Silva Fennica 1992, Vol. 26 N:o 2: 85–96

Skidding by sulky. A literature study

Martti Saarilahti

TIIVISTELMÄ: KIRJALLISUUTEEN PERUSTUVA TYÖNTUTKIMUS JUONTOKAARIJUONNOSTA

Saarilahti, M. 1992. Skidding by sulky. A literature study. Tiivistelmä: Kirjallisuuteen perustuva työntutkimus juontokaarijuonnosta. Silva Fennica 26(2): 85–96.

Speed and load sizes presented in three study reports on sulky skidding were compared with estimates based on ergonomic models. Speed and load size estimates were closely correlated with the observed values, when a 400 W energy expenditure of the subject was used. This corresponds to less than half of his submaximal oxygen intake and matches well with the heart rate given in one of the time studies. It seems possible to develop methods for evaluating the work pace/production rate for sulky skidding in varying terrain conditions.

Tutkimuksessa verrataan kolmessa tutkimusraportissa annettuja keskikuormia ja annetuilla malleilla laskettuja keskijuontonopeuksia ergonomisilla malleilla laskettuihin arvoihin. Lasketut nopeudet ja kuorman koot ovat lähellä kirjallisuudessa mainittuja arvoja, kun laskelmissa käytettiin juontajien 400 W energian kulutuksen tasoa. Tämä on alle puolet työmiesten maksimaalista hapenottokykyä vastaavasta energian kulutuksesta ja sopii yhteen yhdessä tutkimuksista mitatun syketaajuuden kanssa. Näyttää mahdolliselta, että juontotyön työtahdin/työn tuottavuuden arvioimismalleja voidaan kehittää erilaisiin maasto-oloihin.

Keywords: labour-intensity, skidding, ergonomics, production, sulkies, work study.
FDC 305 + 302

Author's address: The Finnish Forest Research Institute, Unioninkatu 40 A, SF-00170 Helsinki, Finland.

Accepted August 28, 1992

1 Introduction

Manual working methods are recommended and applicable for many forests in different parts of the world. Mechanized methods, however, are often preferred to labour-intensive ones. One reason is that manual methods are not used at their best, planning and supervision being neglected. This results in low productivity and high costs giving the advantage to machines. Good planning and supervision need reliable methods for setting tasks. Undemanding tasks lead to uneconomic operations. Too arduous tasks risk workers' health, decrease job satisfaction and lower overall efficiency by increasing labour turnover. More comprehensive work studies are needed to complement time studies in order to develop the most rational way to perform a certain task.

Sulky skidding has been widely studied, but many reports have concentrated on expressing the time consumption only. In this paper some time studies are compared and complemented with an ergonomic frame of reference in order to give guidelines for further development of the study methodology.

Professors Rihko Haarlaa and Reidar Skaar and Ms. Outi Mikkonen, M.Sc.(For.) read the manuscript and suggested improvements. Ms. Maija Tuuri edited the manuscript. Language checking was made by B.A. Paul Service. Their support is acknowledged.

2 Materials and methods

This paper is based on three time studies: Ole-Meiludie and Omnes (1979) (III), Ole-Meiludie (1984) (II) and Saarilahti et al. (1987) (I). The time consumption is calculated from the given equations or taken from the tables. The ergonomic frame of reference is based on models presented by Saarilahti (1992).

3 Concept of skidding speed

Assuming a constant speed, the time consumption equation over a given distance is

$$t = \frac{1}{v} \cdot d \qquad (1)$$

where
t is time, s
v speed, m/s
d distance

However, the empirical black-box regression models usually also have a constant, and since the time model is:

$$t = a + b \cdot d \qquad (2)$$

Theoretically the constant **a** expresses the acceleration and deceleration times and includes possible short delays. The speed is the inverse of the slope angle **b,** eq. (3). If the speed depends on the distance, the time model is not linear but regressive as the speed increases as a function of the distance. Correspondingly, it is progressive if the speed decreases. If the conditions (slope, ground roughness) and the available power stay constant during the whole distance, the speed remains constant and the time model is linear.

$$b = \frac{1}{v} \qquad (3)$$

where
b is constant for the time model
v true speed, m/s

In this study two speeds are defined: the true speed (v_t), which is the slope angle speed (eq. (2)) and the apparent or average speed (v_a), which is the (average) time divided by (average) distance. The true speed is higher than the apparent speed, while the apparent speed approaches the true speed on ever longer distances since the influence of the constant **a** becomes less significant. The energy expenditure and the theoretical models give true speed and so for practical applications some extra time, a constant **a**, must be added.

4 Production model for sulky skidding

4.1 Time elements in sulky skidding

In this report the term sulky skidding is used to cover both the sulky skidding and the sulky forwarding. In skidding, one part of the load is supported by the sulky and the other part by the ground, where the tractive effort consists of wheel/soil and log/soil interactions. In sulky forwarding, the load is totally supported by the sulky and the resisting force consists only of wheel/soil interaction.

Work cycle comprises four active elements:

Return: workers pull the empty sulky from the landing to the loading area in the forest
Loading: workers prepare the load and attach it to the sulky
Travel: workers pull the loaded sulky to the landing
Unloading: workers unhook the sulky and pile the timber on the landing

A work cycle may even contain some necessary and unnecessary delay times.

The total time of a cycle is the sum of elementary times

$$T_T = T_R + T_L + T_S + T_U + T_D \qquad (4)$$

where
T_T is cycle time, s
T_R return time, s
T_L loading time, s
T_S travel time, s
T_U unloading and piling time, s
T_D delay time, s

4.2 Production rate

The production rate is the amount of timber transported during a unit of time:

$$P = \frac{1}{T_T} \cdot V \qquad (5)$$

where
P is production rate, m^3/s
T_T cycle time, s
V load size, m^3

The production rate model contains two submodels, the time model and the load size model.

5 Work element “return”

“Return” consists of the walking from the landing to the stump area. Usually only one worker pulls the sulky and the other walks along carrying the chain. As the slope is given in the loaded direction, the actual slope during the return is $-1 \cdot$ Slope.

The return time depends on the walking speed and the distance. The work load depends on the walking energy and an estimate may be based on the walking speed. Theoretically the return time depends on a certain constant time needed to manipulate the sulky, and on the distance-dependent variable time. The speed here is close to the effective speed. Only on steep (> 35 %) adverse slopes may the sulky pulling time depend on the speed and energy consumption.

5.1 Return speed

It is assumed that at low pulls the workers tend to choose an optimum speed which maximises the energy conversion rate (Saarilahti 1992). The optimum speed on different slopes, v_{eff}, can be calculated by using the model (6).

$$v_{eff} = v_{opt} - v_{opt} \cdot \frac{S_{eff}}{100} \qquad (6)$$

where S_{eff} is the effective slope. Thus

$$S_{eff} = \mathbf{ABS}(S + 10) - 10 \qquad (7)$$

where
v_{eff} is the effective optimum speed on different slopes, m/s

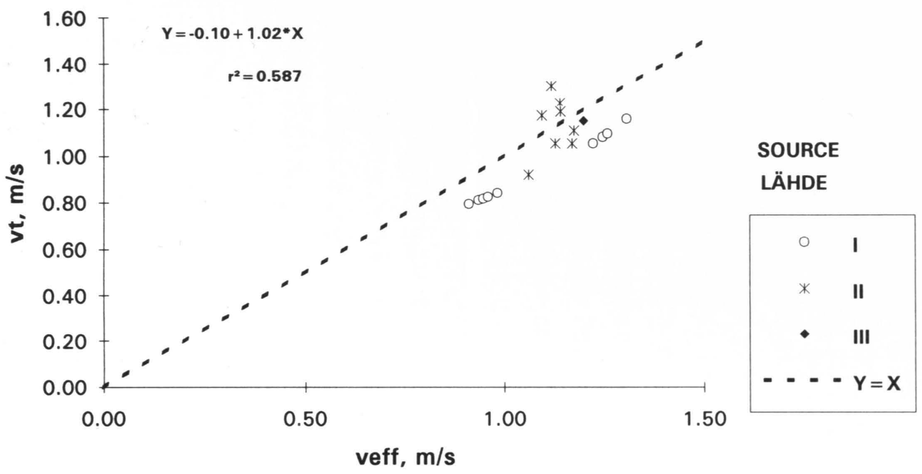

Fig. 1. Estimated return speed, v_{eff}, compared to v_t.
Kuva 1. Paluunopeuden estimaatti, v_{eff}, verrattuna v_t-paluunopeuteen.

v_{opt} optimum speed, m/s
S_{eff} effective slope, %
S slope, %

The optimum speed depends on the physical characteristics and the motivation of a person and is usually close to 1.30 m/s on level ground. In this study the optimum speed 1.20 m/s was used since the work pace seems to be rather low, at least in source I. The calculated true speed (v_t) is compared to estimated effective speed (cf. Fig. 1). The correlation coefficient, r = 0.766, is highly significant, the slope angle close to 1 and the constant rather small, indicating a good fit with the two values. Therefore it seems to be possible to choose an optimum speed between 1.0 and 1.3 m/s depending on the worker's performance. It may also be used as a basic speed for estimates of the return speed.

5.2 Return time

Constant **a** for the return time model was 13 s in sources I and III, and was much lower in source II, the average being 5 s and ranging from –4 to +22 s. Part of the difference is due to the differences in recording the delay times; some 5 s may be added to source II for this purpose. For practical applications the following constants may be used:

5...10 s	for well-organised work, high work motivation, high work pace
10...15 s	for rather well-organised work, medium work motivation, normal work pace
15...20 s	for poorly-organised work, low motivation, low work pace.

About 5 s has to be allocated for different delay times (contingency allowance).

5.3 Energy expenditure in return

The energy expenditure can be estimated based on the walking energy model (8) (Saarilahti 1992).

$$EEC_R = m \cdot (1.3 + 1.67 \cdot v^2 + 0.2 \cdot S_{eff} \cdot v) \qquad (8)$$

where
EEC_R is energy expenditure during return, W
m body mass, kg
v speed (v_t), m/s
S_{eff} effective slope, model (7)

6 Work element "loading"

6.1 Loading time

The loading time depends on the organisation of the cutting operation. After well-organised cutting, no extra time is needed to handle the logs, the time consumption only depending on posing the sulky and attaching the chain.

The average loading time varied from 1.46 to 1.83 ($\bar{x}$ = 1.68) min in source I, from 1.06 to 1.39 ($\bar{x}$ = 1.18) min in source II and was 1.79 min in source III. The average time for all the sources was 1.35 min.

For the loading time models the load size entered as an independent variable in 5 cases, the number of logs in two cases and this time was constant in three cases. The correlation coefficients were generally low (r = 0.14...0.46), indicating that the loading time is rather randomly distributed. Therefore a constant time of 80 s (1.35 min) for the element loading was deemed reasonable.

As working on slopes is more difficult than on level ground, the time consumption probably increases as a function of the slope; and the slope was indeed positively correlated with time. Due to multicolinearity (the load size and the slope are correlated) the effect of each factor cannot be separated from the data source. Three models (9)–(11) may be used for estimating the loading time. The time is likely to be shorter with a high pace and well-organised work. With poorly-organised work, with logs are covered with logging residues for example, some extra time must be allocated. The loading time already contains a contingency allowance.

$$LT = 80 \qquad (9)$$

$$LT = 36 + 33 \cdot NLOG \cdot (1 + \mathbf{ABS}(\frac{S}{100})) \qquad (10)$$

$$LT = 30 + (25 \cdot NLOG + 180 \cdot V) \cdot (1 + \mathbf{ABS}(\frac{S}{100})) \qquad (11)$$

where
LT is loading time, s
NLOG number of logs
V load size, m^3

6.2 Energy expenditure in loading

There has been no study on heart rate or energy expenditure concerning the loading phase. Loading consists of some short-duration lifting and working in difficult postures. The work is not very hard and the estimated energy expenditure corresponds to 0.6 m/s walking. The energy expenditure is about

$$EEC_L = 2 \cdot m \qquad (12)$$

where
EEC_L is energy expenditure in loading, W
m body mass, kg

7 Work element "travel loaded"

During this phase the workers pull the loaded sulky to the landing. This is the most laborious element in sulky skidding. The energy expenditure consists of walking and pulling energy.

7.1 Speed model for the travel loaded

Here the theoretical speed model is based on the following pulling energy expenditure equation (Saarilahti 1992):

$$P = m \cdot (1.3 + 1.67 \cdot v^2 + 0.2 \cdot S_{eff} \cdot v) + 3 \cdot F \cdot v \qquad (13)$$

where
P is power, pulling energy expenditure, W
m body mass, kg
v speed, m/s
S_{eff} effective slope
F pull, N

By solving the positive real root of the quadratic equation, the following speed model (14) as a

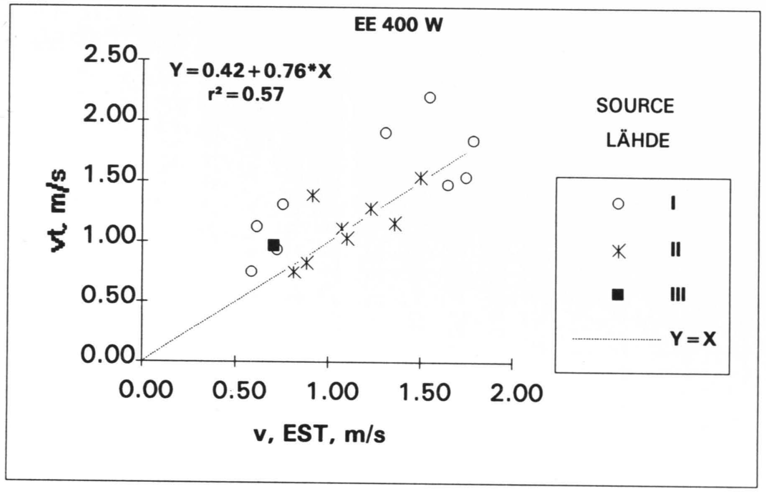

Fig. 2. Estimated speed (model (14)) compared to v_t calculated from sources I–III.

Kuva 2. Mallilla (14) laskettu nopeus (v_t) verrattuna lähteiden I–III malleilla laskettuun (v_t)-nopeuteen.

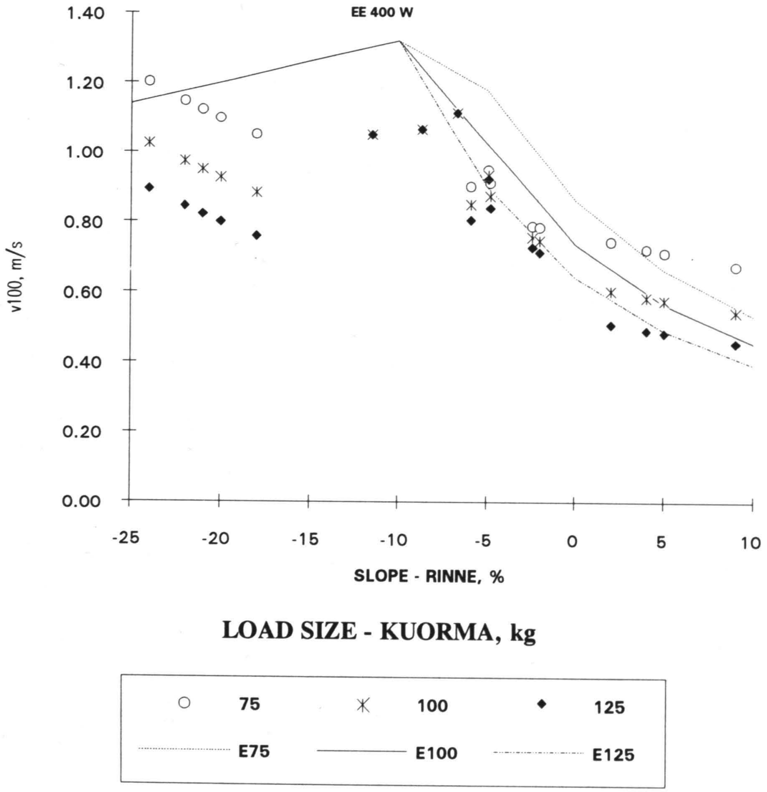

Fig. 3. Speed on different slopes calculated by using model (14) compared to speeds v_{100} calculated by using the travel time models from sources I and II.

Kuva 3. Mallilla (14) eri rinteille laskettu nopeus verrattuna kirjallisuudesta otetuilla kulkuaikamalleilla laskettuun v_{100}-nopeuteen.

function of power (energy expenditure) can be established:

$$v = -0.06 \cdot S_{eff} - 0.9 \cdot \frac{F}{m} + 0.5 \cdot \sqrt{0.0144 \cdot S_{eff}^2 + 0.432 \cdot S_{eff} \cdot \frac{F}{m} + 3.24 \cdot \frac{F^2}{m^2} + 2.395 \cdot \frac{P}{m} - 3.11} \qquad (14)$$

IF $v > v_{eff}$ **THEN** $v = v_{eff}$

The maximum average heart rate in source I was 123 (Table 17, p. 190), which corresponds a capacity under 50 % (see Saarilahti 1986). The maximum aerobic capacity of the workers was less than 900 W. Therefore a 400 W energy expenditure (= power) was chosen here when testing the model (14) with the data (Fig. 2). The observed speed of source I is based on an average daily load size. The distance and the slope and the v_t were calculated by using the model (46) of source I. Observed speeds of source II are based on the average distance and load size and v_t using different thinning models (213–220) of source II.

A certain fit between the two speeds can be found and the correlation coefficient is r = 0.752. The hypothesis that the workers maintain a certain energy expenditure level which regulates the pull and the speed seems acceptable.

The work on favourable slopes becomes easy and evidently the energy expenditure on favourable slopes is less than the assumed energy expenditure. Therefore the maximum speed v_{eff} is added as a limit for the model (14). On the other hand, the factor limiting load size is no longer the pulling capacity of the workers, but the braking and handling. Therefore the model does not fit perfectly on steep (< –15 %) favourable slopes (Fig. 3). It is also possible that the speed models presented in the literature are biased. However, model (14) can be applied for a rather wide range of slopes.

7.2 Travel time model

Constant **a** was high in source I, 40 s. In source II the constant **a** varied from 2 to 40 s, and the average was 18 s. The difference is partially explained by the different interpretation of the delay times: in study II some 5...10 s delay time should be added to the average constant time. The following constant times may be used:

10...20 s	smooth surface, well-organised work, high motivation, high work pace
20...35 s	rather smooth surface, rather well-organised work, medium motivation, normal work pace
30...50 s	frequent obstacles encountered, poor work organisation, low motivation, low work pace.

About 10 s is allocated to different delay times (contingency allowance).

7.3 Energy expenditure during travelling

Energy expenditure is equal to the power and therefore eq. (13) may be used in estimating the energy expenditure. As seen from the development of the speed model (Chapter 7.2), the energy expenditure in the studied cases is around 400 W and the heart rate stabilises at under the 125 beats/min level.

7.4 Load size model

The average load size in source I varied from 0.062 (+9 % slope) to 0.101 m³ (–21 % slope), the average being 0.081 m³ (–10 % slope). In source II the load size was between 0.08 (–5 % slope) and 0.109 m³ (–5 % slope), and the average load was 0.097 m³. The load size in source III was 0.119 m³. The largest load, 0.202 m³, has been recorded by Skaar (1973) on a –20 % slope in a Ugandan study.

With movement at constant speed, the traction generated by the sulky team is equal to the resisting forces from the sulky/terrain interaction (eq. (15)). The load size model breaks into two submodels: the models describing the pull of the team and the models describing the sulky/terrain interaction.

$$F_P = F_R \qquad (15)$$

where

F_P is pull generated by the sulky team, N

F_R total tractive effort from the sulky/terrain interaction, N

Resisting force can be calculated (Saarilahti 1991, p. 69)

Table 1. Pull by apparent strain (from Saarilahti and Fue 1987, p. 294).
Taulukko 1. Vetovoima arvioidun rasittuneisuuden mukaan (Saarilahti ja Fue 1987, s. 294).

Pull – *Vetovoima*	Apparent strain – *Näennäinen vaikeus* Very easy *Hyvin helppo*	Easy *Helppo*	Difficult *Vaikea*	Very difficult *Hyvin vaikea*	Unbearable *Mahdoton*
Absolute, N *Absoluuttinen*, N	–133	134–221	222–318	319–419	420–
% of weight *% painosta*	–20	20–33	33–48	48–63	63–

$$F_R = (W + L) \cdot (\cos\alpha \cdot \mu_R + \sin\alpha)$$

where
F_R is total tractive effort, N
W vehicle weight, N
L load weight, N
α slope angle, °
μ_R rolling resistance coefficient

The model can be simplified to

$$F_R = (W + L) \cdot (\mu_R + \frac{S}{100}) \qquad (16)$$

where
F_R is total tractive effort, N
W sulky weight, N
L load weight, N
μ_R rolling resistance coefficient, N
S slope, %

The pull generated by a man can be estimated by using Table 1. The force a man can exert for a whole work day is about 20...25 % of the body weight (very easy/easy).

By combining eqs. (15) and (16) and by solving the load size, the following load size model for a team of two workers can be developed (eq. (17))

$$L = \left[\frac{2 \cdot F_P}{\mu_R + \frac{S}{100}} - W \right] \cdot 0.1 \qquad (17)$$

where
L is load size, kg
F_P pull, N
μ_R rolling resistance coefficient
S slope, %
W weight of sulky, N (W = 200 N)

As the grade resistance exceeds the rolling resistance on slopes steeper than –15...–20 %, the maximum load of x · mass of team is used. Simulated loads using 100 N (17 % of body weight) and the maximum load equal to body mass (x = 1) are compared to observed loads in Fig. 4. The rolling resistance coefficient 0.2 was used because there always is some obstacle resistance on the forest floor. There is a rather good fit with the model if S_{eff} is used instead of S in the model (17).

For assessing the target load for different working conditions it seems possible to use eq. (17), since the rolling resistance can be based on soil conditions. On hard smooth surfaces a rolling resistance coefficient 0.1...0.15 has to be used. On somewhat rough and/or soft surfaces 0.15...0.20 is adequate. For difficult conditions 0.20...0.25 may be used and for large steep or very rough surfaces even larger coefficients may be used. When estimating the pulling force, a team constant of 0.8...0.9 for a team of two should be used, as the team members have difficulties in synchronising their movements.

It is worth studying if the empirical data fits better with S_{eff} than with S in further studies, where more emphasis is put on studying the real work instead of the time consumption only. Physiologically different muscles are involved in braking on steeper favourable slopes (exentric contraction) than in pulling on gradual favourable or adverse slopes (concentric contraction).

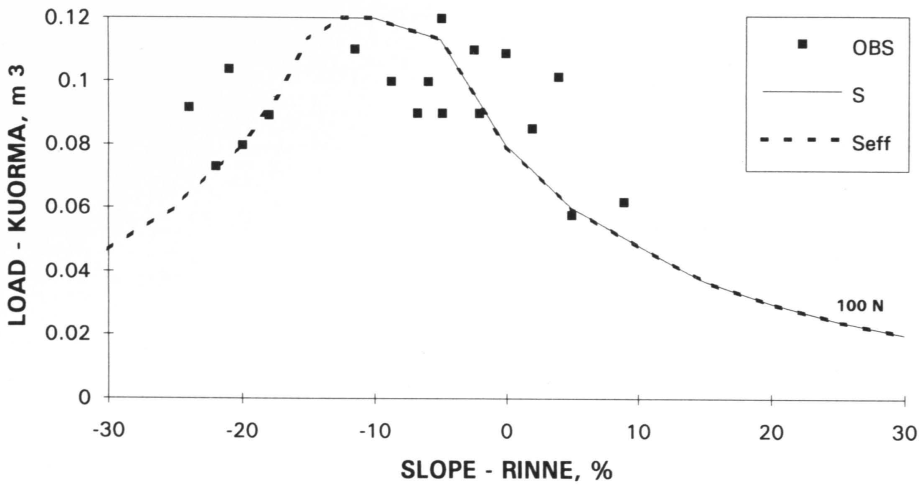

Fig. 4. Average load on different slopes compared to model (17) at 100 N pull per man.
Kuva 4. Keskimääräinen kuorma eri rinteillä verrattuna malliin (17) ja 100 N:n työntövoimaan miestä kohden.

8 Unloading

Unloading is composed of two different operations, the unhooking of the load and piling the logs on the landing area.

8.1 Unhooking time

In source I, unhooking time was constant and independent of the load size or the number of logs, 23 s (0.39 min). In source II the unhooking time was constant in one case, dependent on the number of logs in one case and dependent on the load size in six cases. The average unhooking time was 28 s. The unhooking time in source III was 46 s. The best models explaining the unloading time were

$$T_U = 25 \qquad (18)$$

$$T_U = 17 + 100 \cdot V \qquad (19)$$

where
T_U is unloading time, s
V load size, m^3

8.2 Piling time

In source I the piling time was short and as an average 12 s was used for arranging the logs at the yard. In source II the average piling time was 23 s and it was independent of the load size or the number of logs in three cases. The load volume explained the piling time in four cases and the number of logs in one case. In source III the piling time was highest, 46 s. The piling time was estimated by using models (20) or (21).

$$T_P = 23 \qquad (20)$$

$$T_P = 10 + 140 \cdot V \qquad (21)$$

where
T_P is piling time, s
V load size, m^3

Both the unhooking and the piling time contain a contingency allowance.

8.3 Energy expenditure in unloading

The energy expenditure while unloading is of about the same magnitude as in loading as the work consists of the same type of activities.

$$EEC_U = 2 \cdot m \qquad (22)$$

where
EEC_U is energy expenditure in unloading, W
m body mass, kg

9 Cycle time

9.1 Delay time

The delay time in source I was short. The average necessary (unavoidable) delay time per cycle was 5.5 s and unnecessary delay time was 1.5 s. They represented less than 2 % of the total time. In source II the delay time was 3–9 % of the effective time, the average delay time being 5 % or 13 s per cycle.

9.2 Cycle time

The average cycle time in source I varied from 4.54 to 4.83 min ($\bar{x}$ = 4.68) and the average skidding distance was 46 m on +6 to –24 % slopes. In source II the average effective cycle time varied from 4.28 to 5.59 min ($\bar{x}$ = 4.31) over an average distance of 78 m on slopes between –2 and –9 %. The total times are about 5 % higher after adding the delay times. The total effective cycle time in source III was 5.48 min over a 31 m average distance at ±10 % slope.

10 Allowances

The element times and the load size for the production rate may be calculated by using the models given in Sections 4–8. The times are net times and some allowances are needed to get standard times. The ILO (1979) handbook enumerates the following allowances:

- relaxation allowance
- contingency allowance
- policy allowance
- special allowance.

The relaxation allowance provides an opportunity to recover from the physiological and psychological effects of carrying out a specified job. For *personal needs* about 5–7 % is added. *The basic fatigue* allowance is 4 %. As the average work load stays low, a 10 % relaxation allowance is adequate.

Two or three rest pauses of 15 minutes each are needed for drinking, especially in warm working environments. When estimating a daily production rate, 45 min should be subtracted.

The contingency allowance is a short time to cover different irregularities during the work. The contingency allowance is usually < 5 % of the standard time. Different delay times and a constant in the time equations already in fact include a contingency allowance, but still a 5 % contingency may be added to standard times.

A policy allowance is an increment applied to standard time to provide a satisfactory level of performance under exceptional circumstances. This additional time may be added to the standard time in order to make the use of standard times more flexible.

Special allowances contain different times, which usually are separated as different times outside the work cycle, such as shut-down, cleaning and tool allowance. Some 15 to 30 minutes per day are needed for starting the job and for maintaining the equipment etc.

The learning allowance is used for trainees as their work pace does not equal the pace of skilled workers. It is important to note the learning process when carrying out time studies in early phases of implementing new methods. Standard time should be shorter than the time measured when observing non-skilled workers.

About 20 % of the allowances is to be added to the cycle time as well as 45 to 60 daily work place time minutes in order to obtain a standard work-place time.

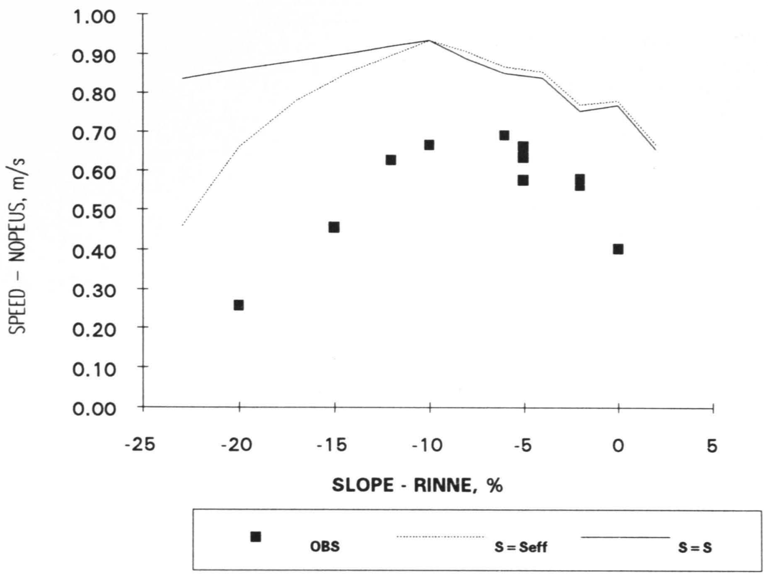

Fig. 5. Average speed of different observations compared to a theoretical speed where the use of the actual and the effective slope is compared.
Kuva 5. Havaintojen keskinopeus ja teoreettisella mallilla laskettu keskinopeus, kun rinnekaltevuutena on käytetty todellista ja tehollista rinteen kaltevuutta.

11 Conclusions and recommendations

The time study results concerning the return and travel speeds were close to figures obtained by using theoretical work study models. Also the load size may be estimated rather well from the estimated capacity of the workers. It appears that the application of some work study methods is useful in developing ergonomically acceptable, efficient working methods. Further studies are still needed and the testing of the reliability of the walking energy and pulling energy model (eq. (13)) is of prime importance. If this model can be improved, then the estimating of production at different power levels becomes reliable and fair production tasks or piece rates can be set. Another weak point is the use of slope/effective slope. The concept in Fig. 5, the average speed (return + travel times over 100 m) at different observations, is depicted together with the theoretical average speeds with a 30 s constant time. It can be seen that the speeds when the actual slope (S) has been replaced with the effective slope (S_{eff}) fit better with the observed speeds. This shows the importance of improving the hypothesis lying behind the calculation method.

References

ILO 1979. Introduction to work study. 3rd edition. International Labour Organisation, Geneva. 442 p. ISBN 92-2-101939-X.

Ole-Meiludie, R.E.L. 1984. The influence of thinning procedures on logging production rates and costs in a Tanzanian softwood plantation. Ph. D. thesis, University of Dar es Salaam, Faculty of Agriculture, Forestry and Veterinary Science, Morogoro. 308 p.

— & Omnes, H. 1979. The use of sulkies in thinning softwood plantations. University of Dar es Salaam, Faculty of Agriculture, Forestry and Veterinary Science, Morogoro. Division of Forestry, Record No 9. 13 p.

Saarilahti, M. 1986. Walk and step test procedure for special project data collection. Lecture Note FO 202, Forest Engineering. Stencil No FEN 65, Appendix 1. Sokoine University of Agriculture, Faculty of Forestry, Morogoro, Tanzania. 20 p. + append.

— 1991. Maastoliikkuvuuden perusteet. Metsäntutkimuslaitoksen tiedonantoja 390. 99 p. ISBN 951-40-1174-0.

— 1992. Man as prime mover, an ergonomic frame of reference for manual timber transport. Seloste: Ihminen vetokoneena, ergonominen viitekehys miesjuontoon. Manuscript for Silva Fennica.

— , Bakena, E., Mboya, G., Minja, T., Ngerageze, T. & Ntahompagaze, J. 1987. Studies on Tanzanian forest work. Silva Fennica 21(2):171-202.

— & Fue, G. E. 1987. Resisting forces in manual timber transportation. Proc. of the 9th International Conference of ISTVS, August 31th–September 4th. Barcelona, Spain. I: 288–295.

Skaar, R. 1973. Skidding of sawlogs from conifer thinnings with a locally made skidding cart. A pilot study. Makerere University, Dept. of Forestry, Kampala, Report 01-73. 18 p.

Total of 9 references