Continual monitoring of fuel consumption and load utilisation of ETT and ST vehicles

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Summary

Carbon dioxide emissions from the transport sector could be reduced by increasing the proportion of HCT (High Capacity Transport) vehicles on the roads. HCT vehicles use less fuel and generate fewer emissions per transported unit. In Sweden, a number of projects are currently under way in which HCT vehicles are being tested in practical operation. Studies show that fuel consumption is reduced by up to 20% in transports using 90-tonne vehicles, and by 8-12% for 74-tonne vehicles, compared with today's vehicles with a gross weight of 60 tonnes.

The aim of this study was to continually monitor and calculate fuel consumption and load utilisation, and to describe how traffic intensity would be affected by a possible switch to some alternative HCT vehicles.

Results and conclusions

- Average fuel consumption of the ETT vehicle was 16.90 ml/tonkm and 55.78 l/100 km. Average fuel consumption of the ST crane truck was 27.57 ml/tonkm and 63.36 l/100 km. Average fuel consumption of the ST group was 25.03 ml/tonkm and 55.14 l/100 km.
- Load utilisation varied between 96 and 98% for the ST vehicles in the study, apart from three of the ST vehicles where load utilisation was only 89% of the maximum permitted gross weight on up to 50% of all their journeys.
- Traffic intensity for timber trucks could be reduced by between 13 and 40% if today's roundwood trucks were replaced with HCT vehicles.
- Better and more accurate crane scales would enable load utilisation to be increased, and weight data could be collected automatically. This would save even more fuel and further reduce traffic intensity.

Introduction

In Sweden, approximately 70 million tonnes of roundwood and primary forest fuel are transported by road annually (www.skogsindustrierna.org; Andersson & Frisk, 2013). Transport of forest-related goods is responsible for more than 20% of all road transports in Sweden (Skogsstatistisk årsbok, 2013). The Swedish Environmental Protection Agency's road map for Sweden is based on national environmental goals and is aimed at reducing emissions. The goal is that, by 2050, Sweden will be free from net emissions. The transport sector and industry needs to implement very forceful measures if the climate goals are to be attained (www.naturvardsverket.se).

According to a survey, fuel consumption of roundwood trucks in Sweden lies between 26 and 30 ml/tonkm for a 60-tonne rig (Löfroth & Brunberg, 2013). The study was based on a survey of hauliers all over Sweden for one particular week in 2008 and the corresponding week in 2013. The hauliers reported fuel consumption for journeys (loaded vehicles) and the payload in question.

One way for the transport sector in Sweden to reduce emissions is to increase the proportion of high-capacity vehicles (HCT vehicles) on the roads, as they generate fewer emissions per transported unit (Löfroth & Svensson, 2012; Cider & Ranäng, 2013). Throughout Sweden, a number of projects are currently taking place in which HCT vehicles are being tested in practical operation.

Vehicles studied in these HCT projects include ETT and ST vehicles. ETT stands for *En Trave Till* ('One More Stack') and the gross weight of this vehicle is 90 tonnes. ST stands for *Större Travar* ('Larger Stacks') and these vehicles have a gross weight of 74 tonnes. Skogforsk initiated the project in 2006, and HCT vehicles have been tested in operation since 2009.

Results from the HCT projects show that fuel consumption per transported ton is reduced by up to 20% for transports using the 90-tonne vehicle, and by 8-12% for the 74-tonne vehicles, compared with traditional 60-tonne rigs (Löfroth & Svensson, 2012; Löfroth, 2010; Edlund et al., 2013).

AIM

The aim of the project was to continually monitor and calculate fuel consumption and load utilisation of all vehicles in the HCT projects, and to describe how traffic intensity would be affected by a possible transition to some alternative HCT vehicles.

Materials and methods

VEHICLE TYPES

The vehicles used in the study were the ETT vehicle (gross weight 90 tonnes), the ST Crane and the ST Group (gross weight 74 tonnes). All vehicles were run on diesel, apart from one of the group trucks that was run on RME during periods when the temperature is not too low (www.okq8.se). Without additives, vehicles can be run on RME down to -12 C and, with additives, down -25 C (www.ecobransle.se).

FUEL CONSUMPTION.

The transport work per vehicle and month was obtained by multiplying the transport distance (including when driven empty) in kilometres by the transported weight in tonnes for each journey, and then all the journeys were totalled for the period in question. The effect of transport distance on fuel consumption per tonkm (B) was analysed with an ANCOVA. In the ANCOVA, the vehicle type (T, i.e. ST Group, ST Crane and ETT) was used, and the inverted transport distance (a) was the covariate, as follows: $B = \mu + T + \beta \times 1/a + \varepsilon$

LOAD UTILISATION

Loading to ensure the vehicle reaches but does not exceed the maximum permitted gross weight (90 and 74 tonnes) is important for transport economics, emissions, and to justify official permits for higher gross weights on road transports. Load utilisation is calculated as follows:

- Payload (Gross weight - tare weight = Payload)
- Attained gross weight (collected weight data)
- Load utilisation per vehicle type (Attained gross weight / Maximum permitted gross weight = Load utilisation)

TRAFFIC INTENSITY

In simple terms, traffic intensity can be described as the relative number of roundwood vehicles with higher carrying capacity that are needed on the roads to perform the same transport work as the conventional crane vehicles that are used today. The greater the carrying capacity, the fewer the vehicles needed to transport the same quantity. Relative traffic intensity (RT) = Carrying capacity of today's roundwood vehicle system (LS) per HCT vehicle type (HCT) RT = LS/HCT.

Results

The number of journeys per vehicle varied between 82 and 676 (Table 1), and average transport distance varied from 93 to 160 km. The study was carried out in 2013 and the number of journeys is related to when the various vehicles were awarded their permits by the Swedish Transport Administration and the Swedish Transport Agency. Consequently, the vehicles were involved in the study for different lengths of time.

Table 1. Average transport distance when loaded, and number of observations (journeys) per vehicle type

ID	Vehicle type	Number of months	Number of journeys	Average transport distance (km)
A	ETT vehicle	9	632	160
B	ST trailer	3	82	112
C	ST crane	4	165	129
D	ST crane	9	676	88
E	ST group	4	239	98
F	ST crane	11	562	93
G	ST crane	9	560	81
H	ST group	3	185	139

FUEL CONSUMPTION

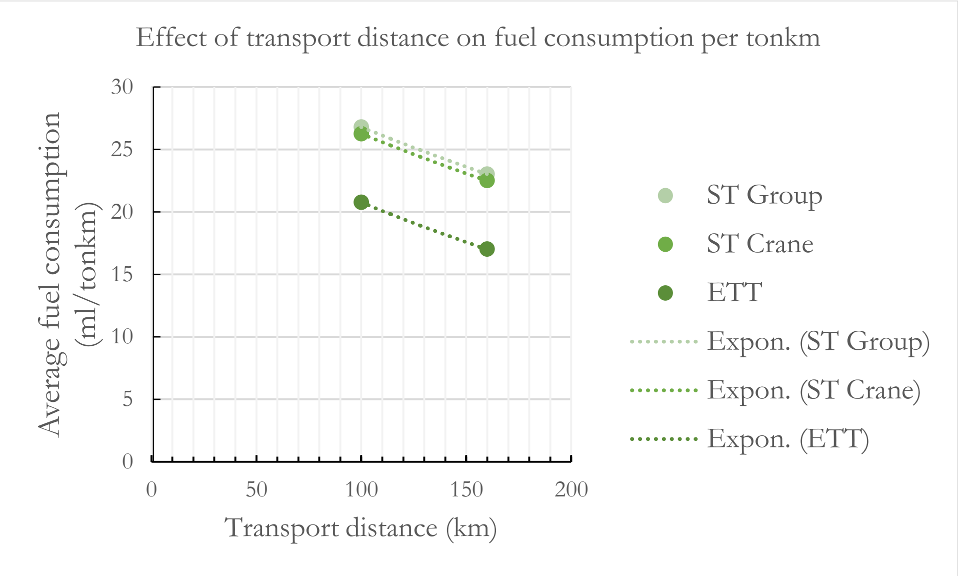

Figure 1. Normalised fuel consumption per tonkm for two different transport distances, 100 km and 160 km.

Fuel consumption was normalised in relation to the transport distance (Figure 1), which enabled the ETT vehicle and the ST vehicles to be compared regardless of the observed average transport distance. The normalisation was based on the covariance analysis of fuel consumption, which resulted in the following model for estimating fuel consumption (b):

$$B = 16.225 - 5.483ETT + 0.534STG + 1001.95/D$$

where ETT = 1 for ETT vehicles, otherwise 0, STG = 1 for ST group vehicles, otherwise 0, and D is the single-journey transport distance. The association should be treated with caution, as all observed transports for the ETT vehicle in the data involved the same transport distance, 160 km.

In Table 2, the average fuel consumption for each vehicle type in ml/tonkm in 2013 is shown. The figures are based on a different number of observations, depending on when the vehicle was commissioned during the year. The fuel consumption for each vehicle type was retrieved directly from Dynafleet and Fleet Management monitoring software. The vehicles used between 55 and 63 litres per 100 km.

Table 2. Average fuel consumption, ml/tonkm and l/100 km retrieved directly from the monitoring program in the vehicle computers

Average fuel consumption Vehicle type	ml/tonkm	(l/100 km)
ETT vehicle	16.9	55.78
ST crane	27.57	63.36
ST group	25.03	55.14

LOAD UTILISATION

The payload varied between different vehicle types, from 47 tonnes up to 65.5 tonnes. This means that the HCT vehicles reached a gross weight of between 96 and 99% of the maximum permitted gross weight (Table 3).

Table 3. Average figures for each vehicle type

	Average				
Vehicle type	Tare weight (tonnes)	Payload (tonnes)	Gross weight (tonnes)	Max. permitted gross weight (tonnes)	Load utilisation
ETT	23.6	65.5	89.1	90	99%
ST crane	25.6	47	72.6	74	98%
ST group	19.7	51.3	71	74	96%

Three of the ST vehicles struggled to reach the maximum permitted gross weight.

Table 4. Load limited by volume for three of the ST vehicles

		Volume-limited load		Gross weight	Load utilisation
ID	Vehicle type	Number of journeys	Proportion	Tonnes	Percent
E	ST group	120	50%	66.9	90%
D	ST crane	79	12%	63.6	86%
H	ST group	84	45%	66.3	90%

TRAFFIC INTENSITY

The relative traffic intensity for a conventional crane vehicle was set to 100 because this type of vehicle is used today. It has lowest carrying capacity because of the crane.

Table 5. Vehicle type affects traffic intensity. (Relative traffic intensity for 60-tonne crane vehicle was set to 100)

Vehicle type	Average payload (tonnes)	Relative traffic intensity
60-tonne crane vehicle*	39.1	100
60-tonne group vehicle*	44.9	87
ST crane**	49.5	79
ST group**	51.5	76
ETT vehicle**	65.5	60

** Average payload according to Löfroth & Brunberg, 2013.*
*** Average payload according to this study.*

Discussion

FUEL CONSUMPTION

Figure 1 shows a comparison of the fuel consumption per tonkm of the various vehicle types (ETT and ST). Since the fuel consumption (ml/tonkm) has been normalised, the two different transport distances could be compared. The result showed that fuel consumption falls as transport distance increases. The comparison also showed a difference between the ETT and ST vehicles, but no internal difference between the ST vehicles (ST crane and ST group).

Table 6 shows a comparison of fuel consumption for each vehicle type, in ml/tonkm and l/100 km.

Table 6. Comparison of fuel consumption of 60-tonne vehicle and HCT vehicles.

	Average fuel consumption	
Vehicle type	(ml/tonkm)	(l/100 km)
60-tonne crane vehicle*	29	58
60-tonne group vehicle*	26	54
ST crane	27.57	63.36**
ST group	25.03	55.14**
ETT vehicle	16.9	55.78**

** Average fuel consumption for various vehicle types according to Löfroth & Brunberg, 2014.*
*** Average fuel consumption retrieved directly from vehicle computers.*

Note that in this study no comparison was made between the ETT/ST vehicles and the conventional 60-tonne vehicles. The values for the 60-tonne vehicles shown in Table 6 were taken from another study, and the figures are not directly comparable with those found in this study as they were collected in a different way.

However, other studies have been carried out using reference vehicles where the same drivers drove the same route under similar conditions, using both ETT/ST vehicles and conventional 60-tonne vehicles. In these studies, both reference vehicle and the ETT/ST vehicles were fully loaded. The results show that an ETT vehicle used 20% less fuel per tonkm than a 60-tonne vehicle (Löfroth & Svensson, 2012), while ST Crane used 8% less fuel (Löfroth & Svensson, 2012) and 6.9% less (Edlund et al., 2013) than the 60-tonne vehicles. The ST group used 12% less fuel (Löfroth & Svensson 2012) and 13.9% less fuel (Edlund et al., 2013) than the 60-tonne reference vehicles used.

What emerges from this study, which is based on actual production and not artificial experiments, is that it can be very difficult to reach sufficiently high payloads; this particularly applies to the ST group vehicles.

LOAD UTILISATION

Load utilisation was relatively high for the vehicles in the study. However, three of the trucks did not reach the maximum permitted gross weight (Table 4), only attaining a load utilisation of 89%. It is unclear why a higher figure was not attained, but one possible reason could be volume limitations, for example that the logs were bucked in lengths that were too short. Another possible explanation could be inexperienced drivers, in combination with crane scales that are not sufficiently accurate. If the scales had been more accurate, the drivers would probably have dared to load more, and thereby come closer to the maximum load utilisation.

One haulier pointed out the importance of bucking longer logs to increase the weight of the load, as the lorry only reached an average gross weight of 71.7 tonnes. Another reason for volume limitations occurs in the spring and summer months when the wood can be too dry and light, particularly spruce timber; two hauliers reporting relatively low gross payload weights encountered this problem during the course of the study.

Another important and possible explanation is that the group vehicles had no cranes, so they were capable of carrying a greater net load than a crane vehicle; this might make it more difficult to reach the maximum permitted gross weight of 74 tonnes.

TRAFFIC INTENSITY

Reducing traffic intensity, i.e. reducing the number of vehicles on the roads, is positive. Using HCT vehicles would make this possible; the extent would depend on the scale of a transition from vehicles with lower carrying capacity to vehicles with higher, and which vehicles are chosen in such a transition. In Table 6, the relative traffic intensity of the vehicle types included in this study is compared with that of today’s timber vehicles. There is great potential to reduce the number of trucks on the roads in Sweden, which would help us to attain the environmental goals.

UNCERTAINTIES

One source of uncertainty in the data is that hauliers and drivers self-reported the loaded distances and payloads. Another uncertainty factor is the total fuel consumption data provided by Dynafleet, which may deviate by +/- 2% (Cider 2014, pers. comm.). The precision attained with the Scania monitoring system, Fleet Management, is unknown, but tyre wear for example is a parameter that affects the precision in both monitoring systems.

One challenge in studies that take place over a long period, and with several players involved, is to maintain focus and engagement throughout the study period. Attempts were made to keep drivers engaged via visits and telephone calls, measures that had mixed results.

The choice of method for this type of study should therefore be considered. One alternative would be to monitor one truck at a time for a shorter period, such through the Focus Weeks method (Edlund, et al., 2013). The advantage of this type of data collection is that the focus lies on one truck at a time, which makes it easier to identify anomalies in data or how data is collected.

A disadvantage of the type of study design employed here is that the drivers may take extra care because they know they are being monitored. It would therefore have been interesting to collect weight data automatically via the vehicle computer. This would eliminate sources of error, such as the driver taking extra care or forgetting to enter data.

CONCLUSIONS

- Load utilisation varied between 96 and 98% for the ST vehicles in the study, apart from three of the ST vehicles that only reached a load utilisation of 89% of the maximum permitted gross weight on less than 50% of all their journeys.
- Traffic intensity would decrease by between 13 and 40% if today's roundwood trucks were replaced with HCT vehicles.
- The trucks in the study would need to be equipped with scales of a higher standard and greater accuracy; this would enable a greater load utilisation because the drivers would dare to load more, and another advantage is that the weight data could be collected automatically.

FURTHER RESEARCH

Road transports will continue to be very important, even though transport by rail may increase. One effective and rapid way of improving the efficiency of road transports is to replace 60-tonne vehicles with heavier vehicles, which would also reduce emissions and fuel consumption. Further research in the form of system analyses would be interesting, such as how more trucks could be replaced with fixed-route trucks. These could be ETT vehicles and 74-tonne vehicles that form a terminal system on routes where rail transport cannot be used because lines are overloaded or because there are no rail connections.

The results showed that some of the ST vehicles did not reach a sufficiently high payload (Table 4). A survey should be carried out of why this is the case. Is it caused by local deviations or does it depend on the type of logging that the ST vehicles are used for? What is the effect of the drivers' experience? This aspect is very important for both emissions and transport economics.

The results from this study showed that the average transport distance varied greatly between the various ST vehicles. Future system analyses could be aimed at identifying the optimal average transport distance for the HCT vehicles, and for example where the breakpoint lies in relation to rail transport for various configurations of vehicle and in various types of transport systems.

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