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Implementation challenges for CTI in Norwegian wood supply

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Abstract: CTI (central tire inflation) or VTPC (variable tire pressure control) is a well-established technology for logging trucks in many forest regions. Norwegian wood supply is sourced primarily from non-industrial private forest owners over a road network with fragmented ownership. Truck transport is done by independent owners/operators while contracting and management is handled by jointly owned transport associations. In this context, successful implementation of CTI may require financing from multiple stakeholder groups.

This paper presents a pilot study on the possibilities for CTI use in Norway. In the first part of the study respondents from three stakeholder groups from coastal and interior regions were interviewed to map consensus on expected implementation effects and willingness to participate in a common financing model. In the second part of the study a method was tested for selecting focus areas for CTI-introduction based on wood supply and forest road data. Results also highlight the additional potential of CTI to gain access to mountainous parts of the study area with steeper road grades.

Keywords: introduction area, bearing capacity, transport distance, gradeability

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1. Introduction

After development of central tire inflation (CTI) for military services during the 1940s and 50s, the technology was adapted to industrial contexts during the 1960s and 70s. The development and use of CTI on logging trucks began during the 1980s and 90s in North America and similar testing began in the Nordic countries after year 2000 (Bradley 2010). Since then implementation in parts of Sweden has increased (Hell 2011, Rådström 2014), particularly in areas of sedimentary parent materials with low bearing capacity (Ramén 2014). Numerous earlier studies have examined the effect of CTI on the traction of logging trucks in mountainous terrain (Bulley & Blair 2001).

Payment for logging truck transport services is similar throughout the Nordic countries, using a tariff formula with a fixed price per cubic meter plus a distance-dependent price per cubic meter and km. In Norway, these tariffs vary considerably between areas because of the varying GVW allowed on different segments of the road network. Although transport from forest to mill has traditionally been paid by the mill customer, suppliers may also bear the extra costs of the transport service when their forest roads do not fulfill agreed standards. The effects of CTI on both bearing capacity and gradeability are therefore of interest for Norwegian wood supply and warrant a closer examination of its application there.

This paper describes a pilot study examining the possibilities for introducing CTI in Norwegian wood supply. The study had two parts; evaluating user views of CTI and finding an area suitable for CTI introduction.

2. Material and Methods

The study of stakeholder views of CTI was based on quantifying response within two themes; the expected effects of CTI and different alternatives for financing CTI-investments. Ten respondents were interviewed; 5 from the mid-coast region and 5 from the interior valley region. The distribution of respondents per region was as follows: forest owners association (2), truck operator/owner (1), transport administrator (1) and forest industry (1). Each respondent was given the same general introduction to CTI technology for conventional logging trucks (56-60 t, 7-axle self-loading truck and trailer combinations with dual tires and tandem-drive). After this they were asked to evaluate 19 formulations on a written questionnaire with a 5-point Likert scale (1=disagree, 5=agree).

The second part of the study tested a method for locating an area with sufficient volumes of suitable conditions for a possible introduction of CTI in Oppland county of southeastern Norway. The approach was based on joining delivery data to forest road conditions. The delivery data concerned one year’s pulpwood deliveries (2014) including date of delivery, landing GPS coordinates, volume, species, distance to delivery point and maximum GVW allowed on the delivery route. The forest road data consisted of a 3-category field classification of road characteristics (2012-2014) including wearing course thickness, road width, shoulder width, ditch function, bearing capacity as well as measurements of the maximum road grade in both unloaded and loaded directions. Bearing capacity (BC) was classified also on the basis of the current frequency of rutting (0=no rutting, 1=shorter sections of rutting, 3=continuous rutting over the entire segment). The joining of the respective landings and road segment positions was done with GPS coordinates in Q-GIS with the nearest neighbor join function (NN-join).

After getting an overview of geographical distribution of potential delivery volumes over CTI-relevant road conditions, supporting cost models were made for the estimating the effect of CTI on typical road maintenance costs and transport costs.

3. Results

3.1. Stakeholder acceptance

High median scores (4 or higher) in the stakeholder interviews gave an indication of existing consensus on CTI effects and financing alternatives (Table 1). Clear consensus exist on the expected points such as increased traction on steep grades (5) and bearing capacity during thaw/rain (5), followed by reduced need for road maintenance (4,5) and storage time at landing during thaw/rain (4).

Concerning the stakeholder group that should cover the costs for CTI, no consensus was seen for any particular group, but it was clear that a mutual or distributed financing alternative was preferred (5). Regarding exactly which costs should be covered, no high scores were found, with only a neutral score for a complete coverage of installment and running costs (3) and a lower score for adjusted tariffs (2,5).

Table 1: Stakeholder agreement (1-5) with claims regarding the expected effects of CTI and potential alternatives for financing and service payment.

Theme	Claim [unit]	Median score [1-5]
Expected effects of CTI	Increased traction on steep grades	5
	Increased bearing capacity during thaw/rain	5
	Reduced need for road maintenance	4,5
	Reduced storage time at landing during thaw/rain	4
	Reduced rutting year-round	3,5
	More even delivery rate during thaw/rain	3,5
	Reduce truck vibrations and increase operator comfort	3,0
	Reduced storage time at terminal/mill	2,0
	Reduce wear on trucks and increase truck life	2,0
	Reduce annual utilization hours	2,0
	Reduce diesel consumption	1,0
CTI should be financed by	Supply organization	2,5
	transporter	2
	Mill customer	1
	Mutual financing model	5
Financing should cover	Complete installment and running costs	3
	Coverage of transporters costs via adjusted tariff	2,5
	Partial installment and running costs	1,5

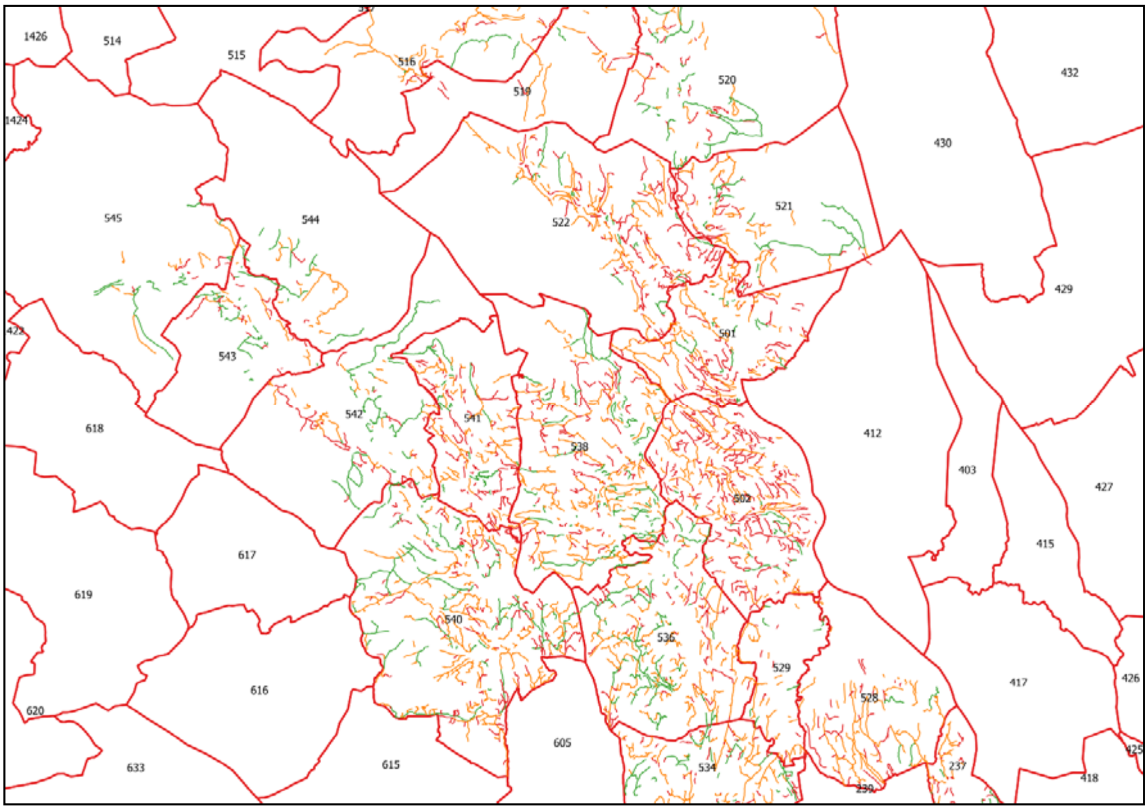

Figure 1: Geographical overview of forest road bearing capacity classes 1 (green), 2 (orange) and 3 (red) in the municipalities in Oppland county (red borders with black numbers).

3.2. Suitable areas for CTI introduction

For the second part of the study, joining spring, summer and fall deliveries with the road segment data showed that approx. 25, 55 and 20 % of delivery volumes came out on roads with bearing class 1 (high), 2 (medium) and 3 (low), respectively. Four municipalities of 27 (no 502, 521, 541 below) had the highest proportions of deliveries linked to road segments with class 3 (Figures 1 and 2).

Six of 27 municipalities had high proportions of volumes linked with forest roads with high adverse loaded grades (Figure 2). These were clustered in two parallel valleys (519/521/522 and 541/542/543) and one intermediate area (538). The three municipalities with low bearing capacity formed a perimeter encompassing most of the municipalities with steep roads.

3.3. CTI costs and potential road maintenance savings

A simple truck cost calculation model was used to quantify the extra cost of CTI. The calculations assume an installment cost of 250 000 NOK per truck with annual maintenance costs of 25 000 NOK per year. Given the initial installation cost, the extra cost of CTI per transported m^3 increased with decreasing yearly production (m^3/yr) and increasing transport distance, yielding an extra cost of approx. 1,5 NOK/m^3 at 50 km and 2,5 NOK/m^3 at 150 km (Figure 3, left). Accumulating the annual delivery volumes over roads of bearing capacity class 3 over increasing transport distances within the relevant municipalities yielded the result shown in figure 3 (right). Given a required annual transport volume of 30 000 to 50 000 m^3 for a conventional logging truck, figure 3 shows that these volumes are available without exceeding a distance of 80 km to pulpwood terminals. The maximum cost for CTI under these conditions is lower than 2 NOK/m^3. These volumes (transport distances < 80 km) were sourced primarily from a single valley (municipalities 501, 502, 519, 521, 522) where the rail corridor offers numerous terminals. The distance from the terminals to the neighboring parallel valley (541, 542 or 543) exceeded the 80 km limit.

Data on forest road maintenance costs was collected from a local road association in a municipality with a high proportion of deliveries over bearing capacity class 3 (municipality 521). In this case the actual road maintenance costs over a two year period averaged 30 NOK per transported m^3. Given that 75 % of road maintenance costs typically consist of gravel and grading (Bjerketvedt & Nyeggen 2007) and CTI typically results in a 20 % reduction in road wear (Bradley 2010) this offers a theoretical reduction in road maintenance of 15 %. For the given case study (15 % reduction of 30 NOK/m^3) this corresponds to a road maintenance savings of 4,5 NOK/transported m^3, more than twice the extra costs of CTI.

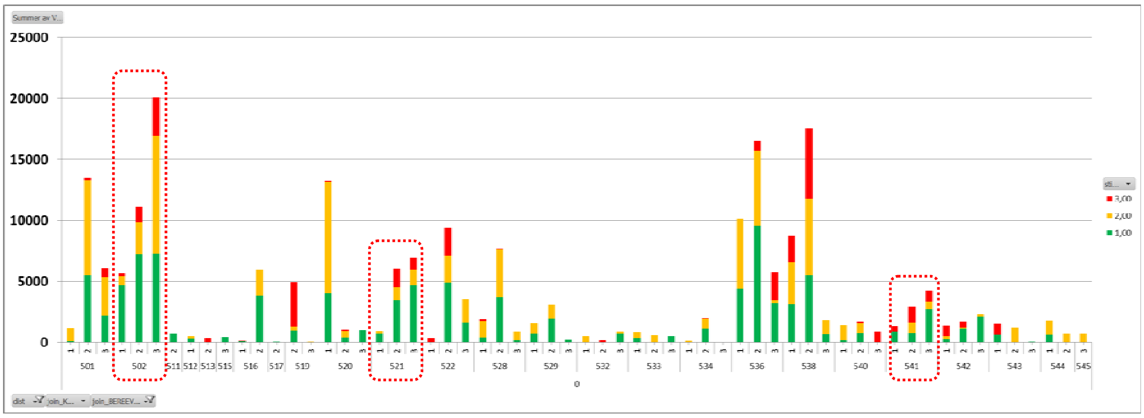

Figure 2: Distribution of spring, summer and fall delivery volumes (m^3/year) per municipality (501-545) and forest road bearing capacity class (1-3 on X-axis). The colors indicate the distribution of volume per class of adverse loaded grade (green= 0-5 %, yellow= 5-10 %, red > 10 %).

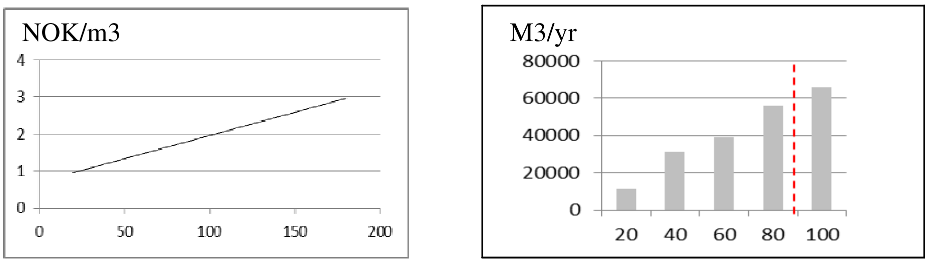

Figure 3: The cost of CTI (NOK/m^3 on y-axis) with increasing transport distances (km) on the left. The annual delivery volumes over roads of bearing capacity class 3 (m^3/year on y-axis) available within a maximum transport distance (km) on the right.

The final question within the pilot study was the expected effects of CTI on the availability of areas with steep adverse grades in winter. For this, straight line gradeability formulas were used from Skaar (1977) and Hjort (2012) together with a selection of winter traction and rolling coefficients (Söderlund & Wickström 1963, Nilsson 1970, Wenger 1984). Given a typical GVW of 56 t with 18,4 t on the tandem drive, typical coefficients (traction = 0,33, rolling resistance = 0,0022) yielded a maximum loaded winter grade of 9 %. Given an 18 % increase in traction with CTI (Amlin & Bradley 1992) the grade increased to 11 %. Applying the 9 % limit for adverse loaded grades on the joined road segments indicates that 33 % of the winter deliveries would require a reduced trailer load without CTI. The use of CTI (11 % adverse grade) reduced this volume to 19 %.

4. Discussion

The first part of the study notes that many of the effects of CTI quotes from previous studies were directly credible for the interviewed stakeholders. The remaining issue concerns the financing of the initial CTI investment and later payment for CTI services. Experiences from the introduction of CTI in Sweden showed a transition from 1) initial investment subsidies (paid by the transport service buyer) for the first vehicles to 2) later service payment solutions with adjusted tariffs. In the Swedish case, the accounting of transport services can be handled via a central forest sector information system (SDC) with contract-specific tariffs, enabling adjustment for CTI-specific tariffs. The architecture of the Norwegian system (SkogData) is similar the Swedish and provides the same possibilities. Wood pricing in Norway, however, has historically been set for delivery to roadside, with transport costs being paid by the mill customer. An increasing proportion of supply agreements have been set with terminal or mill-side prices with transport costs then being paid by the supply organization (in most cases the forest owner's association). This offers the potential to simplify transactions for redistributing eventual CTI costs between relevant stakeholders, such as the owners of marginal forest roads. While the interview results showed a consensus for a distributed financing model (score=5 in Table 2), the respondent scores for financing via single stakeholder groups showed the least pressure on the mill customer (score=1), with a slightly higher pressure on the transporter (score=2) and the supply organization (2,5).

The general consensus on CTI effects include both increased availability and reduced road maintenance costs. These advantages accrue to either the individual forest owner (reduced road maintenance) or the forest owner's association (improved wood availability to fulfill delivery contracts). Assuming a 50/50 distribution of pulpwood and sawlogs, a straightforward use of CTI-tariffs would channel 50 % of the extra costs to the forest owner's association (where pulpwood is priced for delivery to terminal) and 50 % to local sawmills (where sawlogs are priced for delivery to roadside). As noted earlier, limiting the additional cost of CTI to the indicated levels (1,5-2 NOK/m^3) also assumes that CTI-trucks are used year-round on short-haul deliveries, which would reduce the flexibility of fleet management by transport associations. The realism of these assumptions varies between seasons and years and must be examined further with the relevant stakeholders. A straightforward solution for implementation of CTI-specific tariffs is to pass on the additional costs to individual forest owners whose road networks require this technology. This could be handled through the internal pricing mechanisms of the forest owners association.

The second part of the study estimated sufficient CTI-relevant volumes to run a CTI-truck year-round within the indicated perimeter of clustered municipalities, without exceeding a cost of 2 NOK/m^3. This cost compared favorably with a 4 NOK/m^3 estimated saving of road maintenance costs. The estimated savings of road maintenance, however, relies on three assumptions; first, that the road maintenance cost for the selected case (30 NOK/m^3) is representative, second, that all maintenance needs result from logging transport and third, that the year-round reduction of rutting with CTI is really 20 %. A more conservative estimate assuming 20 NOK per transported m^3 with an estimated savings of only 15 % would reduce the net savings to only 1 NOK/m^3. In this case, increased wood availability for the supply organization becomes a more relevant aspect for CTI-financing.

The effect of CTI on winter traction was also relevant in the case area. The latest years have seen an increase of maximum allowed GVW from 50 and 56 to 60 tons. While most of the older forest roads are designed with a maximum grade of 10 % (for 50 t trucks), these may not be as easily available for winter transport for heavier truck configurations. However, an 18 % increased traction for driven tandems with CTI (Amlin & Bradley 1992), almost compensates for the 20 % increase in GVW, maintaining cost savings expected of 60 t trucks (2 NOK/m^3 and 0,05 NOK/m^3/km). On the other hand, the proportion of loads actually delivered with a GVW over 50 t was still under 50 % at the time of the case study because of bottlenecks in the connecting municipal and county roads.

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