The Value of Handheld Computers in Construction

by

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ABSTRACT: Construction is an information intensive industry in which the accuracy and timeliness of information is paramount. Construction projects can experience extensive delays or rework due to information that is unavailable, inaccurate or simply outdated. Handheld computers (HHC) have the potential to solve some of these problems by providing field workers with accurate, reliable and timely information at the location where it is needed. Thus, HHC's can increase the amount of direct work on a project indirectly by directly decreasing the time spent on support work (such as accessing drawings and sending RFI's) and by reducing idle time. Applying a HHC evaluation method to 6 hypothetical construction field activities (punchlisting, materials tracking, MSDS access, drawing access, RFI's, and quantity surveying) showed that HHC's could potentially save time and improve accuracy at the task and activity levels of a construction project. However, barriers related to the HHC's technological limitations and to the nature of the construction industry must be overcome in order to reap the full benefits of HHC's.

KEYWORDS: field data, handheld computers, material tracking, punchlisting, quantity tracking

1. INTRODUCTION

1.1 Problem Statement

The successful and timely completion of a construction project depends on the accuracy and timeliness of a vast amount of information [1, 2]. Craft foremen spend more than 50% of their time in the field where data is difficult to access outside of the site office. Projects often experience extensive delays or rework due to information that is unavailable, inaccurate or outdated. These delays decrease the overall productivity of the project and increase indirect costs due to schedule delays or direct costs due to rework. The construction industry is in need of tools that can provide accurate, reliable, and timely project information *to* the field and gather and transmit up-to-date project information *from* the field. Handheld computers (HHC) can potentially fulfill these needs.

1.2 Research Objective

The objective of this research was to investigate the potential of HHC's to add value to a construction project through impacts on time and money[2] and to evaluate this potential.

1.3 Hypothesis

HHC's can *indirectly* increase direct work by *directly* decreasing the amount of support work and idle time within an activity (see Figure 1).

1.4 Methodology

The following methods contributed to this research: 1) an extensive literature review was performed; 2) informal interviews with construction contractors and IT companies were administered; 3) a simple, systematic HHC evaluation method was developed; 4) HHC hardware, software and other peripherals with specifications suitable and beneficial to the construction industry were classified; 5) six construction activities in which HHC's were thought to have the greatest potential benefit were identified; and 6) an evaluation method was applied to the above activities as case studies. Details of the above methods and their results are presented in [3, 4].

2. BACKGROUND

A HHC is a self-contained electronic device that fits in the palm of a user's hand and possesses, at a minimum, enough computer processing power to surpass the functions of an electronic personal organizer and to run software

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Other measures such as safety, rework, and productivity are also widely used, however, these are intrinsically related to the above three metrics. Although quality is as important as the other two metrics, apart from measuring factors such as rework and owner satisfaction in an effort to quantify it, quality remains an illusive metric.

applications that can extend its built-in functionality.

The use of HHCs on the construction jobsite was investigated as early as 1992 for field data acquisition [5]. The implementations of HHCs in construction discussed in the literature have focused primarily on project management, schedule management, facility inspection, and field reporting applications [4]. Various construction firms have started using handheld computers on the jobsite for gathering schedule, quality, layout, inspection, and other types of information [6, 7, 8, 9]. However, due to the relative immaturity of HHC use in construction, there have been very few applications in construction that may be considered an accepted way of doing business.

A study of the software applications available on the handheld computer market conducted in 2001 showed that there were approximately 40 titles geared specifically toward the construction industry whereas over 300 titles were commercially available for the health industry alone [4]. This seems to indicate a lack of interest in HHCs on the construction industry's part [10] and a lack of interest in developing applications for the construction industry on the part of the HHC hardware and software manufacturers. Of the top 8 HHC manufacturers contacted by the authors, none indicated that they had identified the construction industry as a differentiated customer for their product development and marketing [4]. In contrast, the manufacturing, white goods, process plants, transportation, healthcare, and other industries have been marked as targets by most of the same manufacturers.

In a survey of 179 construction foremen, Alemany [11] showed that foremen who used computers at work saved time on paperwork and spent more time on supervision. Most of the surveyed foremen expressed a desire to automate time reporting, visualizing and interpreting drawings, job progress recording, and tools and materials management functions [11].

In another survey conducted internally by a large construction company the authors found that supervisors spent between 36 to 50% of their time on paperwork related to employee time keeping and material management functions [5]. The above 2 surveys suggest that using HHCs effectively in the field for employee time keeping and materials management alone could enable foremen to spend more of their time supervising. Consequently, this could have positive impacts on productivity and quality. Similarly, providing construction workers with HHCs that can help them locate tools, equipment, and materials, send requests for information (RFI's), and access relevant schedule information (among other important functions) could potentially allow them to spend more time on direct work and less idle time waiting for answers or needed tools and materials. Other benefits of HHC in construction have also been identified in the literature [6, 12, 13, 14].

3. THE EVALUATION METHOD

Several researchers have proposed formal techniques for evaluating IT in construction [15, 16, 17, 18]; however, none of these techniques deal with HHCs. The justification for using HHCs in the construction industry (and other industries) must account for impacts on the organization's IT infrastructure, the construction processes, and so on [14, 19].

3.1 Basis of the Method

Since most technologies are applied at the task level within a project [20], and their impacts propagate up toward the project level, the evaluation of the suitability of using HHCs on a project must begin at the task level. The HHC evaluation method presented herein breaks down a construction activity hierarchically into a detailed set of final elementary tasks [21], and defines time and cost values for each elementary task [22]. As a means of representing the decomposed task hierarchies, information flow charts (also known as decision-action diagrams, logic diagrams, process flow charts, etc.) are also used [21, 22]. Finally, the evaluation method incorporates a simple accounting process whereby elementary task times and costs are accumulated in order to calculate totals [9].

3.2 The Evaluation Process

The evaluation method first requires that the construction process as it currently exists (i.e., the traditional process) be systematically documented. While the traditional process for the same activity may differ from company to company, the change that would occur in the process when HHCs are introduced is the evaluation method's primary concern.

Once the elementary tasks of the construction activity in question are defined, the next step involves assigning responsibilities for each task. From the list of elementary tasks, a flow chart is created in order to capture the sequence of activities and any feedback loops that may exist. Next, minimum and maximum completion times are assigned to each elementary task to capture the variation that may occur. Although, the times assigned may not be entirely accurate, or may differ between companies and/or projects, as already stated, the differences in task times between the traditional process and the HHC process are the focus. Finally, the possible errors and corresponding delay times for each elementary task are documented.

After describing the traditional activity, the same method is applied to the activity as it would exist with the introduction of HHCs. Depending on the activity, certain tasks are changed, combined, or altogether eliminated. Times are reassigned to each elementary task in the HHC process and the potential errors and associated delays are also adjusted.

The final step in the evaluation process is to estimate the total activity time both with and without the use of a HHC. The time difference between the traditional and HHC processes is estimated to determine whether the use of the HHC might be beneficial to that particular activity. Table 1 shows a blank sample form that is used to record task information for each activity.

4. CASE STUDIES

The HHC evaluation method outlined above was applied to 6 construction field activities: 1) punchlisting, 2) materials tracking, 3) MSDS access, 4) drawing access, 5) RFI's, and 6) quantity tracking. Except for the quantity tracking activity's evaluation (which was based on field observations and interviews) the method was applied to theoretical models of the construction activities involved rather than to actual activities on a construction project. The reader is referred to [3, 4] for detailed results and descriptions of these evaluations. A primary assumption made in the case studies below is that the introduction of HHCs in each activity is coupled with an implementation of the Center for Construction Industry Studies' (CCIS) Tier II strategy [22]. One of the central premises of the Tier II strategy is that field personnel have greater access to information and certain decision-making powers without management's approval.

4.1 Punchlisting

The punchlisting activity lends itself well to HHC implementation because it is a field-based activity whose information is typically collected into a form. In addition, the punchlisting process is cyclical, since it may occur repeatedly throughout the project and some items may be re-listed on the punchlist if not satisfactorily completed [23].

Applying the HHC evaluation method to the punchlisting activity showed that the use of HHCs can theoretically eliminate 14 elementary tasks, which could reduce each punchlisting cycle's time by an estimated 40%. The addition of HHCs to the punchlisting process can also contribute to a 39 to 46% reduction in delay time. Overall, HHCs can potentially reduce delay time by approximately 50 to 70%.

4.2 Materials Tracking

Received materials are often improperly recorded, relocated or not recorded at all. Materials that are lost, misplaced or improperly stored can cause major delays and disruptions on a project and drastically affect project cost and schedule [24]. Handheld computers could help resolve some of these problems by eliminating handwritten notes and the reliance on human memory, and by offering foremen access to up-to-date material information. The materials tracking activity was selected because it is field-based and was identified by foremen as a priority for automation in Alemany's [11] research.

Applying the HHC evaluation method to the materials tracking activity showed that the use of HHCs can potentially eliminate 9 elementary tasks. Approximately 26 to 51% of the overall activity time can also be saved by implementing HHCs and the Tier II strategy in concert.

Overall, the potential delay time saved was estimated to be 88 to 95%, with a majority stemming from the addition of a HHC to the process.

4.3 MSDS Access

The MSDS (Materials Safety Data Sheets) access activity was selected because it requires onsite access to large amounts of textual information, and thus lends itself well to HHC implementation. For this evaluation it was assumed that an online MSDS database could be accessed wirelessly (many are currently publicly available) or stored on the HHC itself.

Applying the HHC evaluation method to this activity showed that 5 elementary tasks can be theoretically eliminated. Implementation of the Tier II strategy eliminated those tasks that required information transfer between different hierarchical levels of the organization; while the addition of HHCs to the process eliminated travel and distribution tasks. A 59 to 71% reduction in overall activity time was estimated. The total reduction in the activity delay time was approximately 65 to 75%.

4.4 Requests for Information (RFI)

The RFI activity was selected for investigation because a large number of inquiries arise at the work face and a means of documenting them and receiving answers quickly can eliminate delays. In addition, the process does not involve much data entry and can take advantage of on-site wireless communications to send and receive information. The new HHC process assumes that the Tier II strategy would allow the foreman to communicate directly with the A/E via e-mail, and that the work in question could be viewed in a digital photograph (sent via e-mail wirelessly from the HHC) by the A/E rather than in person.

Applying the HHC evaluation method to the RFI activity showed that the use of HHCs can theoretically eliminate only one elementary task. However, the new process reduces the activity time by an estimated 16 to 23%. While all of that time is saved due to the use of a HHC, the time saved due to implementation of the Tier II strategy is captured in the delays. The reduction in delay time is key in this activity and is due in large part to the elimination of the hierarchical structure that a traditional RFI follows. In addition, the delay between the time that an RFI is generated and answered is greatly reduced because the architect does not have to travel to the site. The new process can potentially reduce delay time by 83 to 91%.

4.5 Drawing Access

The drawing access activity was chosen because it is a field-based activity that requires only access to information, and therefore does not require any data entry. It is assumed that foremen will have access to a central database to which drawings are regularly uploaded. In addition, the assumption is made that in the new process the Tier II strategy will allow the foreman access to the drawing database directly rather than having to go through a superior.

Applying the HHC evaluation method to the drawing access activity showed that the use of HHCs could potentially eliminate 3 elementary tasks. Using the HHC and the Tier II strategy in this process reduces the activity time by an estimated 70%, primarily due to reductions in travel time and time taken to obtain the information through hierarchical channels. Delays associated with the eliminated tasks are also reduced by an estimated 64 to 72% in this activity. While the overall result shows a reduction in delay time, the issue of the HHCs small screen could prove to have adverse effects on the activity’s productivity.

4.6 Quantity Tracking

The purpose of tracking (or surveying) quantities on a construction project is to measure progress in order to control cost and schedule. The quantity surveyor (or tracker) tracks the quantities of materials that have been installed or that are in various stages of installation. These quantities are essential for controlling a project’s cost, schedule, and quality. Therefore, the accuracy of the quantity survey data is critical [4].

Applying the HHC evaluation method to the quantity tracking activity showed that the use of HHCs eliminated 6 elementary tasks and saved approximately 60% of the overall activity’s time; in addition to improving the accuracy of the data, providing an auditing tool to check takeoff quantities in the field, and reducing the chance of quantity over-reporting.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The use of HHCs in six construction activities was evaluated above. The evaluations showed that time savings at the task and activity levels do not translate directly into project-level time savings and that benefits are more likely to be achieved if HHCs are implemented in multiple activities and projects.

Based on the preliminary experiments with a HHC purchased as part of this research (see [4]), HHCs are currently bound by several key technologies that limit their functionality under certain conditions. These limitations involve HHC features such as screen size, screen visibility, processing capability, and input method. Table 2 presents a list of construction tasks that *are* suited for HHCs, followed by tasks that are *not* suited (these tasks do not take into account HHC's extended range of functions when combined with other peripherals).

This research also found that the barriers to HHC implementation in construction are a result of two factors: 1) the HHC technology's limitations and 2) the construction industry's characteristics. The HHC technology's limitations where discussed. The construction industry barriers consist of the physical jobsite conditions (such as temperature, humidity, dust, etc.) as well as organizational issues such as the industry's fragmentation and low risk tolerance, among others [4].

Handheld computers have many benefits that can improve construction processes. The most significant benefit is perhaps the HHC's ability to provide workers with real-time access to relevant information at the jobsite, and to send real-time information back from the jobsite to the appropriate decision makers. In addition, an HHC's ability to improve the accuracy of the information being exchanged is one of its primary added values in construction. The type of information and the transmission method are some of the issues that must be assessed during the design of an HHC evaluation and implementation strategy.

5.2 Recommendations

The lack of empirical data on HHC performance in construction could be improved through well-documented pilot projects at construction companies and through controlled experimentation with HHCs under simulated environments. In addition, future research should also address HHC hardware issues that constitute barriers to their implementation on construction projects.

6. REFERENCES

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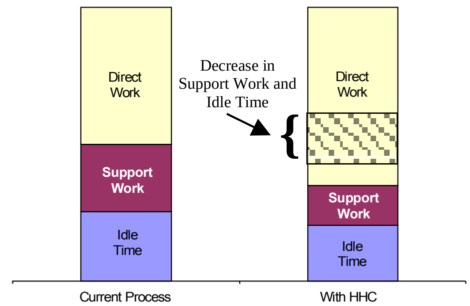

Figure 1. HHC's decrease support work and idle time.

Table 1. An activity task information form

Task ID	Task Description	Labor	Task Time (minutes)		Possible Delay (minutes)		Source of Delay
			min	max	min	max	
10							
20							
30							
40							
…							

Table 2. Tasks for which HHC's *are* and are *not* suited.

#	Tasks that *are* Suited	Example
1	Tasks that require access to large amounts of text information	Reading MSDS sheets, building codes, knowledge base, etc.
2	Tasks that require viewing a small detail of a document	Viewing a close-up of a steel beam connection diagram
3	Tasks that require the entry of binary data	Answering yes/no questions, checking-off items on punch lists
4	Tasks that require the entry of data into a form	Filling-in a safety or equipment usage report, recording material receiving information, etc.
5	Tasks that require instant transfer of small amounts of information to and from a network	Sending and receiving e-mails, looking up the latest material procurement information
#	**Tasks that are *not* Suited**	**Example**
1	Tasks that require computer processing power comparable to that found in desktop computers	Editing a 3-D construction drawings
2	Tasks that require a "big-picture" view of a document	Viewing a drawing or a network schedule
3	Tasks that require a constant (i.e., always on) connection to a computer network	Working with data stored on a mainframe
4	Tasks that require a considerable amount of manual data entry (or writing)	Writing a progress report
5	Tasks that are likely to be performed mostly in direct day light, or under very bright artificial lighting	Working with no roof overhead during the day
6	Tasks that actually put work in place	Nailing, cutting, digging, and etc.