Cable Corridor Installation Times For European Yarders

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ABSTRACT

Cable yarding continues to be an efficient and effective harvesting system for the extraction of timber on steep terrain. Modern European silvicultural strategies result in smaller harvest areas, lower extraction volumes and a shift from clear-cut to thinning operations or single tree extraction. Yarder installation time has, especially as a proportion to the extraction time, increased significantly, resulting in higher extraction costs. This study recorded the set-up and take-down time of 79 cable yarder installations. Another 76 installation times were taken from previously published time studies, for a total sample size of 155. The factorial study design differentiated uphill-or downhill yarding, yarder size and whether or not it was the first installation at a landing, or subsequent parallel installation from the same landing area. The covariates recorded were corridor length, terrain slope, number and height of intermediate supports, and number of forest workers. Both a set-up and take-down time models were developed. This will help estimate future cable installation time requirements, and more importantly, provide improved cost estimates for the new silvicultural treatments.

Keywords: *Cable yarding, installation, set-up, intermediate support, steep terrain harvesting.*

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INTRODUCTION

Cable yarding operations continue to be an important technique for harvesting timber. It is proven to be low impact on both soil and the residual stand, and suitable for steep terrain. It has been used extensively in central Europe since the 1970s when mobile integrated tower yarders were introduced (e.g. [5, 7]). In a country such as Austria, about 57% of the forested area is on terrain steeper than 30% [9]. Currently, approximately 20% of the annual harvest in Austria is extracted by cable yarding [2]. On Austrian federal forests lands 34% of the timber extracted is with cable yarders.

Unlike ground-based operations, considerable time is required for rigging a cable corridor before extraction can begin, as well as taking down the rigging after the extraction is complete. This can be completed by a specialist ‘pre-rigging’ crew prior to the arrival of the yarder, or by the yarding crew itself as is most common in Europe. Basic rigging steps include laying out the guylines, preparing the guyline anchors, connecting them and tightening them appropriately. Working cables are laid out, sometimes with the aide of a small diameter strawline, including the skyline down the main corridor. A haul-back line is laid around the setting, a mainline is attached to the carriage, which is turn is mounted onto the skyline (see also Oregon OSHA Yarding and Loading Handbook [1], Samset [10] or Vyplel [15] for a more complete description of yarder installation procedures and options).

The use of intermediate supports is another specific rigging option that can be employed to extend the terrain range that a yarder can effectively operate. This involves a support jack being rigged into a sturdy tree along the corridor that will suspend the skyline above the ground (Figure 1). The use of intermediate supports in cable corridors can have three beneficial effects; (a) allows the yarder system to harvest on terrain that is not concave, (b) allows the corridor to be extended and (c) allows the logs to remain at least partially suspended as they are being extracted from the stump to the landing.

Cable operations are most efficient in larger clearcut operations, where the proportion of rigging time is small compared to the time spent extracting timber. Also, once a yarder is set-up, subsequent corridors from the same yarder/landing location can be rigged relatively quickly. Although yarder operations in Europe have long been working with relatively small clearcuts or thinning operations, there is even more public pressure now to go towards a single tree select harvest, and maintaining multi-age stands. There is also a trend towards building less new road infrastructure. This type of silvicultural regime in Central Europe is referred to as ‘near to nature’.

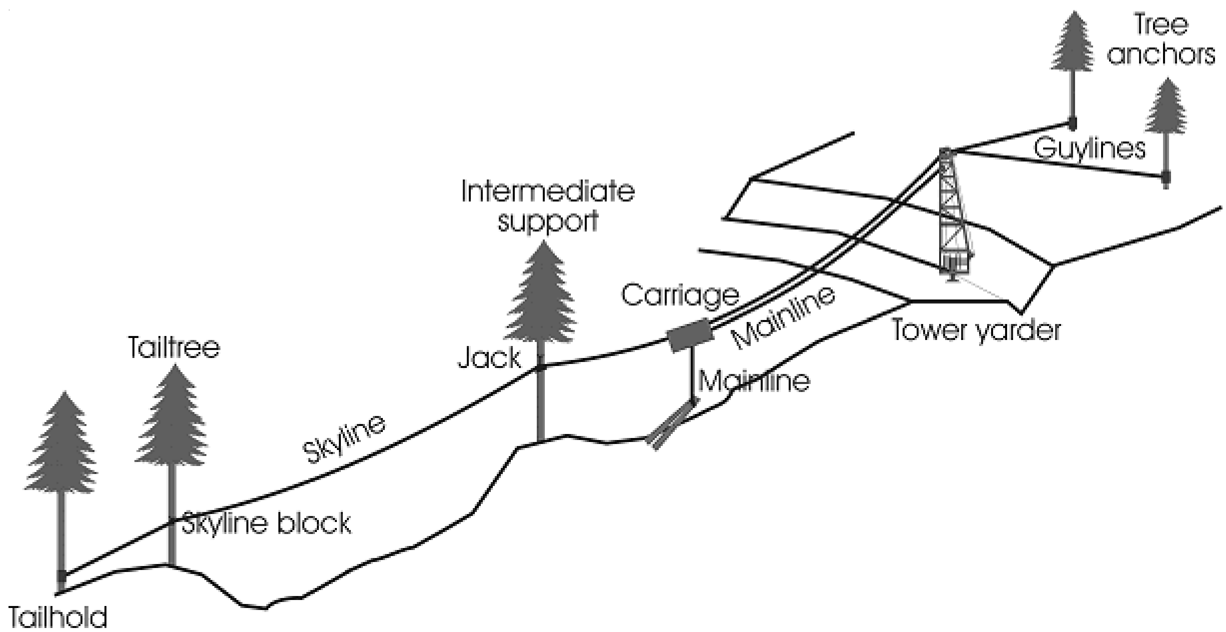

Figure 1. Schematic diagram of a cable yarding corridor showing the use of an intermediate support.

The shift in silvicultural regime from small clear-cut toward maintaining multi-aged stands and 'near-to-nature' silvicultural regimes has an impact on subsequent harvesting operations. For cable operations this means more installation time per cubic meter of timber extracted, longer extraction corridors, and greater need for the use of intermediate supports. With harvesting costs generally increasing it is more important than ever to carefully weigh the benefits of any silvicultural system with the impacts on subsequent harvest operations.

A large number of factors will influence individual yarder installation times. Corridor length, terrain factors, extraction direction, and yarder type have been identified as key factors in central Europe [3, 10, 13, 15]. Frutig and Truempi [3] and Trzesnioswki [13] report that subsequent corridors from the same landing location require shorter installation times. Frutig and Truempi [3] also identify the number of supports used, road access to tailholds and whether or not artificial anchors were used as important factors. Samset [10] and Haynes and Visser [4] suggest crew experience is important. With the changing silvicultural strategy, both the number of intermediate support installations as well as the height of the supports will become more critical for estimating yarder installation times [6].

Three published theses and one dissertation (Institute of Forest Engineering, University of Natural Resources and Applied Life Sciences Vienna, Austria) contain data sets on yarder installation times [8,16,17 and 13]. The goal of this study is to revisit these complete data sets as well as complementing them with a series of new data sets to provide an accurate model for the installation of cable corridors. Such information will be useful for harvest planning and costing. Additionally it should be used to gauge the impact of changing silvicultural regimes.

METHODOLOGY

This study combines previously published data sets together with new data recorded for this project for the development of the cable corridor installation model. Table 1 identifies the sources of the 76 previous cable corridors installation data sets. All the data sets were obtained from the original author. The new data, collected specifically for this study, comprises of 79 individual cable corridors. Of this, 52 of the data sets were recorded using Austrian Federal Forestry crews. The remaining 27 data sets were obtained from a large commercial forestry company Mayr-Melnhof in Styria. All the data sets originated from the mountainous regions of Austria.

Table 1. Summary of the published studies from which yarder installation data sets were used.

Information Source	Cable Corridors (n)	Source
Masters thesis	9	Woitsch 1987 [17]
Masters thesis	8	Mitterbacher 1989 [8]
Masters thesis	5	Wohlmuther 1991 [16]
PhD dissertation	54	Trzesniowski 1994 [13]
New data	52	Austrian Federal Forest Service 2003
New data	27	Forestry Company Mayr-Melnhof 2003
Total	155	

Recognizing the importance of all the variables measured in the previous studies, time of set-up and take-down is expected to be a function of yarding direction, yarder size, whether or not it was the first installation or subsequent parallel installation of the yarder at a landing, corridor length, slope of terrain, number and height of intermediate supports, and number of forest workers [12]. The new data sets collected specifically to complete the existing data sets measured all the variables identified in the previous studies, with the exception of an experience factor. All the crews monitored were considered experienced. Table 2 shows the variables measured and the units used. In addition to the above variables, block factors were used to test for significant difference between the data sets from the different authors, as well as between the private forest and federal forest data sets.

Although there are many different techniques for constructing an intermediate support, most of the intermediate supports used in this study are referred to as an L support (Figure 2). The tree is not topped, nor is it made to lean. A tree climber goes up and secures one to three guylines, typically just above where the jack is suspended. A strap or cable is then used to support the jack, and this is guyed back down to the ground. Finally, a small pulley is mounted in the tree above the jack and the skyline is hoisted into the jack. The support height is reported as the height of the support jack off the ground.

Table 3 identifies the nine different yarders, manufacturer, tower height, and mainline pull used in this study. It also shows the number of corridors data sets recorded on each yarder type. Yarder size was categorized on maximum mainline pulling force. Yarders with mainline force less than 35 kN were classified ‘small’.

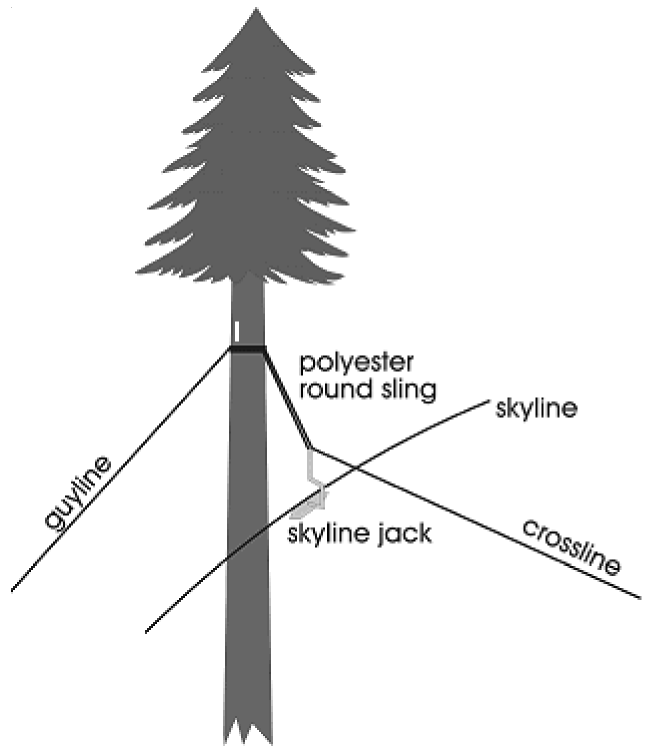

Figure 2. Typical L-support as used in the majority of the cable corridors studied.

STATISTICAL ANALYSES

Variance analysis attempts to quantify the influence of nominal or ordinal-scaled variables. The following steps were carried out on the data set to establish a time model [12, 13]:

- Calculate the effect of each covariate and factor and test for statistical significance.
- Evaluate the non-linearity of the variables.

Table 2. Cable corridor variables recorded for study.

Type	Name	Units	Description
Dependant	Set-up	Hrs	Time it takes to install the cable corridor
Variables	Take-down	Hrs	Time it takes to take down the corridor
Factors	Extraction-direction	1/0	Uphill (1) or downhill (0) extraction
	Yarder size	1/0	Large yarder, mainline pull >35 kN (1) or small yarder (0)
	Corridor type	1/0	Differentiates between first corridor (1) installation or subsequent installation from the same landing location.
	Num workers	Num	Number of workers actively helping with installation
Covariates	Corridor length	(m)	Diagonal slope distance between tower and tailhold
	Slope	(%)	Average slope
	Intermediate support	(#)	Number of supports in the corridor
	Support height	(m)	Height to the support jack
	Tailtree height	(m)	Height in the tailtree (see Figure 1)

Table 3. Yarder types studied and number of measurements collected.

Yarder Type	Manufacturer	Tower Height (m)	Mainline Pull (kN)	Number of Corridors
SKM 5 / PKM 5	Austrian Federal Forest (ÖBF)	8	21	30
SKM 6 / PKM 6	ÖBF	8	34	18
SKM 10	ÖBF	10	41	37
KM 16	ÖBF	15.3	54	14
PKM 12	ÖBF/Wolf-Systembau	12	58	2
Turmfalke	Mayr-Melnhof	10	25	32
Syncrofalke	Mayr-Melnhof	10	30	5
Urus III	Hinteregger	8.5	22	9
Urus 76	Hinteregger	8.2	55	4
Urus 80	Hinteregger	10.8	43	4

- Analyze the compound effect between factors and covariates.
- Estimate the parameter values for the significant factors and covariates through regression analyses.
- Test the model with residual analyses.
- Necessary model refinements.
- Plausibility analyses.
- Model evaluation.

The statistical software SPSS was used to carry out this procedure [14].

RESULTS AND DISCUSSION

Table 4 summarizes and describes a subset of the basic data collected. The average diagonal corridor length was 309 meters. The average terrain slope was 51 percent. In 73 of 155 data sets at least one intermediate support was installed, a second intermediate support was used in only 10 of the corridors recorded. The height of the intermediate support varied between 6 and 18 meters, with the average of 12 meters. The height in the tailtree was on average 10 meters.

Table 4 also shows that on average 18 worker-hours were required to install a cable corridor and 8 hours to take it back down. This means, for a typical three worker crew, the average time is 6 hours for installation and 2.75 hours to take it down.

For both models, the only block factor that showed to be significant was the difference between the current data sets collected from the private forest and the federal forest crews for the set-up installations times ($p=0.001$). All the results presented and models developed are based on the 'private industry yarder' installations. That is, the block factor for federal forest crews is not included, but all data sets were used ($n=155$). The block factors that differentiated the previously published data sets did not show to be significant. Residual analyses indicated that the data was not normally distributed, and a logarithmic transformation resulted in a greatly improved model. All variables used in the equations were significant ($p<0.002$). In the set-up model, the height of the intermediate support was significant and included. In the take-down equation only the presence or absence of an intermediate support proved significant, not the height.

Table 4. Summary of the average, the 5% and 95% percentiles, and the number of individual data points for the data sets used in this study.

Variable	Average	Percentile Range 5%	Percentile Range 95%	Number
Diagonal corridor length (m)	309	144	564	155
Int. Support height (m)	12	6.7	18	73
Second intermediate support height (m)	9.5	6	12	10
Tailtree height (m)	9.6	4,8	15	95
Terrain slope (%)	51	29	71	155
Num. of workers (#)	2.7	2	4	155
Set-up time (worker-hours)	17.9	4.1	55.6	155
Take-down time (worker-hours)	7.8	2	26.8	155

The complete installation time model, including all the significant variables is as follows, whereby the values of the factors are described in Table 2:

Installation time (hrs) = Set-up (hrs) + Take-down (hrs) [Equation 1]

Set-up time (hrs) = e ^ (1.42 + 0.00229 x corridor length (m) + 0.03 x int. support height (m) + 0.256 x corridor type – 0.65 x extraction direction + 0.11 x yarder size + 0.491 x extraction direction x yarder size).

$R^2 = 0.78$ [Equation 2]

Take-down = e ^ (0.96 + 0.00233 x corridor length – 0.31 x extraction direction - 0.31 x int support + 0.33 x yarder size).

$R^2 = 0.64$ [Equation 3]

Figure 3 shows the installation time as both a function of corridor length as well as intermediate support height. Installation time increase exponentially with corridor length, and increases substantially with increasing height of the intermediate support. Figure 4 shows the effect extraction direction, with downhill extraction taking almost twice as long to install as the more conventional uphill extraction. The primary reason for this difference is the need for rigging a haul-back line.

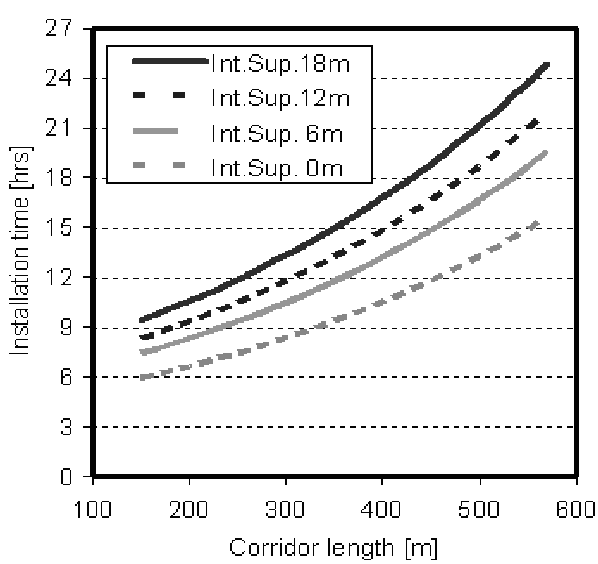

Figure 3. Model Results for installation time showing the influence of corridor length and intermediate support height (with small yarder; uphill yarding; 1st installation.)

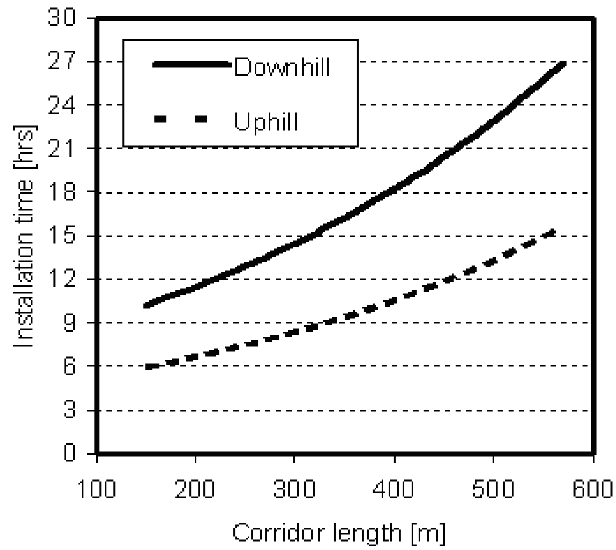

Figure 4. Effect of extraction direction (uphill vs downhill) on the installation time requirement. (small yarder, 1st corridor, 10 m intermediate support height).

Analysis shows large differences in installation times. While an uphill short corridor (150 m) can be installed on average in 6 hours; a 500 m downhill corridor with a single support will require 23 hours. At current Austrian labor rates (US$44/hr for one worked) this represents a US$750 increase between these uphill and downhill corridor options.

Based on the regression equations, the set-up and take-down models explained 78 and 64 percent of the variation respectively ($R^2 = 0.78$ and 0.64). Other sources of variation could possibly be the actual experience level of the workers, terrain slope and roughness, accessibility to intermediate support and tailtrees, line sizes and weather.

SUMMARY

The goal of this study was to develop an accurate cable corridor installation time model. Unlike ground-based operations, cable yarding extraction requires considerable time and effort for installation. Changing silvicultural practices can and will impact installation requirements. Reduced timber volumes per corridor can significantly increase the proportion of installation time relative to productive extraction time, thus increasing harvesting costs (unit costs and total costs).

Based on regression analysis of 155 separate yarder corridor data sets (76 corridors from previous studies and 79 corridors from the present study), models were developed for both set-up and take-down times. These could be combined for a predictive corridor installation time model. Corridor length, intermediate support height, corridor type, extraction direction, yarder size all are significant factors that define set-up time. Corridor type, extraction direction, number of intermediate supports and yarder size were significant factors that determine take-down time.

Accurate estimation of yarder corridor installation time is not only important for harvest planning and costing of operations, it can also help assess cost increases associated with silvicultural recommendation. The present model could easily be implemented in Decision Support Tools, which can offer the forest manager options for steep terrain harvesting considering forest engineering and silvicultural goals at the same time.

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