Exploring the need for feedback on performance

Interviews with harvester operators

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Contents

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Preface

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Summary

Harvesting is a highly complex task for the operator. Modern harvesters measure tree length and diameter in the harvester head, and optimise the use of each stem based on digital bucking instructions. The operator must also register tree species and quality-affecting stem defects for each stem, and ensure they take the correct nature conservation measures, avoid damaging cultural heritage sites, and minimise damage to the forest soil.

When developing different types of operator support systems, it is important to know what type of feedback is needed and requested by the operator and how the feedback should be presented. This study was initiated to learn more about how harvester operators view factors that impact their work and how adapted and relevant feedback could help to improve their overall performance. This report has focused on the operators' views on performance, productivity, and quality in their work in relation to how these factors are measured today. A series of 16 exploratory interviews were held with professional harvester operators from Sweden, Norway, and Germany.

The results from the interviews were compiled and grouped into five categories: operator, harvester, pre-harvest planning, logging site, and other. The responses resulted in a vast amount of information on current work practices and proposals for development. At first glance, operators from all countries seemed to have quite a common view on what feedback they would appreciate. However, when the responses were analysed in more detail, differences in approach between operators from different countries could sometimes be found. The operators had a broad perception of the factors that affect their work, ranging from machine-related issues to the influence of others and their own well-being.

The main objective of a digital coach would be to help operators improve their working methods and practices, without increasing the complexity of their work. The operators requested feedback in many areas through digital platforms, e.g., onboard computer, to facilitate their work. Both the type of information, as well as the interval at which the information is requested, varied greatly between operators, implying that the coach should be customised to individual operators.

A future digital coach could probably analyse data in real-time to develop the coach concept. This could be done by identifying relationships between the operator's behaviour, the wear and tear of the machine, and the value of the products. The coach could then draw its own conclusions on how to increase value recovery.

Sammanfattning

Att köra skogsmaskin i allmänhet och skördare i synnerhet är ett krävande arbete. Dagens skördare optimerar användningen av varje stam med digitala apteringsinstruktioner och baserat på löpande mätning av stammens längd och diameter. Utöver detta ska föraren registrera trädslag och anpassa apteringsbeslutet utifrån kvalitetsfel som rotröta eller krök på stammen. Maskinföraren ska också säkerställa att rätt naturhänsyn tas och att körningen inte åsamkar skador på marken, träden eller eventuella kulturlämningar i skogen.

För att kunna utveckla ett funktionellt stödsystem till maskinförarna är det viktigt att känna till vilken typ av återkoppling de önskar, men också när och på vilket sätt som den efterfrågade informationen bäst presenteras. Den här studien utfördes för att undersöka vilka faktorer skördarförare anser påverkar deras arbete, och vilken typ av feedback som skulle kunna användas för att förbättra deras arbetssituation. Inom projektet diskuterades skördarförarnas syn på prestation, produktivitet och arbetets kvalitet, samt hur dessa faktorer mäts idag, eller skulle kunna mätas. Totalt genomfördes 16 intervjuer med skördarförare från Sverige, Norge och Tyskland.

Resultaten sammanställdes och grupperades i följande kategorier: förare, skördare, planering, skördat objekt och övrigt. Intervjuerna gav en omfattande bild av dagens arbetssätt och förslag till hur dessa skulle kunna förbättras. Vid första anblick gav förarna relativt samstämmiga svar angående vilken typ av feedback de önskade. När resultaten analyserades i mer detalj framkom det dock vissa skillnader mellan förare från olika länder. På totalen hade förarna en bred uppfattning av vilka faktorer som påverkar deras arbete; svaren innehöll allt från maskinrelaterade frågor till påverkan från andra och förarnas eget välmående.

Att operatörerna känner att de kan påverka arbetet stödjer tanken på att utveckla en framtida digital coach. Huvudsyftet med en sådan skulle vara att hjälpa förarna att förbättra sina arbetssätt och metoder, utan att öka komplexiteten i arbetet. Önskemål om såväl vilken typ av feedback, som på vilket sätt denna bäst skulle presenteras, varierade mellan förarna. Detta indikerar att det är viktigt att en framtida coach kan anpassas efter den aktuella förarens önskemål.

En framtida digital coach kommer förmodligen att kunna analysera data i realtid för att på så vis utveckla själva konceptet. Detta skulle kunna göras genom att exempelvis analysera samband mellan förarens beteende, slitage på maskinen och värdet av det som produceras. På så vis skulle coachen på egen hand kunna dra slutsatser angående hur värdeutbytet kan ökas för den aktuella föraren.

Background

Mechanised cut-to-length (CTL) harvesting is the dominant harvesting method in Sweden, Norway, and Germany. Modern CTL harvesters are equipped with onboard computers that optimise the use of each stem, based on digital bucking instructions and length and diameter measurements from the harvester head. In addition to the information from the measurement system, the harvester operator registers tree species and quality-affecting stem defects for each stem. This task is performed at high speed and sometimes under challenging ground and weather conditions. Also, the operator must ensure that correct nature conservation measures are taken, that cultural heritage sites are left undamaged, and that damage to the forest soil is minimised. Harvesting is consequently a highly complex task for the operator (Häggström, 2015).

To assist the operator in choosing the most beneficial working method and maximising the value recovery of each stem, various types of digital operator support systems delivering relevant and timely feedback on operations could be of interest. For operators with limited experience of harvesting operations, this would be helpful in steepening the learning curve. For more experienced operators, feedback is still valuable in supporting further development and for maintaining a high quality of work.

Today, all harvester manufacturers have their own user interfaces and tools built into the onboard computers. However, an interactive and user-friendly operator support system is still lacking on the market. Much of the information that could be helpful to the operator is not readily shared, and must be sought by the operator themselves. Furthermore, it is not always clear how the information should be interpreted, meaning that the operator might need to relate the information to other information found downstream in the process, or compare with others to get an idea on performance. An opportunity to compare themselves with others would complement benchmarking and experience exchange, which is a missing area for many operators today.

It can be assumed that feedback relating to operator behaviour, harvester head measurement accuracy, and value/product recovery are relevant areas to include in an operator support system.

In Sweden, a quality assurance system for harvester head measurements has been developed by Skogforsk and the forest sector. The system is based on self-assessment using manual control measurements of selected stems and regular feedback from third-party harvester auditors. Experiences from more than a decade of applying the system indicate substantial effects on the quality of harvester measurements as well as higher value recovery from the trees (Hemmingsson, 2022). The self-assessment is currently based on manual control measurements of 1-2 stems per shift, which is a small sample if changes in measurement accuracy are to be detected in time.

There have long been calls for a method for more continuous feedback on measurement accuracy. Within the AVATAR project (Forest Value, 2022), a model based on standardised harvester production data has been developed (Hannrup et al., 2020). This model could potentially be developed to assist the operator in identifying machine settings that contribute to improved measurement accuracy.

Manual decisions made by the operator impact the bucking results and thereby the value recovery of the stem. Today, access to regular and tangible feedback on the products harvested is often lacking, leaving operators unaware of the results of the harvest. A tool for continuous feedback on value recovery, using indicators based on standardised

harvester data, therefore has potential to increase resource efficiency and sustainability of forest operations. The demo software Virkesvärde (Wood Value) developed by Skogforsk is an example of a platform for feedback on value and product recovery (Franck & Johansson, 2017).

When developing different types of operator support systems, it is important to know what type of feedback is requested by the operator and how the feedback should be presented. This study was initiated to learn more about what harvester operators think about factors that impact their work, and how adapted and relevant feedback could help to improve their overall performance.

Aim of the study

The main aims of this work were:

- To investigate what harvester operators think about performance and quality of their work in relation to how performance and quality of work is measured
- To investigate the need for feedback in the daily work of harvester operators
- To investigate how harvester operators prefer receiving feedback of various kinds
- To identify which factors have a positive and/or negative impact on the work of harvester operators
- To identify the main common needs for harvester operators in Sweden, Norway and Germany, and potential differences
- To identify which type of feedback would be suitable to include in a digital coach, like the AVATAR concept

Material and method

A series of 16 exploratory interviews were held with professional harvester operators from Sweden, Norway, and Germany. In Germany, the interviews were held through personal meetings with the operators, in Norway by video calls, and in Sweden all interviews were conducted by phone. The German interviews were held by Florian Hartsch, the Norweigan by Ole Bertil Reistad and the Swedish by Karin Ågren. The interviews were recorded.

Selection of interviewees

In Sweden, the interviewees were selected in collaboration with Holmen Skog, a forest company that operates in much of the country. The operators were chosen to achieve a variation in experience, geography and types of harvesters used. In Germany, interview partners were selected based on their accessibility and experience, and in Norway the selection process was based on the operators' experience and location. Figure 1 below shows the age distribution of the participating operators. All major harvester manufacturers (Komatsu, John Deere, Ponsse, Rottne and EcoLog) were represented in the material, and operators were working in final fellings, thinnings, or a combination.
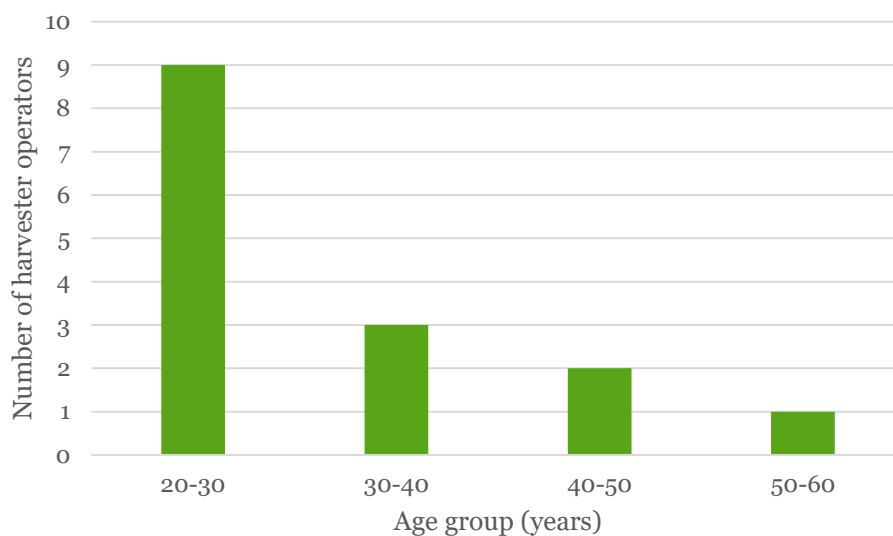
Figure 1. Age distribution of the participating operators.

Interview setup

The interviews were based on an interview guide, and the questions included:

- Demographic data (age, experience, education, training, type of harvester)
- View on performance, and thoughts on the difference between how their employers and customers view performance
- Factors that influence their work in both positive and negative ways
- Thoughts on high quality and ways to measure quality
- Perception of feedback on the harvester's measurement system
- Ideas on how to improve the feedback from the machine regarding performance, quality, and measurement system

An extra focus was placed on how the operators perceived their feedback on measurement quality, as harvester measurements of length and diameter of each stem during processing is important as input for optimising the value for each stem. The interviews were aimed at exploring what type of feedback the operators would consider helpful in their everyday work, as well as how and how often they would prefer to receive that feedback.

The operators could give multiple responses to each question. For example, the question "How do you measure your overall performance?" could lead to several responses. The aim of the interviews was to get a qualitative, rather than quantitative, insight into the operators' everyday work. The interview guide encouraged follow-up questions for deeper understanding.

For the full set of questions, including the demographic data, see Appendices A and B.

Analysis

The results from the interviews were compiled and grouped into the following categories:

- Operator
- Harvester
- Pre-harvest planning
- Logging site
- Other

Not all categories were relevant for all questions.

Similarities and differences between different operators and countries were investigated and explanatory factors sought.

Results

In this section we present the main results from the different topics of the interviews: productivity, quality of work, influencing factors, and measurements. We then go on to discuss different types of feedback and end the section by listing ways in which the operators prefer to receive feedback.

Performance

We asked questions from three perspectives to get a full picture on the definition of performance: from the operator's own perspective, and from how the operator perceived employer and customer perspectives. We focused on performance instead of productivity to explore whether the operators had other ways of defining performance and how the definition may vary between perspectives. The responses showed that the link between productivity and performance was strongest in the operator's own perspective and that the operators stated that, from the customer's perspective, fulfilment of contracted volumes/measured timber at mill was the basis for defining performance.

Performance according to operator

When asked to give their own definition of performance, most of the operators referred to production for a specified time period, measured as harvested number of trees or volume per hour/day/week/month. The German operators also mentioned fuel consumption, which was only mentioned by one Swedish operator and two of the Norwegian. The Swedish operators brought up technical utilisation rate (i.e., the proportion of the working day that the harvester is in operation) and hourly profit. The profitability perspective was given by two of the self-employed harvester operators. For German operators, the wear and tear on the machine was a recurring response. Additionally, in Germany, the impact of the forest stand came up as a factor for measuring the operator's own performance. The Norwegian operators seemed to focus on both produced volume and the quality of the products, as measured at industry, to measure performance.

Performance according to employers

When questioned about how their employers measure performance, the operators' responses slightly changed. Responses regarding harvested number of trees per hour/day/week/month were still common. Technical utilisation rate was mentioned by all but one Swedish operator. In Germany stand damage and quality of the timber were the more common responses, as damage to the remaining stand and the quality of the work delivered, e.g., measurement accuracy and correct calibrations, are key aspects of evaluating harvester operator performance. In Norway, three of the operators reported that their employers did not really follow up on their performance, but that a steady flow of harvested timber was appreciated. Two other operators from Norway also stated that they were followed up primarily on their production.

Performance according to customer

Lastly, we asked the operators their views on how their customers measure their performance. This question led to a variety of responses. Two of the German operators stated that they were followed up by checks on the consistency of the actual amount of timber with onboard protocols. However, they also added that harvester onboard

protocols in Germany are not suitable for accounting, which is why foresters also manually check the amount of timber. The Swedish operators were divided in two groups: one group stated they did not get any feedback from the customers, and another said that fulfilment of contracted volumes and monthly feedback on length measurements and bucking according to customer specification were followed up. Hourly profit was mentioned by one operator. In Norway, measured timber at mill was by far the most common response, given by all operators but one.

Factors influencing the work of the harvester operator

To achieve a broad perspective, we asked for factors that positively or negatively influence the operator's work, who/what can impact these factors, and suggestions for improvements. The responses were grouped in categories and are presented below.

Operator

The operators pointed to their own mindset, attitude, motivation, and overall well-being as important factors that can influence their work. Nearly all operators said something that fits within this category, and pointed out that it can work both ways, both positively and negatively. Factors like alertness, experience, (their own) pressure to perform, and work method can, to some extent, also be affected by the operator. Shift work that in turn affects how the operator feels (tiredness from getting up early, etc) was mentioned by two of the operators as an influencing factor. Relationships with colleagues and employer, and salary levels, are factors that can influence both positively and negatively. Relationships and contact with production controllers and service providers were also mentioned as factors that may influence the work both ways. Positive feedback, regardless of its source, plays an important role for the well-being, whereas excessive pressure from others to perform influences the work negatively.

Table 1. Summary of the operators' responses to the question "Which conditions/factors strongly influence your work?" categorised under "Operator". +/- shows whether the response indicates a positive or negative influence. S represents Swedish, G German, and N Norwegian operators.

Response	+	-	Respondents		
			S	N	G
A positive mindset, attitude, motivation, well-being and will	X	X	4	5	3
Alertness	X	X	2		2
Pressure to perform		X	2		2
Experience	X	X			2
Work method (choice of tree, joint loading, etc)	X	X	1		
Shift work		X	2		
Colleagues and employer	X	X		3	2
Salary	X	X		1	3
Relationships/contact with production controller, customer, and service provider	X	X	2		
Positive feedback	X			1	

Harvester

The harvester is a prerequisite for conducting the work, and is in itself an important influencing factor, both positive, when working according to plan, and negative, when malfunctioning. Besides these general comments, three specific functions of the harvester were discussed: an ergonomic cabin, a crane setting appropriate for the operator, and an intelligent crane. The latter two were both discussed by the German operators, who mentioned that crane settings are a central requirement of productive, ergonomic, and positive working behaviour. Regarding the ergonomics of the cabin, automatic chair adjustments when changing between operators would improve the working conditions and save time. A few of the operators also thought a reminder to move or change position on a regular basis would be helpful.

Table 2. Summary of the operators' responses to the question "Which conditions/factors greatly influence your work?" categorised under "Harvester". +/- shows whether the response indicates a positive or negative influence. S represents Swedish, G German, and Norwegian operators.

Response	+	-	Respondents		
			S	N	G
Harvester	X	X	2	5	2
Ergonomic cabin	X	X	3	5	3
Crane settings suit operator	X				2
Intelligent crane	X				2

Pre-harvest planning

Good planning is vital for operator efficiency. The planning starts when the planner chooses the logging site; it is important to choose the right site for harvest at the right time of year, and to choose a site suited to the harvester. Clear definition of the logging site boundaries and the sequence of working facilitates the work of the operator, and can involve pre-commercial thinning before the harvest, when needed, and preparing the site by marking the boundaries. This is particularly important in Germany, where the planner not only marks the boundaries, but often also decides exactly which trees are to be harvested. During harvest the operators can use depth-to-water maps to avoid moist areas.

Table 3. Summary of the operators' responses to the question "Which conditions/factors greatly influence your work?" categorised under "Pre-harvest planning". +/- shows whether the response indicates a positive or negative influence. S represents Swedish, G German, and N Norwegian operators.

Response	+	-	Respondents		
			S	N	G
Maps, water maps	X	X	1		
Choice of logging site	X	X	1	4	
Planning of logging site	X	X	6	5	1
Harvester suitable for stand	X				3
Pre-commercial thinning before start	X	X	3	2	2
Good preparation of site, marking of boundaries	X	X	2	2	3
Understanding from employer of how things work in practice	X			2	
Variable demand for timber		X		1	

Logging site

Most of the operators reported that ground conditions at the logging site influence their work. The moisture, surface roughness, and slope of the ground affect the mobility of the harvester, and thereby the time taken to perform the work. A lot of young trees may affect visibility negatively. The German operators often work in stands with permanent machine operating trails, and all three mentioned good accessibility as an important influencing factor. The quality of the forests influences the work through tree sizes, crooked trees, presence of root rot, and other damage or defects impacting tree quality. Operating in a certified forest requires extra caution and a higher level of nature conservation measures, which influences the work by adding tasks.

Table 4. Summary of the operators' responses to the question "Which conditions/factors strongly influence your work?" categorised under "Logging site". +/- shows whether the response indicates a positive or negative influence. S represents Swedish, G German, and N Norwegian operators.

Response	+	-	Respondents		
			S	N	G
Quality of forest stand	X	X	4	1	1
Good accessibility to pre-defined skid trails	X				3
Ground conditions (moisture, surface roughness, slope)	X	X	5	4	3
Certified forests (high level of nature conservation)		X	1		
Small amount of young trees	X				1

Other

In the 'Other' category, two influencing factors were brought up: pricing and general weather conditions. Pricing can be both positive and negative, depending on the prevailing price level. Weather conditions, such as snow, strong winds and rain, might affect the rate of work, and working in darkness reduces visibility.

Table 5. Summary of the operators' responses to the question "Which conditions/factors greatly influence your work?" categorised under "Other". +/- shows whether the response indicates a positive or negative influence. S represents Swedish, G German, and N Norwegian operators.

Response	+	-	Respondents		
			S	N	G
Pricing	X	X	1	1	
Weather conditions, darkness	X	X	3	1	3

Quality of work

The next set of questions included the operators' definition of quality, how the operator knows if their work maintains high quality, and reasons why the quality might decrease. In many ways, the responses to the latter resemble what the operators listed as factors that influence their work in general.

What does high quality work mean to you?

In defining quality, the responses varied considerably. However, many of the Norwegian and Swedish operators gave definitions including no ground damage and accurate measurements. Cutting logs of correct lengths was also mentioned. In Germany, two other definitions were more common: dividing the assortments accurately, as this affects the forwarder work, and limiting damage to the remaining stand.

When processing the responses, we found that most of the definitions of quality fit within two main areas:

1. Harvest (including efficient work practices, correct measuring, correct products, well-functioning harvester with low wear and tear, adequate thinning, small amount of damage in the remaining stand, and well-planned landings)
2. Environmental and biological conservation (including reaching environmental goals, conservation measures, using biological fuel and oil).

Some of the operators also raised social aspects, such as good communication between harvester and forwarder, keeping the work team satisfied, being proud of one's work, and having a satisfied landowner.

How do you know if you have performed your work with high quality?

After defining high-quality work, a follow-up question was for operators to describe how they know whether their work has been performed with high quality or not.

In Germany, control measurements are made weekly, or even daily, to check on the quality of work. Operational assessments with forest owners, discussing and comparing work with other contractors, and considering protocols when assessing operation were mentioned as ways of checking quality.

In Sweden, two main ways of checking quality were described. Monthly follow-ups on timber quality and annual checks of completed logging sites, both initiated and conducted by the employer. The first focuses on wood value and the second on environmental and biological conservation.

Five of the six Norwegian operators reported that they relied on harvester data (e.g., measurements, production, fuel consumption) to measure the quality of their work. The operators' own experiences, visual checks of completed logging sites, and production meetings with employers were mentioned as ways to check the quality.

How can the quality of your work be impacted?

Next, we asked the operators about what impacts the quality of their work. The responses, categorised as previously described, are listed below.

Operator

Nearly all operators gave examples of how personal circumstances may influence the quality of their work. Table 6 summarises all the responses given and clarifies whether it is the operator themselves or others that impact the work. In many areas, the operators consider themselves to be responsible for the impact on quality. Comments included actions such as undergoing adequate training, staying healthy, knowing the machine, maintaining good relationships, being open to learning from others, and making correct assessments. Many operators expressed in different ways that their attitude to work also influences the quality of their work. Being part of a team, where the operator can receive feedback and constructive criticism, help and learn from others, and ask questions is a

factor for well-being, which in turn affects the quality of the work. Expectations, both the operator's own and from others, and payment levels, were said to influence the quality. Excessive expectations lead to a stressful work environment.

The fact that the operators feel that they can influence the work supports the idea of developing a future digital coach.

Table 6. Summary of the operators' responses to the question "How can the quality of your work be impacted?", categorised under "Operator". Self/others tells whether it is the operators themselves, others, or a combination that impact the work through the specific response. S represents Swedish, G German, and N Norwegian operators.

Response	Self	Others	Respondents		
			S	N	G
Appropriate skill level (regular training sessions, accurate assessments, e.g., for timber assortments and thinnings)	X	X	1	2	3
Good health, for example getting enough sleep	X		1		1
Familiar with functionality of own harvester	X				2
Being part of your team, keeping good relationships with employer and colleagues	X	X	4	2	3
Correct mindset, will, attitude	X		4	2	
Expectations/pressure, self-criticism	X	X	1	2	3
Payment		X			1

Harvester

The harvester plays an important role in performing high-quality work. As can be seen in Table 7, many different aspects of the harvester work were raised, such as keeping the knives sharpened, having correct bucking instructions, and machine settings, but also indirect aspects such as adequate colour marking of logs. The most often mentioned, however, was sufficient service time/maintenance, and control and calibration of the measurement system. All these aspects, apart from parts of the maintenance, are the

operator's own responsibility. The possibility to get assistance from a digital coach for some of the aspects could therefore relieve the operator in their work.

Table 7. Summary of the operators' responses to the question "How can the quality of your work be impacted?" categorised under "Harvester". Self/others tells whether it is the operators themselves, others, or a combination that impact the work through the specific response. S represents Swedish, G German, and N Norwegian operators.

Response	Self	Others	Respondents		
			S	N	G
Appropriate service intervals, maintenance	X	X	1	2	3
Control and calibration of harvester head measurements	X		1		3
Correct bucking instructions, including colour marking of logs	X		1		
Correct machine settings, e.g. pressure settings for delimbing knives and feed rolls	X		2		

Pre-harvest planning

The planning of the logging site is vital in facilitating the operator's work, as reported by many of the operators in the discussion. Responses included the planner's work beforehand, both preparatory in the office and on site in the forest, as well as the operator's part regarding operational planning, such as planning main extraction roads, and adjusting the plan in cases where the planner might have missed something. The choice of logging site was pointed out as an important factor, i.e., avoiding work on a site that was not readily accessible, for example due to changes in bearing capacity of the ground at different times of year.

Table 8. Summary of the operators' responses to the question "How can the quality of your work be impacted?" categorised under "Pre-harvest planning". Self/others shows whether it is the operators themselves, others, or a combination that impacts the work. S represents Swedish, G German, and N Norwegian operators.

Response	Self	Others	Respondents		
			S	N	G
Detailed and sufficient planning of operations (high quality, easy to understand)	X	X	1	4	2
Sufficient marking at logging site		X			1
Choice of logging site and time of harvest		X	1	1	

Other

In addition to the three main areas mentioned above, two other aspects that impact the quality were discussed. Five of the operators said that their work is influenced by the quality demands of the employer, and that a common view on what defines quality is desirable. One of the operators suggested that increased knowledge among the public about how certified, well-managed, forestry is conducted would probably affect the work of the operators. If the public had a better understanding of both the difficulties and opportunities of forestry, the operators' interest in performing well would increase, the operator assumed.

Table 9. Summary of the operators' responses to the question "How can the quality of your work be impacted?" categorised under "Other". Self/others tells whether it is the operators themselves, others, or a combination that impact the work through the specific response. S represents Swedish, G German, and N Norwegian operators.

Category	Response	Self	Others	Respondents		
				S	N	G
Other	Quality demands from employer		X	1	4	
	Enlightened public		X	1		

Harvester measurements

Correct harvester measurements and adequate measurement systems are important parts of the operator's workday, which is why these issues are given special scope within the AVATAR project. Another part of the project is aimed at developing a tool for feedback on bucking (Hannrup et al., 2021).

There are two main ways for the operator to know if the harvester measures correctly: by checking themselves or by getting measurement information from the employer or customer to compare with. By far the most common response, given by all operators, was that the measurement is checked by manual measurements using a calliper on selected control stems, at regular intervals. A few of the operators also mentioned that the calliper itself should be regularly checked.

Besides control stems, a few other ways of checking harvester measurements were discussed, ranging from feedback from customers based on log scaling at industry, to their own visual checks and discussions about measurements.

When the measurement system of the harvester malfunctions there are three main sources of error: machine settings, calibrations, and mechanical errors.

Need for feedback

In the interviews, the operators were asked what type of feedback they requested, together with how and when they preferred to receive the feedback. In this section we summarise what we learnt from that discussion.

The requested feedback could be divided into feedback on operator performance, feedback on harvester performance, warnings and reminders, and information about the logging site.

Feedback on operator performance

The feedback on operator performance mainly comprised information that the operator would like to see in real-time on the onboard computer while there is a chance to correct potential deviations. This could be information on the operator's behaviour when operating the harvester and how that relates to productivity, fuel consumption and other performance indicators. Operators would also like to see feedback on the choices they made during the work, such as trees selected and assortments for joint loading.

Feedback regarding the products harvested, e.g., minimum diameter of timber, comparisons between harvested output and expected output, and feedback on operator decisions was requested. The latter includes feedback on manual cutting decisions, and the number of high stumps and retention trees that have been left in the forest.

More frequent information on what was measured at mill was also requested to get feedback on the overall production process and to enable change. However, this type of feedback is not always possible while operations are still taking place at a specific harvesting site, depending on lead times.

Feedback on harvester performance

Feedback on harvester measurement accuracy would be helpful for the operators, to ensure the harvester is functioning properly. This could be feedback on the measurement precision and the resulting products, e.g., standard deviation of the diameter measurements, and follow-ups on the control stems.

An idea to implement two systems to measure length, enabling comparison, was mentioned, along with a suggestion to include a forced calibration routine once per week, which would prevent the harvester from functioning if not followed.

Warnings and reminders

The third type of feedback – warnings and reminders – was proposed for situations when the operator needs to be made directly aware of something, e.g., harvester-related issues such as a deteriorating diameter sensor or malfunctioning feed rollers.

Around half of the operators said that they would be interested in self-monitoring programmes in the harvester, e.g., programmes that check the maintenance status of the machine and indicate when parts of the machine need to be replaced.

Reminders when to save retention trees and a notification if the logging site instructions were not being followed were also suggestions for improvement. One of the operators suggested that a warning be given when the production decreases, and that the machine might suggest a pause to give the operator a chance to recover. A reminder to change position at regular intervals would also promote health and ensure that the operator takes regular breaks.

Information about the logging site

This feedback includes measures that would relieve the operator from parts of the responsibility. Examples were to retrieve direct GPS-position from extraction trees, and to receive real-time feedback on the position of the machine operating trails. These suggestions were both brought up by the German operators who usually use a permanent stand accessing system. Linked maps in harvester and forwarder so that they know each other's position was also brought up as helpful information. The harvester and forwarder could therefore avoid meeting when working on the same site.

Automatic detection of tree species (pine/spruce), root rot and the number of annual rings would reduce the number of decisions for the operator to make, and lead to a more alert operator. Based on information about the harvested trees, operators wanted assistance in deciding how many control stems are needed in a particular forest.

Presentation of feedback

Depending on the type of feedback, the ways the operators want it presented varies. The requested means of communication include:

- Presentation on the onboard computer
- Phone calls with other contractors and foresters
- Personal audits with other contractors
- Reports by email
- Regular meetings at which feedback is reviewed
- Mobile phone app
- Training programmes with instructor

The operators stated that it would be valuable for them to get feedback on their own performance from other contractors and foresters (colleagues or customers) to improve their skills. Many of the operators said that they wanted to receive feedback more often than is the case today. However, they also pointed out that the feedback needs to be relevant, clear, and given at reasonable intervals. What counts as relevant and clear, and how a reasonable interval is defined, varies considerably between operators. Hence, the study shows it is important for acceptance and effectiveness that the feedback presentation can be tailored to individual preferences.

Among the Norwegian machine operators, verbal feedback by telephone was considered a simple and flexible form of communication. Those who work at the office, or the work leader, communicate with clients and receive feedback on timber delivered to industry customers. If there are deviations, or positive feedback, the operators can receive this directly by telephone, and this also enables them to justify their choices and decisions. Such a system also makes it easier to discuss issues and solutions arising at the time. Overall, the Norwegian operators find it easier to have discussions over the phone than through email or other digital platforms.

Discussion

Different people were responsible for the interviews in each country. The interviews generated a large amount of information on current work practices and proposals for development. A common template was used for compiling and interpreting the results, but each interviewer was responsible for the interpretating the data generated by their own interviews. Finally, a coherent analysis was conducted by Skogforsk, in close collaboration with the University of Göttingen and Skogkurs.

At first glance, operators from all three countries seemed to have a quite common view on what feedback they would appreciate. However, when the responses were analysed in detail, differences in approach between operators from different countries were sometimes noted. For example, the Norwegian and Swedish operators seemed to focus mainly on the outcome – that they produced enough, and that the harvester measured correctly – whereas the German operators more often emphasised fuel consumption, wear/tear of the machine. and impact on the forest stand. This could be a consequence of different work practices between Germany and Sweden/Norway, but it cannot be ruled out that it is a random consequence, since the sample of interviewed harvester operators was relatively low.

One of the challenges during the interviews was to make the operators think beyond the current information system, to consider what could be part of a future system. In this report, we have given a first insight into how operators define their performance and quality of work. As a next step, we think it would be beneficial if the concept of a digital coach could be further processed and developed together with harvester operators, for example in focus groups. These could be groups of a few operators within or across countries that are asked to discuss how a certain concept could work and how helpful it would be in their everyday work.

The main objective of a digital coach would be to help operators improve their working methods and practices, without increasing the complexity of their work. The operators requested feedback through digital channels, e.g., onboard computer, in various areas, to facilitate their work. However, before developing a digital coach, the type of information already available in the harvester should be investigated. If the information is available today, but not used, it should be investigated whether the operator is not interested in the data, or whether the data is not easily accessible.

A digital coach would be able to address some of today's missing features, but it must be kept in mind that human contact, having a dialogue with another person, and extending networks are motivating factors for many people. The importance of human contact was widely mentioned in the interviews, not only as means to increase the efficiency of work, but also to increase the overall well-being. However, a digital coach that follows the operators continuously throughout the working day could be a good complement to meeting instructors, and a way to follow up on changes in working methods. Additionally, the collected material could serve as an aid in benchmarking, to understand differences between operators and develop working methods.

How interactive should the coach be? As we have learnt from the report, both the type of information, as well as the interval at which the information is requested, varies a lot between operators. This implies that it is important that the coach can be customised. On the other hand, some operators might feel that they have sufficiently good working

methods and would therefore not embrace the new possibilities offered by the coach unless they were specifically presented to them.

A digital coach could probably analyse data to further develop the concept of the coach, by identifying relationships between the operator's behaviour, the wear and tear of the machine, and the value of the products, meaning that the coach would be able to draw its own conclusions on how to improve value recovery.

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Personal communication

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Appendix A

Demographic Data

Interviews with Harvester Operators (AVATAR WP3)

Personal data:

Please state your gender.

☐ Female   ☐ Male   ☐ Other

Please state your age.

_____ Years

Harvester/system:

Which harvester do you operate? Please specify manufacturer and model below.

_____ _____

Which systems/software for follow-up/monitoring of work do you have experience from?

_____ _____

(Forestry operator) Training:

Did you undergo a vocational training programme for machine operators?

☐ Yes   ☐ No

Please specify which training (certificate):

_____

_____

Are you undergoing any type of operator training on a regular basis?

☐ Yes   ☐ No

Please specify which training and how often:

_____

_____

Experience:

How many years of experience do you have operating

Cut-to-length harvester

_____ years

Forwarder

_____ years

Thanks, for your participation!

Appendix B

AVATAR – Guide to interviews in WP3

In WP3, our aim is to investigate the need for feedback as experienced by harvester operators in their work. We also want to investigate what harvester operators consider as high quality in terms of work and how that is related to the same considerations of forest companies.

The following questions should be asked to the selected harvester operators (follow-up questions for deeper understanding are encouraged):

1. How do you measure your overall performance?

    a) What factors are relevant to describe your overall performance?

    b) Do you have means of measuring these factors? How? Ideas for improvement?

2. How does your employer measure your performance?

    a) Which factors are relevant for your employer to describe your overall performance?

    b) Which of those factors are measured? Who is measuring them? How and how often are the results communicated? Ideas for improvement?

3. How does/do your customer/s measure your performance?

    a) Which factors are relevant for your customer to describe your overall performance?

    b) Which of those factors are measured? Who is measuring them? How and how often are the results communicated? Ideas for improvement?

4. Which conditions/factors (strongly) influence your work?

    a) Which conditions/factors positively influence your work? Who/what can impact these factors? Ideas for improvements?

    b) Which conditions/factors negatively influence your work? How can these conditions/factors be improved? Ideas?

5. What does high-quality work mean to you?

    a) Can you describe what is, in your opinion, typical high-quality work?

    b) Can you describe typical reasons for lower quality?

    c) How can you impact the quality of your work?

     d) What can others (who?) do to improve/impact the quality of your work?

6. How do you know if your work is high quality or not?

     a) Do you have a way of measuring the quality of your work? How?

        i. If not, why/would you like to have a way of measuring work quality? Ideas?

     b) Does your employer/customer have a way of measuring the quality of your work? How? How and how often is that communicated?

        i. If not, why/would you like to have a way of measuring work quality? Ideas?

7. If you were to get continuous feedback on the quality of your work, how would you prefer to receive this feedback?

     a) Can you give examples of the type of feedback you're getting today and how it is presented (email, screen, mobile app, web portal, phone call…)?

     b) How often (when) would you like to get feedback and in what form? Are certain parts more suitable for presentation in the machine?

8. How do you know if the harvester is measuring length and diameter correctly or not?

     a) Do you follow up measurement precision today? How? How often? Who is responsible?

     b) When do you need information on the measurement precision of the harvester head? What do you use the information for?

9. If you were to get continuous feedback on the performance of the harvester measurement system, how would that best be presented to you?

     a) What type of information regarding measurement precision would be helpful and when? What would you do with the information?

     b) How often and when would you like the information? In what format (email, screen, mobile app, phone call…)?

10. Is there anything else you would like to share with us regarding the need for feedback in harvesters?

Thank you for your participation!

Appendix C

Table 1. Information on the participating operators' age, harvester, experience and whether they had undergone vocational training. S stands for Swedish, G for German, and N for Norwegian operators.

Operator	Age (yrs)	Harvester	Operator experience (yrs)		Vocational training (yes/no)
			Harvester	Forwarder	
S1	50-60	EcoLog 688	32	3	no
S2	30-40	Komatsu 931XC	13	3	yes
S3	30-40	Komatsu 911TX	15	2	yes
S4	20-30	John Deere 1170G	8	8	yes
S5	20-30	Ponsse Bear	2	8	yes
S6	20-30	John Deere 1270G	6	4	yes
S7	20-30	John Deere 1470 G	2	0	yes
G1	20-30	Rottne H11	4	3	yes
G2	40-50	Ponsse Bear	15	8	yes
G3	40-50	Timberjack 1270	17	0	yes
N1	20-30	Komatsu 931	7	1	yes
N2	20-30	Komatsu 901	7	1 (part time)	yes
N3	20-30	Ponsse Scorpion King	1	4	yes

N4	30-40	JohnDeere 1270D	13	3	yes
N5	20-30	Komatsu 951	7	3	yes
N6	40-50	Ponsse Scorpion	4	3	no