# Forwarder test 2022

Evaluation of functionality according to StanForD 2010

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Rottne F20 (upper left), John Deere 1510G (upper right), Ponsse Buffalo (lower left) and Komatsu 895 (lower right) during the forwarder test. Photo: John Arlinger & Johan J Möller (Skogforsk).

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# Preface

StanForD 2010, the global de-facto standard for data communication with forest machines, comprising standardised messages for production control, production reporting and operational monitoring, has been evaluated in practical use cases by Skogforsk since 1995.

Previously, the Wood Value Trials have only considered harvesters. The tests have been performed in collaboration with machine and control system manufacturers on five occasions, the most recent in 2016. These tests contribute valuable information on the current implementation status on the market and enable monitoring of development over time.

During winter 2021/2022, the first common StanForD 2010 tests focusing on forwarders were conducted together with StanForD members Ponsse, John Deere, Komatsu, Rottne, and Dasa Control Systems. The forwarder tests included evaluation of important functionality, primarily for production reporting, but also for operational monitoring and calibration.

We would like to express our gratitude to all participants for making the tests possible, and a special thanks to those who were present during the tests. We would also like to thank AB Karl Hedin, Stora Enso, SCA and Sveaskog for hosting the tests.

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# Summary

StanForD 2010, the global de-facto standard for data communication with forest machines, comprising standardised messages for production control, reporting and operational monitoring, has been evaluated in practical use cases by Skogforsk since 1995.

Previously, the regular Wood Value Trials have only considered harvesters. The tests have been performed in collaboration with machine and control system manufacturers on five occasions, the most recent in 2016. These tests contribute valuable information on the current implementation status on the market and enable monitoring of development over time.

During winter 2021/2022, the first common StanForD 2010 tests focusing on forwarders were conducted together with StanForD members Ponsse, John Deere, Komatsu, Rottne, and Dasa Control Systems.

The objectives of the forwarder test 2022 were to: 1) describe the available functionality in StanForD 2010 developed for forwarders and describe how far implementation has come for the major forwarder manufacturers on the Swedish market; 2) raise awareness among forest companies and machine owners about the potential benefits of using StanForD 2010 in forwarders and demonstrate how far implementation has come into practical use; and 3) support the manufacturers in their further development. Consequently, the test not only provides a description of the current situation but also considers probable future needs and requirements.

The main question addressed was to test functionality for production control, production reporting and operational monitoring. The test involved four different forwarders, representing the main manufacturers on the Swedish market: John Deere, Komatsu, Ponsse, and a Rottne forwarder with a Dasa computer. Each manufacturer was free to choose which base machine to use for the test.

The results of the test show that all major forwarder systems currently available on the Swedish market perform well. Many forwarders now use the new StanForD 2010 format, and the number of forwarders operating according to StanForD 2010 is increasing rapidly. It should especially be pointed out that 1) correct fpr-files can be generated in all machines, 2) all controllers can read and store the instructions (fdi and foi) correctly, 3) the new file formats have simplified forwarder reporting for the operators and decreased the number of errors, and 4) all forwarders can perform automatic reporting of production and operational monitoring.

Even if the results of the test are positive, there are many potential improvements. For example, manual registration of forwarded volumes currently works well but is based on a subjective estimation of forwarded volumes. This often means that the volumes have systematic errors, in most cases leading to underestimations.

The authors therefore suggest a future solution where the forwarder crane data and harvester data is combined with GIS functionality to generate volumes.

In order to make this type of advanced reporting successful it must be possible to use several different sources for the harvester data (both from cloud or local transmission) and it must be possible to utilise data independently of original type of controller (i.e. not manufacturer-specific hpr-files). This solution is based on combining GIS-functionality, log positioning and high- resolution data from crane/grapple.

# Sammanfattning

StanForD 2010, den globala standarden för kommunikation med skogsmaskiner som inkluderar meddelanden för styrning, produktionsrapportering och driftsuppföljning, har utvärderats av Skogforsk i praktiska test sedan 1995.

Tidigare har endast skördare inkluderats i de återkommande så kallade Virkesvärdestesterna. Testerna har genomfört i samarbete med maskin- och styrsystemtillverkare vid fem tillfällen, det senaste 2016. Dessa tester bidrar med värdefull information om nuläget för implementering av ny funktionalitet på marknaden och skapar möjlighet att följa utvecklingen över tid.

Under vintern 2021/2022 genomfördes de första gemensamma skotartesterna av StanForD 2010 tillsammans med StanForD-medlemmarna Ponsse, John Deere, Komatsu, Rottne och Dasa Control Systems.

Syftena med skotartestet 2022 var att 1) beskriva tillgänglig funktionalitet för skotare i StanForD 2010 och hur långt implementeringen har kommit på den svenska marknaden, 2) öka medvetenheten bland skogsföretag och maskinägare om möjligheterna med StanForD 2010samt hur långt implementeringen har kommit i praktisk tillämpning och 3) stötta tillverkarnas utveckling. Därför innefattar testerna inte endast en beskrivning av nuläget, utan också en beskrivning av troliga framtida behov och krav.

Testerna fokuserade i första hand på styrning, produktionsrapportering och driftsuppföljning. Skotartesterna inkluderade fyra olika skotare, vilka tillsammans representerar de största tillverkarna på den svenska marknaden: John Deere, Komatsu, Ponsse och Rottne med styrsystem från Dasa. Varje tillverkare fick fritt välja basmaskin för testet.

Resultaten från testerna visar att alla de främsta skotarna på den svenska marknaden presterar bra. Många av dagens skotare använder redan StanForD 2010 och antalet ökar snabbt. Det bör särskilt påpekas att 1) korrekta fpr-filer kan genereras i alla maskiner, 2) alla styrsystem kan läsa och lagra instruktioner (fdi och foi) korrekt, 3) de nya filformaten har förenklat skotarrapportering för förarna och minskat antalet fel och 4) alla skotare kan prestera automatisk rapportering av produktion och driftsuppföljning.

Även om resultaten från testet är positive finns det manga potentiella förbättringar. Exempelvis fungerar manuell registrering av skotade volymer bra idag men baseras ofta på subjektiva uppskattningar av skotad volym. Detta innebär att volymerna ofta har systematiska fel, vilket vanligen leder till underskattningar.

Författarna föreslår därför en framtida lösning där data från skotarens kran och skotardata kan kombineras med GIS-funktionalitet för att generera volymer.

För att lyckas med den typen av avancerad rapportering måste det var möjligt att använda skördardata från olika källor (molnet eller lokal överföring) och det måste var möjligt att använda data oavsett vilket styrsystem de kommer från (dvs. inte tillverkarspecifika hpr-filer). En sådan lösning är baserad på att kombinera GIS-funktionalitet, positionering av stockar och högupplöst data från kran/grip.

# Background

Skogforsk has carried out five practical tests of harvesters since the 1990s (Nordström et al 2018). In 2019, it was decided that a similar test should be conducted of all major forwarder control systems. Due to the Covid pandemic the test was postponed to the autumn of 2021 and winter 2022.

All manufacturer members in the StanForD group were invited to participate in the test. All four existing manufacturers of forwarder controllers chose to participate. The term "controller" describes the on-board computer (software and as well as hardware) that is responsible for reading and writing StanForD-files. The controller also includes a user-interface that the operator interacts with.

## Instruction files sent to forwarders: *foi*, *fdi*

The forwarding instructions consist of two different messages: forwarding object instruction (foi) and forwarding delivery instruction (fdi), as illustrated in Figure 1.



**Forwarding object instruction (foi)**
- Object identities
- References to deliveries to be used
- Locations (landing)

**Forwarding delivery instruction (fdi)**
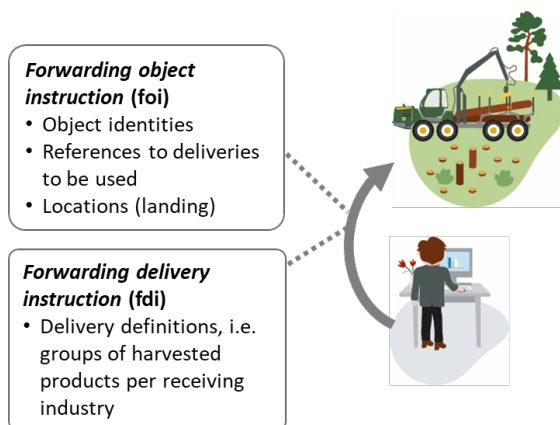- Delivery definitions, i.e. groups of harvested products per receiving industry

Figure 1. Instruction messages sent to a forwarder (adapted from Arlinger et al 2012).

The forwarding object instruction (foi) includes object-specific information such as contract number, object name, and contact information to forest owner and forest company. The message may also include identities and positions of landings (locations). This instruction also includes references to deliveries that are to be forwarded by the machine at a specific Object (work area).

The forwarding delivery instruction (fdi) includes definitions of deliveries. The delivery is the unit the forwarder is reporting, traditionally described as a "forwarder assortment". Each delivery includes references to one or several harvested products. A common example where one delivery consists of several products is pulp wood from two different species that must be managed as two separate harvester products. These are merged into one delivery in the forwarder, as it is transported to one single industry as one unit. Another example is saw timber, which is often divided into 2-3 different quality grades. This means three different harvester products, while these products are merged into one delivery in the forwarder.

One-to-many relationships are therefore often found between delivery and products in the fdi. On certain markets it is always a one-to-one relation between harvester products and forwarder deliveries. The identity of the final mill destination or terminal is normally included in DeliveryDestination, with BusinessID carrying a code identifying the industry.

The instructions can be loaded separately into the onboard computer (controller) of the forwarder or merged into an envelope (*env*) message that can be used to load all instructions simultaneously.

## Files sent from forwarders: *fpr, mom, fqc*

The two most widely used messages sent from forwarders are the forwarded production (*fpr*) and operational monitoring (*mom*), illustrated in Figure 2.

The forwarded production message (*fpr*) includes unloaded volumes per load, delivery (one or several harvested products) and location (landings) as shown in Figure 3. The driving distance, unloading time, mass and number of logs can also be registered for each load. Note that a forwarder load can be divided into several partial loads in cases where the forwarder has co-loaded several deliveries. For example, if different deliveries such as pulp wood and saw logs are transported in a single load.

Operational monitoring data (*mom*) includes individual work elements as well as some aggregated production data, making it possible to estimate productivity and reasons for different down times.
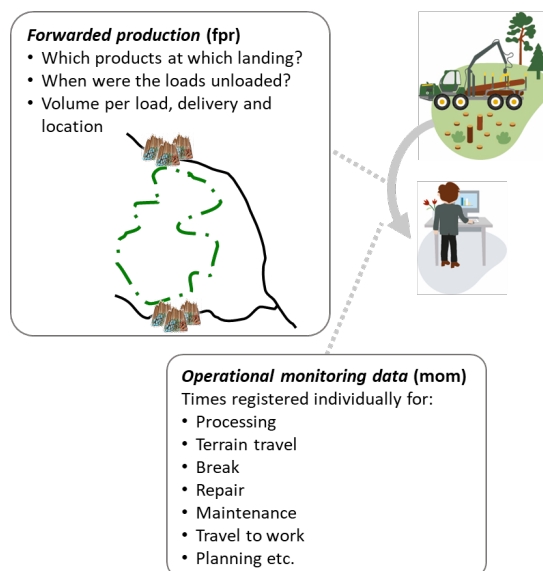


Figure 2. Production and operational monitoring data sent from forwarder (adapted from Arlinger et al 2012).

| ProdKey | ProdInfo | ProdName |
|---|---|---|
| 1 | 0110 | PineSaw |
| 2 | 1000 | PinePulp |
| 3 | 5090 | PineEnergy |
| 4 | 0120 | SpruceSaw |
| 5 | 1000 | SprucePulp |
| 6 | 5090 | SpruceEnergy |

| Location-Key | Location-UserId | Location-Name | Coord. | ObjKey |
|---|---|---|---|---|
| 1 | 101 | South | 60.01,16 | 1 |
| 2 | 202 | North | 60.02,16 | 1 |

| Deliv.Key | Deliv.Info | Deliv.Name | ProdKey | |
|---|---|---|---|---|
| 11 | 0110 | PineSaw | 1 | Saw mill 1 |
| 12 | 0120 | SpuceSaw | 4 | Saw mill 2 |
| 13 | 1000 | Pulp | 2, 5 | Pulp mill 1 |
| 14 | 5090 | Energy | 3, 6 | Energy plant 1 |

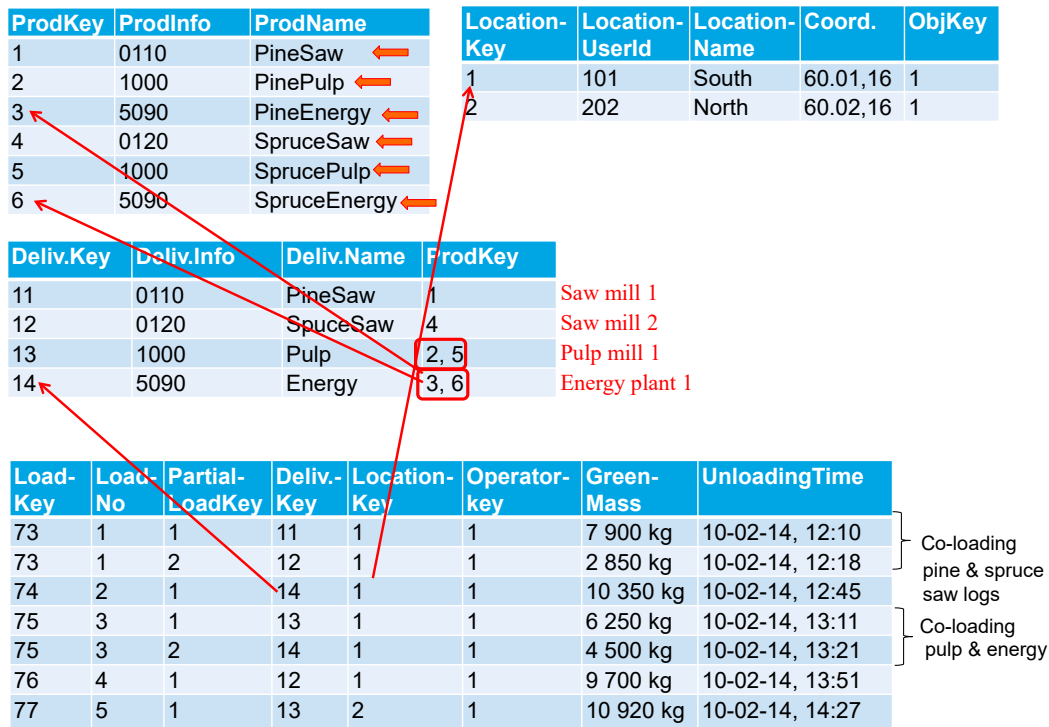| Load-Key | Load-No | Partial-LoadKey | Deliv.-Key | Location-Key | Operator-key | Green-Mass | UnloadingTime | |
|---|---|---|---|---|---|---|---|---|
| 73 | 1 | 1 | 11 | 1 | 1 | 7 900 kg | 10-02-14, 12:10 | Co-loading pine & spruce saw logs |
| 73 | 1 | 2 | 12 | 1 | 1 | 2 850 kg | 10-02-14, 12:18 | |
| 74 | 2 | 1 | 14 | 1 | 1 | 10 350 kg | 10-02-14, 12:45 | |
| 75 | 3 | 1 | 13 | 1 | 1 | 6 250 kg | 10-02-14, 13:11 | Co-loading pulp & energy |
| 75 | 3 | 2 | 14 | 1 | 1 | 4 500 kg | 10-02-14, 13:21 | |
| 76 | 4 | 1 | 12 | 1 | 1 | 9 700 kg | 10-02-14, 13:51 | |
| 77 | 5 | 1 | 13 | 2 | 1 | 10 920 kg | 10-02-14, 14:27 | |

Figure 3. Illustration of basic data structures in *fpr*; note that a significant number of elements have been excluded. The figure describes how each load and partial load are connected to a landing (LocationKey) and delivery (DeliveryKey). The connection between a delivery and harvester products (ProductKey) is also shown.

The forwarding quality control message (*fqc*) includes scale control data as illustrated in Figure 4 and Table 1. Typically, a metal object with a known mass is scaled several times to compare the true mass with the scaled mass. The message can also include a calibration log describing when and how a calibration was conducted.
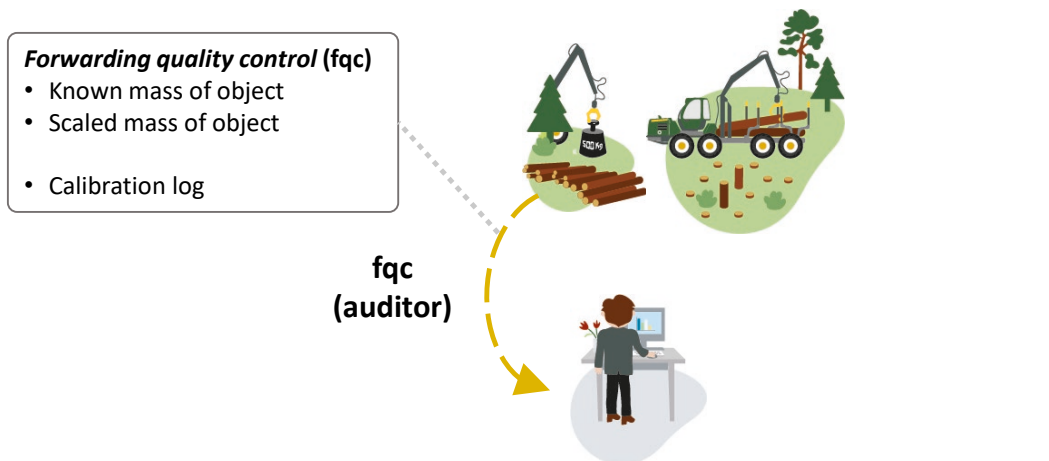


**Forwarding quality control (fqc)**
- Known mass of object
- Scaled mass of object

- Calibration log

fqc
(auditor)

Figure 4. Scale quality control data sent from forwarder (adapted from Arlinger et al 2012).

Table 1. An example of data registered in the fqc.

| Control-Date | Reference mass | No of controls | ScaledMass | scaleWork-Category | scaleControl-Category |
|---|---|---|---|---|---|
| 090227 | 500 kg | 6 | 496, 512, 509, 520, 497, 499 kg | Unloading | Static mass |
| 090307 | 500 kg | 6 | 519, 515, 542, 507, 499, 504 kg | Unloading | Static mass |

An *fqc* with the control measurements as described in Table 1 could also include a calibration log with the adjustment value (ScaleCalibrationAdjustment) of 98 %, as the control measurements on average overestimate the mass by 10 kg (510 kg), thereby necessitating a negative adjustment.

# Objectives

The main objectives of this study were to:

- Describe the available functionality in StanForD 2010 developed for forwarders and to describe how far implementation has come for the major forwarder manufacturers on the Swedish market.

- Raise awareness among forest companies and machine owners about the potential benefits of using StanForD 2010 in forwarders, and to describe how far implementation has come into practical use.

- Support the manufacturers in their further development. This means that the test not only includes a description of the present situation but also considers probable future needs and requirements.

# Material and methods

## Forwarders and control systems

The test involved four different forwarders, representing the main manufacturers on the Swedish market. Each manufacturer was free to choose which base machine to use for the test. Details of the participating systems are presented in Table 2.

Table 2. Tested forwarder systems.

| | John Deere | Dasa/Rottne | Ponsse | Komatsu |
|---|---|---|---|---|
| Machine model | 1510G | Rottne F20 | Buffalo | 895 |
| Software version | TimbermaticF 2.6.9 TimbermaticF 2.5.13 [1] | F30 1.4.5 - 1.4.7.8 | Opti4G 4.770 | MaxiXT 1.5.1.43458 |
| Standard version used in test | 3.2 3.4 [1] | 3.5 | 3.1 | 3.3 |
| Location of test | Sågmyra, Rättvik | Karbenning | Kolsva | Kovland, Sundsvall |
| Date of test | 2021-11-23—24 | 2021-12-08—09 | 2021-12-14—15 | 2022-01-25—26 |

1) The "JD Maps" application was tested on a different harvester using TeamViewer.

Figure 5. Photo from tests of the four forwarders during the winter of 2021/22.

## Test sites

The manufacturers were allowed to decide where to perform the test, as it was not deemed necessary to do all tests at one single site, since the test focused on functionalities not affected by the terrain, the trees/logs, or the climate. All tests were performed in winter conditions, between November 2021 and January 2022.
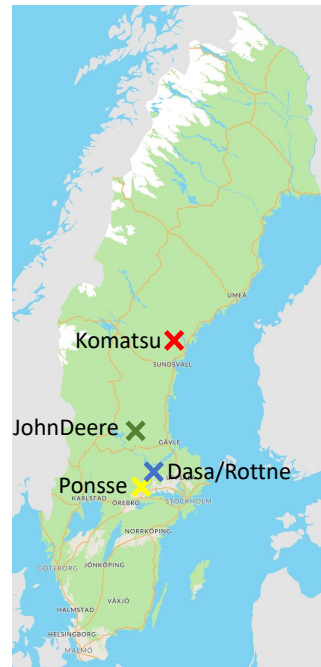


Figure 6. Locations of test sites.

## Test cases

The test was divided into six separate test cases as described below. Depending on the available technical equipment (primarily scale) and software functionalities some test cases were omitted.

Skogforsk created forwarder instruction messages (*env*, *foi*, *fdi*) that were used during the test. All relevant identity variables were included in the instructions. Johan J. Möller was present in the cabin of the forwarder during the tests to obtain direct feedback from the operators, as well as to ensure that the tests were conducted as intended. One test case (JD Maps) was conducted using Team Viewer.

**Test Case 1)**     **Start object with envelope (including both *fdi* and *foi*) and manual registration of unloaded volume.**
Main objective: Check that messages are imported correctly and production data registered according to manual input from operator.

    a. Start new object with complete envelope (*env*) including *fdi* and *foi*. Check that correct density is read from *fdi*.

    b. Manually create two locations including correct coordinates.

    c. Forward two loads from forest to piles at roadside. Register volume using unit m³sub.

    d. Generate and report *fpr* and *mom*. Correct conversion from volume to mass. Complete registration of time stamps was checked as well.
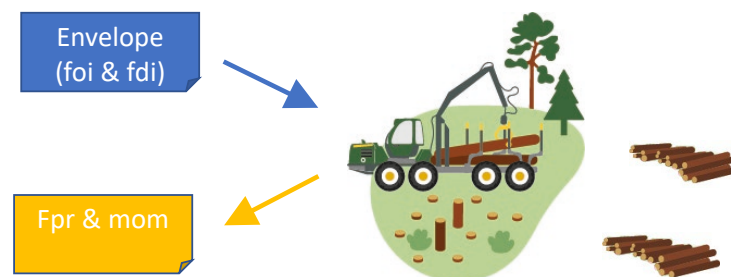


Figure 7. Illustration of Test Case 1.

**Test Case 2)**     **Start Object with new *foi* and manual registration of unloaded volume.**
Main objective: Check that forwarder automatically uses correct deliveries in "machine delivery library" based on *foi*, and that the delivery library is updated correctly when importing updated *fdi*.

    a. Start object with new *foi* with pre-defined location. Same deliveries as distributed and stored in delivery library in Test Case 1.

    b. Forward one load from forest to piles at roadside.

    c. Generate *fpr* including first load.

    d. New *fdi* imported into delivery library including both new and updated DeliveryDefinitions.

    e. Open and activate updated *foi*, which means activating both new and updated DeliveryDefinition.

    f. Forward one load from forest to piles at roadside.

    g. If supported by controller, "move" 1 m³ from saw logs to pulp wood using negative volumes.

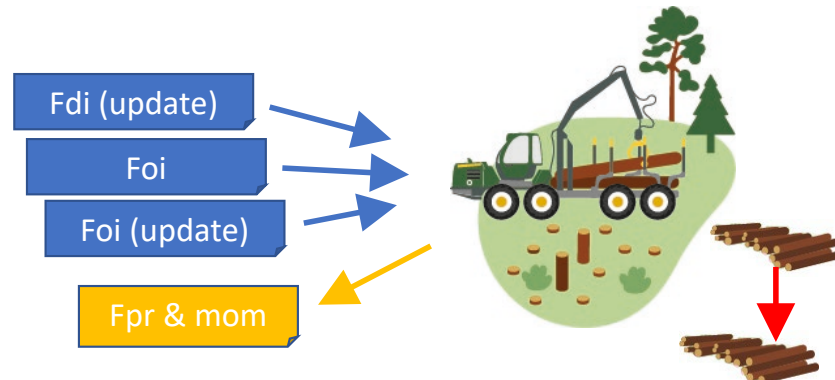    h. Generate *fpr* and *mom* including only the last loads (partial reporting)

Figure 8. Illustration of Test Case 2.

**Test Case 3)** **Start object with new *foi*, register production using scale.**
This test was only carried out if forwarder was equipped with scale.
Main objective: Test whether scale registration works correctly.

a. Start object with new *foi* using existing DeliveryDefinitions.
b. Registration of unloaded mass with scale.
c. When using scale for the first load a second load using manual estimation should be registered.
d. Generate and report *fpr* and *mom*.
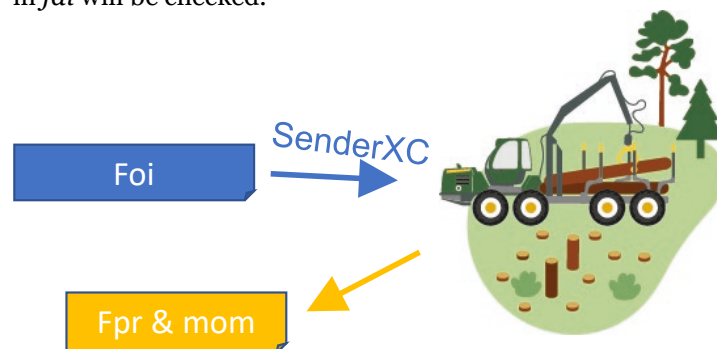e. Conversion between mass and volume (m3sub) using density parameter in *fdi* will be checked.



Figure 9. Illustration of Test Case 3.

f. **Calibration and control of scale.**
Scale control and calibration only tested if forwarder was equipped with scale.
Main objective: Check how calibration and control of scale works.
Run a control and calibration of scale according to manufacturer routines.
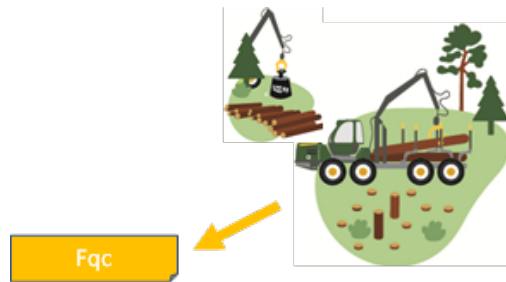g. Control of available functions (settings and randomisation methods).
h. Generate *fqc*

Figure 10. Illustration of Test Case 4.

**Test Case 4)** **Automatic registration of unloaded volume based on *hpr*-data.**
Test carried out only if this type of GIS functionality existed.
Main objective: test functionality to use harvester data with stem positioning in combination with GIS interface to register forwarder production.

    a.   Start with new *foi*/*hpr* or only harvester *hpr*.

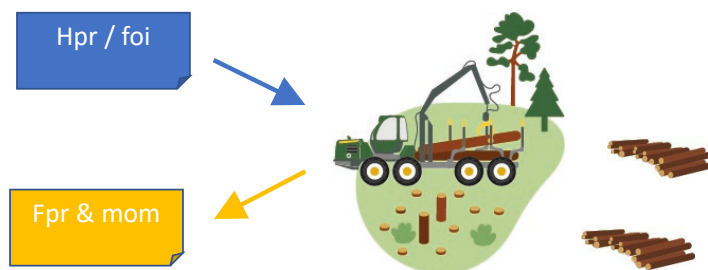    b.   Registration of unloaded volume/mass (generate *fpr* and *mom*).



Figure 11. Illustration of Test Case 5.

**Test Case 5)** **Other functionality**
Test of other functions developed by forwarder manufacturers.

    a.   Using *hpr* information in forwarder machine-GIS.

    b.   Using *hpr* to start a forwarding Object (alternative to *foi* and *fdi*).

    c.   User interface issues:

- Input unit? Can the operator choose between mass or volume? Or only volume? Volume sub or sob (solid under or on bark)?
- Increment levels when registering volume manually? E.g. 0.1 $m^3$ or 1.0 $m^3$.

    d.   Other available functions?

## Forest company interviews

The preliminary test results were presented to a selection of Swedish forest companies as a basis for discussion regarding present and future requirements relating to forwarders.

The following Swedish forest companies were interviewed (March-April 2022):

- Sveaskog, which currently reports *fpr* from approximately 50 % of the forwarders and uses *foi*/*fdi* on 50 % of the forwarders.

- Stora Enso, which currently reports *fpr* from 75 % of the forwarders and uses *fdi* on 25 % of the forwarders. *Foi* is not currently used and there are no plans for

implementation in the near future, as implementing *oin* for harvesters has higher internal priority.

- Sydved, which currently reports *fpr* from 65 % of the forwarders and uses *fdi* on 45 % of the forwarders. *Foi* is not currently used and there are no plans for implementation in the near future.

SCA does not currently use StanForD 2010 in forwarders but plans to start an implementation project soon.

# Results and discussion

The results from the six test cases have been compiled under the different sections below.

## Instructions

Generally, the basic use of instruction files according to StanForD 2010 (*fdi* and *foi*) worked as expected. However, as illustrated in Table 3, there are some possible improvements, such as supporting updates using *foi* and *fdi*. There is currently no strong demand for using *env*-files but it is most certainly a good idea to adjust forwarder controllers in order to make the functionality as similar to harvesters as possible, thereby also supporting *env* in forwarders.

Table 3. Results from tests using forwarder instructions (*foi* and *fdi*)

| | John Deere | Dasa/Rottne | Ponsse | Komatsu |
|---|---|---|---|---|
| Starting object with *env* (*fdi* and *foi* merged into *env* message) | Partly yes (all deliveries inside *env* not imported to library) | No | Yes | Yes |
| Starting object with *fdi* and *foi* | Yes | Yes | Yes | Yes |
| Add new *fdi* during forwarding of an object | Yes | Yes | Yes | Yes |
| Updated *fdi* during forwarding of an object | No (to be added Sept. 2022) | Yes | Yes | Yes |
| Start object with just a new *foi* and use *fdi* stored in the machine library | Yes | Yes | Yes | Yes |
| Updated *foi* during an object | No (new object must be started) | Yes | Yes | No, to be fixed Q2 2023- |
| Manually created Locations kept after *foi* update of object | - | Yes | No | |
| Previous Locations kept and available when starting new object | No | No | Yes | No |
| Automatic receiving instruction e.g. using Sender XC | Yes | Yes | Yes | Yes |
| Start object with *hpr*-data | Yes, in JD Maps [1] (data from cloud) | Yes (IDs and volumes) | No | No |

1) Tested separately using TeamViewer.

## Generating production data

Manual registration of forwarded volumes worked well in all systems. Crane scales could be used for testing for all forwarders except Rottne/Dasa, which was not equipped with a scale. Based on discussions with both manufacturers and forest companies it was noted that the popularity of using scales has decreased significantly during the last couple of years primarily due to high costs and low reliability. However, we did note that the operators of one of the forwarders (John Deere) used the scale continuously, finding it very useful.

There is scope for improvements, such as implementing Tracking (Figure 12), Forwarding status, and semi-automatic selection of location when unloading. Another useful functionality is the possibility to register negative volumes to correct errors or when moving logs from one delivery to another when the object has been completed. It seems that the default volume used when unloading in some forwarders must be set for each new object. It would probably be highly appreciated by the operators if this could be set permanently.



Figure 12. Tracking data from forwarder (not one of the test sites).

Table 4. Results from evaluating production data.

| | John Deere | Dasa/Rottne | Ponsse | Komatsu |
|---|---|---|---|---|
| Manual registration of load data | Yes | Yes | Yes | Yes |
| Crane scale registration | Yes, either when loading or unloading | Yes (not tested) | Yes, when unloading | Yes, when unloading |
| Load space scale registration | Yes (ALS) | No | No | No |
| Registration based on *hpr* data and coordinates | Yes (JD Maps) | No | No | No |
| Mixing scale and manual registration within one object | Yes (not tested) | Yes (not tested) | Yes | Yes |
| | | | | |
| Registered units when using manual volume estimation | $m^3$sub/$m^3$sob/ kg[1] | $m^3$sub/kg | $m^3$sub/$m^3$sob/ bundle volume[1] | $m^3$sub/kg |
| Registered units when using scale estimation (mass) | $m^3$sub/$m^3$sob/ kg[1] | Not tested | $m^3$sub/kg | $m^3$sub/kg |
| Unit for adjusting manual default estimation of volume | $1 m^3$ | $0.5 m^3$ | $0.5 m^3$ | $1 m^3$ |
| | | | | |
| Tracking data registered in *fpr* | No | Yes | No | Yes |
| Tracking data registered in *fpr* including time stamps | No | Yes | No | Yes |
| DistanceFromLastUnloading | No | No | Yes | Yes |
| ForwardingStatus | No | Yes | No | Yes |
| ScaleDefinition | No | No | Yes | No |
| | | | | |
| Semi-automatic selection of Location based GPS coordinates | No (last Location suggested) | Yes | No | Yes |
| SubObject supported | Yes | Yes | No | Yes |
| SubObjectKey used as reference per load or location | In location | No reference | - | No reference |
| Possible to register negative volumes | No | Yes | No | No |

1) Volume units $m^3$sub and $m^3$sob are equal.

It is worth pointing out that different manufacturers register volume units in slightly different ways. This is partly due to how the standard (*fdi*) is constructed. Some major improvements have been made with version 4.0 of StanForD 2010, in that it will be clearly specified which single volume unit is to be used for a specific delivery.

It can also be noted that only one manufacturer seems to have fully implemented SubObjects. Note that from version 4.0 the SubObject reference (SubObjectKey) can only be stored per PartialLoad.

## Control and calibration of scales

Control and calibration, respectively, were conducted for the three systems with a crane scale. The general impression is that the software functionality is user-friendly. The studied *fqc*-files included all relevant information. The procedures were quite similar for all systems, with the main exception that Ponsse has also implemented a functionality for frequent random controls when unloading logs at the landing. This Ponsse procedure did not use a separate metal object with a known mass but scales some logs both during movement and when the crane was still. Ponsse also has a base calibration method that uses a metal object with a fixed weight (Figure 13).

Figure 13. Scale control and possible calibration using object with known mass.

Table 5. Results from control and calibration of scales.

|  | John Deere | Dasa/Rottne | Ponsse | Komatsu |
|---|---|---|---|---|
| Generating *fqc* with control data | Yes | No | Yes | Yes |
| Type of control | Manual fixed weight |  | Manual fixed weight & Random dynamic mass[1] | Manual fixed weight |
| Generating *fqc* with calibration data (adjustment of scale) | Yes | No | Yes | Yes |
| Type of calibration | Loading Unloading | n/a | Loading | Loading |

1) Control specified for either right or left side during random control.

## John Deere

A scale control is done by loading and unloading an object with known mass several times, after which a calibration can be performed based on the control data.

## Ponsse

The scale control is done in two steps.

1. Random grapple loads with logs are first scaled in a static mode (no movement of crane) and then in a dynamic mode. The random control is done once for each load when using the scale. The control data is used for an "operator calibration".

2. Weekly control and calibration are done by lifting an object with known mass into the load space.

Basic calibration can also be performed using an object with a known mass. The object is scaled 15 times outside the load space. This calibration is not logged in an *fqc*-file.

## Komatsu

A scale control is done by loading and unloading an object with known mass several times, after which a calibration can be performed based on the control data.

**Dasa**

The Dasa control system supports using scales for production reporting, but the tested forwarder was not equipped with a scale. The controller does not currently support *fqc*.

## Production reporting

Production reporting worked according to expectations (Table 6). Note that it is not possible to generate an *fpr* automatically every hour in one of the systems, but this is not deemed necessary. What would probably be highly relevant would be to be able to automatically generate an *fpr* each time a new load has been registered. This would basically mean on-line reporting.

Table 6. Results from generating production files and translation of important concept.

| | StanForD | John Deere | Dasa/Rottne | Ponsse | Komatsu |
|---|---|---|---|---|---|
| Possible to report automatically e.g. using Sender XC. | | Yes | Yes | Yes | Yes |
| Automatic storing of *fpr* each load | | | | Yes[1] | |
| Automatic storing of *fpr* each hour | | Yes | Yes | No | Yes |
| Automatic storing of *fpr* each shift | | Yes | Yes (when logging out) | Yes | Yes |
| Automatic storing of *fpr* each object | | Yes | Yes | Yes | Yes |
| "Partial reporting" possible (non-aggregated *fpr*) | | Yes | Yes | No, always aggregated per object | Yes |
| Swedish nomenclature implemented in interface | Delivery= Leverans<br><br>Location= Avlägg | Delivery= Leverans<br><br>Location= Plats | Delivery = Transport-objekt<br><br>Location= Avlastnings-läge | Delivery= Leverans<br><br>Location= Lager/avlägg | Delivery = Leverans<br><br>Location= Plats |

1) The *fpr*-file automatically generated by Ponsse was an "accumulated" file always including all load data previously forwarded.

## Operational monitoring

The most important issue with *mom*-files is that forwarded volumes and short down times are missing in one case. There is also scope for other improvements, such as implementing Tracking and reporting *mom* per shift as default. There is probably no need for reporting *mom* each hour, as it is normally not relevant to calculate key figures for such short periods of time. Reporting per hour has historically also been connected to errors in several controllers.

Table 7. Results from studying operational monitoring files (*mom*).

| | John Deere | Dasa/Rottne | Ponsse | Komatsu |
|---|---|---|---|---|
| Forwarded volume included | Yes (only m³sob) | Yes | No | Yes |
| Short down times included | Yes | Yes | No | Yes |
| Automatic storing of *mom* each hour | Yes | Yes | No | Yes |
| Automatic storing of *mom* each shift | Yes | Yes when logging out | Yes | Yes |
| Store tracking data in *mom* | No | Yes | No | Yes |
| Store tracking data in *mom* including time stamps | No | Yes | No | Yes |

## GIS functionality

Only John Deere currently supports the possibility to report production based on a GIS interface combined with harvester *hpr*-files. This John Deere application (JD Maps) is based on having access to the *hpr*-data through a proprietary cloud application, which means that only *hpr* from a John Deere harvester can be used.

Table 8. Results from studying manufacturer GIS-application.

| | John Deere | Dasa/Rottne | Ponsse[1] | Komatsu |
|---|---|---|---|---|
| Map application available (for example using GIS for reporting *fpr* and presenting *hpr*-data etc) | Yes (JD Maps, only *hpr* from John Deere) | GeoInfo can show prod. data from *hpr* but not generate *fpr*. | OptiMap2 can show prod. data from pri and OptiMap3 from *hpr*. Fpr cannot be generated | MaxiFleet can show prod. data from *hpr* but not generate *fpr* |
| Ghd supported | Yes | Yes | Yes (OptiMap2) | - |
| Ogi supported | No | No | Yes (OptiMap3) | No |

1) Ponsse presently have two different GIS applications: OptiMap2 for Opti4G and OptiMap3 for Opti5G.

## Forest company interviews

No company is currently using *fqc*-files. The same applies for *env*-files. Sveaskog is adopting a new tool for creating and distributing *foi* and *fdi*. Both Stora Enso and Sydved are using a demonstration tool developed by John Arlinger to create *fdi*-files. However, both software SilviA (version 2022.1.1.0, CGI) and ForesterOffice (version 1.8, Dasa) have released new versions supporting these file types.

The proposals from the forest companies can be summarized as follows:

- Importing *fdi* in forwarders should be as simple as importing a pin (product instruction, defines all products that can be harvested) in a harvester. Semi-automatic import when an *fdi* has been saved to the controller, e.g., through SenderXC (Swedish software for communicating StanForD files from machine to a server managed by Biometria), would be useful.

- It is crucial that a simple and clear warning message is given in cases where an foi includes a DeliveryUserID that does not exist in the delivery library of the forwarder. It must also be possible to start forwarding after this type of warning.

- Important that the primary volume unit (i.e. m³sub) is not changed when updating a delivery.

- Manually created locations should be kept when updating with *foi* during forwarding of an object. It is strongly recommended that locations should not be deleted if a forwarding object is updated using *foi*. The recommendation is to make it possible for the operator to keep existing locations manually created in forwarder when updating an object. However, in normal cases, locations should not be reused on different objects unless the same physical landing is used.

- Default volume per load is in some cases lost when a new object is created, e.g. 20 m³ changed to 1 m³.

- The possibility to automatically generate an *fpr* for each registered load would be an advantage. This "on-line" behaviour exists in SCA's current system.

- Sydved does not use *foi*-files, so a solution for starting an object using *hpr* would be a useful function.
  If an object is started based on *foi* while harvested volumes are imported from an *hpr* it is suggested that the following rule be used:
  *Only deliveries included in foi should be used for reporting when starting an object with foi. This is very important if hpr-data is imported, giving the operator information about harvested volumes.*

- A user-friendly search functionality in the delivery library is important, as the libraries are often very large. Important to be able to view and search based on DeliveryName, DeliveryInfo, DeliveryVersion and DeliveryDestination.

- Highly relevant that negative load volumes are supported. Note that the total sum of volume must be non-negative for a delivery.

- *Mom*-files generated once per hour often cause problems, so reporting per shift should be default.

# Summary of test results

All major forwarder systems currently available on the Swedish market perform well. Many forwarders are using the new StanForD 2010 format, and the number of forwarders operating according to StanForD 2010 is increasing rapidly.

It should especially be pointed out that:

- Correct *fpr*-files can be generated in all machines.

- All controllers can read and store the instructions (*fdi* and *foi*) correctly.

- The new file formats have simplified forwarder reporting for the operators and the number of errors has decreased.

- All forwarders can automatically report production and operational monitoring.

The following issues are considered important from a user perspective, based on both test results and forest company discussions:

- Support updating of *foi* and *fdi* during forwarding at an object.

- Implement tracking in *fpr* and *mom*.

- Make it possible to register negative volumes.

- Follow the StanForD 2010 nomenclature for delivery (must be translated to "leverans") and location (translate to "avlägg" in Swedish).

- Forwarded volumes ($m^3$) must be included in the *mom*-files.

- Make reporting of *mom* per shift the default alternative.

- GIS applications should support *hpr* from all manufactures according to StanForD 2010.

Other suggested improvements:

- Implement ForwardingStatus (start time and end time of forwarding to a specific combination of landing and delivery).

- Semi-automatic selection of location based on machine position when unloading.

- *Fpr* automatically generated after each load registration.

- Full support for *env* including *foi* and *foi*.

- Simplify import of *fdi*. Should be as simple as importing a pin in a harvester.

- Important that the volume unit (i.e. $m^3$sub) is not changed when updating or adding a delivery.

- Manually created "locations" should be kept when updating with *foi* during forwarding of an object.

- Default volume per load to be kept when a new object is created.

- Make it possible to compare manually estimated volumes with harvested volumes.

# Forwarder reporting in the future

Manual registration of forwarded volumes works well today but is based on a subjective estimation of forwarded volumes. This often means that the volumes have systematic errors, in most cases leading to underestimations. Another problem is that it is quite common for operators to register one very large load representing the whole shift rather than individual loads.

Forwarder reporting in the future should be made simpler and more robust, perhaps utilising:

- Log pile positioning from harvester registered according to *hpr*-format in combination with forwarder tracking.

- Grapple positioning.

- Automatic determination when opening and closing grapple (moving logs).

- More reliable and precise scales.

The authors therefore suggest a future solution where the information presented above (with or without scale) is combined with GIS-functionality. This would enable a situation where the operator only needs to enter the following for each load cycle (driving from landing - loading in forest - driving to landing - unloading at landing):

- Select delivery being loaded in the forest.

- Confirmation of semi-automatically selected location when starting to unload.

The basic method for estimating and registering the forwarded volume could be:

1. Automatically calculate "loading areas" that includes the approximate polygons where logs have been loaded. This is based on having information about where logs have been loaded using signals from the crane and the grapple.

2. All harvested logs within the "loading areas" included among the operator selected deliveries are used for calculating the total volume per PartialLoad. This requires that the same ProductUserIDs are used by the harvester (*hpr*) and by the forwarder (per delivery in *fdi*).

3. Automatic suggestion of location based on distance when unloading is begun within a short distance from a defined location.

In order to make this type of advanced reporting successful it must be possible to use several different sources for the harvester data (both from cloud or local transmission, e.g. using a USB stick) and it must be possible to use data independently of original type of controller (i.e. not manufacturer-specific *hpr*). This solution is based on combining GIS-functionality, log positioning and high-resolution data from boom/grapple.

This type of functionality must also be able to handle additional manually cut volumes as well as harvested volumes "disappearing" (e.g. wood used for building bridges or short logs left in the forest) or moved from one delivery to another delivery (negative volumes).

A new structure for storing log identities could be added to each individual partial load in the fpr in case this functionality is implemented. This could be done by adding MachineKey, StemKeys and LogKeys from the hpr-data into the fpr. This will be proposed with StanForD2010 version 4.1. This means a significant step towards implementing digital traceability from the standing tree to the logs located at roadside. It would also open the possibility to also trace the logs from the roadside to the mill gate.

# References

Arlinger, J., Nordström, M. & Möller, J.J. 2012. StanForD 2010. Modern kommunikation med skogsmaskiner. – StanForD 2010. – Modern communication with forest machines. 16 s. Arbetsrapport 784. Skogforsk.

Möller, J.J., Sondell, J. & Arlinger, J. 2002. Virkesvärdestest 2001 – Apteringsfrågor. Redogörelse nr 7 2002. Skogforsk.

Möller, J.J., Arlinger, J., Hannrup, B. & Jönsson, P. 2008. Virkesvärdestest 2006. Redogörelse nr. 5 2008, Skogforsk, Uppsala.

Möller, J.J., Arlinger, J., Nordström, M. 2013. Test av StanForD 2010 implementation i skördare. Arbetsrapport 798 2013, Skogforsk, Uppsala.

Nordström, M. Arlinger, J. Hannrup, B. Jonsson, R. Jönsson, P. Möller, J. J. Virkesvärdestest 2016. Redogörelse nr. 55 2018, Skogforsk, Uppsala.

Sondell, J. & von Essen, I. 1996. Apteringsdatortest 1995 – studier av sex apteringssystem. Redogörelse no. 4. Skogforsk.

# Appendix 1) Manufacturer-specific comments

This appendix includes some problems and errors discovered during the test but not included in the main report.

## John Deere

- There are some improvements needed regarding implemented volume units. DeliveryEstimationUnit is "Volume, m³sob" but should have been "Volume, m³sub" in the *fpr*. Unit for forwarded volume in *mom* is only "m³sob", should also include m³sub. Is there a machine-specific setting in the forwarder controller?
  Note that the StanForD standard will be updated with version 4.0 in order to clarify this issue.

- The name of the products (ProductName) must today be identical in *fdi* and *hpr* when generating *fpr* in the "JD Maps" application. This type of references must be based on ProductUserIDs.
  The "JD Maps" application is based on having the *hpr* stored in John Deere's cloud solution using a synchronisation tool. This means that the *hpr* cannot be loaded into the forwarder controller manually in the machine. The application therefore only works with an *hpr*-file from a John Deere harvester.

## Rottne/Dasa

- Delivery "Skinnsberg" (DeliveryKey 64) had the same DeliveryKey in both Test Cases 1 and 2 even if it was updated with different densities. However, the modification date and density were updated. Updating of a delivery should be checked.
  The following figure includes all loads from Test Case 2 where it can be noted that the mass of first load is calculated using density 835kg/m³ while the last load mass is calculated using density 777 kg/m³. If correctly implemented, a second version of delivery "Skinnsberg" should have been included.

## Ponsse

- No conversion from volume to mass implemented in *fpr* when volumes are recorded manually.

- The number of bundles is registered in the *fpr* when using scale. It is not known if this is identical with the number of "crane cycles" when unloading.

- It is probably a good idea to also present a calculated volume in the user-interface when using a scale.

- Noted when comparing *mom* and *fpr*:
  - ContractNo differs (*mom* is not correct) even when ObjectKey is identical.

o ShortDownTimes and TotalForwadedVolume are missing in the *mom*-files.

o LocationDefinition is sometimes re-used on several different objects (same ObjectKey). Not observed in this test.
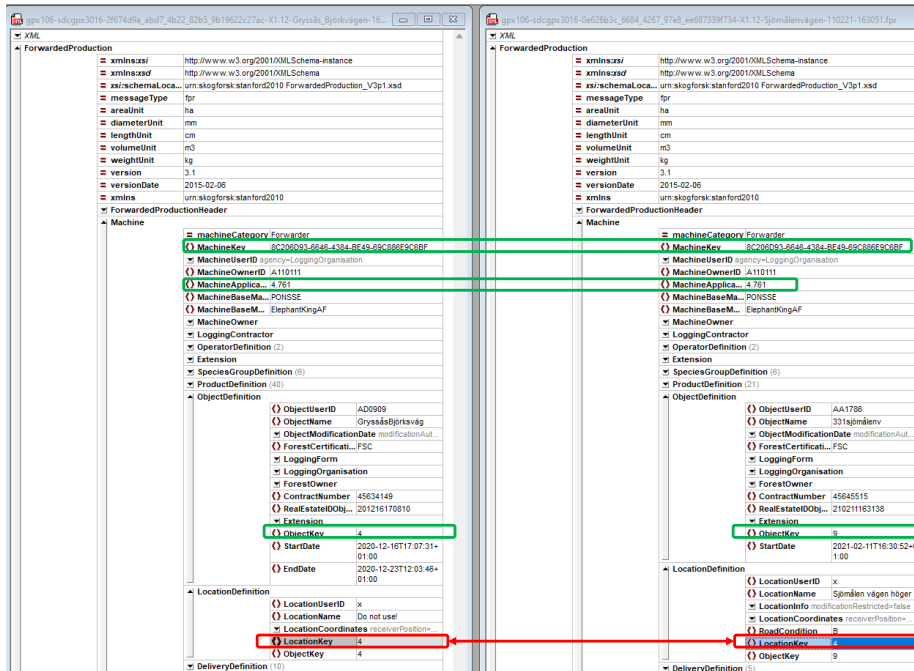


## Komatsu

- Updating object using modified *foi* is not fully supported due to a bug.

- Controller generates an incomprehensible error message in cases where the *foi* refers to a non-existent delivery. An understandable warning should be implemented, and it should be possible to start the work on the object without the missing delivery.