ONBOARD COMPUTING IN FOREST MACHINERY – A PERSPECTIVE FROM AUSTRALIA AND SOUTH AFRICA

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Abstract:
International research has demonstrated gains of up to 30% in improving utilization and productivity of forest harvesting machinery through the use of onboard computers. However, use of onboard computing is very much in its infancy in Australia and South Africa primarily due to lack of local experience in their use.
Trials covering a range of onboard computers, forest machinery and forest types were conducted in Australia and South Africa to study their use under local conditions. The results are being used in these countries to promote the benefits and uptake of onboard computers. In Australia, this has been facilitated through an online selection guide to assist in determining suitable onboard computers. In South Africa, onboard computing research is aimed at identifying operational factors in primary and secondary transport, which have significant impacts on production and utilization of applied equipment.
The presentation briefly describes the trials highlighting what worked and what didn't work and then brings together common findings and lessons learnt.

Keywords: onboard-computer, harvester, skidder, MultiDAT, GPS

1 Introduction

International experience in forest harvesting has shown significant performance improvements (up to 30%) can be made by using onboard computers (OBCs) to get expensive forest machines working more efficiently (Jamieson, 2004). OBCs work by identifying inefficiencies and areas for improvement, faster and more accurately than through human observation alone.

There is considerably less use of OBCs in forest machines in Australia and South Africa than in many other countries where forestry is a major industry. The principle causes are believed to be lack of local experience in their use and lack of access to good information on the types of computers available and which are best suited to different operational needs. An online selection guide has been written in Australia to address these issues (CRC for Forestry, 2011).

Although there are obvious differences between Australia and South Africa in terms of size and population, there are many similarities between their forest industries. Forestry in both countries is predominantly based on plantations of *Eucalyptus* and *Pinus* species with significant domestic markets for sawlogs and export markets for woodchips (though natural forests are also a significant source of wood in Australia). Further plantation expansion is also restricted in both countries by competition with agriculture for suitable land.

South Africa's relatively large population and low wages have resulted in an emphasis on motor-manual forest operations whereas the opposite is the case in Australia. However, in South Africa there has been increasing recognition that mechanization is required for dangerous and physically demanding components of the work such as felling, debranching, debarking and infield transport (Iarocci, 2007).

This report describes the results of a series of OBC trials conducted in Australia and South Africa. Each trial is described briefly followed by a discussion of the common findings and lessons learnt.

2 Onboard computers used in the trials

2.1 MultiDAT (www.feric.ca)

The MultiDAT is an electronic data-logger developed by FPInnovations for use in off-road equipment. More than 2000 are in use around the world, mainly in North America. MultiDATs are used to collect data to improve harvesting equipment productivity and utilization (percentage of scheduled machine working hours for which the machine is actually used to perform its intended function (Van Daele, 2000)). MultiDATs allow users to record machine functions, movement and location, analyze the data and produce reports (Brown et al., 2002).

MultiDATs use an internal vibration sensor to detect a machine's movement and hence determine its true operating time. The optional GPS can be used to collect positional data and determine the area harvested or treated. Data can be exported for further analysis using GIS software.

The MultiDAT Senior has a keypad interface which allows operators to describe work in progress, reasons for machine downtime, and identify the current machine operator.

2.2 Fleet Manager Professional (www.mixtelematics.com)

Fleet Manager Professional is a system that combines hardware and software components into fully integrated solutions designed to monitor, record, analyse and improve driver and vehicle performance. One of the most powerful features of the Fleet Manager system is the ability to monitor, detect and record events that occur within the vehicles.

Most of the functionality included in this device (monitoring and managing driver and vehicle performance, controlling communications costs, reporting on fleet operating costs, real-time and after-the-fact tracking of vehicles and drivers, and location management) are useful mainly for long transportation monitoring and fleet control and management.

The study used only the GPS data from this system. The GPS had been set to record one point every 10 meters. The device was installed in the rear of the skidder's cabin and the GPS antenna was placed on the top of the cabin.

2.3 Dasa (www.dasa.se)

Dasa manufacture OBCs (hardware and software) for forestry machines and other heavy vehicles. Dasa forestry OBCs comply with the StanForD data standard (Skogforsk, 2007) and are factory-installed by a number of forestry machine manufacturers, including Rottne and Bruks. Several harvester head manufacturers also install Dasa OBCs to control their harvester heads.

StanForD compliant data recorded by Dasa OBCs ranges from stem and log dimensions to various machine performance data including machine utilization and productivity. With the optional GPS they can record where a machine has been, navigate within a stand and facilitate exchange of processed log locations from a harvester to a forwarder

2.4 RouteHawk (www.strongeng.com)

RouteHawks are manufactured by Strong Engineering in eastern Canada. They use a touch-screen for data entry and feedback to the machine operator. They were developed for the transport industry and adapted for use in forest machinery. RouteHawks monitor engine RPM to estimate machine utilization and can capture delay causes using the touch-screen. They can also record fuel-use and GPS data. The GPS data can be displayed in real-time on the touch-screen and stored for later analysis. A key element of the RouteHawk design is the use of a central website to store, process and display the raw data downloaded at regular intervals from the field units. This gives office-based managers the ability to monitor the harvesting machines in close to real-time which is common in the transport industry but rare in forestry applications.

3 Australian trials

3.1 Background

Three trials of OBC equipment were conducted in Australia as part of the development of an onboard computer selection and implementation guide. The trial sites were selected to cover a broad range of Australian forest types, harvesting systems and types of OBC (Figure 1). The trials were conducted over a period of eighteen months to gain long-term information about issues related to OBC implementation.

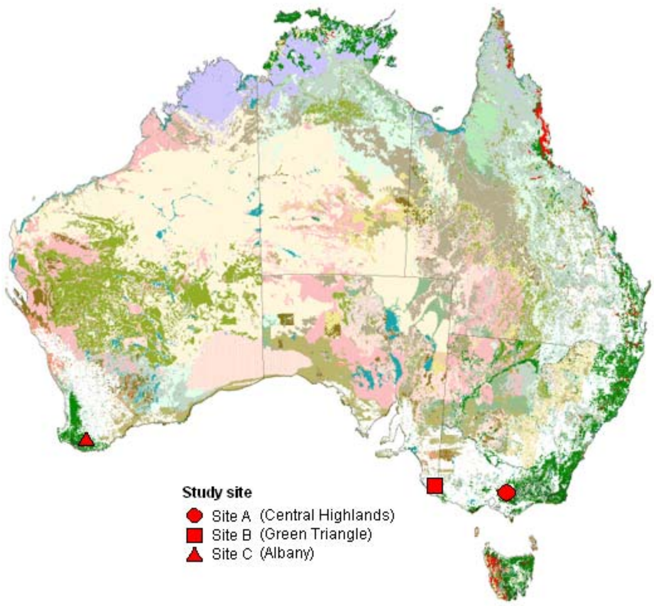

Figure 1: Location of the Australian trial sites

3.2 Case Study 1. MultiDAT

Location: Central Highlands of Victoria

Forest type: Natural eucalypt forest. Main commercial species are Mountain Ash (*Eucalyptus regnans*) and Alpine Ash (*E. delegatensis*)

Log products: Sawlogs and pulplogs

Harvesting system: Harvester, grapple skidder and two excavators with grabs and cutoff saws. The harvester directionally fells each tree and removes the crown. Stems are skidded to the landing by the grapple skidder where they are processed into logs, graded, stacked into piles and loaded onto trucks by the excavators.

OBCs installed: MultiDATs with GPS receivers were installed on the harvester, skidder and one of the excavators. Marine Garmin GPS units (GPSMAP 276C) were installed in the harvester and skidder.

The MultiDATs were installed for eight months to estimate long-term utilization and to investigate delay patterns of the harvesting machines. The harvester (46% utilization) and skidder (55% utilization) were found to be relatively underutilized compared with the excavator (70% utilization) that was processing trees into logs and loading trucks on the log landing. Typical utilization of these three types of machine (based on figures from other studies) is ~65%. All else being equal, increasing the average utilization of the harvester and skidder to 65 per cent would increase their productivity by 20–30 per cent.

Examination of the pattern of delays revealed that the excavator spent a significant length of time waiting for truck drivers to write sawlog details on a log docket after each log was loaded. This finding led the harvest contractor to have his operator load a truck completely and return to work while the driver noted the log details. The next change was to make truck drivers solely responsible for loading trucks using a spare excavator. This resulted in up to three hours per day of machine time being freed for log processing activities on the landing, which considerably improved the throughput of logs. The average utilization of the feller-buncher and skidder increased to close to 60 per cent, and the loader to 74 per cent. This change is circled in Figure 2.

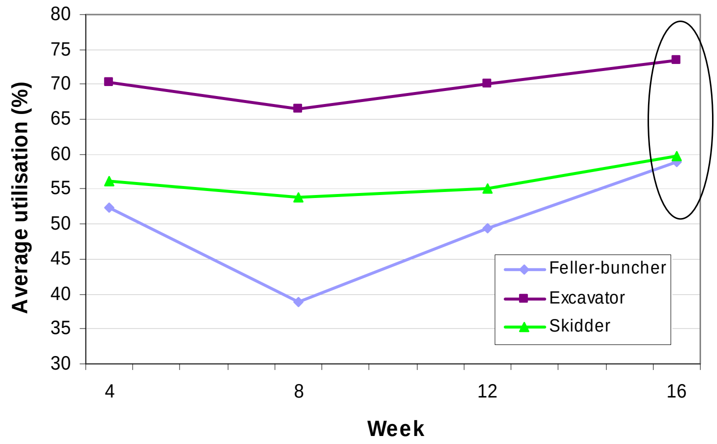

Figure 2: Utilization for the feller-buncher, excavator and skidder averaged at four week intervals

An unexpected outcome was that the log transport was unable to deal with the increased log throughput. This highlights the need to consider all components of the wood supply chain when making any changes.

The Garmin GPS units were intended to be used to warn operators when approaching coupe boundaries. The units were unsuccessful for this purpose as the GPS was not accurate enough and the forest manager did not have established processes to supply mapping data in the required format.

3.3 Case study 2. Dasa

Location: Mt Gambier, South Australia

Forest type: Radiata pine (*Pinus radiata*) plantation.

Log products: Sawlogs and pulplogs

Harvesting system: A single-grip harvester, two to three forwarders and an excavator with a grab. The harvester processes each tree to logs at the stump. The forwarders extract the logs from the stand and stack them at roadside. Truck drivers use the excavator to load their trucks.

OBCs installed: The harvester had a GPS added to the previously installed Dasa 4 OBC. The equivalent Dasa OBC and a GPS receiver were installed in one of the forwarders.

Issues associated with the implementation of GPS on both Dasa OBC showed that GPS technology is not yet mainstream for manufacturer OBCs. Difficulties in getting the Dasa PC working in the forwarder illustrated the complex nature of retrofitting a manufacturer OBC into an existing forest harvesting machine. Dasa have subsequently restricted distribution of this OBC to machine manufacturers only. The experience with the forwarder computer led to the recommendation that manufacturer OBCs such as the Dasa only be ordered as a factory-installed option.

GPS locations of log products were transferred from the harvester for use in the forwarder. The machine operators suggested this information could be useful to plan the forwarder's route for low volume products, and to supply information to a truck dispatch system.

3.4 Case study 3. RouteHawks

Location: Albany, Western Australia

Forest type: Blue gum (*E. globulus*) plantation.

Log products: Pulplogs

Harvesting system: 2 feller-bunchers, 4 grapple skidders, and three in-field flail debarker/delimber/chippers. Feller-bunchers fell and stack trees into bunches. Bunches are skidded to the roadside by the grapple skidders where they are chipped directly into trucks by the in-field chippers.

OBCs installed: Two systems were trialed at this site. The first system consisted of RouteHawk OBCs installed in a feller-buncher, skidder and chipper. The second system consisted of MultiDATs installed in each of the in-field chippers.

The RouteHawk OBCs were found to be poorly suited to use as OBCs in forest harvesting machines. They were developed for truck use and did not cope with the additional vibration and dust associated with harvesting machines. The RouteHawks are designed to transfer data to a central website for collation, storage and reporting. The website was under development during the trial and not completed in time. The approach of using a central website is sound but is dependent on reliable data transfer for its operation. The RouteHawks highlighted the desirability of using an OBC with proven reliability.

The MultiDATs installed in the three chippers have been collecting utilization data and delay causes for 9 months. The utilization data are very variable, which shows that long-term data collection using OBCs is required to confidently estimate this critical input into a contractor's harvest cost calculations. The concerns raised by operators in this trial over the requirement to input delay causes clearly identified the importance of planning for and addressing change-related issues for the successful implementation of an OBC system.

4 South Africa

4.1 Background

Trials were conducted to monitor skidder extraction operations at three different sites: two in the Western Cape (winter rainfall regions) and one site in Kwa-Zulu-Natal (summer rainfall region) with all sites in *P. elliotti*, *P. pinaster* and *P. radiata* stands (Figure 3). **Fehler! Verweisquelle konnte nicht gefunden werden.** describes the trial sites and harvest systems.

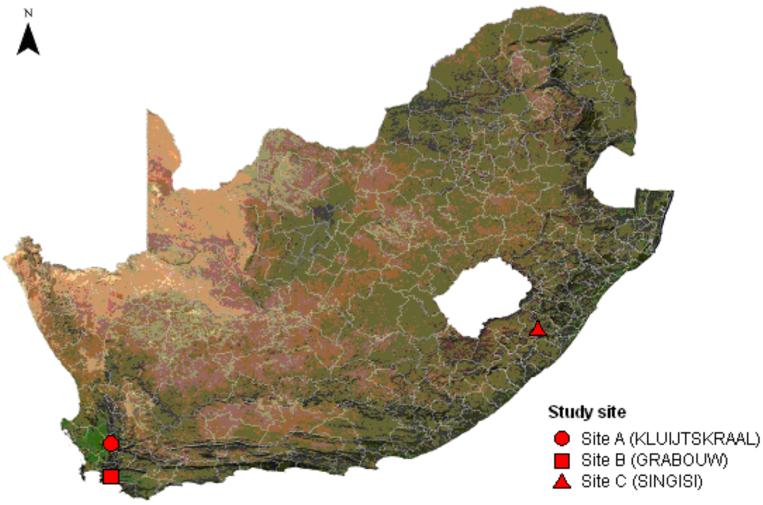

Figure 3: Location of the South African study sites

Table 1: South African study site and trial information

Location	Site A (Kluijtieskraal)	Site B (Grabouw)	Site C (Singisi)
Machine type	Timberjack 380C + motor-manual processing at landing	Timberjack 380C + motor-manual processing at landing	Tigercat 625C + processor at landing
Species	*Pinus radiata*	*Pinus pinaster*	*Pinus elliotti*
Mean slope (%)	0	23	16
Soil moisture	Dry	Dry	Partially wet
N (number of cycles)	33	64	68

The skidders were equipped with two different data collection devices, Fleet Manager Professional (developed mainly for primary transport monitoring) and MultiDATs (developed specifically for forest operation management). Time study data were collected using the MultiDAT vibration sensor and operator-entered stop codes.

Parallel, manual time studies were conducted at each site using a Trimble palm device running dedicated time study software (WorkStudy+). The manual time-study results were used to evaluate the accuracy of the information gathered with the OBC systems and understand possible error causes. Six functional elements were defined: travel empty, choking, travel loaded, unchoking, break and delay. The data recorder time was synchronized with the OBCs, to ensure matching of work element times.

Outfitting a machine with a GPS device allows for the collection and timing of machine variables such as machine working time, speed, distance travelled and elevation changes. The potential for using this GPS data to analyse forest operations performance such as soil disturbance patterns (McDonald et al 2002) and conduct harvesting productivity studies through automated time-study was evaluated (McDonald and Fulton 2005). GPS data were collected from the skidders using both OBCs.

4.2 Time study accuracy

Time study accuracy was expressed as the percentage difference between the manual time-study and OBC results using the manual data as the baseline (Table 2). Figure 4 shows the manual time-study results for each site. Monitored working time was 7h 51min; 13h 13min and 5h 21min for sites A, B and C, respectively.

Table 2: MultiDAT machine utilization and non-working time errors relative to manual time study results

Method	Time component	Site A	Site B	Site C	Average
Vibration Sensor	Machine utilization (% error)	-16.13	-18.69	-5.54	-15.89
	Non-working time (% error)	16.13	18.69	5.54	15.89
Vibration Sensor + User Interface	Machine utilization (% error)	0.74	1.07	-4.25	-2.15
	Non-working time (% error)	-0.74	-1.07	4.25	2.15

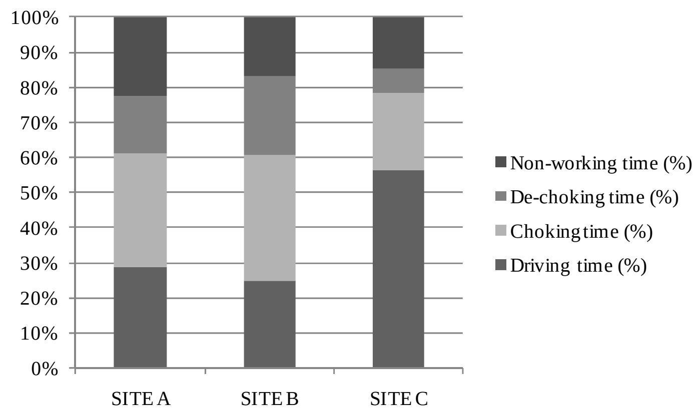

Figure 4: Manual time study results showing proportion of time spent on each time element at each site

Non-working time was over-estimated when only the vibration sensor data was analysed (Table 2) because some choking operations were recorded as delays when the machine was idle for longer than the period set as the minimum to record a delay. Over-estimation of non-working time was considerably less for the grapple skidder (Site C), where choking and dechoking operations were very fast.

When data from the motion sensor was combined with operator stop-code entries, working time estimations became very precise. This option requires that the skidder operator remembers to press the button for every delay or break. Another possibility would be to set the minimum delay time to a higher value which then risks underestimating non-working time.

The higher error in the combined data at the third site (grapple skidder) was probably due to the work being more difficult and intensive thus explaining why the operator occasionally forgot to press the stop-code.

4.3 GPS Data

GPS data were evaluated for their potential to perform automated work-time studies. Analysis of GPS data involved:

- Calculating distance between points using a formula with latitude, longitude and radius of the earth in metres.

- Estimating machine speed between consecutive points by dividing the distance between the two points by the elapsed travel time.

Applying a speed threshold of 3 km/h to identify travel segments where the operator was driving.

A shapefile representing choking and dechoking area (a "geofence") was then defined to identify the points corresponding to these operations and hence the time spent on each of them per cycle. Table 3 reports the mean error in the estimation of the working elements as resulted from this analysis of the GPS output from the two OBCs.

Table 3: Mean differences in time elements estimated from GPS data relative to manual time study results

GPS source	Site	Driving	Choking	Dechoking	Inactive
MultiDAT	Site A % error	0.59	2.83	1.56	-4.29
	Site B % error	-5.33	1.35	2.69	1.29
	Site C % error	-1.74	2.05	4.40	-4.70
FleetManager	Site A % error	1.36	1.34	2.64	-5.34
	Site B % error	-0.01	-4.33	1.15	3.19

The GPS time element estimates were generally close to those from the manual time-study. Identified error sources were:

- Definition of the speed threshold used to detect when the skidder is moving (choking/dechoking over-estimation). Sometimes machine speed was close to the threshold when the skidder was approaching or leaving the choking site.

- Length of the time interval used to detect when the machine was not working (inactivity under-estimation). Nevertheless, an error of no more than 5% seems to be acceptable, especially for long-term time-study.

The GPS tracklog was overlaid on the harvest area block and buffered to show where the harvester has cut, the time spent to harvest a specific area or the number of passes on the same area to evaluate the level of soil disturbance. This was done by transforming the GPS points into a raster map with a 5m x 5m resolution and assigning cell values to indicate the number of machine passes over a given location (Figure 5).

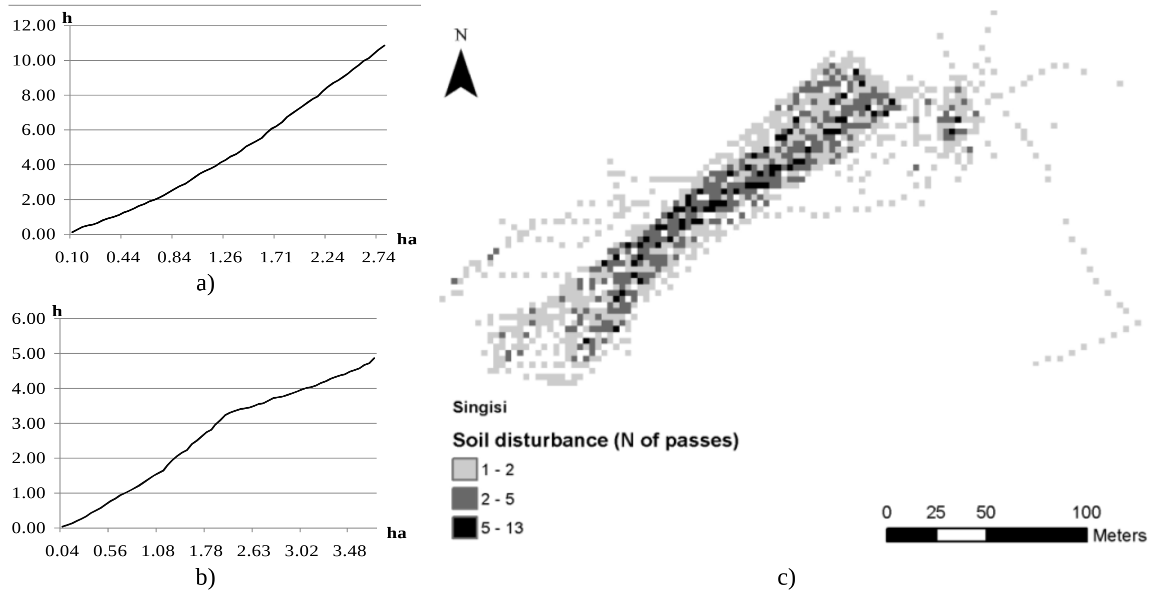

Figure 5: Harvested area (ha) as a function of working time (hr) for (a) Timberjack 380C; (b) Tigercat 625; (c) Map of number of passes of the skidder on the same cell (resolution of 5 m)

5 Discussion

The trial results demonstrated that OBCs can be successfully used in Australian and South African forest harvesting operations to provide data to review and improve machine performance. The key to their widespread adoption by the forest industry in these countries is an understanding of how to move OBCs from research to operational tools. This problem is not unique to the forest industry and indeed confronts most research projects. Working in the favor of the Australian and South African forest industries is that there has been a long history of successful implementation of many of these technologies in other countries.

The two OBCs that were not successfully implemented during the trials (Dasa Forwarder PC and RouteHawk) were both early implementations of these systems in forest harvesting equipment. The potential benefits of new approaches can be great but most forestry organizations do not have the resources or expertise to resolve the issues that can arise from implementation of new technologies. Mature OBC technologies are more suited to widespread implementation as forest harvesting operational tools in Australia and South Africa.

The trials with GPS in South Africa showed that this technology has great potential for use as a flexible management tools for forest harvesting machines. Although the GPS data was obtained from OBCs with a wide range of other capabilities, GPS data loggers suitable for operational forestry use are available for less than AUD$200 (R1500, ~ €145) (CRC for Forestry, 2011). The problem is that there are no software tools currently available to the forest industry that can perform the type of analyses that were carried out during the South African trials.

Implementation of OBCs involves both the physical aspects of installing the hardware and software and the organizational changes required to collect, analyze and interpret the data from the OBCs. It is these changes that are the most important elements in successfully implementing an operational system (Lorenzi and Riley, 2003). They are also often the elements that receive the least attention when planning OBC implementation in forestry.

Organizational changes induced by OBC implementation in forest harvesting frequently involves changes to procedures for forest machine operators, such as entry of delay causes and transmission of data, and also to office procedures where the data has to be collated, stored and analyzed. Each of these elements needs to be considered and planned for prior to OBC implementation. People are often inherently resistant to change and strategies will be needed to overcome this resistance.

A key difference between the use of OBCs in forest harvesting and the introduction of technology in other industries is that the objective in forest harvesting is to use the data to identify areas for improvement in the harvesting operations whereas the performance gains in other industries are usually inherent in the technology implementation for example when a paper-based record system is replaced by a computer-based system. The skill and experience needed to be able to translate OBC data to changes leading to performance gains in forest harvesting operations is also an underappreciated element of forest harvesting OBC implementation.

6 Conclusions

The trials of OBCs in Australia and South Africa demonstrated the potential for OBCs to provide data to improve the performance of forest harvesting operations. However, the physical installation of the OBC hardware and software are relatively minor components of the implementation of an OBC system. The key elements are those associated with identifying and managing organizational changes associated with the introduction of the OBCs and then in being able to make effective use of the data they provide to identify areas where operational changes can lead to machine performance improvements.

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