# INCREASING ON-SITE PRODUCTIVITY THROUGH WIRELESS COMPUTER CONTROL

Increasing on-site productivity

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## Abstract

Improving productivity has been a major objective of the building industry, and indeed in all forms of business for many years. The construction process involves many complex processes, which make it inherently difficult to manage and can obviously lead to much inefficiency within the process. It is possible for a wireless communications system to be adapted for use on construction sites in order to improve management control over tasks and communication between parties involved in the project. This feasibility study shows that the implementation of such a system could lead to significant time savings over traditional paper-based management and administration systems.

Keywords: Productivity, Site, Wireless, Control, Construction, Computer, Data

## 1 Introduction

Improving productivity has been a major objective in all forms of business and industry as technological development has accelerated more and more rapidly over the last decade. Computer control has been applied to the manufacturing industry with great success and is being continuously refined, to bring higher efficiencies in design, production and delivery of goods. It is the repetitive nature of the processes within this industry that lend themselves to computer control. The construction industry however, often involves complex, one-off projects, with many variable processes and so requires a more flexible system of control. Applying information technology and control systems to this industry, with its unique nature, requires adaptation of existing technologies to suit its own specific (but not entirely dissimilar) requirements.



*Studies ( Horner et al. 1996) have shown that the potential for increase in labour productivity in the UK construction industry may be more than 25%, and that large inefficiencies arise mainly from interruptions between activities and processes as well as delays within individual operations. These interruptions are often a result of poor planning, insufficient design information and supply-chain problems. A system that could enhance co-ordination and communication whilst providing ready and rapid access to relevant data would go a long way towards reducing many common on-site delays of this nature.*

Attention has recently been focused on regarding construction as a process rather than as a series of discrete functions. It is improving continuity of the construction process that is of greatest importance in the on-going quest for greater efficiency. Integrated computer control systems, which could cover all stages, from the conception and development of a design, through completion of a building, seem to be an obvious choice in aiding this development. This is a huge area of study and this feasibility study report focuses on site processes only, developing a model for computer control, which will incorporate wireless technology in an attempt to smooth the transitions between complex processes and improve general productivity on construction sites. The system will in essence allow traditional office based tasks, access to information and information flow between parties, to be performed virtually anywhere, through a mobile communications system.

## 2 Wireless technology

Wireless Local Area Network (WLAN) technology uses electromagnetic waves (radio or infrared) to communicate information from any location without relying on any physical connection. The data being transmitted is superimposed on the radio carrier so that it can be accurately extracted at the receiving end (http://www.cwc.nus.sg/) WLAN must not be confused with other wireless systems such as mobile phones, and data transmission over cellular or packet radio. These systems require costly infrastructure, provide much lower data rates, and require users to buy bandwidth on time or usage basis. On premise wireless LAN requires no usage fees and provides 100 to 1000 times the data transmission rate (http://www.cwc.nus.sg/).

Mobile communications technology has seen major growth and development over the last few years and continues to advance as on-the-move applications become more widespread. Wireless data technologies have been proven through more than fifty years of application in commerce and by the military. Robust designs of proven WLAN technologies and the limited distance over which signals are required to travel result in connections that are far more robust than cellular phone connections and provide data integrity performance equal or better than wired networking (Hills et al. 1996).

Many construction companies have ‘computerised` in recent years, with most businesses using computers to store information or perform tasks for varying proportions of their operations. A recent survey has showed that 83% of decision makers in the industry have access to a personal computer (Cole 1997). The issue

now is *access* to this information. The availability, ease and speed of access to information and the efficiency with which this can be used is now often what will set one company apart from another. Mobile communication technology is a tool for a potentially more advanced form of communication allowing spoken/written word and image to be sent and accessed more freely than ever before. The possibilities of mobile communications technology have only just begun to be explored as applications for this new technology is gradually realised. For example, Newton mobile computers have already been applied to many small and large businesses and also parts of the healthcare system in both America and France. More comprehensive prototype systems have been tried in the Bellevue police force near Pittsburgh, various hospitals across America, and AEG's Daimler-Benz maintenance and engineering feedback system (for more case studies see web site:http:www.wlana.com). These industries have profited from productivity gains of using hand-held terminals and notebooks to access and transmit real-time information to centralised hosts for processing.

"*The ability to access information on demand at any location confers distinct competitive advantage on users in an increasingly mobile world. As users become more dependant on this ability, the span of access of data repositories will have to grow. The increasing social acceptance of the home as a place of work is a further impetus to the development of mechanisms for mobile information access*." Satyanrayanan (1996)

## 3 A construction site WLAN model

A construction site is usually contained in a small enough area to make use of a high-speed wireless WAN, allowing wireless devices to communicate rapidly from any part of the site. It is also possible to imagine a network structure which would link all parties involved in the construction process from architect, to main contractor, to sub-contractor and even to materials suppliers, providing a potential level of co-ordination and communication that has never been seen before. A radio communications controller linked to base stations located around the site would manage data traffic and also provide the link to the host computer (located in the site office). The host computer, hard wired into the LAN (e.g. BT Construct system) would be able to provide access to parties such as architects, quantity surveyors, engineers, etc. This network would allow direct access to all available design and construction data, through use of a mobile device anywhere on the site. Fig. 1 illustrates the proposed site infrastructure for a WLAN system. End users access the WLAN through wireless LAN adapters that are implemented as PC cards in notebook computers, ISA or PCI cards in desktop computers, or integrated within hand-held computers that can read bar codes and smart cards. As well as providing increased information access and management for use on site, the system should be able to facilitate all day-to-day construction tasks such as logging materials delivered, checking against materials specified and ordered. This would be achieved through a database, contained on the host computer being automatically updated remotely by a handled device as deliveries and other important data are entered by site staff**.** This

system would eliminate much paper work, storage and retrieval time, checking and validating by hand. Material ordering could be co-ordinated by the host computer drawing on information within its database on programming, state of work in progress, material specifications.

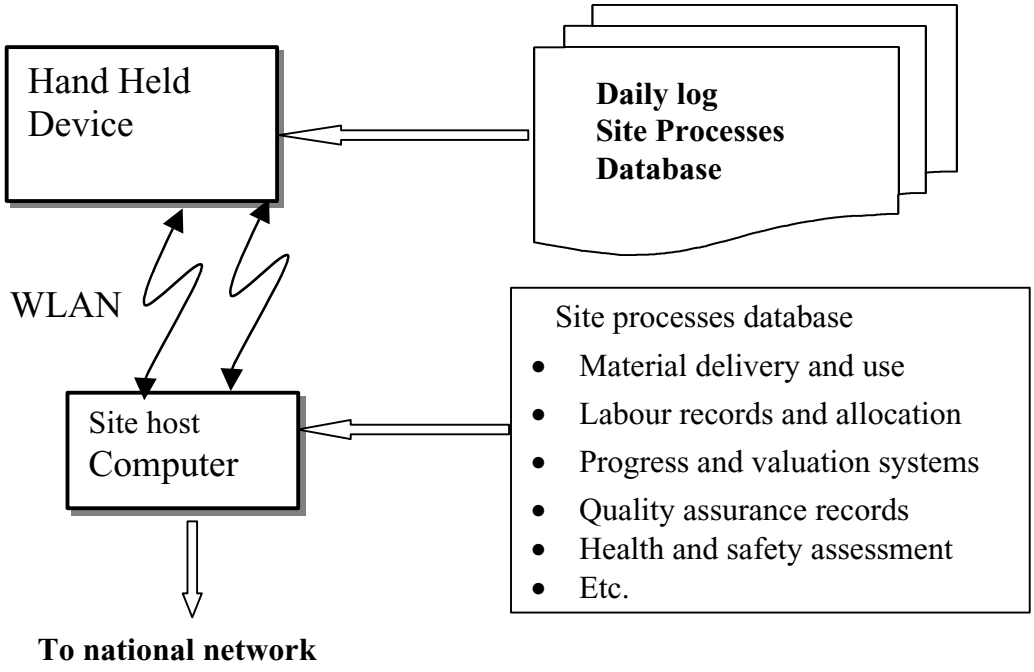


**Fig. 1: Site infrastructure for a WLAN system**

An intelligent materials ordering system could do more than just aid the administrative process, but also prompt, check and advise, allowing much tighter resources management from site and head office to see if site is on progress. Deliveries could be logged using wireless hand-held devices, and information sent to the host computer which would check against the ordered material, record delivery and trigger the payment process. As this technology becomes more common materials could be labelled with easily accessible bar codes for even more efficient scanning and logging as they arrive on site. Availability of up-to-date design information, control over actual work in progress and collection and recording of information relating to work in progress are important factors in maintaining quality construction. Collecting, co-ordinating and processing information on site processes is a relatively lengthy process and involves several stages of recording, checking and processing which often leads to unnecessary errors. A mobile wireless network could allow immediate access to constantly updated design information, and allow users to remotely access and log data, reducing delays caused by waiting for information and manual recording of site information.

The site system would hold a database of all relevant plans and performance specifications relating to the particular project. Any variations, new drawings, design information etc. are logged and updated automatically by communication with the consultant through the LAN. The site system database can be checked remotely by a hand-held device, so that users can check data such as measurements, quality assurance documents, health and safety assessment forms and specifications, and other relevant site documentation, ensuring that work in progress conforms to specifications. Logging of operatives on site, day work sheets, adherence to programme, notes to consultants and personal reminder notes could all be entered via a hand held device from anywhere on site. The benefits for a busy site co-ordinator are obvious, with speed of access-to, and recording-of information made faster and easier, reducing delays and mistakes. Additions to the system to improve it's usefulness could include audible reminder notes and pre-set prompts linked with the site-diary, calendar and construction programming functions. Survey data obtained using a computerised system equipped with GPS (global positioning system) could be used to facilitate setting-out through integration with the wireless computer network. Regular valuations are essential both for the contractor (in order to calculate cash flow) and for monthly payment by the client to the contractor. Computerisation of the interim certificate system, allowing data regarding payment to be sent to various parties electronically, should increase control over, and speed up the monthly payment process. A computerised measuring process would also be possible by way of a hand held device. Using this device the quantity surveyor would be able to walk around site, entering progress data on the spot through the use of database and plan-view software. The system possibilities are endless.

## 4 Field survey

In order to estimate how useful a wireless communications system might be in use on construction sites, a questionnaire has been used to try to gauge the savings that might be made in certain areas, were it to be installed, and some factors which might influence the choice of the system over traditional methods. The questionnaire was sent to fifty construction companies, both large and small in an effort to quantify how much time is spent on site administration processes which might be benefited by the system, and any possible increases in efficiency which may result from a wireless-based approach.

The questionnaire posed three questions. The first question required the respondents to estimate how much time was spent on--site each day performing the following operations:

- materials ordering
- checking materials on delivery
- invoice validation and processing
- recording and processing day work
- handling and processing variations
- correspondence with consultants

- correspondence with sub-contractors
- waiting for design information

The recipients were asked to indicate for each operation, a time, which they felt appropriately described how much time was taken up on-site. Choices rose in increments from 10 minutes to 5 hours per day. The second question required recipients to estimate how much time they considered the system could save. The same operations were listed as in question one, but this time the answer was expressed as a percentage time saving. Choices were between 0 and 100% with a 'don't know' option included. The estimated productivity improvements are based on a limited broad knowledge of the system with a limited idea of its scope. Question three required recipients to rate the following factors in order of importance in the choice of a wireless communications system over a more traditional site administration approach. It was hoped that this would give some idea of the viability of the system while at the same time trying to gauge how willing contractors would be to implement change.

- set-up costs
- training and familiarisation
- reduction of mistakes and errors
- efficient information storage and retrieval
- quick, on-the-spot access to construction information and records
- intelligent construction programming and materials handling
- overall productivity gains
- potential for easier and improved communication between consultants sub contractors, etc.
- potential for long term competitive advantage

## 5 Survey results

Estimated duration and productivity improvement is depicted for each operation. From this, typical duration and time savings are estimated for each operation. The findings of the survey are as follows:

### *5.*1 Materials ordering

Figure 2 shows that estimations of time spent ordering materials each day varies from 10 minutes to 3 hours but by far the greatest agreement was in the 30 minute bracket. Estimated time saving of between 25-50% suggest that 5-15 minutes would be a typical saving each day under a mobile communications system.

### 5.2 Checking materials on delivery

Figure 2 shows that estimated time spent checking materials on delivery is very similar to answers given for materials ordering i.e. 30 minutes average. However, estimated time saving is viewed by most to be greater using bar-coding systems etc. Savings would seem to be in the order of 15-20 minutes per day.

### 5.3 Invoice validation and processing

Some respondents claimed invoice validation. was performed at head office and therefore not relevant. However, over half of the respondents estimated a 25% productivity improvement giving a saving of around 15-30 minutes per day as indicated by Fig. 2 and 3.

### 5.4 Handling and processing variations

Estimated duration range from 10 minutes to two hours as shown in figure 2. A large proportion of respondents estimated a 25% productivity saving which suggests time savings of between around 10-30 minutes per day (see Fig. 3).

### 5.5 Recording and processing daywork

Results show estimations of between 10 minutes and one hour for administration involving daywork. Figure 3 shows a typical time saving of 10% suggesting improved efficiencies in the order of 5-15 minutes per day.

### 5.6 Correspondence with sub-contractors

The majority of answers as represented by figure 2, indicate that time spent on correspondence with subcontractors is between one and two hours per day. An average estimated saving of 10-25% suggests savings of around 20 minutes per day.

### 5.7 Correspondence with consultants

Results for estimation of time spent and possible savings in correspondence with consultants is very similar to that for correspondence with sub-contractors. Typical time saving could be around 10-20 minutes per day (see Fig. 2 and 3).

### 5.8 Waiting for design information

Estimation of delays relating to inadequate design information range from 10 minutes to 2 hours per day but indicate that little improvement is expected in this figure. A large number of answers indicate 0% improvement but others suggest that the potential for improvement could be as much as 75%. An estimated 15minute saving per day is a fair representation of the results.

## 6 Implications

It is obvious from these results that the marginal time savings in each activity represent a substantial collective daily time saving and an even more impressive saving when projected over a year as has been represented in Table1. Opinions about how effective the system may prove to be are varied amongst the recipients of the questionnaire but whatever the magnitude of the saving may be, the cumulative effect over time would appear to be significant (an average of 40 days per savings).

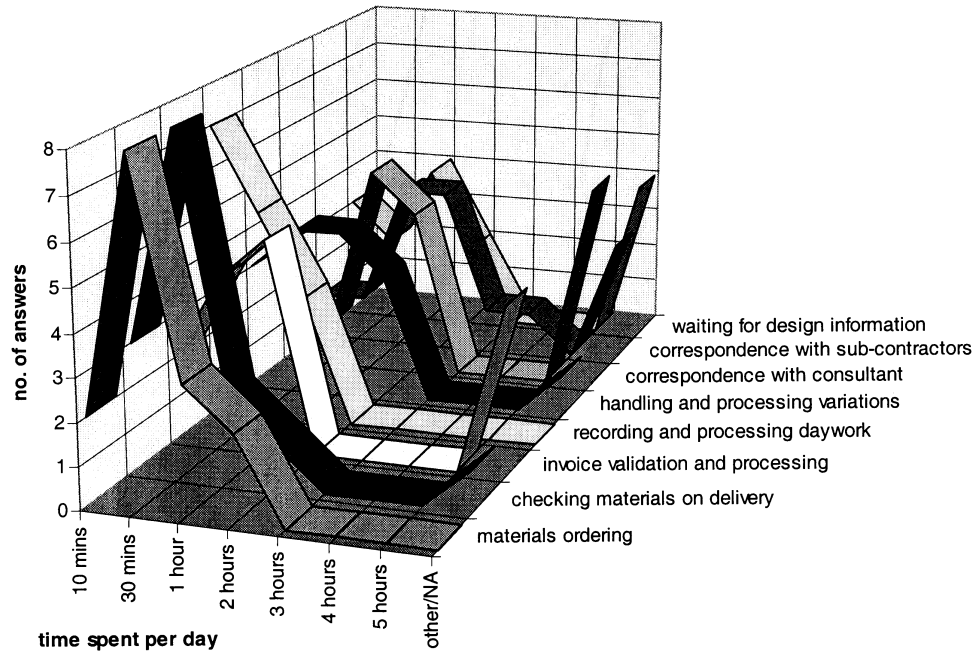


**Fig. 2: Time spent on site**

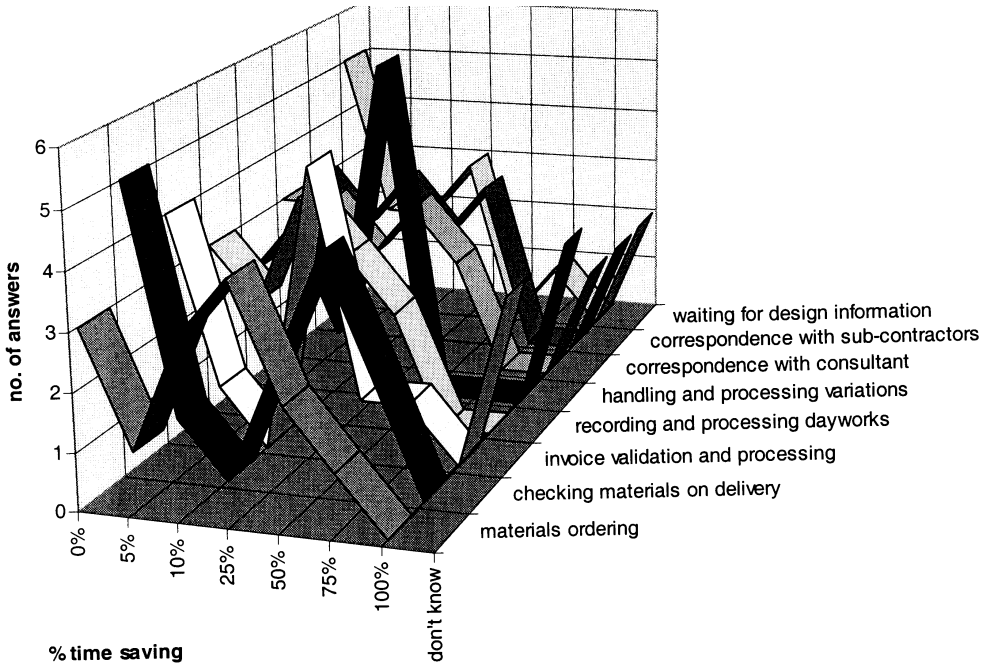


**Fig. 3: Estimated productivity improvements**

**Table 1: Estimated productivity improvement**

| | Max. time saving | Avg. time saving | Weekly time saving (mins.) | | Annual time saving (mins.) | |
|---|---|---|---|---|---|---|
| | minutes/day | minutes/day | max | average | max | average |
| Materials Handling | 15 | 3 | 82.5 | 16.5 | 4042.5 | 808.5 |
| Checking materials on delivery | 15 | 5 | 82.5 | 27.5 | 4042.5 | 1347.5 |
| Invoice validation and processing | 30 | 15 | 165 | 82.5 | 8085 | 4042.5 |
| Handling and processing variations | 30 | 10 | 165 | 55 | 8085 | 2695 |
| Recording and processing daywork | 30 | 10 | 165 | 55 | 8085 | 2695 |
| Correspondence with sub-contractors | 60 | 20 | 330 | 110 | 16170 | 5390 |
| Correspondence with consultants | 30 | 10 | 165 | 55 | 8085 | 2695 |
| Waiting for design information | 60 | 15 | 330 | 82.5 | 16170 | 4042.5 |
| Total minutes | 270 | 88 | 1485 | 484 | 72765 | 23716 |
| Total hours | 4.50 | 1.47 | 24.75 | 8.07 | 1212.75 | 395.27 |
| **Total days** | | | | | **121.28** | **39.53** |

Note: calculations based on a 10 hours/day, 5.5 days/week and 49 weeks/year

## 7 Perceptions of the system

The third question was included in the questionnaire in an attempt to try to gauge how ready contractors might be to install such a wireless communications network on site in practice. Fig. 4 shows that the main factors that contractors are likely to take into consideration are long term competitive advantage and storage & retrieval capabilities, with factors such as set-up costs appearing down the list. Opinions vary mainly according to company size obviously, as the economics of such a move will work in the favour of larger contractors.

## 8 Conclusion

The field survey results demonstrated that a wireless-based approach would be both possible and beneficial to the construction industry. The results of the survey indicate that *time savings in the order of 40 - 120 days per year* could be possible if the system was to be applied. Above all these results show that the use of this new communications technology could be of great benefit to the industry heralding a leap forward in communication during the construction process and that such technology should not be discredited or ignored.

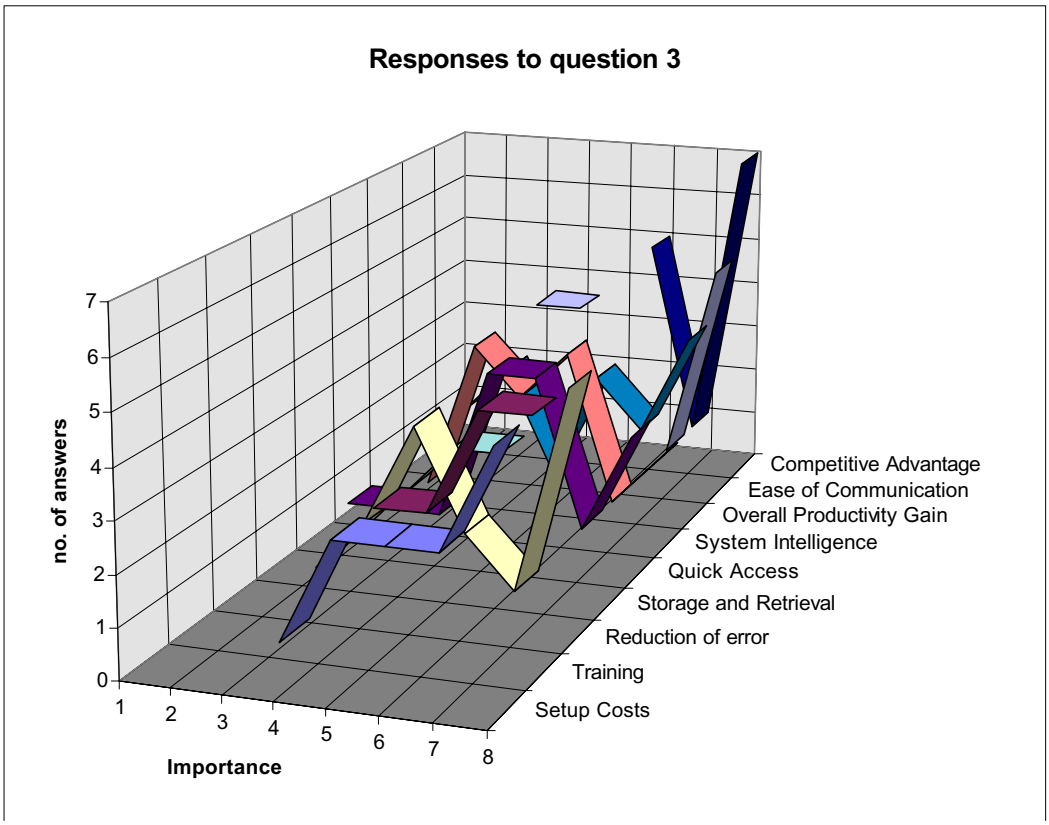


**Fig. 4 Factors considered in implementing wireless technology**

## 9 Reference


Centre for wireless communication http://www.cwc.nus.sg/cwcdocs/intro.html

Cole, M. (1997), Dawn of the electronic age, Construction Computing, Issue No:57, July, PP12-13.

Hills, A. and Johnson, D. B., (1996), Wireless Data Network Infrastructure at Carnegie Mellon University, IEEE Personal Communications February

SaTyanarayana, M., (1996), Mobile Information Access IEEE Personal Communications

Wireless ATM LAN http://www.cwc.nus.edu.sg/cwcdocs/page8.html

Horner, R., Duff, R., Rainsberry, A., (1996**),** Improving Construction Productivity - A practical demonstration of a process-based approach, 2nd International Congress on Construction Productivity in Construction-International Experiences