Theme:

Title:

Construction Field Data Inspection Using Pocket PC Technology

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Abstract: *Construction projects are characterized by the large amount of data that needs to be collected, processed, and exchanged among the different project participants. Collection of construction inspection data, in particular, allows field personnel to monitor project performance with the ultimate goal of improving productivity and lowering costs. Current practices for recording and filing of field inspection data are mainly paper-based. This manual process using paper forms is a time consuming and tedious task. Not only is the clerical expense of this process very high, but also the organization and review of the information commands an inordinate amount of time by a project manager, of which most managers posses very little.*

Continuous evolvement and improvements of the Pocket PC and its hardware/software technologies, including more powerful processors, smaller storage devices, higher quality displays, and wide availability of third party application software, have made it possible for these devices to become stand alone systems with powerful functional capabilities. Because of their high mobility characteristics due to their small size and light weight, Pocket PCs can be used in the construction field to perform various tasks including recording of inspection data. This paper describes an application for automating the collection process of field inspection data using Pocket PCs. The application allows for recording, processing, and distribution of quality compliance inspection information of various tasks performed in the field. The application is developed using HandBase^{TM} database software from DDH Software, Inc. and is implemented using a Compaq iPAQ H3870 Pocket PC.

Keywords: *Pocket PCs, field inspection, pocket databases, Handbase ,wireless*

1.0 Current Techniques in Field Data Collection:

The construction industry is inevitably characterized as one which generates vast amounts of data. Effectively managing such an immense volume of information to insure its accuracy and availability in a timely manner is crucial to the successful completion of any project. Inaccuracies or holes in information can readily lead to project delays, uneconomical decisions, or even the complete failure of a project. It is for these reasons, therefore, that the efficient collection of onsite construction data and the timely communication of that data is such a critical concern to all members of the construction industry [5].

Many different types of construction data are typically collected in the field, often on a daily basis. These different information sets can be categorized as follows:

- Chronological files of project correspondence and memorandums, including RFIs
- Change order and submittal requests
- Quality control and assurance records
- Construction field activity and progress logs
- Resource and inventory logs, including tracking of labours, equipment, and materials

Traditionally, each of these categories of onsite data collection have been recorded through the use of paper forms, a method still commonly used in today's construction industry as well. Once a site representative has collected all information, these forms are usually sent back to the office where they are manually sorted. Additionally, forms can be further processed by copying desired information from multiple forms into one form or even into a computer spreadsheet. A calculator or the spreadsheet program may be used to further analyze the data to produce reports. Some type of filing method for the

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collected information usually follows. Forms are most often categorized into a filing cabinet to be stored ready for retrieval at a later date.

Time spent in collecting, filing, and distributing paper forms in this manual process raises many concerns, however. Not only is the clerical expense of the process very high, but also the organization and review of the information commands an inordinate amount of time by a project manager, of which most project managers possess very little. In response to such concerns, a first attempt to solve this problem is to transfer the information once collected to a computer database where it can be viewed, manipulated, and distributed electronically.

The conceptual model for transforming the manual data processing and filing effort into an automated database management system is a relatively easy concept to understand. Essentially, a computer database is nothing more than an automated version of the manual process, all occurring, however, within a centrally contained environment. For example, like a filing cabinet, a computer database accepts and stores information in a structured format that the user defines. These areas of storage are known as database tables. In addition, as with paper-based forms, the use of a digital form interface in database applications helps facilitate the entry of information into these tables. Specific portions of the stored information can then be retrieved through the use of a query language, and calculations and comparison processing is possible with the support of built in functions. To conclude the process, graphs, charts, and reports can then be formatted and displayed based upon queried results.

Although this second method helps save vast amounts of time in terms of the processing and presentation of data, it does very little to eliminate the use of paper forms altogether. Specifically, this process still requires double manipulation of data, once in the field as well as re-entry of the data in the office. This issue raising additional concerns, for it increases the possibility for typographical errors, causing inconsistencies in information as well as loss of information in some instances.

With the introduction of new and improved Pocket PC technologies in recent years, however, a more complete solution to the problem of duplicate manual entry of data has emerged. Through the use of such devices, portable databases can now be taken to the site in a form small enough to fit in the palm of one's hand. Data can then be digitally recorded the first time without the use of paper forms and then directly transferred to an office PC either through a docking station or through wireless communication, thus eliminating double entry. This process is illustrated in Figure 1.

Obviously, such applications exhibit considerably increased control over data accuracy and efficiency as well as offering a much improved solution to the two most vital concerns in construction: saving time and improving communication. Prototype applications of such fully automated data collection efforts have already become evident in today's construction industry.

1.1 Current State of Knowledge:

Since the early 1990's, the academic and industrial sectors have been investigating the use of pen-based devices, including the recently introduced Pocket PCs, for developing applications used in field data collection. Examples include implementations for schedule progress updating, tools tracking and control, materials management, and tracking of personnel. This section presents a brief overview of some example applications that have been developed in recent years.

McCullouch [1] studied the possible automation of construction data collection with pen-based computers. His study specifically covered employee timekeeping, materials purchasing functions, and a daily report form. A Travelite pen-based device was used in conjunction with EasyTouch software to develop the applications. It was found that pen-based devices have the capability and potential to automate field construction data collection. McCullouch [2] also conducted research to demonstrate the use of pen-based computers in road maintenance operations. Two applications were investigated: sign repair/inventory and crew cards. Problems associated with the operating system of the personal digital assistant (PDA) were first explored. Savings in the time needed for data collection were also identified.

UPDATER[TM] [12] is a Pocket PC application developed for automating the collection of schedule progress data in the field. UPDATER[TM] allows for exchanging schedule information with Primavera Project Planner[®] (P3). Recorded progress information in the field using the Pocket PC can be automatically uploaded to P3 on the desktop for rescheduling and updating. Wickes Lumber [7] developed a mobile version of their desktop application BuilderCentral[TM]. Workers in the field can use the mobile application to view change orders, contracts, purchase orders, construction timelines, to do lists, and material price lists . WorkSafe International [8] developed applications to conduct safety audits
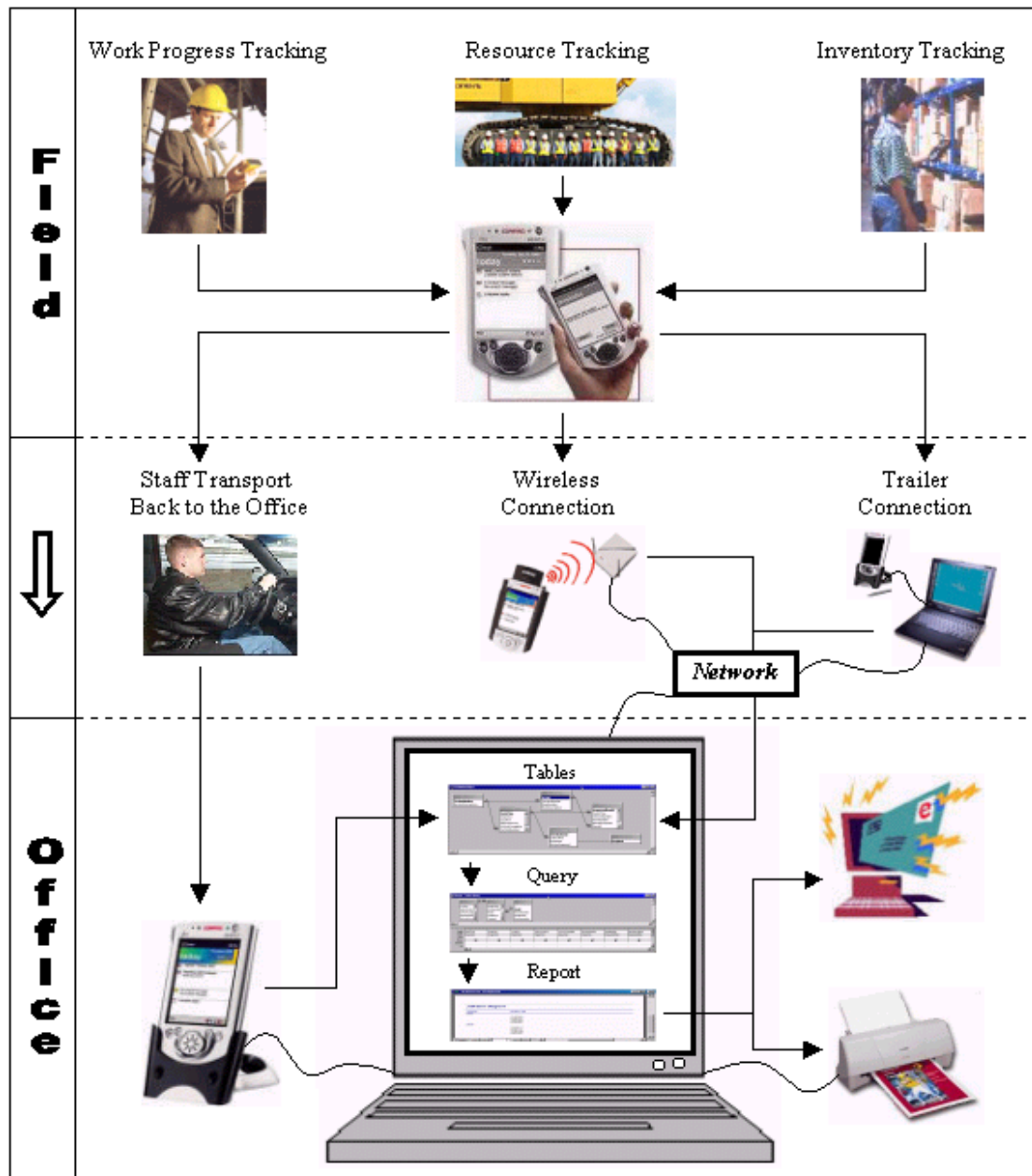
Figure-1: Conceptual implementation of PocketPC applications for automated field data collection

in the construction industry. The main purpose of these applications is to reduce the use of paper sheets and clipboards while performing safety inspections in the field.

ToolTrac[TM] [3,11] is another application designed to interface with handheld units to track and manage tools, including repair history, location, and inventory management. TimeTrac[TM] [3] is designed to keep track of the hours worked by a company's personnel. The application allows for scanning of employees' ids, allowing the employer to keep a record of the hours worked by each employee.

2.0 Example Application:

Construction inspection data allows field personnel to monitor project performance with the ultimate goal of improving productivity and lowering costs. Examples of recorded inspection data include such things as weather conditions, quantity and location of materials delivered and stored on site, quantity and

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quality of work performed, project progress status, accident records, and so on. Construction inspection data has traditionally been recorded on paper forms, sometimes referred to as inspection daily reports or IDRs.

Figure 2 illustrates an example IDR used in this study. The example IDR represents a Quality Control Field Inspection Checklist used by the contractor field personnel to document compliance of inspected work items to quality standards. On any given business day, the contractor's field staff will take a series of these forms to the site and check off whether the associated inspection items are compliant or noncompliant with the contract documents for the project. Notice that each form is primarily categorized by the division or section of construction being inspected (1). In the case of the form in Figure 2 below, the inspector will be inspecting all *Site Utilities* at a specific location. Additionally, each form contains fields for the inspector to enter his or her name, the date upon which the inspection takes place, the location at which the inspection is performed, the name of the subcontractor performing the work, and the percentage of work completed (2). These fields are then followed by a predefined list of items to be inspected (3). To the right of each item, the inspector must indicate whether that item is compliant or non-compliant with the terms of the contract (4). He or she can then make comments about each item if desired. Lastly, at the bottom of the form, the inspector is given a list of distribution options (5). In the list, the inspector can indicate each recipient that should receive a copy of the inspection report. In addition, the inspector can make a request for a specified recipient to take action on all non-compliant items.

Figure-2: Inspection Daily Report (IDR)

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3.0 HandBase Implementation:

To implement the Quality Control Inspection process described above, several portable database solutions were explored for use on the Pocket PC. The research focused on those databases that offered the capability to create a built-in form interface. Table 1 illustrates a comparison analysis of some of the database functionality features explored. Upon testing of the different databases, *HanDBase^TM* , from DDH Software [6], was chosen for the implementation effort.

Functionality	Portable Databases						
	AbcDB	DB Anywhere	HanD Base	Pocket Card	Pocket Database	Sprint DB	Visual CE
Form Elements							
Security Features			X				X
Run Forms on Desktop			X	X			X
Calculated Fields	X		X	X	X	X	X
Date Picker	X	X	X		X	X	X
Multi-page Tabs						X	X
Jump command control	X		X	X		X	X
Lookup controls	X		X	X	X	X	X
Grid (Subform) control	X					X	X
Desktop Connectivity							
ODBC Synchronization (including MS Access)	X	X	X		X	X	X
Beam Records			X		X		X
Text file import / export	X	X	X	X	X	X	X
Finding and Viewing Data							
Query Editor	X	X			X	X	
Single and multi-record viewing	X	X	X	X	X	X	X
Filter / Sort	X	X	X	- / X	X	X	X
"Wild Card" searching	X	X	X	X	X	X	X
Development Environment Features							
Create and edit forms on the desktop			X	X			X
Macro programming	X			X		X	X
Required fields			X		X		X
Range constraints			X				X
Mask edit controls				X			X
Autonumbering					X	X	X
Field indexing	X			X	X		X
Expression Builder	X	X			X	X	
Data Integrity Rules					X		

Table-1: Portable Database Comparison Analysis Chart

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HanDBase[TM] provides a quick and easy solution to the challenge of converting the Quality Control Inspection forms into a portable database format. The most attractive function of the HanDBase application is its ability to be run and or developed on a desktop computer as well as a Pocket PC device. This function is unique to the HanDBase[TM] software, for most other portable databases available today can only be manipulated on the PDA to which they are installed. Having a desktop module, however, saves a considerable amount of time when first developing the application, for the same process is much more tedious if done on a PDA alone. Once a HanDBase[TM] application has been developed on a desktop computer, it can simply be downloaded to a supported device. If the user wishes to make changes to the database on both platforms, the information can be synchronized and combined once connected.

Across both the desktop and Pocket PC modules, HanDBase[TM] provides many advanced functions that allow for dynamic application development. One feature of greatest importance is the software's ability to allow multiple forms to relate to one another by jumping from one form to another. In this way, forms can be kept to a minimal size in order to accommodate the limited screen area of the Pocket PC device. HanDBase[TM] also allows the user to include predefined lists or lookup fields in order to support the use of static field values. This approach not only reduces redundancy in the entry of data, but also ensures that users are only entering data from an acceptable range of values. This is particularly useful in the case of the Quality Control Inspection forms, as there are many static inspection items that must be checked for compliance with each new inspection. These item values can simply be separated out into their own form and then accessed through a lookup control in order to link the information to each compliance issue that it fulfils. Figure 3 illustrates the completed implementation of the Quality Control Inspection forms into a prototyped HanDBase[TM] module on the Pocket PC. This framework was first developed on the desktop module and then download to the device. The same forms can then be used on the Desktop as well.

The entire inspection process can be completed in three separate steps using four developed HanDBase[TM] forms.

Step-1: The process is started by loading the *General Inspection Information Form*. On this form information such as the division or section to be inspected, the inspector name, inspection date, inspection location, subcontractor name, and percentage of work performed are all collected. Each of these fields can either be populated through manual entry of data or through the use of pop-up menus containing a list of acceptable values.

Step-2: Using a command link at the bottom of the form entitled "Inspection Items", the user can jump to the next form in the process. On the resulting form, known as the *Inspection Items Form*, the user can check off the compliance or non-compliance of different inspection items associated with the division being inspected. Since the same items are to be checked with each new inspection, a predefined list of these items is kept in a separate form, categorized by division. In order to reference the list from the *Inspection Items Form*, a link has been established between the two forms in order to allow the user to scroll through the list and return the particular item for which they wish to enter a compliance status. This link is established by clicking on one of the arrows located to the left of any one of the first three fields in the *Inspection Items Form*. This action triggers the lookup control in HanDBase[TM] from which the *Items Form* is subsequently displayed. The list of items can then be filtered to find the particular items associated with the division being inspected. Once a single item is selected, the user is automatically returned to the *Inspection Items Form* where the *Section*, *Item*, and *Description* fields are automatically populated with the values selected. Then, the only remaining task is to indicate whether the item is either compliant or non-compliant and make additional comments if necessary. This process can be repeated for each item to be included in the inspection report.

Step-3: Upon the completion of Step-2, the user must then return to the *General Inspection Information Form*, in order to link to the *Distribution Form* where distribution requests are made. This link is established by the command control found at the bottom of the form entitled "Distribution". In the resulting form, the user chooses from a predefined list of recipients to whom the collected data for the associated inspection should be sent. In addition, the user can indicate whether or not action must be taken by the recipient to follow up on non-compliant items. Step-3 completes the process of entering an inspection using the new HanDBase[TM] application.
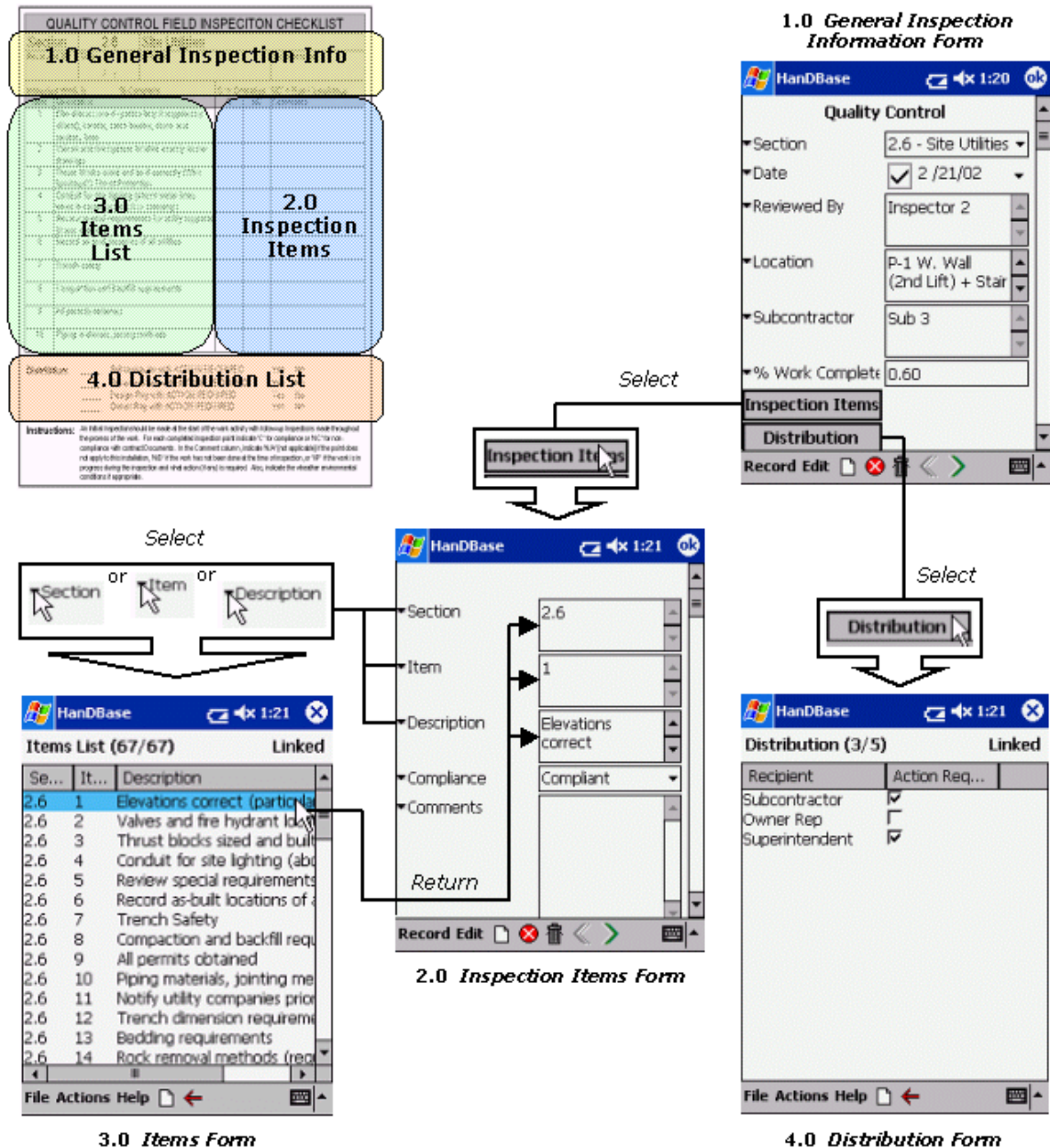
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Figure-3: Quality Control Inspection application for the Pocket PC using HanDBase^{TM}

Overall, the use of these four database forms for collecting inspection data in the field has done much to streamline the process. Typographical errors have been reduced as well as time saved through the use of predefined drop down lists rather than manual entry of data. Also once the data is collected using the Pocket PC in the field, it can simply be uploaded and synchronized with a desktop computer once back at the office. This is done through a two-way synchronization conduit also available from DDH Software. If a user wishes to produce dynamic reports based upon data collected, an additional add-on is available that allows for synchronization with Microsoft Access on the desktop computer. Once data has been transferred to Access, any number of reports can quickly be generated using a built-in query editor and reports wizard. This overall connectivity framework is shown in Figure 4.
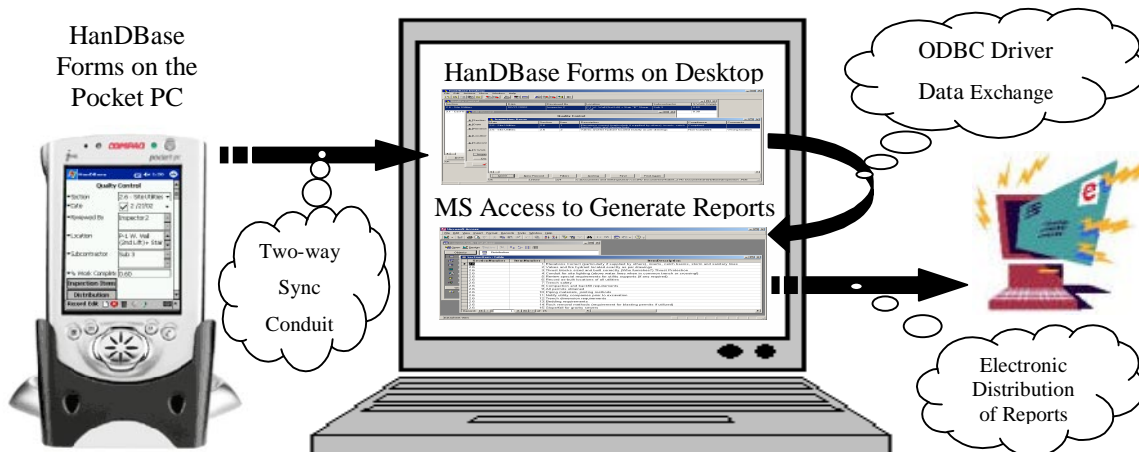
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Figure-4: HanDBase^TM connectivity model

5.0 Conclusion

In summary, automation of the field data collection process can help eliminate double entry of recorded data, which in turn minimizes errors. Other benefits include the reduction of paperwork, automatic generation of reports, and faster distribution of electronic data. Combined, these advantages translate into cost savings through decreased delays and reductions in labor time [4, 9].

It should be pointed out, however, that implementation of new technologies is always accompanied by many challenges. First, there are some problems related to usability and personal usage. One issue to consider when implementing change is management buyout and support. Each user must be open to explore a new technology in order for it to have a chance to succeed and produce benefits in an organization. Another issue to be addressed is the variable learning curve associated with Personnel training in the use of the new technology. Similarly, concerns related to technological needs should be considered. Some of these requirements deal with the type of system selected, storage and retrieval of data, display capabilities, data entry techniques, and ruggedized considerations [10].

Further research at Virginia Tech is currently underway to investigate the use of Pocket PCs with wireless technologies for transmission and distribution of construction data directly from the field.

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