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Analyzing and estimating delays in wood chipping operations

Raffaele Spinelli[a,*], *Rien J.M. Visser*[b,1]

[a]IVALSA, CNR, Madonna del Piano 10, I-50019 Sesto Fiorentino (FI), Italy
[b]Department of Forestry, Virginia Tech, Blacksburg VA 24061, USA

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ABSTRACT

Productivity studies are still frequently used to describe, understand and improve forest operations. Delays are recognized as being one of the major factors that limit chipper productivity in most operations and are therefore an integral part of most time studies. Accurately recording and subsequently interpreting delay events is within the relatively short observation period of a typical time and motion study. This paper analyzes the delay component of sixty-three chipper time-study data sets, from thirty-six different chipping machines. All the studies were set up and carried out with the same principal investigator. Three delays' categories were used; mechanical, operator and organizational and other. The overall average utilization of the chipper was 73.8%. Regardless of operation type, two thirds of the total delay time are represented by organizational delays, which emphasizes the crucial role of operation management. Optimization measures should not be limited to the individual machine, but address the operation as a whole. The more productive the operation, the more sensitive it is to both delays as well as poor planning.

1. Introduction

The world-wide boom of renewable energy has generated an increasingly strong interest towards biomass recovery, reviving such practices as in-woods chipping. As the forest industry explores the potential of a new growing market, the number of operations is increasing. Many operators prospect the acquisition of their first chipper, or the upsizing of their current fleet. A number of studies are now available that can support such decisions in most of the industrialized world [2,10,15]. With a detailed productivity study we can easily estimate the net productivity of a chipper, based on its type and on the working conditions under which it is used [17]. However, what determines the final cost of any operation is gross productivity, inclusive of delays [16].

The importance of delays in all phases of production was noted long ago [7], but a major problem exists in the reliable recording and evaluation of such time. In the field there is the inherent difficulty of obtaining representative samples of a typically erratic phenomenon from relatively short observation periods. This makes it difficult to translate into practice the results obtained from models able to predict work only productivity, otherwise very accurate and potentially useful. Stampfer and Steinmueller [19] noted that for efficient generation of productivity models for harvesters it is simpler to only capture the data for the work time components and then using a delay model from literature.

However, no such delay models exist for chipping operations, except for individual values from specific time studies. Little scientific work has addressed the development of

* *Corresponding author*. Tel.: +39 055 5225641; fax: +39 055 5225643.
E-mail addresses: spinelli@ivalsa.cnr.it (R. Spinelli), rvisser@vt.edu (R.J.M. Visser).
[1] Tel.: +1 540 231 6924.
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reliable delay factors, and the translation of net production data obtained from scientific time studies into scheduled time performance is obtained by applying best estimates, or the results of studies coming from a long distance in space and time [6]. The use of scientifically grounded empirical utilization factors is by far a preferable method for determining appropriate chipping productivity expectation [9]. Attempting to apply utilization factors from an individual study requires an accurate understanding of the operational conditions under which the origin data are collected.

For most productivity studies the data collection procedure consists of a set of detailed time and motion recordings conducted at the cycle level. In general, detailed time studies are more discriminating than shift-level studies and can provide a better understanding of operational dynamics [14]. However, it is not only the equipment and personnel, as well as the stand and terrain conditions that dictate the outcome of a given time study, but also the data collection protocol used by the researchers. There have been a number of attempts at standardizing work study collection protocols for forestry [1,4,8,13]. Differing definitions still occur to reflect local work condition, and although most proposed protocols agree in principle and are relatively clear and simple, problems exist in their application in the field [18].

Detailed time studies are inherently short and may not accurately represent an erratic phenomenon as the occurrence of delays [3]. Combining a larger number of detailed time studies into a larger data pool can support more ambitious modeling efforts [18]. This includes establishing utilization and delay averages, as well as analyzing possible trends associated with delays depending on machine type, stand and operating conditions.

The goal of this study is to produce and analyze chipper delay factors that can be applied to the estimated net work time productivity. This paper analyzes a data set of sixty-three chipper time studies, whereby the studies were carried out by the National Council for Research (CNR), Italy, as part of a long term study on mechanized equipment. This would allow translating the theoretical estimates of many studies into a more workable pool of knowledge, ready for application in the field. Example applications include being able to estimate the actual time consumption and or operating costs under operational conditions, as faced by commercial operators.

2. Materials and methods

Sixty-three complete times studies were used for the analyses of delays. All the time studies were set up and carried out by the same principal investigators and with the same methods. All time elements and the related time-motion data were recording with Husky Hunter® hand-held field computers running Siwork3® time-study software [11,12]. The study protocol and terminology followed the general prescription made by IUFRO [5].

The studies totaled 524 h of observation; approximately 65 working days. The average total length time study was relatively short, 8.3 h, ranging from 1.1 to 26.4 h for the individual studies. The short study time reflects the typical conditions of biomass chipping operations in mountain areas, where comparatively small residual volumes are accumulated at narrow landings. Many of the tested chippers have a theoretical production capacity of over 20 ton per productive machine hour and can often empty a single landing in less than a day.

Productive work time was recorded as two entities, the first simply as ‘chipping’ (any time the machine is actually chipping wood) and the second as ‘supporting’ (any time the operators are retrieving or positioning material to chip). All remaining time was considered delay.

All the time studies used three clearly defined delay types, and namely: (1) mechanical delays, that include breakdowns, knife replacement, all maintenance outside the standard preparation and end-of-shift times; (2) operator delays, i.e. rest, break, physiological, smoke, phone call, and (3) organizational and other delays, including waiting for the biomass (hot deck operations only, i.e. those operations where the chipper does not work from stacks, but is supplied by the extraction units in real time) or for the trucks, interference, reconnaissance and planning, refuel, preparation.

Delays caused by the study itself, including giving instructions and measuring logs have all been excluded. Delays for the main meal (if the operator took any) and relocation to and from site are also not included in the data sets. All other delays are included.

Assuming just three delay categories, the scheduled machine hour can be defined as:

$$SMH = PMH + H_{mech} + H_{op} + H_{o\&o} \quad (1)$$

whereby SMH = Scheduled Machine Hours, PMH = Productive Machine Hours, H_{mech} = Hours of Mechanical Delay, H_{op} = Hours of Operator Delay, $H_{o\&o}$ = Hours of Organizational and other Delay.

In most published reports, delays are reported as a percent of the total scheduled time. Normally delays are presented as a percentage of SMH. For example for Mechanical Delays (MechD),

$$MechD = \frac{H_{Mech}}{SMH}100 \quad (2)$$

whereby: MechD = Mechanical Delay (%), H_{mech} = Hours of Mechanical Delay.

Spinelli and Visser [18] showed that if there is no correlation between delay types, then it is more correct to express delay as a factor (DF) that is added to the productive machine hours.

$$DF_{mech}(\%) = \frac{H_{mech}}{PMH}100 \quad (3)$$

DF_{mech} = Mechanical Delay Factor (%).

The total delay time for all the categories (in %) can then simply be summed.

$$SMH = PMH\left(1 + \frac{DF_{mech} + DF_{op} + DF_{oth}}{100}\right) \quad (4)$$

whereby: DF_{tot} = Total Delay Factor (%), DF_{mech} = Mechanical Delay Factor (%), DF_{op} = Operator Delay Factor (%), DF_{oth} = Other Delay Factor (%).

The delay factor representation is used throughout the analyses and results.

Each data set allows itself to be categorized depending on the type of chipper, the type of material it was chipping, and