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RESEARCH

Idle times of forest machine and truck fleets in Finnish logging and timber-hauling enterprises

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Abstract

In the forest sector, the idle time of machinery has a significant impact on fuel consumption, greenhouse gas (GHG) emissions, and operating costs. This study investigated the idle times of forest machinery and timber trucks in Finland. Study materials were collected through questionnaires from small- and medium-sized logging (*loggers*) (N = 817) and timber-hauling (*timber-haulers*) (N = 339) enterprises (SMEs). The response rate from the loggers was 17.9% (n = 146) and 25.7% (n = 87) from the timber-haulers. The study revealed that only a quarter of the loggers and a half of the timber-haulers were aware of the idle times of their fleets. Of these, 55% of the loggers and 61% of the timber-haulers estimated their idle times at 6–14% of the total operating hours of their fleets. The results also indicated that idle time should be lower compared to current levels: respondents that were aware of idling suggested that 2–5% was a more desirable proportion, while the respondents that were unaware of idling rated desirable idle time at < 2% of total operating time. Respondents who had detected the idle times of their fleet noted significantly more opportunities to reduce idling than those who were unaware of idling. The work phases with the greatest potential to reduce idling times during logging operations were "Planning on the harvesting site" and "Operator breaks". Correspondingly, "Waiting time at the destination (i.e., timber reception of the mill)" and "Driver breaks" were the phases with the most potential to reduce idling during timber-hauling. This study concluded that there is significant potential to reduce fuel consumption and GHG emissions by improving the awareness of the forest machine operators and truck drivers with regard to the idle times of machinery and vehicles. As such, more research data and operator/driver training are needed.

Keywords Forestry · Fuel consumption · GHG emissions · Wood harvesting · Timber trucking · Small and medium-sized enterprises (SMEs) · Wood supply chain

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Introduction

During the last decade, global warming has progressed rapidly in comparison to the early 2000s (European Commission 2024) driven by global greenhouse gas (GHG) emissions, which were 37.4 Gt in 2023, an increase of 1.3% on 2022 emissions (International Energy Agency (IEA) 2024). Consequently, concerns with regard to increased GHG emissions have grown (Hagan et al. 2022), and new actions on climate change mitigation are required (European Commission 2020). As such, the European Union has set a goal to reduce GHG emissions by 55% (from the 1990) level by 2030 and achieve net-zero GHG emissions by 2050 (European Commission 2020). Among other things, the aim is to promote new low-emission solutions for non-road mobile machinery (NRMM) (Ministry of the Environment 2022), as well as maximize their energy efficiency (European Union 2019). This has accelerated, for instance, the introduction of new obligations and regulations for fuel suppliers, such as higher prices for fossil-based fuels and carbon dioxide (CO_2) emissions (Söderena et al. 2024). For example, the Effort Sharing Sector (i.e., sector outside the Emissions Trading System, excluding the land use sector) in Finland, which covers 60% of total GHG emissions, faces new requirements with regard to reducing emissions from industry, agriculture, transportation, and NRMM. Together, NRMM and transportation are responsible for 44% of emissions under the Effort Sharing Sector (Ministry of the Environment 2024). More specifically, logging and timber-hauling operations account for approximately 2.5% of the emissions of the Effort Sharing Sector in Finland (Poikela and Strandström 2023).

Fuel consumption is an essential part of logging and timber-hauling operations. Poikela and Strandström (2023) calculated that the total fuel consumption associated with logging operations and timber road transportation in Finland in 2022 was approximately 220 million liters (L) and the total emissions were approximately 500 t CO_2-eq. This corresponds to 1.2% of total GHG emissions in Finland, which were 40.6 Mt CO_2-eq in 2023 (Ministry of the Environment 2024). Earlier studies that have examined logging and timber-hauling have shown that factors, such as the fleet, operational conditions, and the operator/driver have a significant effect on fuel consumption (e.g., Rieppo and Örn 2003; Menzies 2005; Kenney 2015; Ghaffariyan et al. 2018; Kärhä et al. 2024). However, some alternative fuels, such as hydrotreated vegetable oils (HVO fuels) or liquefied biogas have been found to produce lower GHG emissions (Rahman et al. 2014; Huuskonen et al. 2025; Pesonen et al. 2025), although they can increase total fuel consumption (Emberger et al. 2021).

With regard to forest machines, research has tended to focus on the fuel consumption associated with the different cutting methods and working techniques (e.g., Ovaskainen 2012, Hiesl and Benjamin 2015, Hiesl et al. 2015, Ghaffariyan et al. 2018, Kärhä et al. 2023). For instance, Rieppo and Örn (2003), Eliasson et al. (2023), and Kärhä et al. (2023) reported that the cubic meter-based fuel consumption of harvesters and forwarders in Nordic countries was, on average, 1.05–1.43 L m^{-3} and 0.70–0.89 L m^{-3}, respectively. In contrast, Spinelli and de Arruda Moura (2019) and Pandur et al. (2018) reported average values of 1.38 L m^{-3} (cutting) and 1.18 L m^{-3} (extraction) in southern Europe and South America. For timber trucks, Lijewski et al. (2017) and Poikela and Strandström (2023) observed that fuel consumption during road transportation averaged 0.73–1.52 L m^{-3}, while the kilometer-based fuel consumption of timber trucks was 55–71 L 100 km^{-1} (Svenson and Fjeld 2015; Anttila et al. 2022; Huuskonen et al. 2025).

With lower fuel consumption and improved efficiency, the profitability of logging and timber-hauling operations can be increased (Haavikko et al. 2022). One possibility to improve efficiency is to reduce idling time, which refers to engine running time while stationary at low rotation speeds between 600 and 1200 rpm (Lutsey et al. 2004). Based on previous research information, idling account for approximately 22% of the total operating time of forest machines in Sweden (Viklund 2012) and approximately 15% in Poland (Polowy and Molińska-Glura 2023). Correspondingly, idling has been found to be responsible for around 34% of the total operating time of timber-haulage trucks in the USA (Lutsey et al. 2004). Nowadays, the fleet management systems (FMSs) and telematics systems provide continuous and accurate data concerning, for instance, engine running time and fuel consumption of the machine/truck, which can also be used to track idle times (Ovaskainen and Kivilinna-Korhola 2016; Sharpe and Schaller 2019). In most cases, idling causes needless fuel consumption and increased engine running time (Menzies 2005; Haavikko et al. 2019). According to Ghaffariyan et al. (2018), the fuel consumption of a feller-buncher during idling was approximately 2.5 L h^{-1}, while Viitala (2019) reported that the fuel consumption during idling of timber trucks was 7.8 L h^{-1}.

Unproductive working time (i.e., time excluded from the actual cutting, extraction or secondary transportation time) is often described as delays (Nurminen et al. 2006; Nurminen and Heinonen 2007; Mousavi et al. 2011; Mousavi and Naghdi 2013). However, delays occur rather erratically during operations and so are a challenge to quantify precisely (Spinelli and Visser 2008). For instance, Nurminen and Heinonen (2007) found that delays accounted for 4% of the total time consumption of timber-hauling operation, while Spinelli and Visser (2008) concluded that delays accounted for approximately 11% of total time consumption. Although all delays cannot be avoided, with appropriate planning they can be reduced, which also helps to reduce idling time (Vitorelo et al. 2011). For example, suitable planning could reduce the unexpected waiting times (i.e., operational delays) that may occur during operations (Mousavi et al. 2011; Magagnotti et al. 2012; Mousavi and Naghdi 2013), which would also help to reduce the idling time of logging machines/timber trucks.

However, under extreme conditions, a certain degree of idling may be desirable, especially in very cold or warm weather, where idling can be used to heat or cool the cabin of the machine as well as the engine of the machine (Allman et al. 2021). For example, Stodolsky et al. (2000) reported that the acceptable idling time for heavy-duty diesel-powered motor vehicles in temperatures of under − 6 °C was 20 min due to the required heating activities. On the other hand, Ponsse (2025a) suggested that, in order to enable battery recharge at − 10 °C, the engine should be running to heat the cabin of the machine, which can take up to one hour. In most cases, however, idling is considered redundant, as shown by Molari et al. (2019) who reported that 67% of all idling time of agricultural tractors was unnecessary, and resulted in wastage of 1.6% of the fuel used. This corresponds to Mörk (2012) who found that it was possible to achieve fuel savings of 1.5% in forest machines with lower idling times. Longer idling periods also affect the operation of the diesel particulate filter by obstructing cleaner combustion (Komatsu Forest 2017). Consequently, a comprehensive assessment of the working environment can identify possibilities to reduce idling time (Ghaffariyan 2024).

Operator training is also important to make operations more efficient, in conjunction with minimum engine running time and maintenance, as well as low fuel consumption and GHG emissions (Hassani 2020; Vilkuna 2020; Hartsch 2023). According to Burk et al. (2023, 2024), training of operators with a simulator was found to be a safe and cost-efficient way to improve their knowledge. However, skills acquired through simulator training tend to ignore the characteristics of the actual working environments (Burk et al. 2024). Therefore, training should be continuously aimed towards maintaining more efficient operating techniques under real-world operating conditions (Ghaffariyan et al. 2018; Sigurjonsdottir et al. 2022; Kärhä et al. 2023). For instance, Sigurjonsdottir et al. (2022) sought to improve the efficiency of trucking operations by training the drivers, which resulted in approximately 7% lower fuel consumption and 9% lower proportion of idling time after training. Jeskanen et al. (2023) reported that it was possible to reduce the idling times of a Finnish timber-hauling enterprise by approximately 10% by actively engaging with the drivers.

Fuel consumption may be lowered through optimization and adjustment of the detailed settings of harvester heads for instance, as well as the utilization of eco-modes in the forest machines (Prinz et al. 2018, Metsäalan Ammattilehti Magazine 2020, Kärhä et al. 2023). Moreover, Haavikko et al. (2022) found that allocation of forest machines based on the properties of the harvesting site could improve the efficiency of the machines and operations. Menzies (2005) and Zietsman et al. (2018) showed that various technologies, such as auxiliary power units, could help reduce fuel consumption of trucks during idling periods. Knowledge of life-cycle costs, warranties, and maintenance requirements of the fleet can also guide forest enterprises to conduct more efficient operations (Menzies 2005). For instance, Ponsse (2025b) suggested in their maintenance guide that forest machines should be maintained every 900 h. In the absence of unnecessary idling, maintenance requirements occur less frequently, which result in cost savings and a longer life cycle for the machine or truck (Mörk 2012; Shancita et al. 2014).

In Finland, all logging and timber-hauling services are provided by small and medium-sized enterprises (SMEs). In this research, the idle times of forest machines and timber trucks were analyzed. The objective was to determine the levels of current and desirable idle times based on the insights of these SMEs in Finland. A specific goal was to determine the impact of awareness on the effects of idling on idle time estimations, as well as whether operator training and incentives could reduce idling time. Furthermore, this study evaluated the possibilities to reduce idling in different operational phases during both logging and timber-hauling operations.

Materials and methods

Survey

The data for this study were collected in two separate surveys, which were sent to logging (*loggers*) and timber-hauling (*timber haulers*) SMEs operating in Finland. The first survey questionnaire was sent to 339 timber-haulers (i.e., all members of the Association of Finnish Timber Trucking Entrepreneurs) in February 2023 by the Association of Finnish Timber Trucking Entrepreneurs, of which 87 responded (response rate of 25.7%). The second survey was sent to 817 loggers operating in Finland (i.e., all members of the Trade Association of Finnish Forestry and Earth Moving Contractors) in May 2023 by the Trade Association of Finnish Forestry and Earth Moving Contractors and 146 responded (response rate of 17.9%).

Both surveys had a similar structure and were created using the electronic survey system Webropol (Webropol 2025). The surveys were divided into four sections, in which different information was collected from the respondents with open and fixed answer questions (Table 1). In the first section, general information, such as operating region (i.e., southern Finland, western Finland, eastern Finland, and northern Finland) and key performance indicators (i.e., annual volume and fleet size) were collected with three questions. Within the second section, awareness of idling times was determined by evaluating whether the respondents had previously paid attention to idle times of their fleet. Awareness of idling was described with one question with options of "Yes" and "No". Otherwise, the same questions were presented to all respondents regardless of their level of awareness.

Table 1 Survey questions in the questionnaire displaying the section titles, number of questions, content, and category

Section	ID	Question	Category
General information	Q1	In which region does your enterprise mainly operate?	Numeric (1–4)***
	Q2	What was the annual volume of your enterprise in 2022?	Scale (1–4)
	Q3	What was the total fleet size of your enterprise at the beginning of 2023 (including subcontracting network)?	Numeric***
Awareness of idling	Q4	Has your enterprise examined the proportion of idle time in relation to total operating time?	Binary (yes, no)***
	Q5	What applications are used to track idle time in your enterprise?	Numeric (1–6, 1–5)*
	Q6	What applications are used to track idle time in your enterprise?	Open
Proportion of idling time and the potential for reduction	Q7	What is the current level of idle time in your fleet in relation to total operating time?	Scale (1–6)***
	Q8	What do you consider as the optimal/desirable level of idling for logging machines/timber trucks?	Scale (1–6)***
	Q9	Has your enterprise provided training to operators/drivers and shared information on reducing idling?	Binary (yes, no)***
	Q10	Has idling time of your fleet decreased due to the training provided and information shared?	Binary (yes, no)**
	Q11	Has your enterprise used incentives to reduce idling time?	Binary (yes, no)
	Q12	In which phases of logging/timber-hauling do you think it is possible to reduce idling?	Scale (1–5)
	Q13	If you wish, provide suggestions to reduce the idling of logging machines/timber trucks	Open
Further research	Q14	Is your enterprise willing to collaborate in reducing idle times with the research scientists of this study?	Binary (yes, no)

*Six most frequently used fleet management systems (FMSs) for loggers and five most frequently used FMSs for timber-haulers

**Question only sent to loggers in the survey

***Question asked during the non-response follow-up

If the respondents had indicated an awareness of the idle times of their fleet, the applications used were clarified based on the six most frequently used FMSs in forest machines: JDLink (John Deere 2025), Komatsu MaxiFleet (i.e., Smart Forestry) (Komatsu Forest 2025), Ponsse Manager (Ponsse 2025c), Savotat (Savotat 2025), Kiho (Kiho 2025), and Datapankki (i.e., a database created by the Trade Association of Finnish Forestry and Earth Moving Contractors) (Koneyrittäjät 2025). In addition, five applications: Volvo Dynafleet/Connect (Volvo Trucks 2025), Scania Fleet Management (Scania 2025), Add-Secure Econen (AddSecure 2025), Mercedes-Benz Fleetboard (Mercedes-Benz 2025), and Kiho (Kiho 2025), were determined as the most common FMSs in timber trucks. In case the respondents had used another application to detect their idle times (than the most common ones), the second section of the survey included one open question concerning the applications used to track idle times (Table 1).

The third section of the survey focused on current and desirable proportions of idling, as well as the potential to reduce idling in the different phases of operations. For logging operations, a total of 11 phases were predefined: planning on the harvesting site, planning in the cabin of the machine, refueling the machine, initial work on the harvesting site, operator breaks, maintenance work, changing work shifts, sending the performance data from the machine, finishing work on the harvesting site, and preparing machine relocation. Correspondingly, ten phases of timber-hauling operations were predefined: receiving the timber for transportation, loading the timber, attaching the payload, planning in the cabin of the truck, refueling the truck, driver breaks, waiting time at the destination (i.e., timber reception at the mill), removal of payload sheets, and unloading the timber.

When gathering information on current and desirable idle times, we used the following idle time classes: $<2\%$, 2–5%, 6–9%, 10–14%, 15–19%, and $>19\%$. Furthermore, the potential to reduce idling was assessed on a 1–5 scale (1 = No potential, …, 5 = Very high potential). This allowed the entrepreneurs to evaluate each operational phase on the same scale, thereby enabling determination of the phases with the most and least potential to reduce idling. Suggestions to reduce idling were also asked with an optional open question. In addition, the respondents were asked about the amount of training and incentives they have provided to reduce idling. Upon a request from the Trade Association of Finnish Forestry and Earth Moving Contractors, the survey sent to loggers also contained one question concerning the impact of training on reducing idle times. The final section queried the interest of the respondents to reduce idling time in their operations in the future through working with the research scientist of this study (Table 1).

Non-response follow-up

A non-response follow-up was conducted via phone to improve the credibility of the data. Every sixteenth logger respondent (N = 54) was systematically selected from the total population (N = 817) by the Trade Association of Finnish Forestry and Earth Moving Contractors. Moreover, every tenth timber-hauler respondent (N = 34) was selected from the total population (N = 339) by the Association of Finnish Timber Trucking Entrepreneurs. The non-response follow-up included the six same questions as in the surveys (cf. Table 1), focusing on the background information of the respondents (i.e., operating region and fleet size), awareness of idling times, the amount of training provided to their employees, and insights into preferable idle times. Of those respondents selected in the non-response follow-up, five loggers and seven timber-haulers had already responded to the survey. Conversely, seven loggers and two timber-haulers were unwilling to participate in the non-response follow-up. Furthermore, 11 loggers and five timber-haulers had retired, sold their fleet, or could not be reached. Respectively, a total of 51 new responses from 31 loggers and 20 timber-haulers were gathered during the non-response follow-up. Statistical analyses were conducted to compare the responses gathered with the non-response follow-up with the responses gathered with the original two surveys.

Data analysis

For the analysis, depending on the level of awareness (i.e., knowledge of the amount and effects of idling time) expressed by the respondents, we formed the following groups: *Aware loggers*, *Unaware loggers*, *Aware timber-haulers*, and *Unaware timber-haulers*. Statistical analyses were conducted using IBM SPSS Statistics 29.0 software (IBM 2025). Initially, the data were tested for the assumption of normal distribution with the Kolmogorov–Smirnov test, which indicated that the data was not normally distributed. Therefore, the non-parametric Mann–Whitney U test was used to conduct the statistical analyses. The significance of statistical values was evaluated at the 95% confidence level ($p < 0.05$).

Proportions, average values (means, medians, and modes), and standard deviations were calculated for the defined groups using the same scaling (1–5) used in the surveys. Current and desirable idle times were determined by calculating the distributions of the responses within each idle time category. With regard to the potential to reduce idling during operations, the exact values were determined by calculating the mean values of the responses given on the scale (1–5). The effects of operator/driver training and incentives were described by calculating the mode of the current idle times for those respondents who had trained their operators/drivers or used incentives, and correspondingly for those respondents who had not trained their operators/drivers, or used incentives.

Enterprise data

Approximately 65% of the loggers reported an annual volume of < 100,000 m^3 solid over bark (sob) in 2022, while 12% reported an annual volume of > 300,000 m^3. At the beginning of 2023, 43% of the loggers had less than three forest machines and 21% had over ten machines. In 2022, 67% of timber-haulers reported an annual volume of < 200,000 m^3. Of those timber-haulers, approximately 50% transported < 100,000 m^3 annually. Furthermore, 15% of the timber-haulers reported an annual volume of > 300,000 m^3. At the beginning of 2023, 48% of the timber-haulers had less than three timber trucks, and 7% had more than ten trucks.

Results

Current idle times

The surveys showed that 27% of loggers and 51% of timber-haulers had previous awareness of idling time in their enterprises. The most used applications to detect idling times among loggers were JD Link, Komatsu MaxiFleet, and Ponsse Manager, while timber-haulers most frequently used the FMSs of Volvo and Scania.

There was no statistically significant difference between loggers who were aware and unaware of idling (test value (U) = 1709.5, $p = 0.060$). The median proportion of idle time was 2–5% with aware loggers and 6–9% with unaware loggers. Idle times of < 2% were declared more frequently by loggers unaware of idling (15%) than loggers aware of idling (3%) (Fig. 1). In turn, there was a statistically significant difference between timber-haulers aware and unaware of idling (U = 634.5, $p < 0.05$). Most of the timber-haulers that were aware of idling (41%) revealed that the idling proportion ranged between 6 and 9% (median values) in

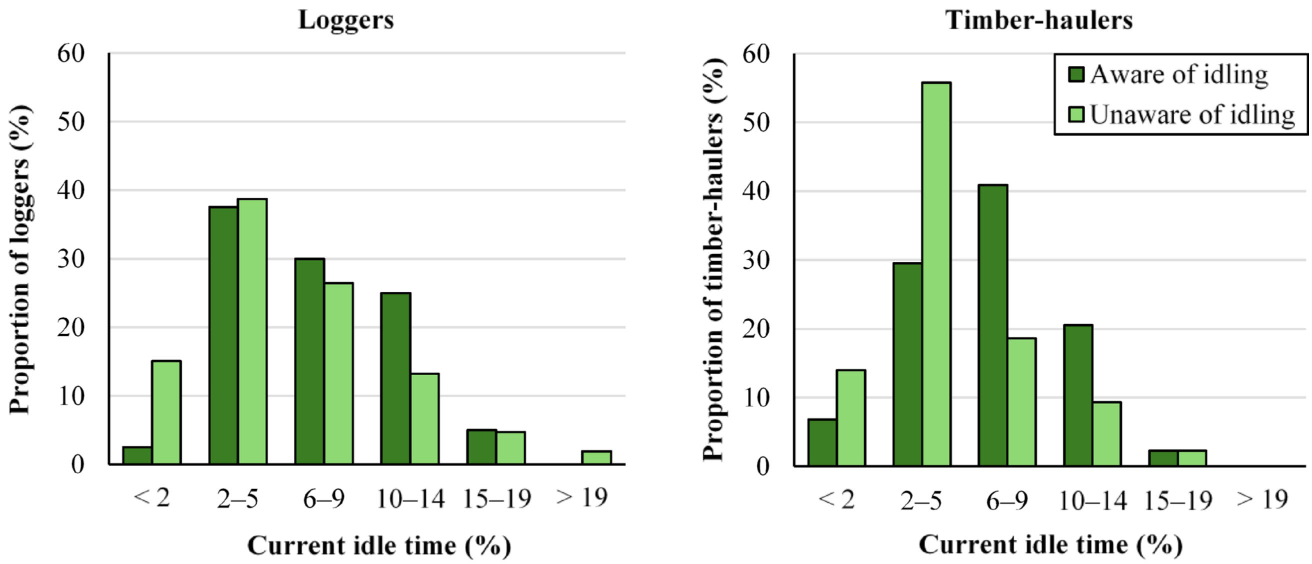

Fig. 1 Distribution of estimations on the proportion of current idle times as expressed by loggers (n = 146) and timber-haulers (n = 87), who were aware and unaware of idling time

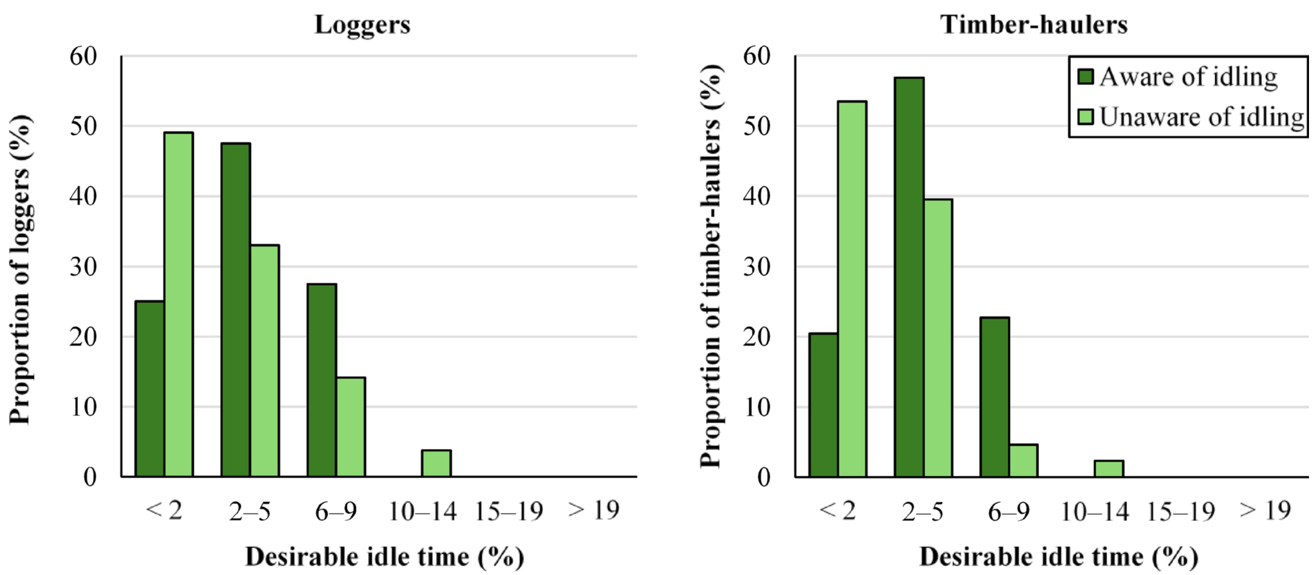

Fig. 2 Distribution of estimations on desirable idle times as expressed by loggers (n = 146) and timber-haulers (n = 87), who were aware and unaware of idling time

their operations. Conversely, 56% of the timber-haulers who were unaware of idling estimated their idle times to be around 2–5% (median). A total of 23% of the aware timber-haulers estimated their idling to be > 9%, while the proportion among the unaware timber-haulers was approximately 12% (Fig. 1).

Desirable idle times

With regard to desirable idle times of forest machines, a statistically significant difference was observed between the loggers that were aware and unaware of idling (U = 1620.0, $p < 0.05$). The median value of preferable idle time was 2–5% for both aware and unaware loggers. Almost half of the aware loggers indicated that their preferable proportion of idling was between 2–5%, while approximately one third of the aware loggers indicated 6–9% (Fig. 2). However, almost half of the loggers unaware of idling perceived that a proportion of idle time of < 2% was desirable. In addition, a statistically significant difference was observed between timber-haulers that were aware and unaware of idling (U = 591.0, $p < 0.001$). The median value of preferable idle time was 2–5% with aware timber-haulers and < 2% with unaware timber-haulers. Over half of the aware timber-haulers (57%) indicated that a proportion of 2–5% was preferable, while 53% of the unaware timber-haulers reported preferable idle times of $<2\%$ (Fig. 2).

Operator/driver training and incentives

A total of 53% of the loggers and 77% of the timber-haulers had trained their operators/drivers with regard to engine idling time, although there were no statistically significant differences in relation to the effects of training on current idling time (loggers: $U=2647.5$, $p=0.971$; timber-haulers: $U=641.5$, $p=0.761$). The mode value of current idling time among those loggers who had trained their operators was 6–9%, while the proportion among loggers who had not trained their operators was 2–5%. More than 80% of the loggers who trained their operators reported that their idle times had reduced because of the training. The mode value of current idle time of timber-haulers who had trained their drivers and who had not was in the range of 2–5%.

The surveys showed that only seven loggers and six timber-haulers had used incentives, such as a bonus payment, to reduce idling in their enterprises. No statistically significant differences were found in idle times in relation to the use of incentives (loggers: $U=448.0$, $p=0.710$; timber-haulers: $U=225.0$, $p=0.750$). Four loggers and four timber-haulers who had provided incentives were aware of idling times of their fleet. The loggers and timber-haulers who were aware of idling and provided incentives reported median values of 6–9% in current idle times. Conversely, loggers and timber-haulers who were unaware of idling and provided incentives reported slightly lower median values (2–5%) in current idle times.

Operational phases

The work phases with the greatest potential to reduce idling times during logging were found to be during planning on the harvesting site (3.95, std 1.02), operator breaks (3.78, std 1.03), and the initial work tasks on the harvesting site, such as uploading logging and bucking instructions to a harvester (3.75, std 1.03) (Fig. 3). The work phases with the least potential were maintenance tasks and during possible visits on harvesting site, for example, by forest landowners or logging supervisors and officers (3.05–3.08, std 1.25–1.47). The largest differences between the loggers aware and unaware of idling occurred in the work phases: refueling the machine, operator breaks, and planning on the harvesting site (0.65–0.99). A statistical difference between the aware and unaware loggers occurred almost in every work phase ($p<0.05$), with the exception of sending the performance data ($U=1858.0$, $p=0.307$) and visits on site ($U=1735.0$, $p=0.115$) (Fig. 3).

During timber-hauling, the work phases with the greatest potential to reduce idling were assessed as: waiting at the reception of timber mill, driver breaks, and refueling the truck, which overall, averaged from 3.83 (std 1.32) to 4.39 (std 0.81).The work phases with the least potential to reduce idling were loading and unloading of the timber (1.88–2.45, std 1.19–1.21). The greatest differences between the aware and unaware timber-haulers occurred during refueling, planning in the cabin of the truck, and attaching the payload (0.60–0.70). In addition, a statistical difference was observed for waiting time at the mill ($U=626.5$, $p<0.01$), planning in the cabin of the truck ($U=635.5$, $p<0.01$), attaching the payload ($U=661.0$, $p<0.05$), and refueling the truck ($U=664.0$, $p<0.05$) (Fig. 3).

Discussion

Data and methods

While interest in studying idle times has grown over the past decade (cf. Ghaffariyan et al. 2018; Haavikko et al. 2019; Polowy and Molińska-Glura 2023; Kärhä et al. 2024), extensive studies have been conducted less frequently (i.e., Lutsey et al. 2004). In this study, idle times were examined based on the experiences and views of 146 loggers and 87 timber-haulers currently operating in Finland. The data were collected by two separate surveys in early 2023, which were originally sent to 817 loggers and 339 timber-haulers of SMEs. The average response rate of this study was approximately 20%, which enabled us to gather more responses than would have been possible, for instance, with one-to-one interviews with a limited number of respondents. The fleet sizes of the respondents varied from one to more than ten logging machines or timber trucks. There are approximately 1500 logging and 550 timber-hauling enterprises in Finland with a typical fleet size of 2–4 logging machines and 1–3 timber trucks (Palojärvi 2024; Saarijärvi 2024). In this study, the respondents accounted for 10% and 16% of the estimated total number of loggers and timber-haulers, respectively, operating in Finland. Consequently, the data in this study were sufficiently comprehensive to capture the visions and expectations of the logging and timber-hauling enterprises with regard to concerning idle times.

Among loggers, 27% expressed previous awareness of idling, while the corresponding proportion of timber-haulers was 51%. This resulted in a total of 40 aware loggers, 106 unaware loggers, 44 aware timber-haulers, and 43 unaware timber-haulers. All respondents expressed some interest in reducing idle times regardless of their current level of awareness. According to Haavikko et al. (2019), 10–15% of loggers and timber-haulers consider idling to be

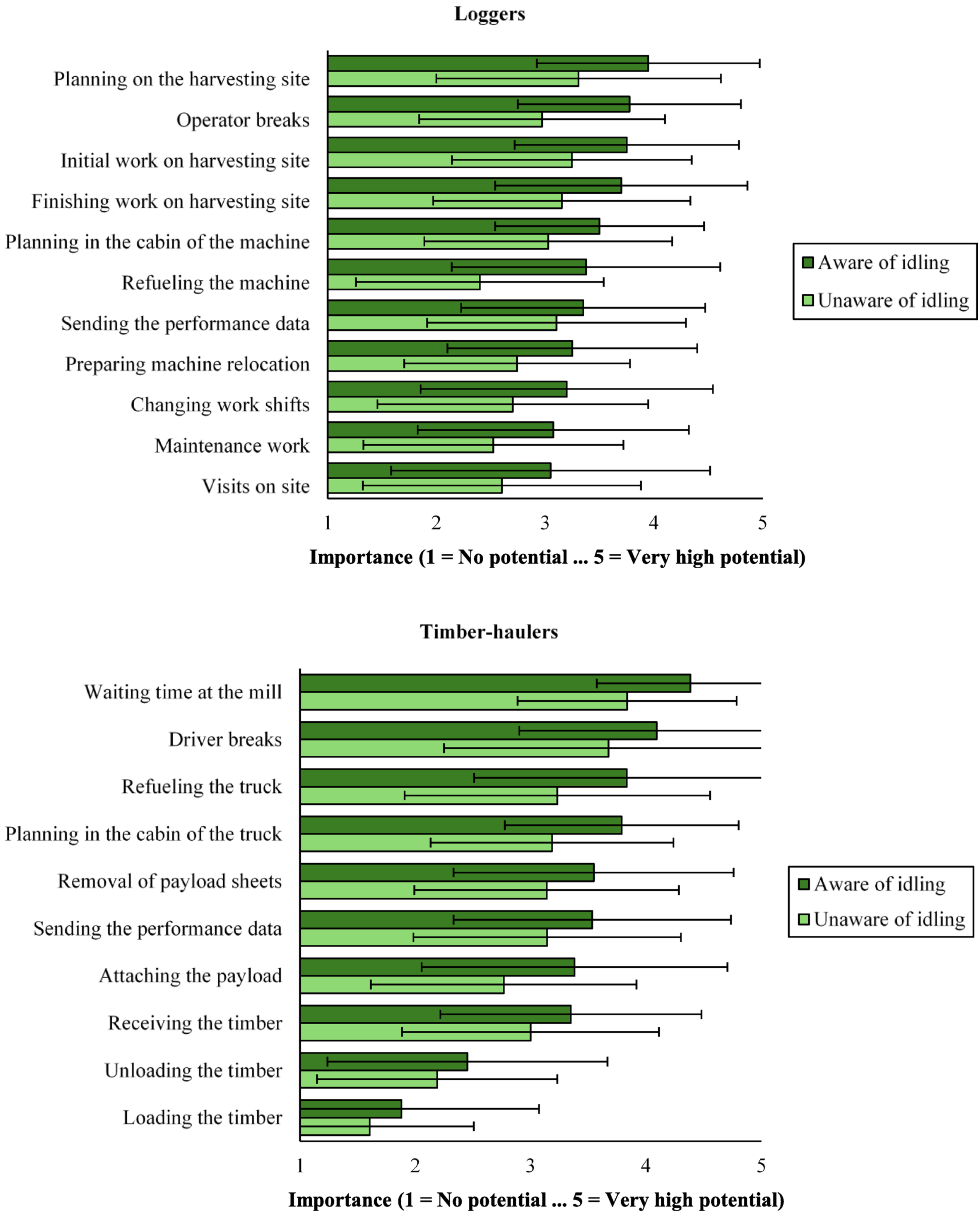

Fig. 3 Estimated potential to reduce idling in logging operations as indicated by loggers (n = 146), and in timber-hauling as indicated by timber-haulers (n = 87). Black error lines represent the standard deviation

an extremely important factor to improve the efficiency of their operations. Furthermore, Haavikko et al. (2019) also reported that timber-haulers consider fuel consumption to be a more significantly more important factor (than loggers do) on efficiency. Therefore, since idling mainly causes needless fuel consumption and fuel costs (Menzies 2005, Mörk 2012, Molari et al. 2019), timber-haulers may be more pro-active in searching for ways to reduce fuel consumption than loggers. Furthermore, in this study, timber-haulers responded to the survey more frequently than loggers, which could explain the significantly greater proportion of timber-haulers who displayed awareness of idling.

The content of both questionnaires overlapped and addressed the idle times that occur during the different work phases for both loggers and timber-haulers (cf. Table 1), and the overall number of responses was comparable. The use of the same classification scheme and statistical analyses allowed a direct comparison between the loggers and timber-haulers, and also permitted evaluation of the views expressed by the aware and unaware respondents. However, we were unable to verify the accuracy of the respondent's estimations, so overly optimistic estimates may have occurred. Nevertheless, a non-response follow-up was conducted with both loggers and timber-haulers, which resulted in a total of 51 new responses (31 from loggers and 20 from timber-haulers) in addition to our survey data. Statistically significant differences were only observed in the estimations of current and desirable idle times among loggers between surveys and non-response follow-up, and in the number of timber-haulers who had trained their drivers (Appendix 1): 68% of the loggers who participated in the non-response follow-up estimated that the current idle time of their fleet was > 5%, whereas the corresponding proportion of loggers who responded to the survey was 51%. Furthermore, none of the loggers who participated in the non-response follow-up and 42% of the loggers responded to the survey desired idle times of less than 2%, respectively. In addition, 77% of the timber-haulers who responded to the survey reported that they had trained their drivers, while the corresponding share was 55% among timber-haulers who participated in the non-response follow-up. Nonetheless, we were able to illustrate the views of logging and timber-hauling entrepreneurs considering idle times as well as the effects of being aware of idling on the idle time estimations.

Discussion of the results

The results of this study showed that most of the loggers and timber-haulers who were aware of idling (58%) estimated their current idle times as between 6 and 14%. Moreover, the corresponding proportion of loggers and timber-haulers who were unaware of idling estimated their idle times at < 5% (cf. Fig. 1). Previous studies have indicated that the idle times of forest machines and timber trucks were around 20% (Mörk 2012; Allman et al. 2021). Thus, the results of this study highlighted that the estimations from the respondents who were aware of idling were better aligned with the previous research compared to the unaware respondents. One reason may be that the respondents who had paid attention to idle times may have a more comprehensive vision on the factors that affect idling. Nevertheless, regardless of the awareness of the respondents, the estimated idle times in this study were still lower than, for instance, the proportion of idle time calculated from automatically collected machine data (cf. Polowy and Molińska-Glura 2023).

As for desirable idle times, 50% of the unaware respondents underlined that the proportion of idling should be < 2%, while half of the aware respondents indicated an idle time of 2–5% (cf. Fig. 2). This exposed the need to improve the knowledge of the respondents who considered lower idle times. This study also revealed that only 5% of the loggers and 7% of the timber-haulers had used incentives to favor the reduction of idle time. This is considerably lower than the values reported by Lutsey et al. (2004), who found that 24% of timber-haulers had used incentives. As noted by Haavikko et al. (2019), operator/driver skills are the most important factor that influence energy-efficient working methods. Therefore, idling can also be reduced by encouraging respondents to use incentives to motivate their operators/drivers. However, a certain level of idling is also needed to maintain efficient operations and the comfort of the operators/drivers across a wide range of operating conditions (Stodolsky et al. 2000). Thus, the lack of awareness with regard to idling may distort the respondent's perceptions on the situations where idling could be reduced and by how much, thereby causing overly optimistic expectations.

In this study, several occasions to reduce idling during logging and timber-hauling operations were detected. During logging operations, planning on the harvesting site was seen to cause the most unnecessary idling, while the work phase with the most potential to reduce idling during timber-hauling was waiting time at the reception of the mill (Fig. 3). However, logging and timber-hauling operations tend to be examined through fewer operational phases. For instance, Nurminen et al. (2006), Nurminen and Heinonen (2007), Mousavi et al. (2011), and Mousavi and Naghdi (2013) combined maintenance and operator/driver breaks into one operational phase among other delays. Consequently, since delays occur irregularly during operations (Spinelli and Visser 2008), detection of the causes of idling becomes more difficult. Therefore, more specific assessment of the work phases of logging and timber-hauling operations could result in more accurate identification of the causes of idling. Nevertheless, it should be noted that idling cannot be completely avoided (Nurminen and Heinonen 2007), although with good planning, needless idling can be reduced in all phases.

Comprehensive planning can reduce, for example, the need for machine relocations during logging operations (Haavikko et al. 2022). In this study, we found that preparing work for machine relocation was among four of the work phases with the least potential to reduce idling during logging operations (cf. Fig. 3). However, Väätäinen et al. (2021) reported that the waiting time before machine relocation only accounted for approximately 1–3% of the total working time. Furthermore, Kärhä et al. (2007) found that ordering the relocation, as well as cleaning the machine after operations accounted for approximately 20% of the time spent during the total preparation work for machine relocation. Consequently, there are possibilities to reduce the engine running time, especially during these waiting and miscellaneous times. Machine or truck manufacturers have maintenance instructions (e.g., Ponsse 2025b) that are largely based on operating hours. Since idling increases the engine running time, the need for maintenance occurs more frequently (Shancita et al. 2014). Therefore, the work phases with limited potential highlighted in this study are also important to improve energy-efficiency, while at same time, maintaining performance (Ikäheimonen 2017).

There are ways to improve the efficiency of operations and assist the operator in minimizing idle time. As the results of this study have shown, logging and timber-hauling operations involve various work phases where the machines or trucks are stationary (e.g., waiting times, planning, sending the performance data) (cf. Fig. 3). Hence, so-called stop-and-go systems implemented in timber trucks could help the driver to better control the engine running time (Volvo Trucks 2017). Indeed, stop-and-go systems in forest machines are expected to become common technology in the future (Kangas et al. 2023), which may be derived from existing practical solutions concerning the adjustment of the settings of forest machines (Prinz et al. 2018). Moreover, Rahman et al. (2013) noted that truck stop electrification could also be a feasible option to reduce fuel consumption and idling, while still allowing for heating and air conditioning to maintain the comfort of the drivers. This could be exploited, for example, during operator/driver breaks, which were found to have considerable potential to reduce idling in both respondent groups in this study (cf. Fig. 3).

By concentrating on the mindset of the operator/driver, in addition to a more efficient fleet, logging and timber-hauling operations could be completed with less idling (Haavikko et al. 2019). According to Pagnussat et al. (2020), the results of operator training become visible after approximately nine months of comprehensive training. As the results of this study have indicated, many respondents had considered operator training as one option to reduce idling, although we were unable to verify the training methods. The results showed that more than 80% of the loggers who participated in this study reported positive effects of training with regard to idling, although operator training was found to have no benefit on lower idle times. This questions the validity of the training or is indicative that idle times were considerably greater before the training as compared to those respondents who had not given training to their operators. Consequently, more effort should be aimed towards improving the operator skills in order to better establish the positive effects of lower idle time.

Conclusions

In this study, the experiences and views of loggers and timber-haulers with regard to idle times were examined. More specifically, an overview of the estimated proportion of idle times in logging and timber-hauling operations was conducted, and expectations with regard to the proportion of desirable idle times were identified. In addition, the potential to reduce idling in the various operation phases were mapped. Differences in the responses based on the awareness of idling were also highlighted. The results showed that those respondents with knowledge with regard to idle times provided estimates that were better aligned with previous findings. Furthermore, the results indicated that idle times could be lowered from current levels. In addition, this study emphasized that it is possible to reduce idling in several work phases during logging or timber-hauling operations.

Lower idle times could eventually lead to lower operating costs, as well as more environmentally-friendly operations. To promote these positive effects, awareness of idling must be improved among loggers and timber-haulers, as well as among their machine operators or truck drivers. Thus, it is recommended that future operator/driver training should be expanded to cover the effects of idling in forest operations. Moreover, further research should also focus on evaluating the effects of operator/driver training. However, the achievement of lower idle times requires continuous and long-term leadership, where the data provided by the FMSs, combined with communication between the forest SMEs and their operators and drivers, can result in noticeable benefits. Once increased attention is paid to idling, logging and timber-hauling can be conducted more efficiently, thereby leading to lower fuel consumption and GHG emissions.

Appendix 1

Comparison of survey and non-response follow-up responses and statistical significance. Question/variable has been shortened from the questions presented in Table 1.

Question/variable	Loggers				Timber-haulers			
	Survey (n = 146)	Non-response follow-up (n = 31)	Test value	Signif	Survey (n = 87)	Non-response follow-up (n = 20)	Test value	Signif
Q1: Operating region (%)			2251.0	0.961			801.5	0.569
Northern Finland	24.0	9.7			23.0	15.0		
Eastern Finland	32.9	29.0			33.3	35.0		
Southern Finland	13.7	9.7			27.6	15.0		
Western Finland	29.4	51.6			16.1	35.0		
Q3: Fleet size (%)			2039.5	0.383			657.0	0.063
1–2	42.5	45.1			48.3	75.0		
3–4	19.2	19.4			13.8	5.0		
5–6	8.9	12.9			21.8	10.0		
7–10	8.9	12.9			9.2	5.0		
> 10	20.5	9.7			6.9	5.0		
Q4: Focused on idling (%)			2227.0	0.857			865.0	0.963
Yes	27.4	25.8			50.6	50.0		
No	72.6	74.2			49.4	50.0		
Q7: Current level of idling (%)			1608.5	< 0.01			842.5	0.816
< 2%	11.6	0.0			10.3	15.0		
2–5%	38.4	32.3			42.6	40.0		
6–9%	27.4	22.5			29.9	25.0		
10–14%	16.4	32.3			15.0	20.0		
15–19%	4.8	9.7			2.3	0.0		
> 19%	1.4	3.2			0.0	0.0		
Q8: Desirable level of idling (%)			1497.0	< 0.001			703.0	0.147
< 2%	42.5	0.0			36.8	25.0		
2–5%	37.0	80.6			48.3	45.0		
6–9%	17.8	12.9			13.8	30.0		
10–14%	2.7	6.5			1.1	0.0		
15–19%	0.0	0.0			0.0	0.0		
> 19%	0.0	0.0			0.0	0.0		
Q9: Operator training provided (%)			1996.5	0.233			678.5	< 0.05
Yes	53.0	64.5			77.0	55.0		
No	47.0	35.5			23.0	45.0		

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Author contributions JP and KK conceptualized the study. JJ, MK, and KK collected the survey data. JP performed statistical analyses and wrote the manuscript. KK was responsible for funding acquisition. KK, RP, HO, and PK supervised the study and commented the manuscript.

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Declarations

Conflict of interest The authors declare no competing interests.

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