips over the observation period.

operators, loading crews, lubricants and machine depreciation.

Loading at lower landing

A front-end loader was used to load the log hauling units at the lower landing. The daily production of the loader depended on the availability of logs transported over the skyline as well as availability of the log hauling units at the landing. Without delays, the loader had a daily production capacity of about 116m^3, however, the observed production was 50m^3 per day. There is imbalance here also since this requirement is 5m^3 more compared to the daily volume brought down from the upper landing. Yet this is also short of daily mill demand by 15m^3. On the overall, the loader had considerable delay time, which accounted for about 77% of the total workplace time The delays were due to waiting for enough logs to accumulate or arrival of hauling trucks. The actual production cost, which includes fuel, oil, driver's wage and depreciation, was 656Tshs/m^3. This was relatively lower compared to the other stages. This stage had the most favourable conditions in terms of productivity and unit cost.

Log hauling to the mill

Two 6x4 logging trucks, each with an average carrying capacity of 10m^3, were used to haul timber from the lower landing to the mill. The average one-way distance was 1.2km; however the road condition was generally poor. The daily production target was 60m^3. In contrast, the total productivity achieved averaged 50m^3 per day. The imbalance is the same as that of the loader.

The hauling costs for this stage, which included wages for a driver and two helpers, fuel, oil and depreciation was 1,995Tshs/m^3.

Mill demand

The factory worked for one shift, with an average capacity of 65m^3 per day. However, due to the low capacity of some of the timber harvesting operations, raw material and the market demands, the mill's daily production was set at 60m^3, working 5 days a week.

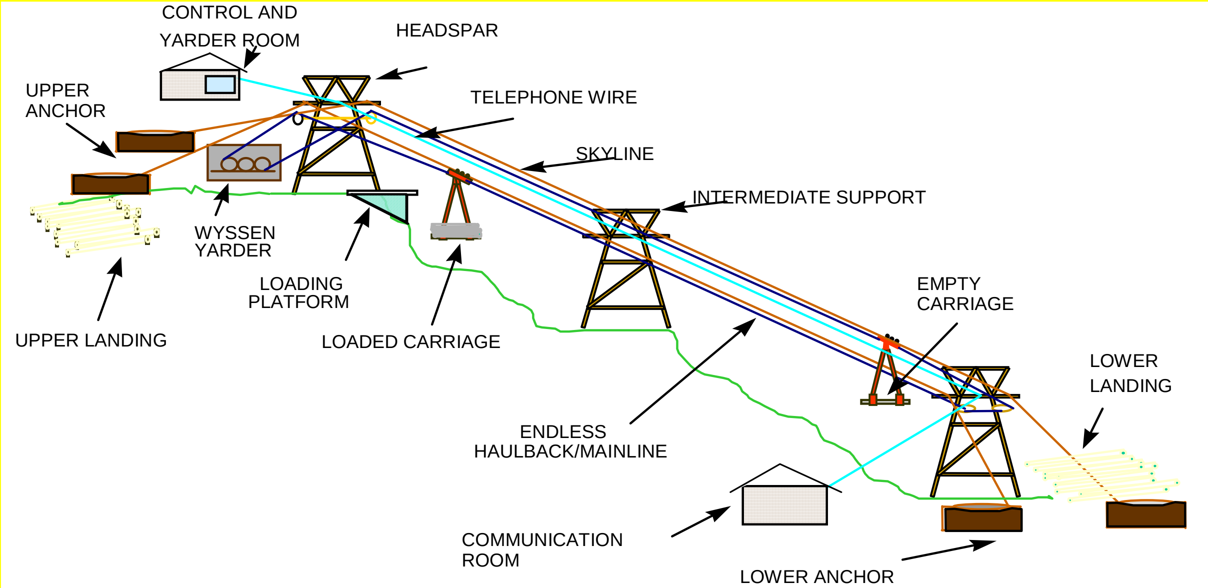

Figure 2. Layout of Mkumbara skyline in Tanzania, the airlifting stage of the three stage transportation system.

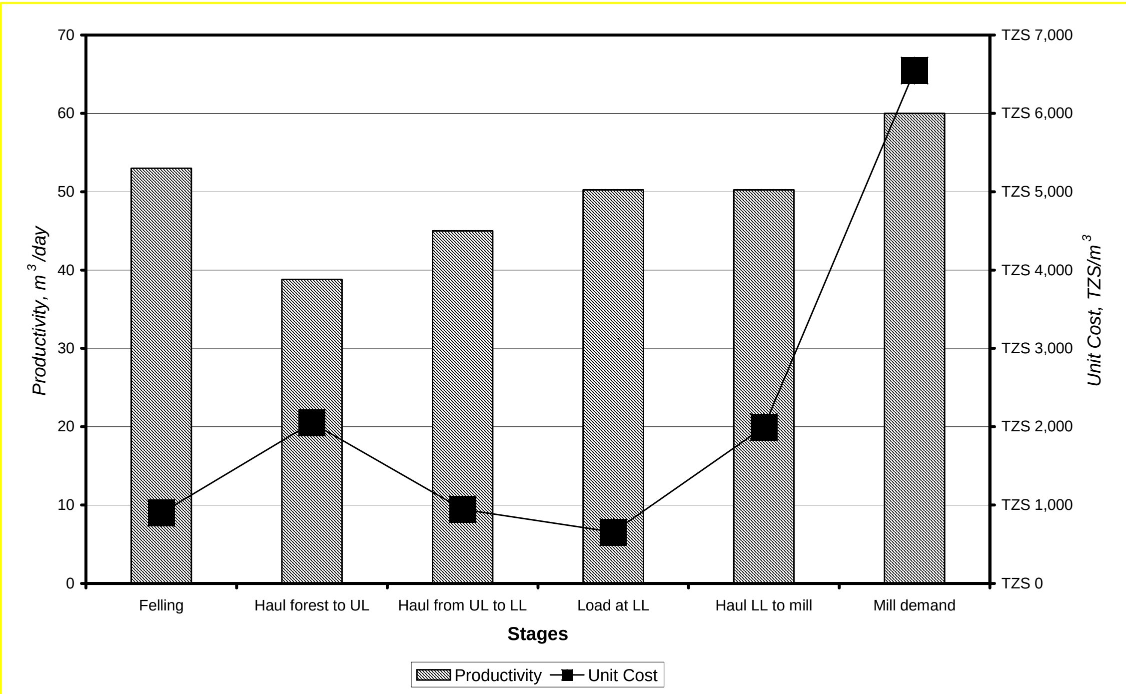

Figure 3. Production and costs for the stages of Mkumbara skyline system.

System balance

Productivity in cubic metres per day

Figure 3 indicates the achieved production rates per day for the various stages of the harvesting system. Log hauling from the forest to the upper landing was the most limiting stage. Three scenarios can be argued here: First scenario considers production maximization by pegging to the stage with highest capacity. The stage in this case is loading at the lower landing, $116m^3$/day. This scenario overshoots the normal daily mill capacity by far, hence not technically feasible. Second scenario considers the most limiting stage, which was hauling from the forest to the upper landing (Table 1 & Figure 3). However, this is only 60% of the mill demand, hence not economically feasible.

Third scenario, which is technically and economically feasible, would be to peg productivity on the mill demand, which was scaled down to 60m^3 to accommodate resource availability and market demand. To attain this level of production the following need to be addressed:
Add one more felling crew, and improve felling efficiency to full capacity of 6m^3/day per crew; Increase number of trips from the forest to the upper landing to 6, as well as improving loading to attain the capacity of 10m^3 per trip; Improve the productivity of the skyline by proper loading to achieve the capacity of 2m^3/carriage; and improve loading activities to scale down the observed 19 minutes per trip to the efficient time of 15 minutes or less. The study revealed that in presence of enough logs and manpower, with no interlude between loading the rail-wagons and the carriage that is "hot logging", the skyline should make 34 trips which meet the felling and the mill's production target.
The loader at the lower landing does not need any improvement, however, to achieve the lower landing to mill truck productivity to the 60m^3 capacity by increasing hauling unuts and/or increasing the number of trips.

The study revealed that time factor was used to 'balance' the system. The mill normally shuts down for 2 days (weekends) in a week while other stages operate. In a longer term, the mill will be required to shut down for some days to allow for availability of raw materials. Likewise the skyline has to shut down for some time to allow log accumulation.

Unit Cost, Tshs per cubic metre

Road transportation stages contributed the higher unit costs than the other stages. The highest unit cost was that of hauling from the forest to upper landing stage (Table 1 & Figure 3), which amounted to 30% of the total cost. Contrary to expectation for a 'balanced' system that the most expensive stage should have the highest productivity (and *vice versa*), we see here the same stage to be limiting in productivity and also most expensive. Improving this stage alone will therefore impart a significant development towards system balance, both in productivity and cost.

The operating costs for the wheel loader was relatively low compared to the other stages followed by skyline system. This was due to the fact that operation costs were low. Skyline had low operation costs given that it operated by gravity, required low labour input and had low depreciation costs due to long service life (since 1985).

The total cost of a cubic meter at the mill amounted to Tshs 6,550/-, with significant difference of costs between stages (Figure 3). The differences in unit production costs between stages could be explained by the manpower involved, method and mainly by the machine characteristic. Operating costs by the tractors were uncharacteristically higher than those of the hauling trucks. On the overall, The fuel and lubricants consumption by old hauling tractors/trucks was relatively high due to their old age. This observation agrees with other findings by Abeli and Dykstra (1981) who reported high operational delays and costs for the very old skidding tractors and hauling trucks in miombo forests, Tabora. This may be justified as well by high road grade, especially from the mill to the lower landing. Fuel consumption and maintenance costs also increase with increase in road grade (Abeli & Ole-Meiludie 1990).

CONCLUSION AND RECOMMENDATIONS

The study revealed that productivity and costs in all stages were different. Although

the daily mill capacity was 65 m^3, the production target was set at 60 m^3 to balance with capacities of other stages, raw material and the market demands. Productivity was highly affected by: labour-intensive activities particularly in the felling and the upper landing operations; operational delays; poor supervision and; frequent breakdown of the log hauling machines (both trucks and tractors) due to their old age. Log hauling from the forest to upper landing was the critical bottleneck, having the lowest productivity (38.8m^3/day) and highest unit cost (Tshs 2,050/m^3). Proper log arrangement at the roadside, servicing of tractor/trailer units and proper supervision could further improve the log transport from the forest to the upper landing. Improving this stage alone will therefore impart a significant development towards system balance, both in productivity and cost.
It is recommended that technical supervision to the operating crews was necessary so as to perform at their capacity instead of relying only on contract terms. Furthermore, repair and maintenance of the hauling trucks/tractors would significantly increase productivity and reduce unit costs. It may not be necessary to incur large capital investments to purchase new logging and log transport machines.

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