Mobile Computing:
Characteristics, Business Benefits, and the Mobile Framework

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Abstract

Mobile computing offers significant benefits for organizations that choose to integrate the technology into their fixed organizational information system. Mobile computing is made possible by portable computer hardware, software, and communications systems that interact with a non-mobile organizational information system while away from the normal, fixed workplace. Mobile computing is a versatile and potentially strategic technology that improves information quality and accessibility, increases operational efficiency, and enhances management effectiveness. A detailed analysis, supported by selective presentation of published literature, is used to elucidate and support these asserted benefits of mobile computing. Additionally, a set of heuristics called the MOBILE framework is developed. The MOBILE framework assists information technology professionals in achieving the stated benefits of mobile computing by defining the types of problems, opportunities, and directives that are best addressed through mobile computing technology.

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Mobile Computing:

Characteristics, Business Benefits, and the Mobile Framework

Introduction

The fundamental purpose of this paper is to illustrate that mobile computing is a versatile and potentially strategic technology that improves information quality and accessibility, increases operational efficiency, and enhances management effectiveness. A successive examination of the characteristics and benefits of mobile computing is used to achieve this goal.

As a starting point, a definition of mobile computing is provided. Next, the technologies that make mobile computing possible (hardware, software, and communications) are examined. The discussion of mobile computing technologies leads into an overview of the types of applications that are commonly found on mobile computers. With this background established, the following two sections demonstrate the ability of mobile computing to improve both information quality and information accessibility. Using this knowledge in conjunction with mobile computing case examples, the ability of mobile computing to improve operational
efficiency is subsequently supported. Then, the ability of mobile computing to increase management effectiveness is similarly supported.

The previously discussed improvements in information quality, information accessibility, operational efficiency, and management effectiveness are then used to demonstrate that mobile computing is a versatile technology. Additionally, three separate existing frameworks for understanding the strategic nature of information technology are used to illustrate the strategic qualities of mobile computing.

As with any technology, mobile computing must be used appropriately in order to attain the benefits that have been discussed. To this end, a set of heuristics called the MOBILE framework is developed by the author to assist information technology professionals in achieving the stated benefits of mobile computing. The MOBILE framework assists information technology professionals by defining the types of problems, opportunities, and directives that are best addressed through mobile computing technology.

Before concluding, the paper discusses the continuous evolution and change that is occurring within the field of mobile computing. Two examples of new technologies that will impact mobile computing in the future are examined. The paper concludes with a review of the material covered and a reassertion of the stated benefits of mobile computing.

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Mobile Computing Defined

The term "Mobile computing" is used to describe the use of computing devices--which usually interact in some fashion with a central information system--while away from the normal, fixed workplace. Mobile computing technology enables the mobile worker to: (a) create; (b) access; (c) process; (d) store; and (e) communicate information without being constrained to a single location. By extending the reach of an organization's fixed information system, mobile computing enables interaction with organizational personnel that were previously disconnected. Throughout this paper, the concept of mobile computing will be further refined through: (a) an examination of the technologies that make mobile computing possible; (b) an analysis of the many benefits of mobile computing; and (c) the presentation of the MOBILE framework, that provides guidance on when mobile computing is best applied to a problem, opportunity, or directive. Mobile computing is an extremely versatile, capable, and exciting technology that offers many otherwise unattainable benefits to organizations that choose to integrate it into their fixed information system.

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Mobile Computing Technology

Mobile computing is accomplished using a combination of: (a) computer hardware; (b) system and applications software; and (c) some form of communications medium. Powerful mobile solutions have recently become possible because of the availability of: (a) extremely powerful and small computing devices; (b) specialized software; and (c) improved telecommunications. ("SOLID White", 1998) This section provides a brief overview of the general types of hardware, software, and communications mediums that are commonly integrated to create mobile computing solutions.

Hardware

The characteristics of mobile computing hardware are defined by the: (a) size and form factor; (b) weight; (c) microprocessor; (d) primary storage; (e) secondary storage; (f) screen size and type; (g) means of input; (h) means of output; (i) battery life; (j) communications capabilities; (k) expandability; and (l) durability of the device. Using these hardware characteristics, mobile computing hardware can be grouped into the following general categories: (a) Palmtop; (b) Clamshell; (c) Handheld Penkey; (d) Penslate; and (e) Laptop. The following table (Table 1)--based on an amalgamation of data--depicts the prevalent characteristics of mobile computing hardware in each category. (Buyer's Guide, 1998) (Intermec Technologies, 1999) (Product Comparison Guide, 1999) (Intermec Technologies, 1999a)

<table>
<thead>
<tr>
<th>Form Factor and Average Size</th>
<th>Palmtops</th>
<th>Clamshells</th>
<th>Handheld Penkeys</th>
<th>Penslates</th>
<th>Laptops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Weight</td>
<td>0.5 pounds</td>
<td>1 - 2 pounds</td>
<td>1 - 2.5 pounds</td>
<td>2 - 4 pounds</td>
<td>6 - 10 pounds</td>
</tr>
<tr>
<td>Form Factor and Average Size</td>
<td>Rectangular. Fits easily in one hand. Average size: 3.5&quot; x 5.5&quot; x 0.7&quot;</td>
<td>Screen folds down to cover keyboard. Average size: 8&quot; x 4&quot; x 1.3&quot;</td>
<td>Elongated rectangular shape. Can be held in one hand. 4.5&quot; x 8&quot; x 1.5&quot;</td>
<td>Rectangular or square. Laptop sized or slightly smaller. No integral keyboard. 10&quot; x 8&quot; x 1.5&quot;</td>
<td>Rectangular or square. Screen folds to cover full-size keyboard. 12&quot; x 10&quot; x 1.8&quot;</td>
</tr>
<tr>
<td>Microprocessor</td>
<td>Primary Storage</td>
<td>Secondary Storage</td>
<td>Average Screen Size and Type</td>
<td>Means of Input</td>
<td>Means of Output</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------</td>
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<td>---------------</td>
</tr>
<tr>
<td>Low-Power RISC.</td>
<td>1-4 Mb (battery-backed) Used for storage and program execution.</td>
<td>None. Some have compact flash slot.</td>
<td>160x240 pixels. Backlit LCD.</td>
<td>Pen on touch screen and a few buttons (&lt; 5). Microphone. Writing recognition.</td>
<td>Screen, speaker, Light emitting diodes (LED).</td>
</tr>
<tr>
<td>Intel 386 or 486 Class.</td>
<td>8 - 32 Mb (battery-backed) Used for storage and program execution.</td>
<td>None. Most have PCMCIA and compact flash slots.</td>
<td>640 x 240 pixels. 8&quot; diagonal. Backlit Grey-scale or color.</td>
<td>Keyboard, pen on screen, microphone.</td>
<td>Screen, speaker, LED, VGA to external monitor.</td>
</tr>
<tr>
<td>Intel 486 or Pentium Class.</td>
<td>1 - 16 Mb</td>
<td>256 Kb - 4 Mb flash ROM. 2 Mb - 540 Mb solid state or PCMCIA drive.</td>
<td>From 2.5&quot; 160 x 200 pixels to 7&quot; 640 x 480 pixels. Backlit Grey-scale.</td>
<td>Pen on screen, buttons or keypad on face, laser barcode scanner, magnetic card reader.</td>
<td>Screen, LED, speaker.</td>
</tr>
<tr>
<td>Pentium MMX or PII class.</td>
<td>8 - 48 Mb</td>
<td>340 Mb - 4 Gb hard drive.</td>
<td>640 x 480 pixels. 8 - 12&quot; diagonal. Backlit Grey-scale or color.</td>
<td>Pen, buttons on face of unit. Writing recognition. Microphone.</td>
<td>Screen, LED, speaker.</td>
</tr>
</tbody>
</table>

Means of Output

<table>
<thead>
<tr>
<th>Average Battery Life</th>
<th>Microprocessor</th>
<th>Primary Storage</th>
<th>Secondary Storage</th>
<th>Average Screen Size and Type</th>
<th>Means of Input</th>
<th>Means of Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 - 30 hours. Alkaline or rechargeable.</td>
<td>Low-Power RISC.</td>
<td>1-4 Mb (battery-backed) Used for storage and program execution.</td>
<td>None. Some have compact flash slot.</td>
<td>160x240 pixels. Backlit LCD.</td>
<td>Pen on touch screen and a few buttons (&lt; 5). Microphone. Writing recognition.</td>
<td>Screen, speaker, Light emitting diodes (LED).</td>
</tr>
<tr>
<td>8 - 12 hours. Alkaline or rechargeable.</td>
<td>Low-Power RISC.</td>
<td>8 - 32 Mb (battery-backed) Used for storage and program execution.</td>
<td>None. Most have PCMCIA and compact flash slots.</td>
<td>640 x 240 pixels. 8&quot; diagonal. Backlit Grey-scale or color.</td>
<td>Keyboard, pen on screen, microphone.</td>
<td>Screen, speaker, LED, VGA to external monitor.</td>
</tr>
<tr>
<td>8 Hours. Rechargeable.</td>
<td>Intel 386 or 486 Class.</td>
<td>1 - 16 Mb</td>
<td>256 Kb - 4 Mb flash ROM. 2 Mb - 540 Mb solid state or PCMCIA drive.</td>
<td>From 2.5&quot; 160 x 200 pixels to 7&quot; 640 x 480 pixels. Backlit Grey-scale.</td>
<td>Pen on screen, buttons or keypad on face, laser barcode scanner, magnetic card reader.</td>
<td>Screen, LED, speaker.</td>
</tr>
<tr>
<td>2 - 4 hours. Rechargeable.</td>
<td>Pentium MMX or PII class.</td>
<td>32 - 128 Mb</td>
<td></td>
<td></td>
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<tr>
<td>---------------------</td>
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</tr>
<tr>
<td><strong>Expandability</strong></td>
<td>Memory, external modems, external wireless hardware.</td>
<td>PCMCIA and compact flash memory, wireless modems, GPS, and other devices.</td>
<td>Bar code readers, magnetic stripe readers, integrated printers.</td>
<td>Optional keyboards, floppy drives, CDROM, GPS, bar code readers.</td>
<td>Very expandable through memory slots, USB, PCMCIA, swappable bays, docking stations.</td>
<td></td>
</tr>
<tr>
<td><strong>Durability</strong></td>
<td>Not designed for harsh environments.</td>
<td>Not designed for harsh environments.</td>
<td>Almost all are designed to withstand harsh environments.</td>
<td>Most are designed to withstand harsh environments.</td>
<td>Some are designed to withstand harsh environments, but most are not.</td>
<td></td>
</tr>
<tr>
<td><strong>Comments</strong></td>
<td>These devices are commonly referred to as PDAs, HPCs, or Palm Computers.</td>
<td>Recent trend towards larger screens (640 x 480 pixels) and keyboards.</td>
<td>Quintessential category of mobile computing hardware.</td>
<td>Powerful, portable, and rugged. Easily mount in vehicles.</td>
<td>Laptops offer similar functionality and performance to desktop systems.</td>
<td></td>
</tr>
</tbody>
</table>

Users need and want access to their data wherever they go, and they will use a wide assortment of mobile computing devices to get it. Except for possibly high-end laptops, none of the categories of mobile computing hardware are replacements for a loaded desktop PC. Instead, each category of device fills a niche that helps to
satisfy the demands created by mobile users' many computing needs. Although a lot of mobile hardware has many eye-catching characteristics, the decision about which hardware to employ should be based entirely on clear business needs. (Radcliff, 1998) Defining these needs, and having a solid strategic plan for how the new hardware will be used, is the best way to avoid disappointment and missed opportunities. (Paisner, 1998) While many specific makes and models of hardware exist, the general categories of mobile computing hardware depicted in the previous table adequately characterize the majority of mobile computing devices available today. References to mobile computing hardware during the subsequent analysis of the benefits of mobile computing will make reference to these categories.

Software

Mobile computers make use of a wide variety of system and application software. The most common system software and operating environments used on mobile computers include: (a) MSDOS; (b) Windows 3.1/3.11/95/98/NT; (c) Windows for Pen Computing; (d) Windows CE; (e) PenDOS; (f) PenRight!; (g) Palm OS; (h) Psion EPOC32; and (i) Unix. (Buyer's Guide, 1998) (Boling, 1998, xiii - xv) These operating environments range in capabilities from a minimalist graphically-enhanced-pen-enabled DOS environment (PenDOS and PenRight! for DOS) to the powerful capabilities of Windows NT.

Each operating system/environment has some form of integrated development environment (IDE) for application development. Most of the operating environments provide more than one development environment option for custom application development. For example, Windows ons between mobile devices. This allows the developer to concentrate on the application and not the specifics of the hardware being utilized. (Besaha, 1998)

All mobile computing application software does not have to be custom-designed. Prewritten application software can be purchased for many application areas, such as sales force automation. Additionally, many companies that develop mobile computing software offer systems integration services, and will work with the client to modify their existing application to fulfill the client's specific needs.

Communications

The ability of a mobile computer to communicate in some fashion with a fixed information system is a defining characteristic of mobile computing. The type and availability of communication medium significantly impacts the type of mobile computing application that can be created.

Modes of communication.
The way a mobile computing device communicates with a fixed information system can be categorized as: (a) connected; (b) weakly connected; (c) batch; and (d) disconnected. (Muller, 1998, 112-113) The connected category implies a continuously available high-speed connection. The ability to communicate continuously, but at slow speeds (i.e. < 28 Kbps), allows mobile computers to be weakly connected to the fixed information system. A batch connection means that the mobile computer is not continuously available for communication with the fixed information system. In the batch mode, communication is established randomly or periodically to exchange and update information between the mobile computer and fixed information systems. Mobile computers may operate in batch mode over communication mediums that are capable of continuous operation, reducing the wireless airtime and associated fees. Disconnected mobile computers allow users to improve efficiency by making calculations, storing contact information, keeping a schedule, and other non-communications oriented tasks. This mode of operation is of little interest because the mobile device is incapable of electronically interacting and exchanging information with the fixed organizational information system. Exchange of information with a disconnected mobile computing device can only be accomplished by manually entering information into the device or copying from the device's screen and manually entering the information into the fixed information system. This mode of information exchange is no more efficient than using paper and is effectively nonexistent, since virtually all modern mobile computing hardware is capable of some form of native electronic data communications.

Available technologies.

There are many communications technologies available today that enable mobile computers to communicate. The most common of these technologies are: (a) Wireless Local Area Networks (WLANs); (b) Satellite; (c) Cellular Digital Packet Data (CDPD); (d) Personal Communications Systems (PCS); (e) Global System for Mobile communications (GSM); (f) RAM and ARDIS data networks; (g) Specialized Mobile Radio (SMR) service; (h) one and two-way paging; (i) plain old telephone system (POTS); (j) Internet; (k) infra-red; (l) docking (serial, parallel, LAN); and (m) disk swapping. These diverse communications technologies make available a continuum of connectivity that provides communications capabilities ranging from manual-assisted batch transfers to high-speed continuous communication.

Making the choice.

The specific mobile application, hardware, software, and operating location/environment determine which communications mediums are appropriate to use for a mobile computing solution. (Muller, 1998, 303-392) Achieving the desired communication capability requires matching the communications medium with the appropriate mobile computing hardware. Most mobile computing
hardware is designed to take advantage of multiple communications mediums. Specialized hardware and software is also available which enables many mobile computing devices to utilize communications mediums for which they were not originally designed. Again, the desired operating location and environmental conditions within which the mobile device will operate must significantly impact the choice of communications medium. The proper selection and utilization of the communications medium ensures that the mobile computing device is capable of reliable communications to support the mobile computing application and fulfill the business need.

*Mobile Computing Applications*

The real power of mobile computing becomes apparent when mobile hardware, software, and communications are optimally configured and used to accomplish a specified mobile task. Although many varied applications exist, mobile computing applications can generally be divided into two categories—horizontal and vertical.

**Horizontal**

Horizontal applications have broad-based appeal and include software that performs functions such as: (a) email; (b) Web browsing; (c) word processing; (d) scheduling; (e) contact management; (f) to-do lists; (g) messaging; (h) presentation. These types of applications usually come standard on Palmtops, Clamshells, and laptops with systems software such as Windows 95.

**Vertical**

Vertical applications are industry-specific and only have appeal within the specific industry for which the application was written. Vertical applications are commonly used in industries such as: (a) retailing; (b) utilities; (c) warehousing; (d) shipping; (e) medical; and (f) law enforcement and public safety. (Dhawan, 1997, 15-57) These vertical applications are often transaction oriented and normally interface with a corporate database.

**Application Categories**

The specific requirements of a mobile computing application generally determine the type of hardware and operating environment required to support the application. The following table (Table 3) depicts the common types of applications for each category of mobile computer. (Pen Computer Solutions, 1999) (Dhawan, 1997, 78)
<table>
<thead>
<tr>
<th>Common Horizontal Applications</th>
<th>Palmtops</th>
<th>Clamshells</th>
<th>Handheld Penkeys</th>
<th>Penslates</th>
<th>Laptops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Vertical Application Functions</td>
<td>Contact Management, to-do lists, simple text editing, scheduling, email or messaging, voice memos.</td>
<td>Contact Management, to-do lists, word processing, spreadsheets, presentations, scheduling, email and messaging. Web browser, voice memos, fax.</td>
<td>Generally do not have integrated horizontal applications.</td>
<td>Generally capable of executing same software as laptops. Not normally used for office automation due to slightly limited resources and lack of keyboard.</td>
<td>Normally come preloaded with common office automation software: Word processing, spreadsheets, presentation, email, Web browser, fax, databases.</td>
</tr>
<tr>
<td>Common Vertical Applications</td>
<td>Automated data collection, remote database access, information retrieval.</td>
<td>Automated data collection, remote data access, limited office automation.</td>
<td>Automated data collection, remote data access, transaction processing.</td>
<td>Automated data collection, remote data access, remote processing.</td>
<td>Automated data collection, remote data access, remote processing.</td>
</tr>
</tbody>
</table>
This list is by no means exhaustive. Other application areas include: (a) mining; (b) forestry; (c) agriculture; and (d) surveying. (Lauzon Computer, 1997) The application areas depicted in the table demonstrate the general capabilities offered through mobile computing. Many of these application areas will be examined in further detail during the subsequent sections of this paper that discuss the benefits of mobile computing.

**Content Dimension**

Mobile computing enables information to be captured at its source, that is, its point of creation. The obvious advantage of this type of data capture is that it eliminates the need to reenter the data at a later time by transcribing it into a computer from the original paper copy. Besides eliminating redundancy, source data capture with mobile computing offers additional advantages. Complex and complete information can be quickly and easily captured through special mobile input devices such as barcode readers. The amount of information captured by special input devices and the speed with which it is captured could not be duplicated by human-based input means. The software application on the mobile computing device can be programmed to use error-checking routines that ensure the captured data is complete and free from errors. Furthermore, the software can use context sensitive questions and intelligent forms to ensure that the proper scope of information is retrieved and that no extra, unnecessary or irrelevant information is accepted. The mobile computing device may also perform preprocessing on the data that is being collected before it is ultimately transferred to a fixed information system. Since the information being transferred from the mobile device to the fixed information system is high quality, the information that is transferred back from the fixed information system to the mobile computing device will generally also be of higher quality. Mobile computing application software can be used to intelligently request information from the central fixed information system, so the mobile device only receives the desired information from the central system. These characteristics of mobile computing enable it to improve the content dimension (accuracy, relevance, completeness, conciseness, and scope) of information quality.

**Form Dimension**

Mobile computing applications use hardware and software that are specifically configured so that information can be viewed in a format that is: (a) easy for the mobile user to use; and (b) unambiguous. Since the information that is transmitted or stored in the mobile device is in digital format, it can normally be: (a) viewed in either a detailed or summary form; (b) sorted as required; (c) manipulated into tables or charts as required; and (d) viewed on the screen or printed out. Mobile computing applications can use a wide variety of devices which enhance the ability of the mobile worker to capture and distribute data. Mobile computers can take advantage of: (a) barcodes; (b) magnetic stripe readers; (c) portable printers; (d) signature capture; (e) smart cards; (f) radio frequency identification; (g) voice recognition; (h) still image capture; (i) video image capture; and (j) the Global Positioning System (GPS). (Intermec Technologies, 1998) Additionally, the internal storage and processing capability of mobile computers allow immediate access to large quantities of localized digital information. For example, a utility employee may carry a mobile device that contains a CDROM with maps of the entire city within which she works. From this discussion, it can be seen that
mobile computing improves the form dimension of information quality by improving the characteristics of clarity, detail, order, presentation, and media.

**Overall Quality**

Mobile computing improves the time, content, and form dimensions of information quality. Since each dimension is improved, the resulting overall quality of information generated by an organizational information system that utilizes mobile computing is also improved.

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**Improved Information Accessibility**

Mobile computing enables improvements in information accessibility. The degree of improvement is directly dependent upon the mobile hardware and communications equipment in use. For example, a Penslate computer that is operating in the connected mode via a wireless local area network will have much greater information accessibility than a clamshell mobile computer that is operating in batch mode and only connects randomly throughout the day. The degree of information accessibility required--which defines the hardware and communications requirements--is determined by the business needs that are driving the mobile computing application. Mobile computing technology (hardware, software, and communications) provides a wide range of options that can be mixed and matched to fit the needs of each individual mobile computing application.

The improvements in information accessibility enabled by mobile computing result in improved information flow both to and from the central fixed information system. The mobile computer enables quick and efficient information retrieval from the central information system. The ability to access central information and make fixed or ad hoc queries of corporate databases enables employees to get the information they need to complete the job. The mobile computer also enables transmission of current operational data, in native digital format, from the mobile user to the central fixed information system.

Once transmitted to the fixed information system, the data from the mobile user can be processed and made available for all other users of the central information system. Thus, the information available to a mobile user from the central information system reflects current information from other mobile users as well. Mobile computing eliminates the delay that occurs when an employee must physically return to the office at the end of the day and submit paper forms so that data entry personnel can enter the information into the central information system.

Even employees that are not continuously connected to the fixed organizational information system via a wireless link will experience significantly improved
information accessibility through mobile computing. One phone call at the end of the day from the mobile user via a standard modem is all that is required to transmit the entire day's transactions to the central computer, saving travel and data entry time. Additionally, any scheduling or assignment changes for the mobile employee for the following day can be transmitted to the employee during the same phone call.

Mobile computing also significantly speeds information accessibility when other media, such as: (a) facsimile; (b) audio files; or (c) still images are concerned. Digital images or audio files can be accessed by the mobile user or transmitted from the mobile user to the central fixed organizational information system.

If matched properly to the work environment and task to be accomplished, the mobile computer will always be in the possession of the mobile worker during the course of the day. Especially in the connected or weakly connected modes of operation, this means that the mobile employee may be contacted throughout the workday via the mobile computing device. Additionally, it means that the employee has access to other mobile employees via email or other messaging schemes. As with many mobile computing applications, the type of mobile application and the hardware, software, and communications used to support it will normally determine the degree and type of information accessibility.

The direct measurable results of improved information accessibility--both to and from the mobile worker--are many. They include: (a) improved customer service; (b) reduced cycle times; (c) greater accuracy; (d) fewer complaints; and (e) a reduction in required intermediate support staff. Improved information accessibility can also support many other improvements such as: (a) elimination of extra travel; (b) reduction of selling times; and (c) saving lives. (Dhawan, 7-14)

**Increased Operational Efficiency**

Mobile computing enables improvements in the operational efficiency of organizations that integrate the technology into their fixed information systems. It enables the computing power and information contained within the fixed information system to be structured around the optimum work flow of a mobile worker, instead of altering the mobile worker's work flow to meet the optimum configuration for computing. The mobile computer stays with the mobile employee, instead of the employee being required to travel to the computer. Mobile computing can improve efficiency in many ways, including: (a) saving time; (b) reducing waste; (c) cutting cycle times; (d) reducing rework; (e) enabling business process reengineering; (f) improving accuracy; (g) decreasing time spent on
customer complaints; and (h) reducing unnecessary travel. (Dhawan, 14)
Representative examples from actual real-world mobile computing implementations will be presented to demonstrate the ways in which mobile computing can improve the operational efficiency of an organization.

Field Sales

The operational efficiency of sales personnel is significantly enhanced through mobile computing. An excellent example of these improvements can be seen by examining how mobile computing improves the efficiency of remote insurance and financial planning sales. The mobile computer frees the sales agent to meet with the client at the client's home, office, or other location. Customer data is collected, estimates and comparisons are immediately calculated, the customer decides on the program of choice, the central computer is immediately updated, and the customer is enrolled in the insurance or financial planning program. (Dhawan, 34) Without mobile computing, this sales process would take days instead of minutes. In addition to accessing and updating customer account information, mobile sales personnel can accomplish tasks such as printing invoices or other information to leave with the customer. (Automated Wireless, 1999)

Transportation and Shipping

The transportation and shipping industries benefit greatly from mobile computing. Using mobile computers in conjunction with GPS/GIS and an accompanying vehicle information system (VIS), the operations of an entire transportation fleet can be managed from a central location. The central office knows the location, status, and condition of all vehicles, and operators have two-way communication with the operations center. Using this information, vehicles can be optimally dispatched to maximize efficiency as measured by: (a) time; (b) fuel consumption; and (c) delivery priority. (Dhawan, 52) The mobile computers enable significant performance improvements, achieved simultaneously with operational cost reductions.

Averitt Express, a North Carolina trucking company that specializes in less-than-truckload deliveries, significantly improved its operational efficiency with a mobile computing solution that utilizes Penkey computers and continuous wireless connectivity. Before the mobile computing solution was introduced, the company managed its trucking assets using a manual tracking system and two-way voice radio. The system was not providing the desired efficiency or quality of customer service that Averitt needed for competitiveness. Using the new system, dispatchers enter customer pickup information directly into the central computer, which automatically selects and notifies the appropriate truck via the driver's Penkey computer. Drivers record information about deliveries, such as the time of delivery and the person who signed for it, on the mobile computer. This information is automatically transmitted to the central computer and customer service
representatives can use it to provide better delivery information to customers. Since the introductions of the mobile computing solution, operations are more efficient and customers are happier. (Intermec Technologies, 1998a)

**General Dispatching**

Mobile computers used in conjunction with Global Positioning System (GPS) and Geographical Information System (GIS) data allow significant improvements in the operational efficiency of various dispatch operations. (Dhawan, 27) For example, the central computer at a taxi company can track the location and status of all its taxicabs and electronically dispatch the most appropriate car to a customer’s location. Additionally, the central computer can calculate an accurate approximation of when the taxi will arrive, enabling improved customer service.

**Hotel Operations**

Connecting the cleaning and hospitality staff of a hotel with mobile computing can significantly improve the efficiency of hotel operations. As guests check out and rooms are vacated, the central computer wirelessly signals cleaning staff that the rooms are ready for cleaning. Problems that are identified during cleaning, such as broken appliances or faulty plumbing, are immediately communicated to the mobile maintenance team for action. As soon as cleaning is complete and repairs are accomplished, the cleaning staff member wirelessly updates the central computer and the room is immediately available for check-in by a new guest. The same system can be used to efficiently direct mobile hospitality personnel in response to guest requests for information and service. (Dhawan, 57)

**News Reporting**

Mobile computers dramatically improve the efficiency of news media operations. Reporters equipped with mobile computers and accompanying electronic devices can cover a news or sporting event, take digital video or still photographs, digitally record audio interviews, compose the text of the news story, and transmit the completed product back to the central agency for editing and immediate publication. (Dhawan, 56) In the media industry, the timing and quality of news coverage is critical. Mobile computing increases the quality of the information from the media crews and significantly decreases the time required to process and transmit the story for publication.

**Health Care**

Mobile medical care, whether in-home, on the road, or within a hospital, is more efficient with mobile computing. The mobile healthcare worker can access patient records for reference purposes, and is able to update records with current diagnosis and treatment information. Emergency medical technicians (EMTs) responding at
the scene of an accident can use mobile computers to capture patient information, treatments accomplished, vital signs, and other critical data. This information is wirelessly transmitted to the receiving hospital, which then prepares to receive and treat the patient, or recommend another hospital facility with more appropriate treatment facilities—depending upon the nature and severity of the injuries. The more efficient hand-off between ambulance EMTs and hospital staff made possible by mobile computing can save lives that otherwise might have been lost. (Dhawan, 44-46)

**Car Rental Agencies**

Car rental agencies have taken advantage of the improved operational efficiency made possible by mobile computing. Using handheld computers, rental company employees can now process a rental car return without the customer ever being required to enter the office. The process works as follows: (a) The customer arrives with a car for drop-off; (b) an employee greets the customer, receives the keys to the vehicle, and performs an interior and exterior vehicle inspection; and (c) upon inspection completion, the employee uses the mobile computer to settle the account and record the car as returned. Additionally, the vehicle cleaning and maintenance staff is automatically notified when the vehicle is returned, so it can quickly be returned to a rentable status.

**Fieldwork**

Almost any form of fieldwork can be made significantly more efficient through the application of mobile computing. Parking control officers and utility inspectors are two examples of field workers who can receive operational benefits from mobile computing. Parking control officers use handheld computers to check the registration and violation history of parking offenders. Parking violations are issued immediately and towing/backup can be requested when required. Utility inspectors have historically used paper forms to capture information such as consumer power consumption and utility equipment status (transformers, transmission towers, etc.). Using mobile computers, inspectors can be given instructions on inspections to be accomplished and information can be captured and validated at the source. (Dhawan, 50-51)

**Mobile Automation**

General business travelers also reap the benefits of mobile computing. E-mail, spreadsheets, presentations, and word processing are the four primary tasks accomplished by these business travelers. Laptops, Palmtops, and portable Clamshell computers with usable-size keyboards enable businesspeople to stay in touch and accomplish the tasks they need for job effectiveness. (Gillin, 1998) Using powerful mobile computers in conjunction with high-speed connectivity,
mobile workers can perform work normally accomplished at the office while on the road or in the field. (Dhawan, 77)

Results

These examples have demonstrated the types of operational efficiency improvements that can be gained through the use of mobile computing technology. The improvements in efficiency made possible by mobile computing are impressive. Mobile computing technology can be applied to a diverse range of problems and achieve similar improvements in operational efficiency.

Increased Management Effectiveness

Mobile computing technology can improve management effectiveness by improving information quality, information flow, and ability to control a mobile workforce. It makes the most current and accurate information available to both the mobile worker and the users of the fixed information system with which the mobile worker communicates. These benefits can be seen in all areas of the information system, from the fixed reports generated by a management information system all the way to ad hoc systems such as decision support and executive information systems. Many of the management benefits of mobile computing have already been seen in the examples previously presented in the operational efficiency section of this paper. Companies like Averitt Express not only improved their efficiency through mobile computing, but they also improved their ability to manage operations. Often, it is the improved ability to manage operations that is partly responsible for the performance improvements seen in companies that introduce mobile computing technology. Several examples will be presented in this section, in order to further demonstrate the ability of mobile computing to improve management effectiveness.

Campus Access

Elected government officials, such as state senators, have dramatically improved their management effectiveness through the use of mobile computing. A wireless LAN is used to connect the senators to a campus-wide network. Through this network, senators access private and global information; allowing access to: (a) private files; (b) email; (c) current legislation; (d) scheduling information; and (e) many other services. Additionally, the mobile computer makes the senator continuously accessible to his or her office staff. (Dhawan, 49) This type of system can be implemented using laptops, pen-slates, or even hand-held computers, depending on the individual processing needs and information requirements of each senator. By staying in touch and having continuous access to current information
and works-in-progress, senators are better able to manage their time and the many political requirements of the job.

**Sears**

Sears, Roebuck & Co. uses mobile computers to improve their ability to manage over 14,000 service technicians that are dispersed throughout the United States. Using specially designed, durable laptop computers and wireless connectivity, Sears directs the activities of its technician staff. Each morning, technicians download their schedule for the day, including customer information and service history. Throughout the day, the technicians record their progress on the mobile computer. During service calls, the technician uses the computer to accomplish tasks such as verifying the price and availability of repair parts. Once a service call is complete, the central dispatch facility is automatically notified via wireless communication. Technicians that finish service calls early, or that have cancelled appointments, can be dynamically redirected to another service call in the immediate area. The mobile computing solution has dramatically improved the ability of Sears to manage its mobile technician staff. (Flanagan, 1998)

**Other**

Stock traders use handheld mobile computers to gain immediate access to financial data and manage transactions. (Dhawan, 36) Airlines use handhelds with built-in barcode scanners to scan baggage as it is moved through the handling system, improving the ability to real-time track and manage baggage movement. (Dhawan, 41) Mobile computers and wireless networks have also proven to be a significant management tool to assist with coordination during disaster recovery operations.

**Results**

Just as mobile computing enables improved operational efficiency, it also enables improved management effectiveness. Mobile computers make more timely and accurate information available to managers. Mobile computers improve the manager's ability to track work in progress. They also improve the ability of managers to communicate with mobile personnel. Additionally, mobile computers provide better information to mobile employees, so they can make more informed decisions locally and minimize the need for management decisions from the central office.
As can be seen from the previous examples, mobile computing is an extremely versatile technology. It can be instrumental in: (a) process reengineering; (b) reducing operational and administrative staff; (c) improving communications; (d) improving customer service; (e) reducing manufacturing costs; (f) shortening business cycles; and (g) many other benefits. The variety of hardware, software, and communications systems available and the many ways they can be integrated to solve problems add to the versatility of mobile computing. Mobile computers can be used in harsh outdoor environments as well as indoor office environments. They can be operated by workers while standing, walking, or driving. They can be operated by workers with no existing keyboard skills as well as those that work with gloves on or who normally only have one hand free. Anyone who understands how to use a pen and paper can easily be trained to use most mobile computers. (Lauzon Computer, 1997)

**Examples of Versatility**

The true versatility of mobile computing can be seen by recalling examples of how it is currently being utilized to enhance business and other operations. It delivers critical medical information from mobile emergency medical technicians to emergency rooms, so the doctors can be ready to treat the patient immediately upon arrival. It enables a salesperson to demonstrate product options, calculate delivery fees, check availability, verify customer credit, and accept payment all during one short visit. It makes it possible for a regional manager to quickly reference his region's current and past performance with a Penslate computer and WLAN connection; answering important questions without ever leaving the meeting table.

**Versatility Summary**

Yes, mobile computing is versatile. It extends the reach of an organizational information system and enables interaction with employees who otherwise would not have access. The versatility of mobile computing will continue to expand over the next few years as a predicted proliferation of new mobile computing devices and the expanded usage of existing devices comes to fruition. (Needle, 1998)

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**Strategic Nature of Mobile Computing**

"The strategic role of information systems involves using information technology to develop products, services, and capabilities that give a company strategic advantages over the competitive forces it faces in the global marketplace." (O'Brien, 1996, p. 402) Mobile computing is a key enabling technology for the creation of strategic information systems.
**Five Competitive Forces**

Mobile computing’s strategic nature can be seen by examining how mobile computing influences the five competitive forces that impact businesses. As discussed by O'Brien, (1996, pp. 402-408) the five competitive forces described by Michael Porter are: (a) rivalry among competitors; (b) threat of new entrants; (c) threat of substitute products; (d) bargaining power of suppliers; and (e) bargaining power of customers. An organization can counter these competitive forces by pursuing one or more of the following strategies: (a) cost leadership; (b) differentiation; (c) innovation; (d) growth; and (e) alliance. In each case, mobile computing information technology can be an important part of implementing the competitive strategy. Mobile computing can significantly reduce the operational costs associated with business processes. These savings can be passed on to the customer and enable a cost leadership strategy. Mobile computers can enable a more satisfying experience for the customer or an entirely new and innovative way of doing business, enabling a differentiation and/or innovation strategy. Mobile computers simplify: (a) the capture of data; (b) communication; and (c) the management of complex operations, thus enabling growth. Mobile computing technology enables real time tracking and management of business operations, which are both important for attaining the performance and reliability required for inter-organizational alliances such as just-in-time inventory agreements. Additionally, a strategic information system that is aligned with company goals and takes advantage of the benefits of mobile computing technology represents a significant barrier to entry for any other businesses that are considering entry into the market.

**Categories of Strategic Systems**

The strategic nature of mobile computing can be further seen by examining how it supports the primary categories of strategic information systems. Although a multitude of specific examples of strategic information systems exist, all these systems can generally be classified as belonging to one or more of four main types of strategic information systems. (Ward & Griffiths, 1996, p. 21) The defining characteristics of these four categories of strategic information systems are: (a) those that change the nature of a relationship with consumers, customers, and/or suppliers by sharing information via technology-based systems; (b) those that improve the organization’s value-adding processes by more effectively integrating the use of information; (c) those that use information to develop, market, produce, and deliver enhanced or new services or products; and (d) those that support executive management decision-making in the areas of development and implementation of strategy, by providing them with information. Each of these categories is directly supported and enhanced by mobile computing. As seen in previous case examples, mobile computing can be directly responsible for changing the nature of relationships, improving key processes through information, enabling new products or services, and supporting executive decision making. These
examples further support the assertion that mobile computing can play a major role in strategic information systems and thus is a strategic technology.

**Strategic Value of Information Technology**

The key categories of information technology application that define the sources of information technology strategic value have also been defined by Applegate, McFarlan, and McKenney (1996, pp. 365-368). They have defined these categories as: (a) process performance improvements; (b) individual/work group decision quality and workgroup improvements; and (c) competitive advantage. It has been shown that mobile computing improves business process performance. Mobile computing enables better individual decision quality by the mobile worker because the mobile worker with a mobile computer has access to more information and computing resources than one without. Potential for improved group decision making is also possible because more current and higher quality information is made available through the use of mobile computers.

**Strategic Nature Summary**

Regardless of the measure, it should be clear that mobile computing has many strategic characteristics. Capitalizing on these characteristics by incorporating mobile computing technology into the fixed organizational information system will only strengthen the strategic nature of the overall information system.

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**Achieving the Benefits of Mobile Computing (MOBILE Framework)**

Accurately recognizing situations where mobile computing is an appropriate technology to address an organization's problems, opportunities, and directives is important if the promised benefits of mobile computing are to be achieved. In the spirit of--and partially based on--James Wetherbe's PIECES framework, as presented by Whitten & Bentley in their 1998 book *Systems Analysis and Design Methods* (pp. 79-81), I have developed a framework that specifically applies to mobile computing--the MOBILE framework. The MOBILE framework is used to determine when it is most appropriate to use mobile computing technology to address a problem, opportunity, or directive. The name MOBILE is derived from the first letter in each of the six categories that make up the framework.

The six categories are:

- **M** the need for *mobility*
- **O** the need to improve *operations*
the need to break business barriers

the need to improve information quality

the need to decrease transaction lag

the need to improve efficiency

Mobility

1. Freedom of movement is required to accomplish the task.

2. Information must be gathered, accessed, or processed during movement or while at a remote location.

3. Contact must be made while personnel are mobile or at remote locations.

4. The location or status of personnel must be known throughout the workday.

Operations

1. Current operations are not keeping pace with competitors due to a technological disadvantage.

2. Management is not able to properly oversee operations due to a lack of information.

3. Workers lack information required to operate at their full potential.

4. There is a significant economic, public safety, or crime prevention value that can be gained by improving the system. (Dhawan, 13)

Barriers

1. Geography. Business operations or expansion is hindered by the geographical dispersion of business activities. Key business processes or activities are not being accomplished where they are best performed or most needed. (O'Brien, 414)

2. Cost. Current processes carry significant costs in labor, inventory, operating locations, or travel expenses. (O'Brien, 415)
3. Structure. Current communications capabilities and the existing business structure lack the agility, ability, and information required to support innovative operations and strategic alliances. (O'Brien, 415)

**Information**

1. Information sent to or received from mobile personnel is not timely, current, or frequent enough.

2. Information sent to or received from mobile personnel is not accurate, complete, concise, or relevant enough.

3. Information sent to or received from mobile personnel is not clear, detailed, or presented appropriately

**Lag**

1. The mobile worker cannot quickly complete a transaction while at the remote location because access to information or authorization from a central location is required.

2. Return trips to a remote location or multiple contacts are required to complete a transaction.

3. The continuation of any process is delayed until the mobile worker physically returns to the central business location with the collected information.

**Efficiency**

1. Data is input from paper, input more than once, or not captured at its source.

2. Method of data capture is slow, awkward, or labor intensive.

3. Questions must be re-asked or locations must be revisited because data was not completely or correctly gathered on initial visit due to a mistake or oversight.

4. Work cannot be completed at remote site due to lack of information from the central business location.

5. Travel time is wasted due to inefficient scheduling, dispatching, or the need to return to the home office for further instructions or information.
6. Materials or supplies are wasted by people or machines.

Businesses can decide if mobile computing is an appropriate technology to utilize by analyzing their current operations and performance with respect to the MOBILE framework. If the problem, opportunity, or directive is one that is covered in the MOBILE framework, then mobile computing technology should be seriously investigated as part of the overall solution.

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Technology Will Change

When considering information technology, the only certainty is change. This change has implications for Systems Analysts and other information technology professionals who work closely with technology. The fact is that today's hot technology can be tomorrow's dinosaur. The functionality, technical implementations, and application heuristics of today may not be as applicable in the near future.

New Technologies

Exciting new technologies are being developed that will drastically alter and improve mobile computing capabilities. Two of these technologies are low earth orbit (LEO) satellites and wearable computers. Current LEO satellite developments promise ubiquitous and high-speed network access using extremely small and low power devices. Soon, it will be possible and economical to provide all mobile workers with a connected mode for all mobile computing operations. Advances in microcomputer, display, and natural interface technologies are making the first wave of commercially useful wearable computers possible. These devices are still in the experimental stages, and are not commonplace, but are finding applications in areas like aircraft inspection; where a hands-free operating environment and access to large amounts of information is required. In the future, wearable computers are predicted to replace the myriad of personal electronic devices (computers, cell phone, pagers, tape recorders, and cameras) with an integrated and unobtrusive wearable replacement that merges the user's work space with his or her information space. (Mann, 1998) (Jastrzembski, 1997) The ways in which these types of technologies can be applied to solve problems is only limited by the creativity and skill of the developers.

Adapting to Change
The field of mobile computing is still evolving. Even more advanced and yet unimagined mobile technologies will certainly be discovered. Many of the advances will be evolutionary, but some will be revolutionary. The key to integrating these new technologies into the organizational information system will be forward thinking, adaptability, life-long learning, technical competence, an explorative spirit, and the use of tools such as the MOBILE framework. The result will be hardware, software, and communications systems that are even more mobile and more capable of accomplishing organizational objectives.

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Conclusion

Mobile computing is an important, evolving technology. It enables mobile personnel to effectively communicate and interact with the fixed organizational information system while remaining unconstrained by physical location. Mobile computing may be implemented using many combinations of hardware, software, and communications technologies. The technologies must be carefully selected and the applications designed to achieve the business needs required from the overall organizational information system. The MOBILE framework can assist information technology professionals in determining the applicability of mobile technology to an organizational problem, opportunity, or directive. Mobile computing is a versatile and potentially strategic technology that improves information quality and accessibility, increases operational efficiency, and enhances management effectiveness.

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References


