Effective Practices in Deploying Mobile Computing Devices for Field Operations in Process Industries

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The deployment of mobile devices in process industries promises greater efficiencies in operations and more effective uses of limited plant resources, compared with current practices. Yet, the adoption and use of these devices has been limited. This paper reports effective practices, applications, and lessons learned from deploying mobile devices for field operations in the refining and petrochemicals industries. Six petrochemical production facilities participated in the study. We interviewed various stakeholders at these facilities on their culture, business drivers, field operations, current use of mobile devices, infrastructure and platforms in place, current applications, and potential needs. Four general areas were identified as critical to the success of deployment: 1) Organizations, Policies and Processes, 2) Applications, 3) Infrastructure, Hardware and Software, and 4) Training.

INTRODUCTION

Technology advances for the process industries are coming in various forms, from advanced process control and real-time optimization algorithms, to procedural automation, to wireless sensing and mobile computing. However, adoption of these technologies will not occur for technology's sake. Rather, the technology must address top-priority business drivers facing an industry or market, and provide sufficient return on investment (Venture Development Corporation, 2002). In addition, the success or failure of the technology deployment into a manufacturing site, or an industry as a whole, can have far less to do with the sophistication and reliability of the technology as it does with the deployment processes used, organizational culture to be overcome, and end-user involvement (Cochran & Bullemer, 1996).

Mobile computing devices present an opportunity to provide business-relevant software applications to enhance the performance of field operations in these process industries (Weiss, 2002; Venture Development Corporation, 2002; Archstream Solutions, 2002). The applications currently used on mobile devices are somewhat limited in terms of business-oriented support for operations, focusing more on supporting maintenance departments than field operations activities. The results of our industry survey suggest that, to be effective, mobile devices and applications need to integrate into the field operators' work processes and integrate with other plant information systems, as opposed to creating "new work" for the operator.

An example of a work process for a field operator after first going on shift is shown in Figure 1. During the shift, the operators interviewed for this research reported that they typically have a finite set of tasks. These tasks could include performing surveillance rounds, preparing equipment for maintenance, preparing lineups, and taking lab samples. In the case of surveillance rounds, the operator typically takes the following steps:

1) Initially, equipment is checked and readings are taken.
2) The readings are compared with their set limits.
3) If there are no exceedances, the round is finished.
4) If there are exceedances, the operator determines if the problem can be resolved at the equipment. If yes, corrective actions are taken and notes are entered. If no, additional steps are performed.
5) Depending on the exceedance, the supervisor and/or equipment specialist is notified to resolve the problem.

Mobile devices have the ability to support this work process by providing the following to each of the items noted above:

1) An efficient and consistent way to enter readings (i.e., automatically via a probe or wand device or manually via a keyboard or stylus): This consistency in data collection translates directly into more reliable and accurate data; maintenance personnel can then trend equipment parameters more precisely as well as make more reliable decisions on the performance of that equipment.
2) Alerts and messages regarding exceedances.
3) Feedback on the status of rounds: This includes, for example, how many pieces of equipment are left to be completed on this round and the time to complete the round.
4) Task guidance, checklists, or procedures to make the corrective actions when an exceedance has been observed: Supporting information such as schematics or "checklists" may be accessed for troubleshooting. If warranted, the operator may enter and confirm a work order request that gets transferred to inventory management system.
5) Automated notification to the supervisor and/or equipment specialist with appropriate logged information from the operator.

The reported research surveyed effective practices and applications of mobile devices for field operations in the refining and petrochemicals industries, and identified lessons learned from deployment.

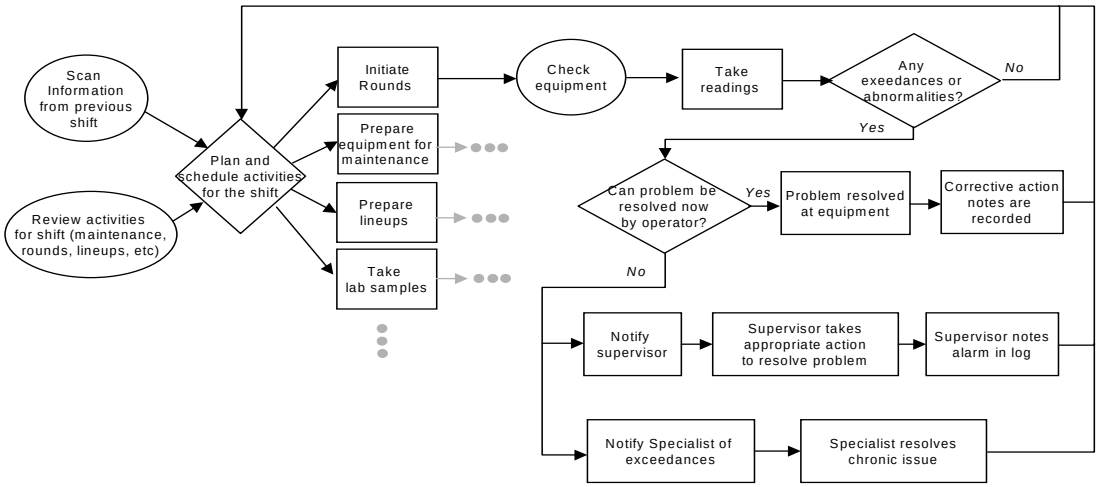

Figure 1: Example of work process for operator conducting rounds.

STUDY APPROACH

We surveyed six production facilities in the refining and petrochemicals industries – four refineries and two chemical plants in the Houston and Los Angeles areas of the United States. Interviews and surveys were conducted at each site over a one-day visit. The interviews and surveys were conducted with a range of employee roles that were using the mobile devices at the site, including the departmental supervisor, the application engineer(s), deployment engineer(s), the field operators, and IT support personnel.

The interviews and surveys covered the following areas:

- Overview of Site, Leadership and Organizational Structure
- Business Drivers for Use of Mobile Devices
- Field Operations Processes and Tasks
- Current Use of Mobile Devices
- Infrastructure, Architecture, Platforms
- Current Applications
- Improvements and Potential Applications

The sites that were visited used one of two manufacturers of mobile device technologies: SKF or Symbol Technologies. The SKF technology used a docking station to upload and download information; the Symbol technology used wireless communications. Both devices were predominantly implemented to support equipment reliability-based programs, maintenance, equipment surveillance (e.g., checks, vibration, and temperature), and process measurement gathering (e.g., samples).

DRIVERS FOR THE USE OF MOBILE DEVICES

From the site visits, the top 5 drivers were noted for current and future uses of the mobile devices and wireless networks in field operations. The order presented is indicative of the relative perceived priority.

- ***Improved Reliability and Utilization*** – Mobile devices are seen as enabling improved consistency in measurement and reliability of data over manual, hand-recording of field data. Typically, before mobile devices were implemented, there were different ways of recording information (e.g., operator touch, visual inspection), and this was inconsistent from operator to operator with different levels of expertise.
- ***Improved Production Optimization and Efficiency*** – Mobile devices enable the collection of timely and more accurate data regarding the process that are not currently available on the distributed control system (DCS) (e.g., time-stamped lab samples). Accuracy and time-dependence in measurement are critical aspects in managing the process.
- ***Reduced Costs*** – Mobile devices and wireless applications are seen as enabling the decrease of maintenance costs. These costs are associated with unplanned outages and sub-optimal equipment maintenance. Automated work notification requests based on management's failure criteria could improve efficiencies. Automating work orders electronically could reduce error. Second, the use of mobile devices in field operations has to potential to lower insurance premiums if reductions in recordable accidents and abnormal situations are realized as a result. Also, premiums could decrease by automating safety observations for ease of implementation and identification of contractor/operator training needs. Finally, mobile devices could enable the attainment of OSHA VPP "STAR" status because it could provide the ability to capture plant data necessary for analysis.
- ***Improved Safety*** – The use of mobile applications is seen to inevitably decrease incidents and increase safety, by enabling more effective monitoring of equipment that can lead to improved equipment maintenance. This can result in operating equipment without injury due to malfunction and equipment not reaching the critical point of failure.
- ***Improved Work Process Efficiency*** – Mobile devices can enable the optimization and prioritization of maintenance

and schedules, because of more timely and accurate data being collected. Mobile applications also are seen to help manage operations and maintenance goals for optimal value, minimizing the frequency of unplanned, severe equipment repair which is costly.

CURRENT USES OF MOBILE DEVICES

The top common uses of mobile devices include the following:

- ***Equipment Surveillance and Condition Monitoring*** – This is the most common use of mobile devices in field operations, resulting in a significant reduction in paper work and its associated inefficiencies. Readings are taken from pumps, tanks, heat exchangers, compressors, etc. during routine, scheduled, and as-required rounds. These readings include conditions, noise, levels, flow, vibration, pressures, densities, and temperatures. Across the sites surveyed, the routine rounds range from every 4 hours to once per shift; each round can take from 20 minutes to 90 minutes.
- ***Round Reporting and Analysis*** – Most of the sites have reporting features that summarize the results of the rounds across people and shifts. The supervisor can check and approve rounds. The information collected includes: equipment exceedances, the time data were collected, the person who collected the data, the number of scheduled rounds vs. completed rounds, and trending of the data. This application provides a means for equipment data analysis over time and accountability in field activities.
- ***Integration with Other Management Systems*** – Some sites have a functional connection between the database used to collect mobile device information and other plant systems. Examples include notifications that are generated based on equipment variable exceedances, or rounds that are created based on equipment health information. This connection is critical for analyzing and communicating field data with other plant systems for effective decision making. However, sites have mentioned this integration needs to be user-friendly.

The unique uses of mobile devices include the following:

- ***Task Guidance*** – At a couple of sites, there is an indication presented to the field operator if something is out of range when measurement is taken. There are also different levels of criticality associated with these exceedances (e.g., economic, safety issues). Based on the exceedance, there is some guidance on what operator should do (e.g., notify supervisor, perform procedure or other tasks).
- ***Notification Systems*** – One site implemented a unique automated notification system based on the information collected in the round. For example, the equipment specialist and shift supervisor receive an email of the exceedances at the end of the day. The email message includes a table of when the reading was taken, the questions answered, the exceedance, the action taken, the unit, and who took the reading. This information is tracked, and a proactive strategy for maintenance is formulated. This information also links into the plant's work order system.
- ***Asset Tracking at Dock and Rail Cars*** – Mobile devices have been extended to dock operations (tanks and pumps) and rail operations (identification of what is in the railcars). A pilot RFID (Radio Frequency Identification) tag system is currently being done for rail cars. This provides more a reliable, timely indication of what is coming in and out of the plant.

Benefits and Limitations

Benefits reported by sites that successfully deployed mobile devices for maintenance and surveillance activities include the following.

- ***Increased Consistency and Reliability of Data Collection –*** Applications were designed for people to enter information in the same way across shifts for the same tasks. Most sites mentioned the consistency and reliability in data collection across shifts were previous areas of concern.
- ***Increased Awareness of Equipment Health –*** Through the use of the technology, the operator can gain an awareness of the equipment health, by viewing current, historical (e.g., trends), and equipment-reference information. At one site, operators had successfully identified and resolved machine problems with equipment as a result. As this awareness has increased, the time between failures has increased and preventive maintenance schedules have been adjusted outward. In addition, the equipment specialists and maintenance groups have focused on more critical issues.
- ***Cost Savings –*** A number of sites reported cost savings when using mobile applications in conjunction with reliability program initiatives. For example, one site reported the first year had seen savings of greater than $500,000 in equipment repairs, from earlier detection of abnormalities (excluding lost profit opportunities).
- ***Improved Communications across Plant Roles –*** The technology enhanced communications across functions. An example is a notification system that sent role-relevant information regarding equipment surveillance. Also, the general platform was useful for both machine experts and operators; this promoted the use of a common language across plant roles and responsibilities.
- ***Decreased Paperwork*** – Rounds that were previously done by paper were difficult to track. The mobile device and applications provided the ability to store collected data in one place and easily query that collection of data.

		Sites						
Success Factors		**C**	**E**	**B**	**A_1**	**A_2**	**F**	**D**
Organization, Policy, & Processes								
1	Strong management commitment, as demonstrated by adequate budget, personnel, etc. to engineer and deploy mobile solutions	+	+	+	~	~	~	--
2	Tied to business initiative (e.g., reliability-based maintenance program)	+	+	+	+	+	--	~
3	"Champion" from Operations for initiative & technology	+	+	~	+	--	--	--
4	Reason for data collection and business impact communicated back to operations regularly	+	+	+	+	--	--	--
5	On-going measurement and evaluation of performance and business impact	+	+	+	~	--	+	--
6	Cross-functional deployment team across all stakeholders (e.g., management, engineering, IT, operations, union representatives)	+	+	+	+	--	~	+
7	Human-centered design process (e.g., end user involvement, usability design, piloting solution before full deployment)	+	+	~	+	+	--	~
Applications								
8	Use is part of iniative work process (not "make work" activities)	+	+	+	+	+	--	~
9	Integrated with databases and other information systems	~	+	~	+	+	+	--
Infrastructure, Hardware, & Sofware								
10	Reliable and robust data storage, transmission	~	~	+	+	+	--	--
11	Ergonomically designed hardware and accessories (e.g., measurement probes)	~	~	+	+	+	~	--
Training								
12	How to use device and applications on device	+	~	+	~	~	~	+
13	What the information being collected is used for (i.e., why data collection with mobile device is important and what the business impact is)	+	+	--	~	--	--	--
14	How the appliation supports Operations objectives (in general)	+	+	+	~	--	--	--
	Degree of Successful Mobile Device Deployment	+	+	+	+	--	--	--

LEGEND
+ interview or survey indicated factor was STRONGLY present
~ interview or survey indicated factor was only mildy present
? interview or survey indicated factor was NOT present

Table 1: Summary of identified success factors present at the sites visited. The six sites are notes as A (2 units), B, C, D, E, F.

Despite these benefits, a number of limitations were noted:

- ***Procedures –*** Most sites noted that mobile device functionality associated with the integration of procedures was very limited.
- ***Connections to Other Programs and Databases –*** The mobile device applications need to be inter-linked with other management system software and databases. Connectivity to other applications would be beneficial.
- ***Usability of Reporting –*** Some sites have noted that the reporting functions required a lot of practice. These sites have also noted that it could be overwhelming to sort through the information that was collected. The usability needed to be improved.
- ***Device Capacity Issues Related to New Applications –*** The mobile devices were perceived to take a long time to upload and download information from a wireless network. There was a concern that as new applications are developed (e.g., procedures, access to control system data), this limited capacity in bandwidth would significantly decrease performance of the application and increase frustration.

EFFECTIVE PRACTICES FOR DEPLOYMENT

Table 1 summarizes the results of the interviews and surveys across the six sites and seven units studied.

In general, successful sites had:

- a champion in operations that advocated the use of the mobile device for the intended operations activity and strong management support in terms of budget and resources
- a multi-functional team spanning stakeholders to define the initiative and work process that used the mobile device
- a business initiative and work process enabled by the mobile device, as opposed to creating or duplicating work with the mobile device
- ongoing, regular feedback on business benefits from the work process enabled by the mobile device
- trust from the end users that was established prior to deployment via demonstrated reliability for both infrastructure, hardware, and software

The most exemplary site also clearly followed a human-centered design process, involving field operators as part of the design and deployment process, focusing on supporting work practices and usability.

While mobile devices were generally introduced to support a specific business initiative (e.g., reliability-based maintenance), once the mobile devices have proven useful in making the initiative successful, new opportunities for other initiatives are often more easily identified and readily adopted by stakeholders.

Failure Modes and Lessons Learned

One critical failure mode observed at one site was to have the field operators collect data on sensor points already being automatically collected through the DCS. The operators were aware of which points were on the DCS and perceived this requirement by management as a way of “checking up on them”. This site had continual acceptance issues with the initiative and mobile device technology.

There was also a caution communicated to the site visit team to avoid assigning operators more tasks using mobile devices as momentum builds from its successful implementation. Figure 2 shows the potential of task

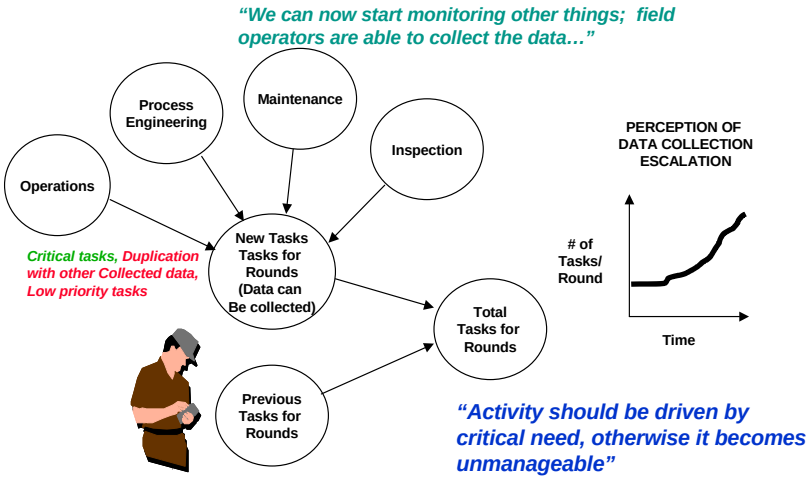

Figure 2: Potential escalation of tasks with mobile devices.

escalation as more stakeholders see the advantages of mobile devices for collecting process and equipment data for analysis and optimization. A strategy and process needs to be put in place to prioritize field tasks that use mobile devices, and manage this potential problem.

In addition, safeguards against unintended use were necessary. In at least two sites visited, people had taken advantage of the vulnerabilities of the mobile device to circumvent the intended process. At one site, instead of scanning equipment barcodes in the field as they collected the data, operators used barcode sheets and entered the data without being at the equipment. At another site, operators were able to delete applications from the mobile device because the software was not locked. At a third site, operators were excessively rough with the mobile device hardware itself, resulting in mobile device failures. Finally, disappearing devices may be a common problem when the use of the field device is more optional; to prevent such disappearances, ways to track these devices might be needed.

To mitigate some of these risks, three suggestions were mentioned. First, a site should focus on the high-level success drivers and ground use in accepted work processes. Second, a site should involve end-users in development and deployment. Third, sites provide regular feedback on the uses of information collected and its impact on operations.

CONCLUSIONS

The objectives of this research were to survey current uses of mobile devices in field operations, and identify lessons learned from deployment. Four general areas were identified as critical to the success of deployment: 1) Organizations, Policies and Processes, 2) Applications, 3) Infrastructure, Hardware and Software, and 4) Training. The results presented support the notion that technology alone will not guarantee the appropriate use of the mobile device or achievement of business objectives. However, those sites that used a human-centered design process, provided periodic feedback on the business impact of the work process enabled by the mobile device, and had strong operations champions, did see appropriate uses of these devices.

While the six sites provide important insights into the successful deployment of new technology in plant operations, there are some limitations to this research. First, the use of mobile devices in the industries studies is still quite limited. The full potential needs to be further investigated; this can lead to additional insights into appropriate uses of the technology and successful deployment strategies. Second, we only surveyed six sites within one main industry group. The inclusion of more sites within this industry as well as in different industries that have deployed mobile devices could provide additional insights not presented here.

These limitations provide areas for future research. In particular, a cross-industry study on the deployment of mobile devices for field operations could reinforce the results presented here and provide complementary insights. In addition, studies of the deployment of new applications, such as operations coordination facilitated by mobile devices, would further provide useful insights into the capabilities and limitations of the technology.

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