

# **Modeling Computer Integrated Construction Site Management**

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By

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From

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**June 2003**

## ***Declaration***

This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

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**Jae Ho Lee**  
**June 2003**

# Abstract

Construction is one of the most information-dependent industries compared to other sectors. Computers have been used to improve the efficiency of management in most businesses including the construction industry. Treating information efficiently is the key to maintaining an edge over competitors and for success in business. However, in order to succeed, companies must choose a management system that is most suited to their operations. The difficulty about computerization in civil engineering is that the construction industry does not have trained IT experts with Civil engineering or Management background. Although there are many computer applications for project management, almost all the applications required some form of manual modification for updating information.

In a construction project, time and accurate information is vitally important in order to accomplish scheduled completion. A small change in plan costs money and time in both the traditional methods as well as current IT applications. The main reason is that there is no direct link between the head office and the regional site office and there is no “quick” link between site office and site engineers who are out in the field for most of the time. This study proposes the design of an information transfer system to improve construction site management. A Web-based Construction Site Management system called “WCSM” will be developed. WCSM incorporates some major features including: Integration of Web technology and mobile computing into construction site management and automatic project schedule updates.

The performance of WCSM is evaluated through virtual simulations, and comparisons with other relevant applications are reported. These evaluations showed that WCSM required significantly less time, for initial project set up and modifications during project implementation, when compared to MS Project and Micro Planner.

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# Terminology

AP	Access Point
CAD	Computer Aided Drafting
CIC	Computer Integrated Construction
CIM	Computer Integrated Manufacturing
DWF	Drawing Web Format
ERP	Enterprise Resource Planning
FEA	Finite Element Analysis
GUI	Graphic User Interface
HTML	Hyper Text Markup Language
IFC	Industry Foundation Classes
IS	Information System
IT	Information Technology
MUI	Multimedia User Interface
PAN	Wireless Personal area Network
TCP	Transmission Control Protocol
UMTS	Universal Mobile Telecommunication System
VR	Virtual Reality
WAP	Wireless Application Protocol
WCSM	Web-based Construction Site Management
WML	Wireless Markup Language
XML	Extensible Markup Language

# Chapter 1

## Introduction

---

### 1.1. Background

Information Technology (IT) and Information System (IS) has been widely applied across many industry sectors in order to increase their profit and competitiveness and to reduce unnecessary project costs. Basically, The Oxford Concise English Dictionary defines IT as ‘the study and use of systems for sorting, retrieving and sending information’. Also, IT is defined as “the use of electronic machines and programs for the processing, storage, transfer and presentation of information” (Bjork, 1999).

Use of IT and related IS have positive and negative effects, but there are more advantages than disadvantages, when it is applied to the construction industry sectors. The advantages of using IS are to improve productivity and time efficiency in conjunction with cost savings. The question is how to develop a suitable IS, how to apply on a specific project and how system operators can use it most efficiently.

During the past decade, the use of IT for information management has been investigated and many researchers reported that it will deliver huge business benefits. Compared with other industry sectors, computerised current applications in construction are not very advanced (Nam and Tatum, 1992; Tucker et al. 1994). There are few reasons for the slow adoption of IS in construction companies. He emphasised that most of the construction company do not have the IT-based environment for communications of all project participants (Tucker et al. 1994). However construction industry has traditionally been slow to accept IT. Recently, managers and clients have recognised the importance of IT-

based IS and are prepared to adopt it. Time and cost can be saved, when IS replaces traditional approaches.

Construction project management is the process of planning schedule, organising, managing a construction tasks and resources, etc. normally several thousands of information, which included document, drawing and other files. Most companies use some part of computerised application for their projects, but there is no efficient communication tool for the whole construction jobsite process. From this perspective, this study will focus on construction jobsite efficiency, such as establishing construction job scheduling, automatic updating and monitoring of construction progress. Many project related application has been developed to bring a huge advantage for this kind of management. However, this study will add Web-based applications with mobile computing to improve efficiency of project control.

## **1.2. Modeling Construction Site Management System**

IT has been used efficiently to support processing and analysing large volumes of information quickly, accurately and economically. The quality of construction project management decisions depends on quality of information available, ability to access the information effectively.

This study proposes the design of a construction job scheduling system to improve jobsite management. A system called “WCSM (Web-based Construction Site Management system)” is developed, that comprises some major features such as, the implementation of Web technology into site management and automatic project schedule update.

WCSM is based on existing IT technologies, and developed for Web and wireless mobile computing environments for application on construction site management. Figure 1.1 shows the conceptual design and life cycle of WCSM for construction site management. Figure 1.1 (a) shows that WCSM is a wireless Web-based mobile device solution to provide better construction site management. Figure 1.1 (b), shows the life-cycle of WCSM and the investment to set up the system on site. Later on companies can upgrade the system to keep up with more site control and the current technology or their competitors. The potential advantage of using wireless devices is the superiority of mobility that helps WCSM. Site engineer will check all construction activities and therefore manual modification by job schedule manager is not required. The results of

field work can not be directly monitored at the office. Use of wireless devices gives a new contribution in this area. WCSM provides quick a link between construction field and office.

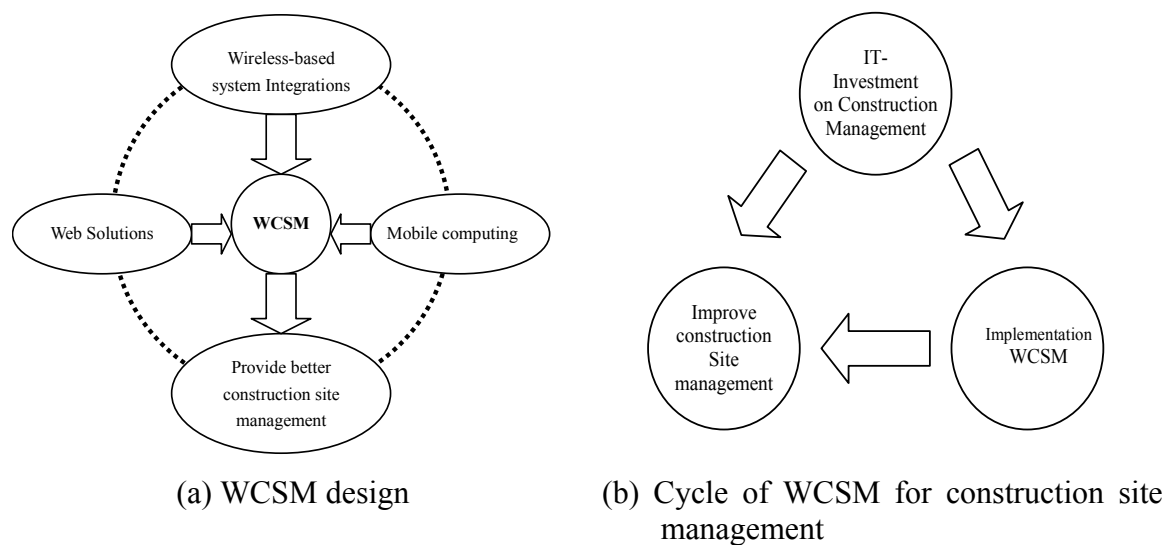


Figure 1.1 Conceptual design and life cycle of WCSM

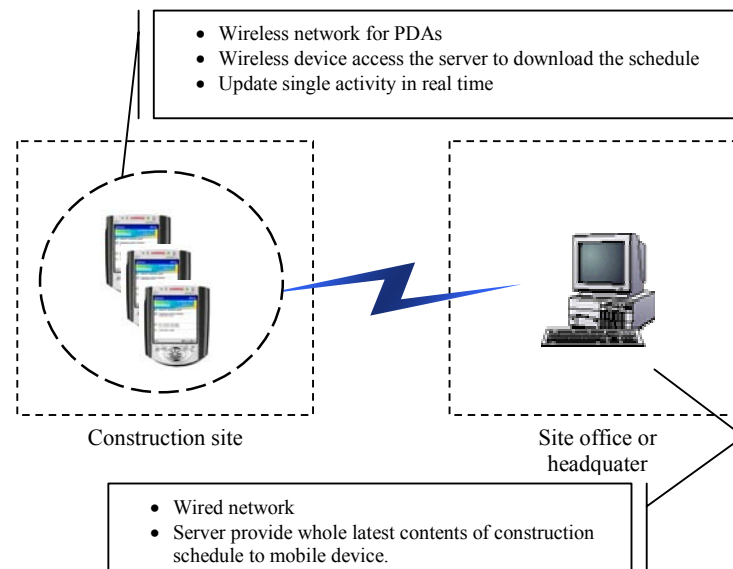


Figure 1.2 WCSM mobile solutions for site management

The mobile solution of WCSM is shown in Figure 1.2. Mobile device will get daily-information in Web format from server through wireless network. Before using WCSM system, system administrator or schedule manager must input the entire detailed information such as initial construction schedule and other necessary information using a PC in site office or in head office, which is connected with the web server through wired network. This initial modeling will be coordinated by DIGINICS (<http://www.diginics.com>). This IT-company will develop hardware networking of this model, based on its modeled Web-design.

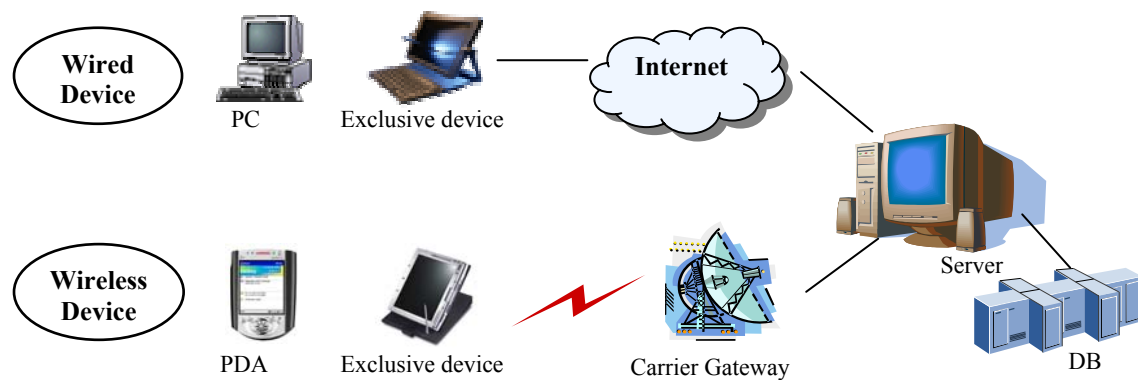


Figure 1.3 Network Stream of WCSM

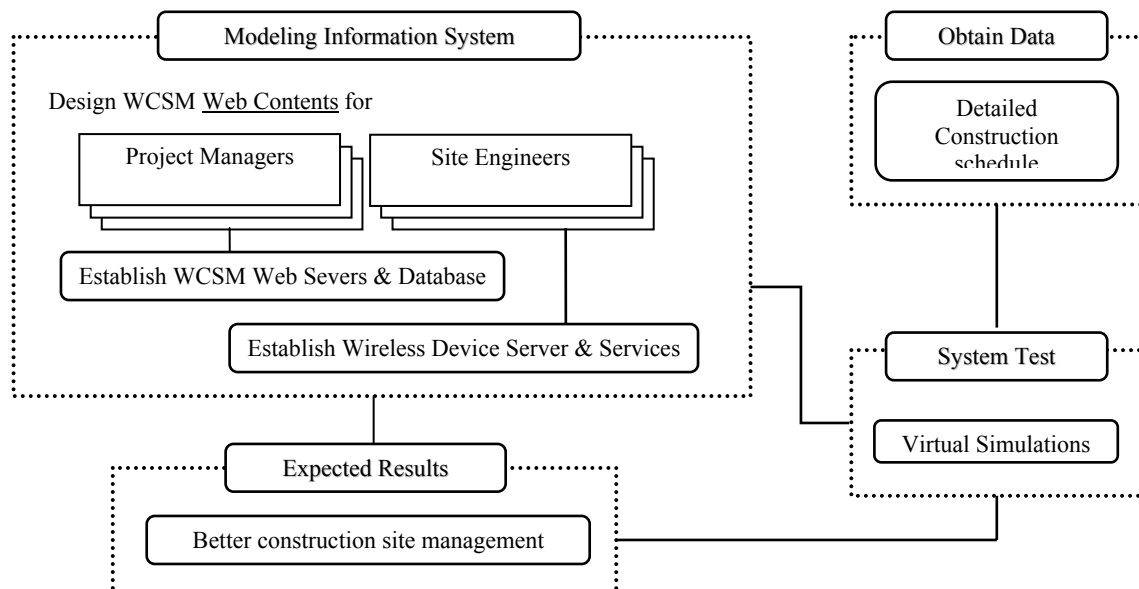


Figure 1.4 Development of WCSM

The technical component of Computer Integrated Construction (CIC) implementation requires good organisation between computer systems. However, the difficulties lie in establishing common standards, construction Process and project management skills (Gibson and Bell, 1992). There are many factors involved in designing Web-based Information System, such as planning of the project, construction process, cost, material and human resource control etc. WCSM design will focus on project planning.

### **1.3. Aims**

There is no “Quick Information Connection” to directly transfer the information between project site and management office. The main advantage of a Web-based mobile computing jobsite management system is to provide information communication tools between those two points. The aims can be summarised as follows.

1. Establish an Information System for construction jobsite management.
2. Adopt mobile computing technologies.
3. Providing better communication at the construction site.
4. Reduce modification time for rescheduling of the construction task plan.

In order to verify the efficiency of the WCSM, system it was tested by virtual simulation, based on a previously constructed project.

### **1.4. Outline of Report**

The construction industry has adopted new technologies in the past, but not many involving IT. The application of IT has only been adopted by very few construction contractors. The main reason is that there are not many IT trained professionals with civil engineering or management background. Implementation of construction IT systems will provide new solutions, which will help to improve the control of construction projects.

A literature review of the practical use of Information Technologies (ITs) and Information System (IS) in construction industries will be presented in chapter 2. Current situation of computerised information in construction industry will also be reviewed. A



Web-based project management system and its model as well as a mobile computing solution for the construction industry will also be introduced.

Chapter 3 deals with modeling a WCSM. This chapter covers the features in the design of the WCSM and introduces contents of design.

Chapter 4 deals with testing and analysis of WCSM. This chapter presents how test data was generated and how tests were conducted. Test results are evaluated for comparison of performances with other models.

Finally, Chapter 5 consists of a summary and conclusion of this MPhil study and recommendation for further study.

## Chapter 2

# Information Management in the Construction Industry Using Information Technology - Literature Review

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More than 30 years ago, Champion (1967) wrote that *"One of the most common problems in relation to the use of computers generally in the building industry is that of finding a satisfactory coding system for information. Whereas individual firms can quite easily devise their own coding systems, the use of computer techniques throughout the industry as a whole will depend to a large extent on all parties agreeing on one generally accepted coding system. One of the difficulties is that different sections of the industry may require different forms of coding; what is ideal for the quantity surveyor for producing Bills may not be satisfactory for the architect for his own use, and vice versa"*. However, after over 30 years, the development and research of construction Information Technology has still been very slow and hesitant to adopt it.

The construction industry has been addressing the problem of how to get benefit from increased integration across construction life-cycle through the use of ITs. Many industries have taken advantage of new technologies. The changes in information management are defined under 10 categories by Tapscott (1995). He has characterised the new economy along the following terms. ① From analog to digital; ② Traditional semiconductor to microprocessor technology; ③ Host to client / Server computing; ④

Garden path bandwidth to information superhighway; ⑤ Poor access device to information appliance; ⑥ Separated data, text and images to multimedia; ⑦ Priority to open system; ⑧ Poor systems to intelligent networks; ⑨ Craft to object computing; ⑩ GUI (Graphic User Interface) to MUI (Multimedia User Interface) and VR (Virtual Reality)

The communication of project information between designers and contractors traditionally has been mainly based on paper documents (Luiten et al.,1998). The demand for improving project communication is a major issue in the construction industry. In order to address this issue, many construction organisations are strategically investing large amounts of money in IT to obtain competitive advantage (Betts, 1999). However, many of them are disappointed with the results of their Information System (IS) due to the difficulty in measuring Business Process Re-engineering (BPR) before the implementation of system. Recently, researchers have attempted to evaluate IT-induced improvement on construction project, such as empirical investigation about user's perceptions of a web-based tool used to instantly share and communicate project information between project participants (Mohamed and Stewart, 2003).

The current state of the use of IT applications in construction industry is gradually increasing, which means most construction companies perceive the use of its efficiency and manpower saving for planning, organising and controlling of entire project. The application of IT has only been deployed by very few construction contractors. Use of ITs as communication tools in construction has been much advantageous to deal and transfer the information more effectively and accurately during the construction process, but most construction industries still use traditional information handling methods or part of IT applications. Using IT in information handling, storage and exchange of techniques can be the most important key factor that leads to success or failure of that particular construction project (Tam, 1999). However, normally contractors recognise that IT can help to cut project costs but IT applications cannot help increase turnovers or competitiveness. The reason is that IT has not yet been sufficiently developed to control cost which is due to the lack of IT knowledge in construction staff (Mak, 2001). However, Construction Information Technology has recently been involved in maximising the integrated utilisation of information system throughout the entire life cycle of the project. Construction companies have many reasons for hesitating to invest a lot of initial setting-up costs without guarantees on return.

Most construction industries provide traditional form of information such as detailed drawings and photos, budget reports, cost and risk analysis sheets, contract documents, planning schedules etc. The amount of information generated and exchanged during project period is enormous even for a small size project (Tam, 1999). The time and accurate information is vitally important in order to accomplish scheduled physical activities. A small change in plan costs money and time in traditional methods and current IT applications for the construction jobsite management. The main reason is that there is no direct link between the head office and the regional site office as well as there is no “quick” link between site office and site engineers who are out in the field for most of time. The methods and tools of communication cannot be ignored in construction projects. Even company using IS for their project, system still needs to manually input modified information in order to update the project information. Bad communication and inaccurate information between engineers and site office can result in delay to the project deadline, endurable construction, loss of time, costs etc.

There are two sets of topics that are related with Construction IT (Turk, 1998). First, technology is focused on several civil engineering disciplines such as product modeling, integration and concurrent engineering. Second, life-cycle phases are issued in construction documentation, management and economics. As mentioned in chapter 1, modeling computer integrated construction site management that should be included into first categories of Turk’s opinions.

This literature review is going to mainly deal with information management for construction industry using Information Technologies, comparisons between traditional methods, the trend of IT usage in the real field through conducted survey results and benefits expected.

## **2.1. Early Development of IT Solutions for Construction Industry**

The World Wide Web (WWW, W3 or Web) was introduced in 1993. It is a graphically-based tool for sharing information such as text, full colour graphic, photo, audio and video. The electronic web pages are more accessible than printed pages, and can be accessed 24 hours and provide the fastest way to access information or to promote commercial services or products. Currently, use of Internet is becoming a huge network

of millions of computer hosts from many countries and organisations and communicating via a common set of protocols.

The early stage of concept of Computer Integrated Construction (CIC) is mainly derived from manufacturing industry such as Computer Integrated Manufacturing (CIM) (Sanvido and Medeiros, 1990). It refers to the integrated information for the technical and operational tasks of an industrial enterprise. This good example of define CIC as being better use of computer technologies to integrate the management, planning, design, etc. In order to efficiently use of management tools system has to be designed logical and systematic with real field situations. Planning an IT-based solution for construction management has no typical formula (Miyatake and Kanggari, 1993).

Fergusson (1993) has investigated the integration of quality aspects in an industrial facility and has proposed three dimension of computer integration such as Industry functions (eg., planning, design, manufacturing, construction and operation), disciplines (eg., architecture, mechanical, etc.) and time. According to this previous research, modelling a WCSM will focus on “time efficiency” for construction jobsite management. The early implementation of computer technology for the construction industry has been used to analyse and synthesise the information. For example, during 1970s and 1980s, the first application was introduced such as Finite Element Analysis (FEA) and Computer Aided Drafting (CAD) software. These applications have changed the way in which structures are calculated and drawn. Also, Fruchter expects using Internet-based application together with CAD will improve the design step in construction progress (Fruchter et al., 1996).

The early stage of construction life-cycle, such as specific requirements, inspection, feasibility, design and planning, is focused on the processing of information. During a construction project, the process is broken into several sub-processes, which are related with other sub-processes, due to its complexity. Bjork (1996) emphasised two major types of processes such as material and information processes. Also, Turk (1997) has re-defined information and material processes. Figure 2.1 shows the period of material production and construction process and generation of information. IT has been used for this material process for sorting information from raw resources.

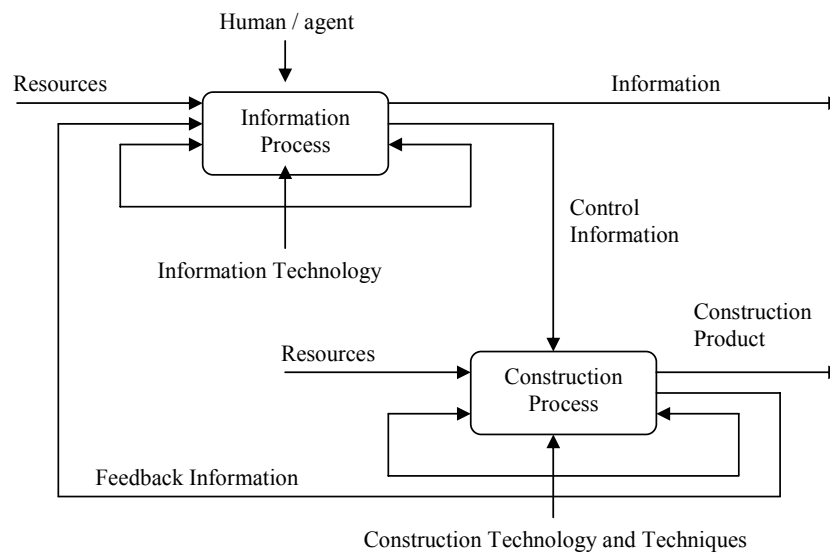


Figure 2.1. Information and Material Processes (Turk, 1997)

Processing information follows several steps such as find, retrieve, store, use, store, and use in order to access to exact and accurate information within shortest time (Turk, 1997). Also, Turk summarised the traditional and IT supported technologies used in the construction information processes in Table 2.1, by having the aspects of scope, actors and time. Scope is directly related with project, company specification, industry wide information and general information. Actors are related among man, application and machine.

Table 2.1 Traditional and IT supported technologies (Turk, 1997)

	Item	Traditional Technology	Information Technology supported
Scope	Project	Drafts, folders	Document management, product and process models.
	Company	Archive, microfilm	Data warehouse
	Country	Library, building regulations	National construction Information Systems
Actors	World	Journals, conferences	Global IT networks
	Man with man	Speech, phone, fax, mail	Email, video conferences
	Man with application		Visualization, 4D, virtual reality, graphical user interfaces
	Man with machine Application with machine	Direct manipulation	NC tools, robotics, remote sensors
Time	Just-in-time	Book look-up, library look-up, phone call to expert	Database lookup, Internet search, discovery and search agents
	Just-in-case	Reading books, magazines, journals, school, visiting conferences.	Subscriptions to customized content, distant learning.
	Once-in-time	Watching TV, listening to radio.	Not-archived discussion systems, push and –cast service.

Managing a construction project can be difficult, no matter the size of project. Managing a project involves hundred of thousand of documents that must be shared by project teams. However, well-developed ERP (Enterprise of Resource Planning; business software for running every aspect of a company including managing orders, inventory, accounting, and logistics.) will deliver great job efficiency. Those systems for a construction project will have high possibility for success, economically and efficiently. More advanced solution to forecast and ensure the project, the virtual and real-field construction management system (VR-Coms) has been introduced to evaluate the productivity and safety as virtual simulations (Maruyama et al., 2000). VR-Coms is integrated with virtual construction simulation, planning and performance management as well as it offers supporting modules for learning and discovering solutions that are based on previous experiences and evaluations. This system consists of two parts, one real construction field and one virtual construction field. In the virtual field, building design and the scheme of execution is generated before real construction is started. Moreover, this system can be used by the site manager to plan a construction project and management. The Computer simulation has been used successfully for a variety of problems. It is one of the ways of reducing time, cost and risk. The nature of communication on a construction site and development of a model of data-flow in a form suitable for simulation has been considered to improve construction quality (Scott et al., 1995). They were proposed such a simulation that identifies problems and then using ITs on-site for improving constructability. Figure 2.2 shows the steps of process, communication and supervision. Initial tasks and resources are changed by interactive user through communication channel. The first information for single task, which involves activities and resources, has high possibility to be changed in the real situation. Thus, this approach proposes supporting a IT-based communication tools to reduce time to modify the initial information. It is clear that the costs for estimation of project in construction communication using IT are much cheaper and efficient than traditional approaches.

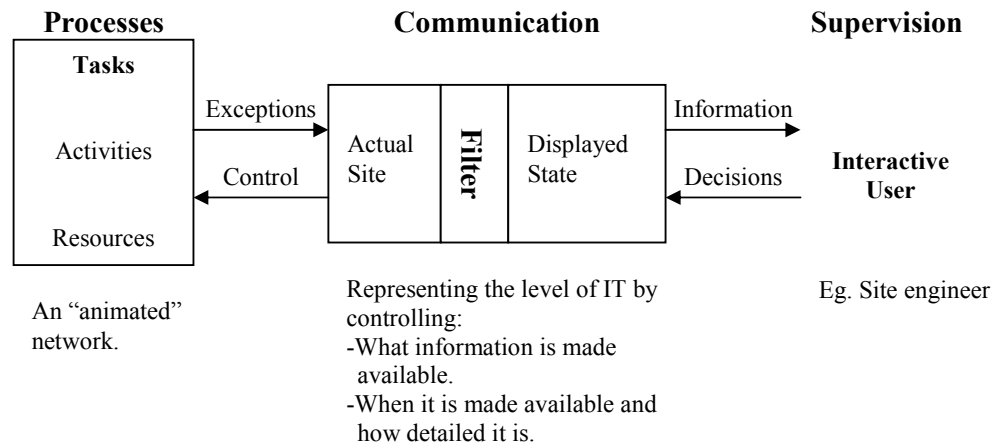


Figure 2.2. The System under development (Scott et al., 1995)

## 2.2 Web-based Construction Project Management System

The impact of the Internet technology on business has been discussed in several literatures. Bridges (1997) briefly expected transforming the business into internet that will change the industry such as transforming professions, open collaboration, business structure and business methods. He mainly discussed world-wide linked users allows the instant creation of work-groups and also mentioned about computer network time and location.

ITs-based solutions for construction project have been proposed by many researchers. For example, Web-based construction daily report system has been reported (Liu et al., 1996). This system used HTML (Hyper Text Markup Language) for link between the documentations, where construction project information can be easily handled and shared by many project participants and at different locations (Thistlewaite, 1997).

Designing a Web-based project management system for a large construction company operation required that the system needs reliable, inexpensive and almost instantaneous worldwide access available to centralise the project information system. In order for construction to be well managed, data from past projects stored in database as well as new data must be rapidly available (Abudayyeh, 2001). Also he implemented Internet-based cost control system. The architecture of that system is data input as Web format into database and then queries are used to develop cost report. The system generating three different format of report such as labour cost, payroll and material cost report.



Database (DB) is one of the most essential components of any kind of project management system. The technology of establishment of DB for engineering term has been emphasised by many researchers. When WWW was in its early stage of implementation, Shah et al. (1995) has redefined functional requirement of DB such as design coordination, design process management, integration of design and manufacturing, design reuse, configuration and design management.

Following points were recommended by ZDnet (<http://www.zdnet.com.au>) as minimum functional requirements of planning Web-based Information System.

- ☐ System must be providing right information at right time and place.
- ☐ System must be efficient to do task that leads to reduce cost and time.
- ☐ Providing continuous information that is able to be shared by different users.
- ☐ System users are able to modify the information.
- ☐ Be easy to use and operate the system.
- ☐ Provide online review and coordination
- ☐ Task tracking functions requires in order to record users' activities.

Tam (1999) has emphasised on the superiority of using Internet technology in construction communication and proposed Web-based solution, which called a Total Information Transfer System (TITS) that connects with global network. TITS has six major functions including: data exchange and remote log in, Internet chat enhanced with on-screen drawing, live video-cam, search engine and e-mail system. Also, this system has developed more than conceptual design such as design both hardware and software together. He tried to prove superiority of TITS through comparison of cost expenditure between TITS and traditional approaches.

The current stage of using ITs in cost control for construction projects has not been able to efficiently achieve results. This is due to the nature of the procurement system in construction, which still uses traditional methods (Mak, 2001). The reason for the reluctance in applying ITs in cost control is due to the lack of IT expertise in cost control by construction and accounting staff.

Web-based collaborated construction computer environment WISPER (Web-based IFC shared Project Environment) has been proposed recently (Faraj et al., 2000). The system environment is based on user interfaces, business logic and database which are kept

separate as well as Web and IFC-based (Industry Foundation Classes-based) computer integrated environment. This system supports design (CAD), Visualisation (VR and Drawing Web Format - DWF), estimating, planning, specifications and supplier information. Figure 2.3 shows system structure of WISPER. Web browser allows remote interaction and access to distribute applications.

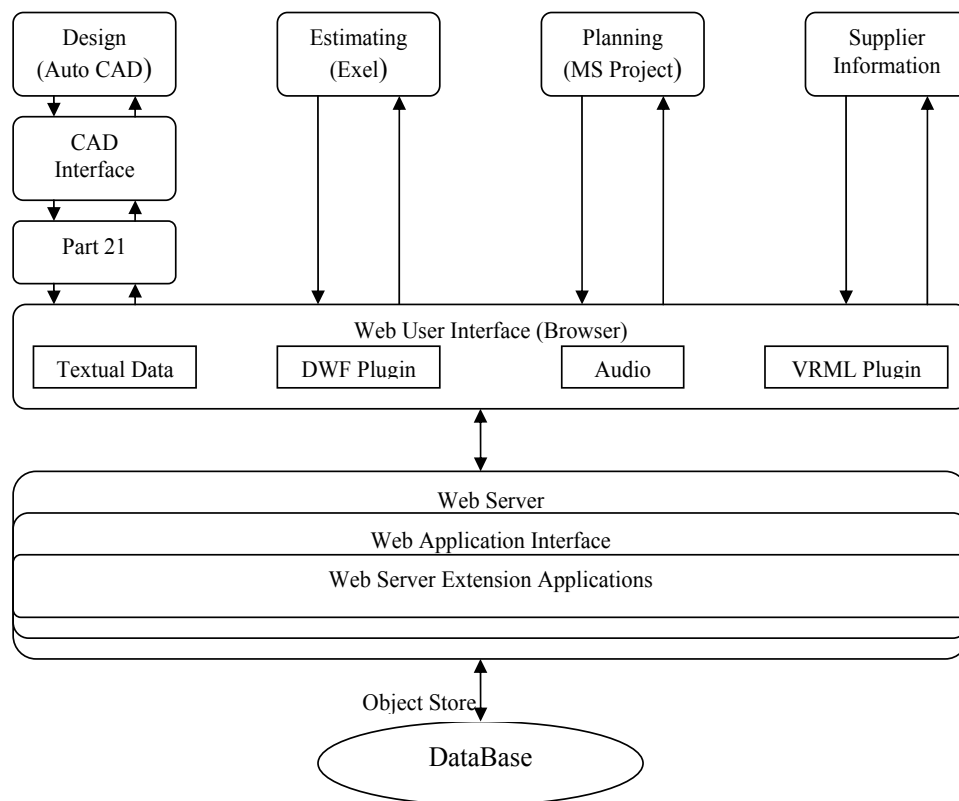


Figure 2.3. Overview of WISPER (Faraj et al., 2000)

## 2.3 Mobile Computing

Mobile computing has recently become popular and the use of mobile devices (laptops, PDAs and wearable computers) is growing rapidly. According to recent surveys conducted by mobile device manufacturers and their forecasts of tendering of wireless network market, there will be over a billion wireless devices, which counted mobile phones, will be in use by the year 2003. Also, they expect that number of mobile internet capable wireless terminal will be greater than existing fixed lines.

Some cases of mobile computing for intranet wireless network has limited service area as well as wireless network service also has service area limitation. Theoretically AP

(Access Point) for internal wireless network has approximately 100 metres service area limitation as well as wireless network by commercial ISP offers normally. The use of limitation of mobile service is called PAN (Wireless Personal area Network) that has been discussed in recent research (Zimmerman, 1999). He emphasised the role of XML (Extensible Markup Language). This markup language is used as WAP (Wireless Application Protocol) for WAP enabled mobile phone or PDAs etc. The principle of WAP is optimised for long latency and low bandwidth and is binary transmission for high compression of data as well as it can operate over wide variety of wireless transports. Accessing wireless communication has been limited by capabilities of devices and wireless networks. That is one of the reasons for developing Wireless Markup Language (WML), which is used to produce WAP content and to display on small-size screen devices. Following points are disadvantages of WAP that leads to users still hesitant in adopting it.

- ☐ The speed of data transmitting is still slower than other protocol such as TCP (Transmission Control Protocol).
- ☐ WAP brought more setup costs for contract with service company
- ☐ In user's point of view, WAP application interface is not convenient than web because it is based on text.
- ☐ Web application will carry large amount of data that will include text, graphic and other multimedia sources. However, WAP cannot take that much of data with desired network speed and limitations of display on screen.

Data can be transferred in short period of time, which can measure system's efficiency in construction communication. The raw data rate (Maximum transfer speed) is depends on selection of ISP (Internet Service Provider). However, some wireless service such as the third generation mobile telecommunication network (UMTS, Universal Mobile Telecommunication System) will provide approximately 300 kbps and even more, which is 5-10 times more efficient network speed (Wiklander, 2001).

## **2.4 Mobile Computing in Construction Industry**

The main purpose of the use of mobile computing in construction industry is its mobility. The mobility of handheld computers is adequate to use in construction site for inspection, task tracking, etc.

In construction industry, mobile computing is still not popular. The main reason for this is existing mobile solutions do not meet the requirement and setup costs are high.

Recently mobile computing has been used as off-line to record project information into PDA. For example, construction progress updates, material supply deliver records using basic functionalities of system (Bidcom, 2003).

Another solution has been introduced by a Japanese IT-company that developed large-scale mobile computing system (Daito, 2000). This system involved the construction of the use of Personal Handy-phone System (PHS) and PDA with built-in video camera. That system made the progress monitoring of construction sites easier and greatly increased productivity. Using the above system project managers can make decisions in the office without onsite confirmation, which considerably reduced the communication time between the site engineer and project manager.

In Australia, Project Management Information System (PMIS) has been tested utilising mobile telecommunications systems, in a large multi-national construction organisation in South East of Queensland. The proposed PMIS could handle numerous networked sites to manage large quantity of text and visual information and the system can be used to instantly share and communicate project information between project participants including clients, consultants, sub-contractors, suppliers and other authorities (Stewart et al., 2002).

## **2.5 Benefits of IT Implementation**

Majority of the establishment of Information System (IS) is going to be automated construction. That is to provide more convenient working environment in order to save time and cost and to expect more accurate construction project results. The current stage of using ITs in construction industry has been increased piecemeal. According to a recent survey, the Internet-based or Internet related Information Technology (IT) solutions were

reported to be very useful and at various degrees in construction industry (Deng et al., 2001). Mostly general internet related solutions includes E-mail, transfer files with E-mail attachments, shared database, Intranet (Internal Internet), Internet (World Wide Web, WWW). Among those solution, E-mail is the most useful application with 83% responding rate facilitates managers in 500 firms and Internet responding rate of 15%. Without exception, all solutions are expected to become more useful in the next 5 years. Also, 48% respondents indicated that Internet has been considered as a great potential in the construction industry (Deng et al., 2001). This survey highlighted that only a small number of construction companies used designed Information System for construction management. Also those levels of technology for Web-based system and Intranet are not sufficient to automatic construction. This result also shows indirectly that construction-IT still requires lots of developing for more advanced construction communication.

Another recent survey was conducted by Rivard's (2000). He investigated the impact of IT on the Canadian architecture, engineering and construction industry. The survey was conducted by mail to sample 1000 firms in the AEC industry across Canada during November 1998 and March 1999 with slightly less than 50 percent responding rate. The evaluation of computerised business processes and the results are shown in Figure 2.4. The answers are classified into three categories, such as highly computerised, partially computerised and mostly manual. In this Figure, the scheduling shows that still 30 percent of the scheduling process is still mostly done manually even though cheap applications, such as Microsoft Project, are available. About 40 percent use some scheduling applications. This is a strong evidence on the lack of Information System for construction scheduling control. Developing a more advanced system is required.

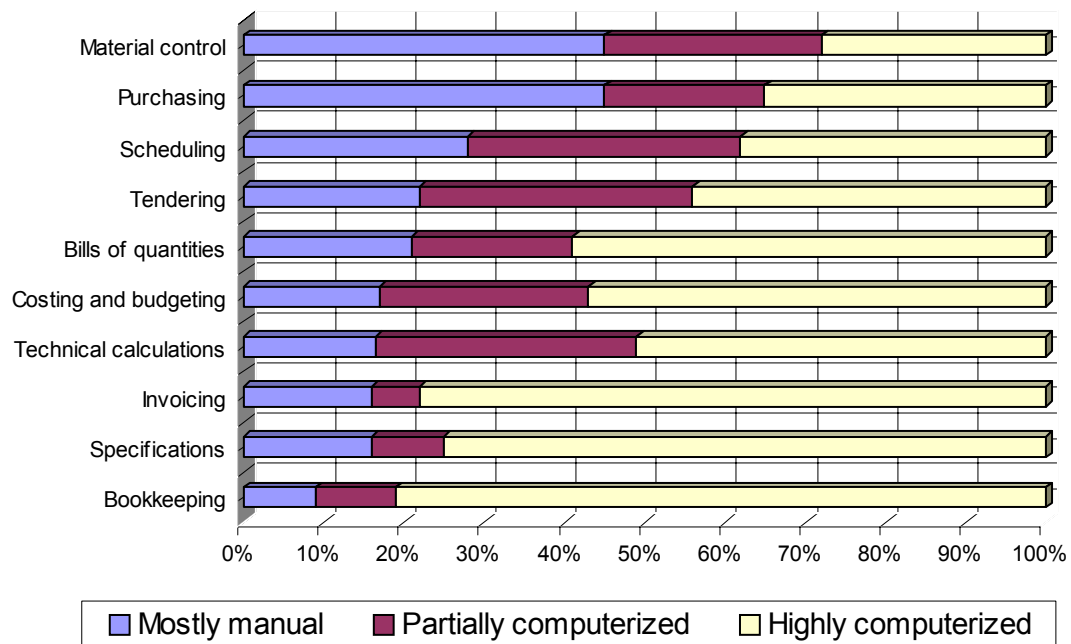


Figure 2.4. Extent to which processes are computerised (Rivard's (2000) survey).

Internet has emerged as one of the most essential tool of communication in any section of organisation. The advantage of using internet is to share the same resources at the same time within activated network. Thus, the potential advantage of using Internet technology, as a communication tools, can help information transfer most effectively during the construction process. Also, use of Web-based communication results in reduction in time and costs. It provides speedy information transmission, so information can be reached quickly and accurately by users. If this technology is applied to international construction site, such as construction sites overseas, the information may be accessed much more efficiently between head office and overseas construction sites.

Rivard's questionnaire had four questions where respondents selected the three most expected statements for their firms. All details are illustrated in Figure 2.5 that shows the results of these cumulative ranking with respect to their plans for investing in ITs. The main reason for investment in IT is expectation of better quality work, work done more quickly, better financial control, better communication and faster access to information.

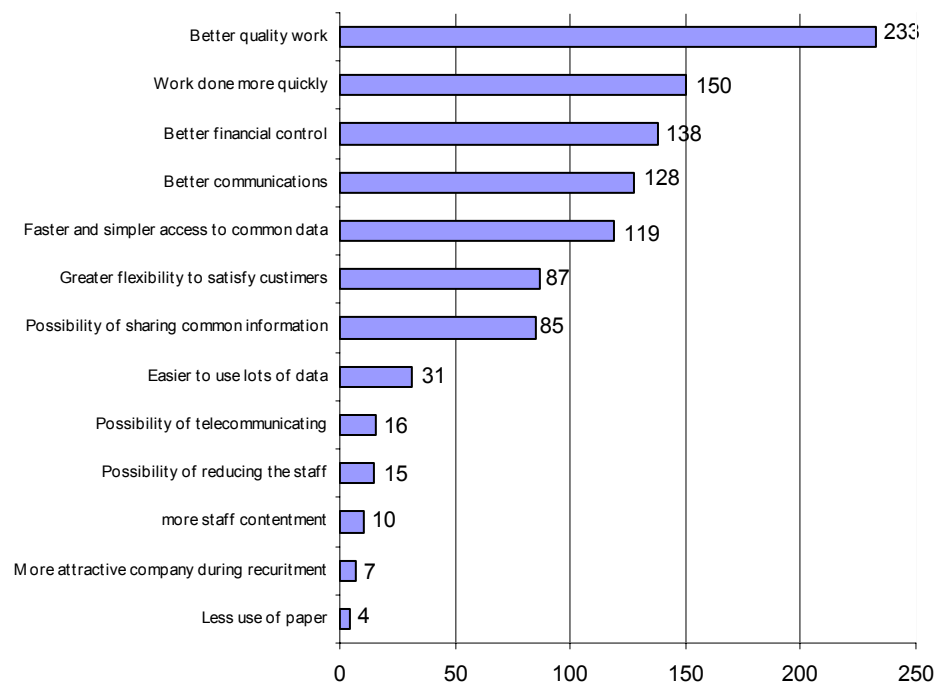


Figure 2.5. Future plans regarding investments in information technologies  
(Rivard, 2000)

The data of computer integrated construction project has focused on the idea of a central database that is linked to various applications such as CAD and project management tools etc (Cooper, 1995). The major feature of database would be to allow user to share data. Also, it has minimum geometric limitations, which means it can be used between long distances.

## 2.6 Summary

“Internet” is known as the international system of digital communication, emerging from the agglomeration of thousands of networks that interact on a number of common protocols world wide. Use of Internet communication skills and technologies gives a smarter way to succeed in business. Internet Technology has become one of the potential tools if it is well applied on a project. Many construction companies still hesitate to apply ITs on their businesses. Introducing IS to replace previous traditional systems requires potential investments and efforts.

It has been noted that the use of IT in construction industry has been very slow and least as compared to other industries. The conceptual design and solutions to some critical problems have been developed by researchers and IT-companies. However, developed solutions have not been popular with construction companies. The main reason for slow development and provision of insufficient solutions is due to the lack of IT expertise in the construction industry.

The early IT-solutions for construction companies adopted the concept of CIC from manufacturing industry and the stream of information and material process. The focus of analysis of this modeling study is to be time efficient in establishing and modifying project information.

Web-based construction project management systems were also reviewed. HTML-related solutions such as TITS and WISPER were discussed. Generally, those systems operate under Internet environment to transfer and share files.

Mobile computing and the trend of mobile computing in construction jobsite management were also discussed. Many researchers have indicated that advantages can use result from the use of mobile solutions such as PHS and PDA.

Benefits of IT-solution for construction industry through reported survey results were also analysed. The current status in the use of IT-related solutions require more research and development.



# Chapter 3

## Design of WCSM

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### 3.1. The layout of WCSM

IT techniques have been used efficiently to support processing and analysing large volumes of information quickly, accurately and economically. Communication technologies are also undergoing rapid advancement. Construction management can also benefit from these technologies. In future, the construction management will require more accurate information, efficient information handling and quality output to make right engineering decisions at the right time.

The proposed WCSM system is an internet technology based project operation and schedule tracking and reporting system designed specially for construction industry. This communication tool will help construction companies to schedule and track each job activity. This system can also allow several users to access system to input project information, thereby reducing the total input time.

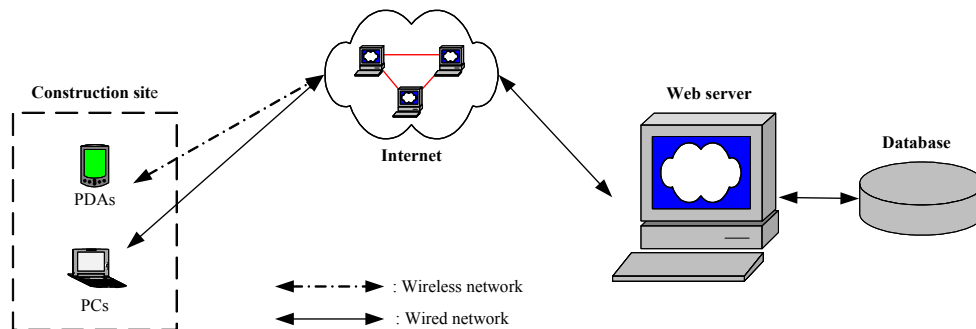
WCSM can be used to manage multi-construction site management (Figure 3.1). Basically, WCSM consists of a server, mobile devices and PCs. However, multi-site operation may require more high capacity servers as well as several PCs and mobile devices.

A more detailed account of each component of WCSM is as follows:

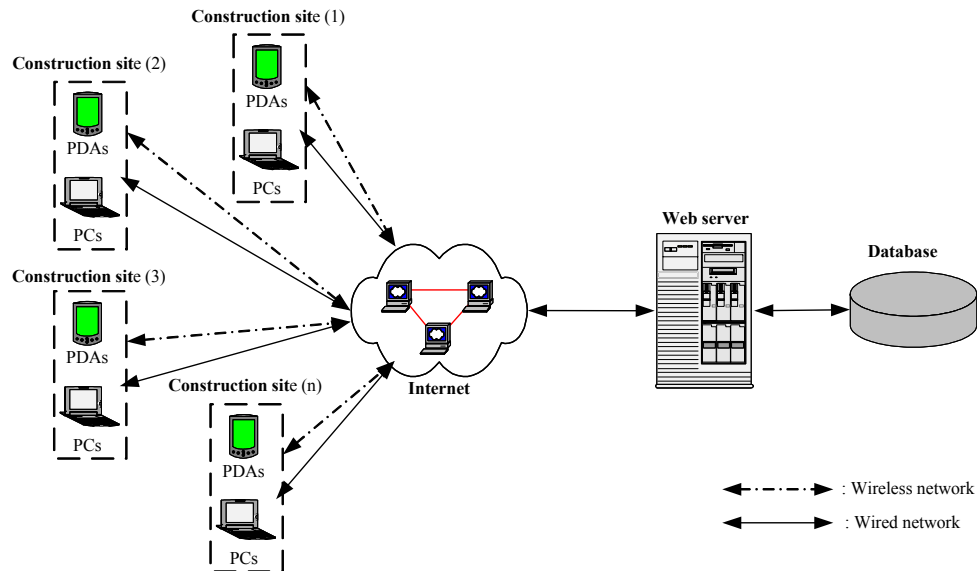
- Web server: hardware that provides access to a network. Generating HTTP requests to retrieve different length files according to a particular distribution. The server will

characterize as a maximum achievable number of connection per second while maintaining the required file mix.

- Mobile device: PDA (Personal Digital Assistant) is a wireless device. Sometimes WAP (Wireless Application Protocol) enabled mobile phone can also be used. WCSM will use built-in Web browser that will reduce initial setup costs.
- Personal computer: PCs will be located in the site office or head office to input initial information and monitor the project.



(b) For single construction site operation



(b) For multiple construction site operations

Figure 3.1. WCSM network system

Figure 3.1 (b) illustrates multiple construction site operations. Server may require faster and stable network line due to traffic on the network. System may require good performance of broadband router or network optimizer equipment to figure out this network traffic distribution in multi-site operations.

### **3.2 Development of WCSM**

At development stage, establish the Web-based content and DB (DataBase) for client. Current web technologies are adequate to enable most functions of WCSM. Designing contents for the PDA requires few considerations: there are several screen sizes of PDA, connection method and battery-operated devices. The detail of these considerations is as follows;

- Screen size: Most of hand-held computer have a 160×160 pixels for mono, 340×320 or 640×480 pixels for colour. Some screen have monochrome or grey-scale displays, while others can display anywhere from 256 to 64,000 colours. Screen size will vary among PDAs and larger screen means more readable space. In practice, handheld PC can access many standard web site successfully, but may still have problems because it cannot use full featured browsers and difficulties in displaying information at the same time. Normal web applications provide many link buttons and up-front bars. However, on hand-held computer, web-page should contain the most essential information without extras. The proposed WCSM assumes a screen size of 640×480 pixels with coloured panel.
- Limited input: Built-in keyboard dialog on the screen is not efficient compared to normal input devices such as desktop keyboard and mouse. Attachable keyboard is available in PDA, but it is not convenient due to the size of input device. Thus, design has to incorporate less input by user for convenience, maximum efficiency and mobility.
- Performance: The speed of processing information, which ranges from 16 MHz to 33MHz with 2K to 64K built-in memory, this is much slower than high performance personal computer.
- Data storage: Hand-held computer of WCSM will not require much data storage space, as the device will only be used for browsing. However, in order to efficiently run the browser may require some spare storage in the hard disk drive.
- Battery: Batteries require small capacity. To prevent disconnection during performing a task, users have to frequently re-charge the device. Thus, PDA operators must consider to charge up the battery before performing the tasks. A battery monitor will be incorporated, which displays the estimated battery capacity and running time left on the PDA screen.

### 3.2.1. Web Server

In general, Web server is computer hardware running a server program to provide service to other computers within network. It can control file management, sharing other devices such as printers and other network equipments, supervision of whole network and connect to other networks. WCSM Web server also supports for wireless device networks. Figure 3.2 shows that WCSM will perform under authorised identification when client requests information. The requested information (ASP request) will go through browser to server through wire / wireless network. The server will request database as SQL to find relative information or to save their information. Once the process is complete, the data will be transferred to the requested user via server.

Single web and DB server of WCSM system can cover up to 40 clients (site engineers). The capacity or numbers of servers required increase in multi-construction site operation.

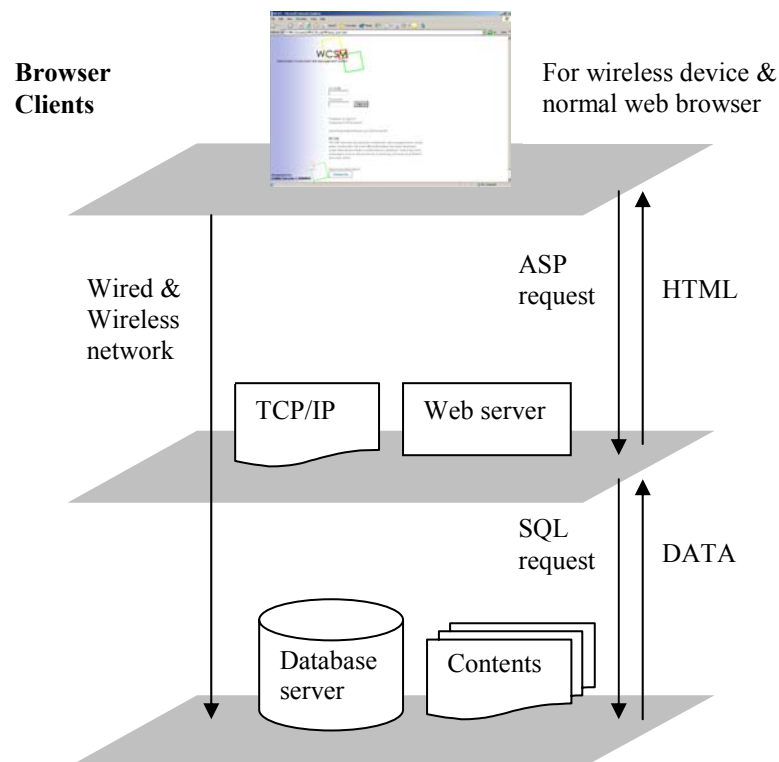


Figure 3.2 Application Architecture Layers

### **3.2.2. Interface of PCs for project manager.**

The personal computer of the project manager or system administrator will be located in the construction site office or headquarters. All the detailed initial project information is required to be input by a PC user. This initial information will be stored in the server to be downloaded by wireless device users for daily project schedule. Also, PC user will need an authorised identification to access the server as illustrated in Figure 3.3. The server will provide environment as web-formatted to input the schedule and other information by PC user. WCSM provide communication function as SMS (Short Message Service) for PC and PDA user and between PDA users. This communication function will help users performing the tasks.

### **3.2.3. User interfaces.**

Personal Digital Assistant (PDA) or any other portable wireless device is a hand-held computer that will be used by site engineers to access the system. System will allow downloading daily construction tasks to mobile device. Some PDA with internet browser software is available as built-in to communicate with application server. These kinds of devices will lead to less development cost. Basically, for wireless internet access, users (construction company) must subscribe to a wireless internet service from ISP or to install internal wireless network at the construction site. Construction company that uses WCSM system with the wireless ISP, have to pay costs for data usage and connection time under contract period with wireless ISP. This is only operation cost for wireless device connection of WCSM mobile users.

Various wireless network methods are available. WAP-based wireless connection is one of the economic solutions, but WCSM has been designed as a Web-based system. Sometimes project managers have to access the system directly for rapid information checks or for modifying the information with site engineer. If WCSM choose WAP method for mobile device, project managers can access system, but cannot get graphic information. Thus, for the most real situations, WCSM system should embrace a Web-enabled mobile device and design.

The major functions of all WCSM users and server and the interface between them is illustrated in Figure 3.3. The system will also support some communication tools such as SMS between users.

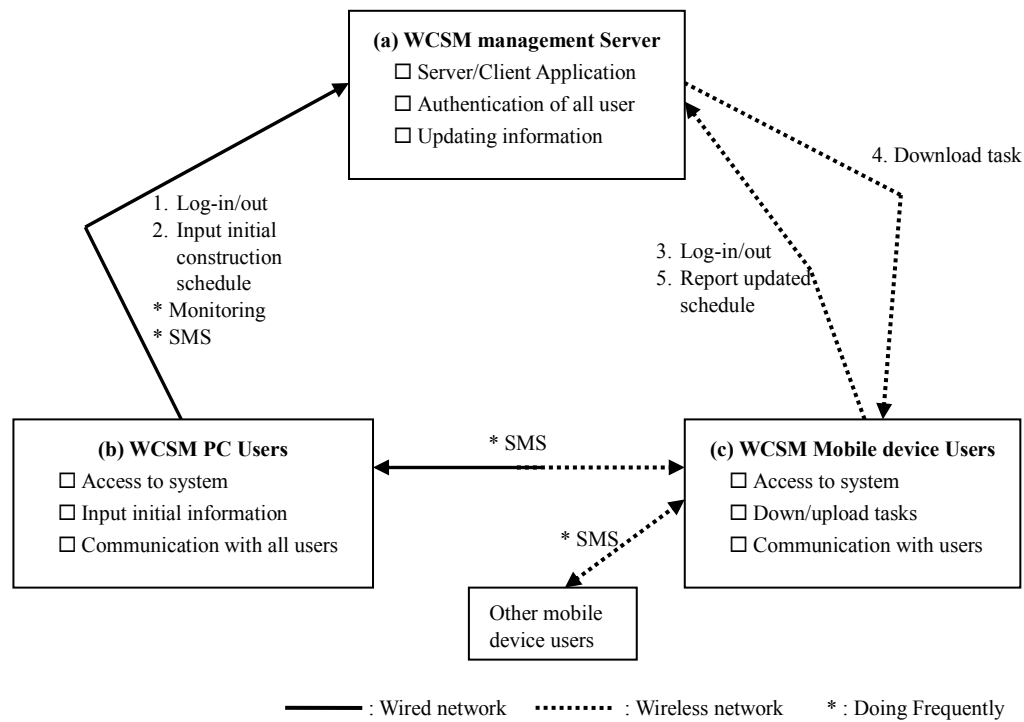


Figure 3.3. Interface of WCSM Users

### 3.3 Design of WCSM Web-Contents

Design Web-contents has two categories for user groups such as PCs user (for project managers) and wireless mobile devices (for site engineers).

PCs users who will perform establish the initial schedule and supervise the project. This initial construction master plan has to be completed before construction begins and for mobile device users to operate WCSM. This stage of initial information of WCSM included construction site information, site engineer's information, resources information and task information.

Each mobile device user will get daily tasks from the system. Once this information is stored into mobile device, it will report to WCSM the rate of completion of each task. Reported information will be used to rearrange the whole project schedule using the WCSM system. In other word, project schedulers will obtain latest tasks information by site engineers. In real time, project managers can monitor the rearranged project process through viewer mode such as Gantt chart and PERT chart

### 3.3.1 Design Contents for PC Users.

Figure 3.4 shows the stream of Web contents for project managers. It shows user has to select construction site after logging into the system and then input construction site and site engineer's information. After general stages, user has to input resources and tasks information. This is the most important stage to establish project schedule. Information can then be checked with variable viewers such as Gantt chart and PERT chart and so on. If input user finds any mistakes or other errors in viewer mode, the wrong information can be easily corrected at that stage. The input mode of WCSM has similar functions and procedures for current applications.

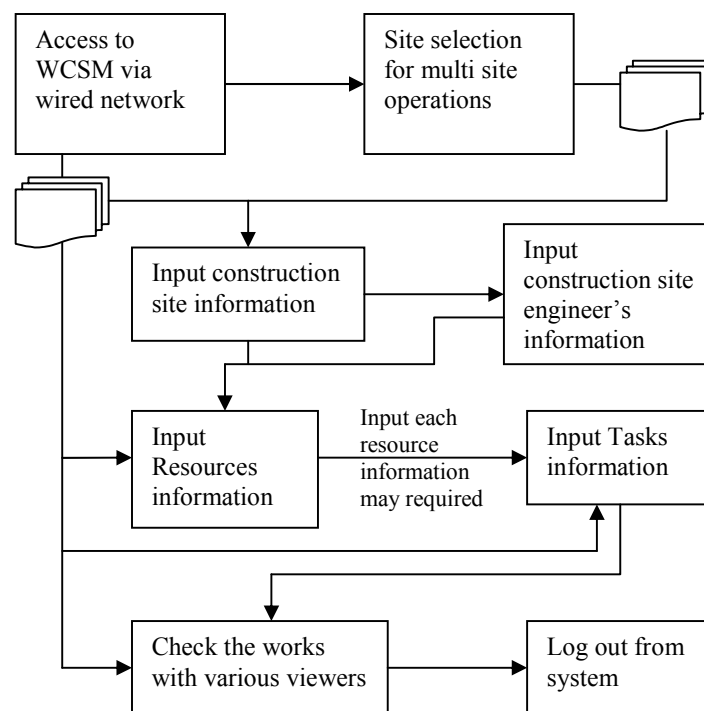


Figure 3.4. WCSM Web-content stream from project manager's point of view

In order to establish initial information for WCSM, PC users have to follow input mode procedures. The contents of WCSM input mode are as follows:

□ Input general information of project.

In the first stage, the user (project manager) has to create very general information of the project in order to distinguish between projects.

1. Check or generate user's identification: In order to enter the main application, project manager has to input authorised user's identification. This identification, such as user ID and password, will enable WCSM to distinguish between user and system administrator. The authorisation stage as first screen of the system is shown in Figure 3.5.
2. After user's identifications stage, WCSM requires for three more stages of general information such as site selection, site information and site engineer's information. Site Information & Site Selections: Figure 3.6 shows a typical screen for inputting the name of project, project identification, location, period of construction and so on. This stage is required to recognise between projects, when WCSM is operating several construction sites. In subsequent access to system for the same project, WCSM will not prompt for this input and user will by pass this screen to "Site Selections" shown in Figure 3.7.

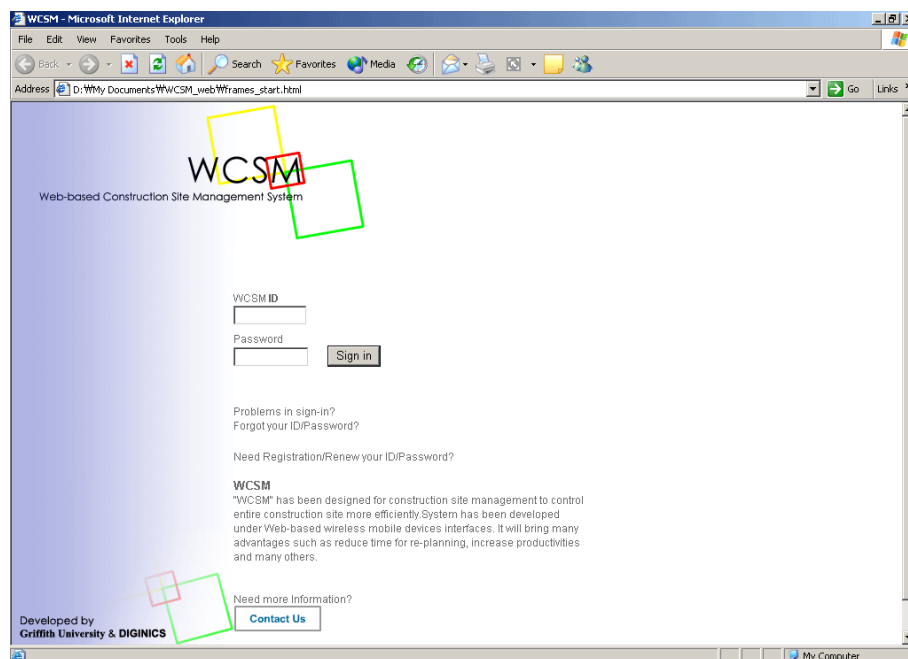


Figure 3.5 WCSM log-in screen



WCSM Site Information - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites Media Print Mail News RSS Feeds

Address D:\My Documents\WCSM\_web\WCSM\_input mode.htm Go Links

WCSM  
Web-based Construction Site Management System

Log Out  
Site Selection  
Input Information  
Map  
Project Viewers  
Site Information  
Site Engineer's Information  
Resources Information  
Tasks Information

Construction Site Information

Project ID

Project name

Site location

Expected duration  days

Start date  day  month  year

Finish date  day  month  year

Scope

My Computer

Figure 3.6 Construction Site Information

WCSM Site Selection Mode - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites Media Print Mail News RSS Feeds

Address D:\My Documents\WCSM\_web\WCSM\_Site selection.htm Go Links

WCSM  
Web-based Construction Site Management System

Log Out  
Site Selection  
Input Information  
Map  
Project Viewers

Construction Site Selection

Project ID

Project name

Site location

Developed by Griffith University & DIGINICS

Done My Computer

Figure 3.7 Site Selection

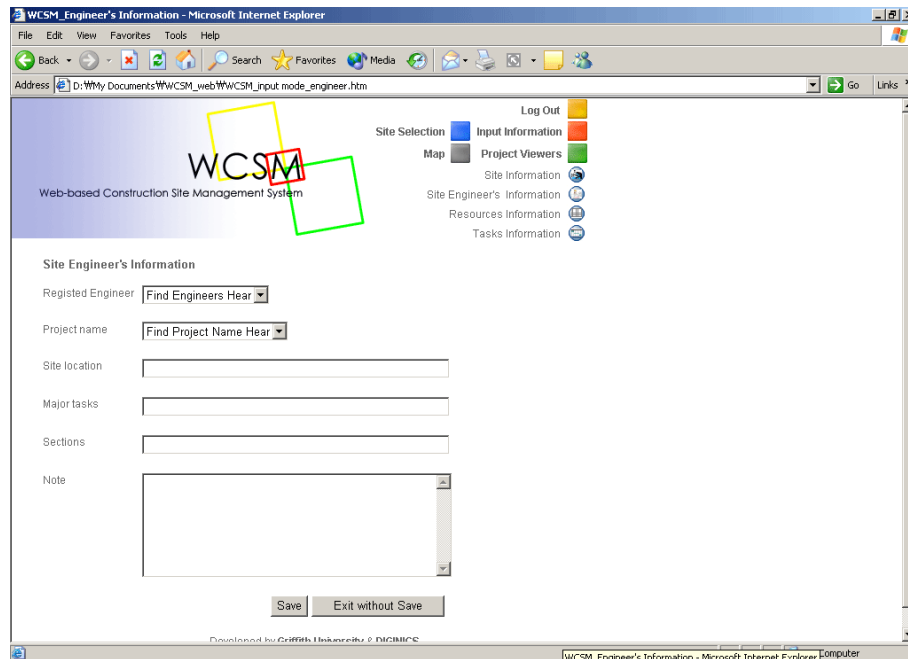


Figure 3.8 Site Engineers' Information

3. Generate Information on Site engineers: In the next general information input stage, WCSM will prompt for information of site engineers, about their identification, duties and locations shown in Figure 3.8. This is required in order to recognise their information and to provide the correct daily task to each user.

#### □ Input of Resources Information.

Before task input stage, system prompts for resources information input, so that a resource list can be established. The user can then choose from it during task input information stage. The content of resources information such as shown in Figure 3.9 will display resource name and ID, maximum available unit by percentage, cost, and over time charge. In order to input more resource information, project manager has to repeat the above step.

Figure 3.9 Resources Information

#### □ Tasks Information Input

After completion of major phases, WCSM prompts for tasks information such as name and their durations, required resources. User has to set work schedule: define number of working days such as five days per week or six days per week as well as specify the special non-working day such as holiday, which can be typed in the date box or input from calendar box.

1. Input task name and its durations: The project manager will spend relatively more time to input information. Each task will have ID, name, expected date, engineer in charge and required resources. This resource information can be selected from the resource list on the bottom of the screen. Also, user provides more information about the relationship between task activities to prevent clash between the tasks (Figure 3.10).

In more detail, project manager has to define type of predecessors such as “As late as possible”, “As soon as possible”, “Finish no earlier than”, “Finish no later than”, “Must finish on”, “Must start on”, “Start no earlier than”, and “Start no later than”. Those selections will be listed in the predecessors’ box and the user can select from a drop down menu.

Figure 3.10 Tasks Information

Figure 3.11 System log out

□ System Log out Stage

After the input stage, which includes general information stage, resources and tasks information stages, user can modify, delete or add up more information through various project viewers such as Gantt chart. The authorisation of every information belongs to the project manager. Also, the project manager can update project information at anytime during the project.

### **3.3.2 Design Contents for WCSM Mobile Device users.**

The second user group of WCSM consists of the mobile device users. They are an important component of the WCSM and are expected update all project activities on a day today basis. Figure 3.12 shows the contents stream from a mobile device user's point of view. User has to log into the system via wireless network and the system would direct the user to the relevant site automatically. After secure user's identification stage, system will provide daily construction tasks to mobile user. Screen shots of mobile user's pages will be shown and discussed in Chapter 4. Before the day closed user will report task activities by filling in task "completion" as a percentage. A 100 percent recorded for a task would indicate that this task was completed on time. However, if less than 100 percent is recorded, then WCSM will schedule another day to complete it.

For better construction communication, WCSM also supports SMS (Short Message Service). This SMS is the ability to send and receive text messages among the users. The text can comprise of words or numbers or alphanumeric combinations. It will help communication between the site engineers.

The main advantage of WCSM is that site engineers can individually upload their progress for the day and WCSM will update the whole project information, automatically, in real time. As such the project manager will not be required to manually modify or update the project schedule information.

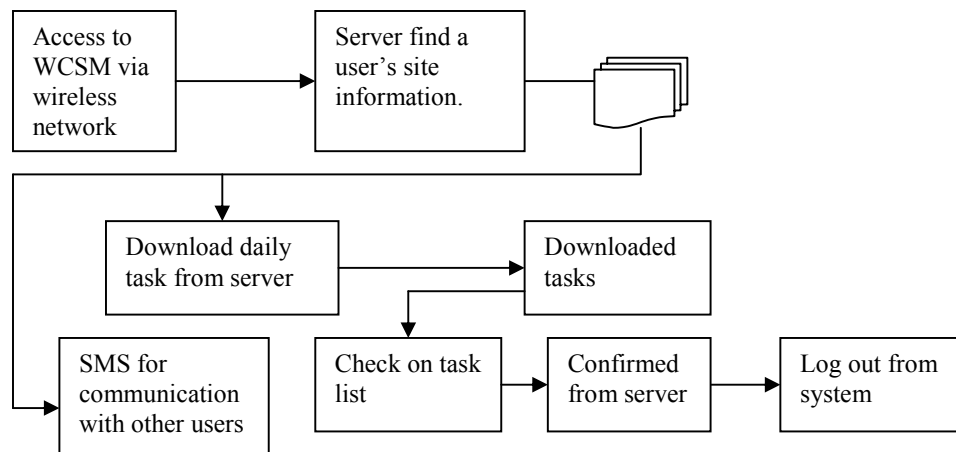


Figure 3.12 WCSM Web-contents stream from mobile device user's point of view

### 3.4 Summary

WCSM is a combination of recent computer communication technology and advanced features from existing applications to support efficient management environment for construction sites. WCSM modeling for site management was developed in this study, using existing IT technology. Each component of WCSM is upgradeable in line with advancement in wireless network technology. The effectiveness of this model in construction site management would require user awareness on the following features:

- ☐ Conceptual model has been designed to improve the efficiency in construction site control.
- ☐ WCSM is a Web-based mobile devices interface for site control system. It does not have any geographical limitation; i.e. it is equally effective for overseas project sites.
- ☐ Server in construction site or headquarter must be connected reliably to internet network with adequate network speed. Wireless mobile devices have to be selected carefully so as to display Web contents without problem.
- ☐ WCSM saves time and cost in project management as it eliminates the need for manual input from the project manager during project progress. Input information can also be shared by several users.

# Chapter 4

## Testing and Analysis

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### 4.1 Virtual Simulation

This chapter describes about the tests performed on the developed WCSM system. Data from a real construction project was used in these tests. This included the start and finish date of each task and resources. Two tests were performed. Both test models involved the original plan and modified plan. Tests were conducted twice; one for original input time measurement and the other for modification time measurement. The second test model was more complex, as the numbers of tasks were more than that was encountered during the original task input. The second test was aimed at comparing the time efficiency with the amount of data involved.

Well-established Information System (IS) is becoming a key source of success in construction project management as well as other business sectors. WCSM (Web-based Construction Site Management) system brings a new concept in real time managing and tracking a project information to deal with managing more rapid, reliable and accurate information between management office and construction site. Users of existing applications have to deal with entire project data during input and modifications. However, WCSM users do not require to open or have access to the entire project information data to input new data during daily updating. This is the major advantage of the WCSM system.

The main concern of virtual simulation tests of WCSM in this chapter has arisen due to the need to reduce the load on management. The large amount of time spent by the

managers during project establishment, modifications, scheduling, etc. has prompted concern for efficiency. One of the objectives of development of WCSM is to improve on project load and handling efficiency. As such time factor has been given importance in the analysis.

ERP systems for construction projects include many functions for analysing project information. The focus of every module of functions in ERP system is also connected with accounting module to report and to make decisions. MS Project and Micro Planner are two of the most popular applications in the construction industry. As such the proposed WCSM system has been compared with these two applications.

The simulation test data was obtained from Daewoo Construction Company. The data was on the headquarters of Korean Industrial Bank project conducted during July 1996 ~ April 2001. The general layout plan of the project is shown in Figure Appendix II-1. Project data obtained for three weeks August - September 1998 was used for the tests. The data was broken down into several tasks to simulate detailed construction site operations. Second test had more detailed amount of tasks than the first test. For example, the formwork, which took 5 days to complete in the first test, was than subdivided into tasks such as setting out, fixing formwork, water proofing and inspection of formwork. These subdivided tasks took 0.5, 4, 0.5 and 0.5 days to complete. This data was then used in the second test.

#### **4.1.1 Establishment of Construction Project Data**

Testing data were obtained for a short period of a real construction project that was carried out in year 1998. Time adjustment of system is not difficult to change; test team reset the time to the main server and the system recognises present time as August 1998. Thus, original test data has not been changed to present time scale.

Working area consisted of more than 8 sections. Testing was performed on three sections (see Figure 4.1). WCSM was used to simulate the work of three site engineers and at least one project manager (project scheduler) in these tests.

In the first test, each site engineer was assigned different tasks for their sections as illustrated in Table 4.1. Tasks for other sections are tabulated in Appendix II. The six main tasks listed in Table 4.1(a) were broken down to 26 smaller task elements as listed in Table 4.1 (b). The same procedure was followed for sections 2 and 3. Thus, the total 18 tasks used for the first test became 78 smaller tasks for the second test.



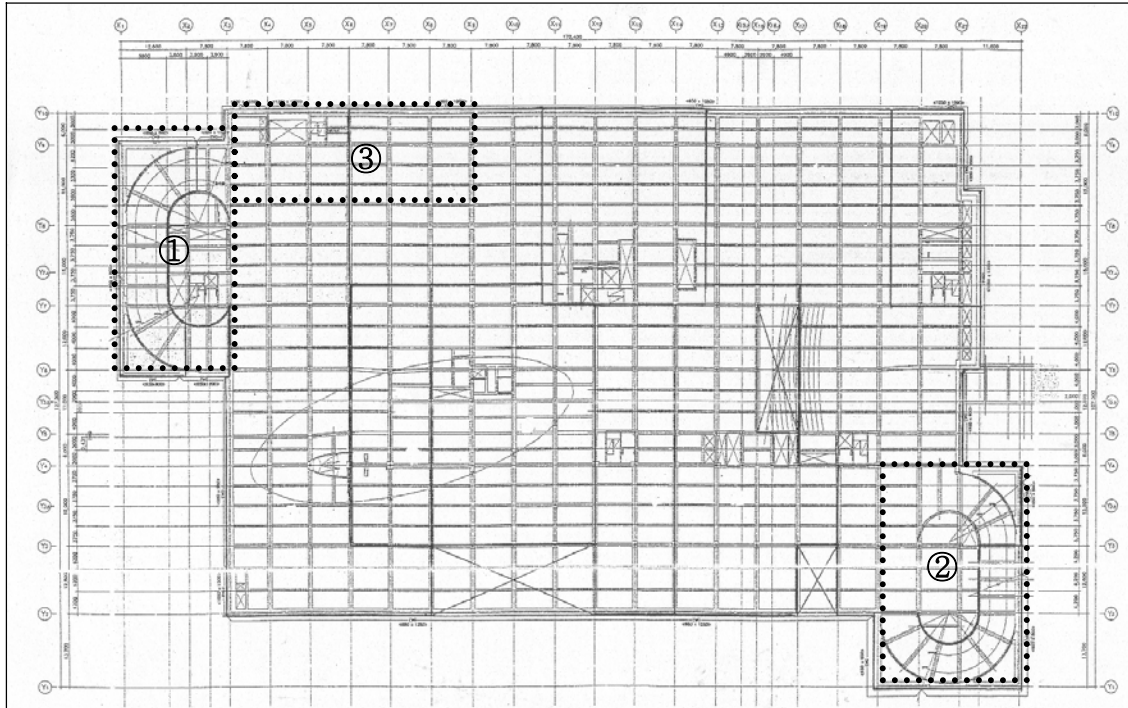


Figure 4.1 Defined site engineers sections of working area: Drawing for 2<sup>nd</sup> basement of Korean Industrial Bank headquarter Project in Seoul, Korea (July 1996 ~ April 2001). (Note: ① ② ③ means Section1, 2 and 3)

Table 4.1 Initial Test data for Section1

(a) Test data 1

ID	Task	Duration	Start Date	Finish Date
1	Section 1	21 days	20/08/1998	16/09/1998
2	Formwork (Section 1)	5 days	20/08/1998	26/08/1998
3	Rebar (Section 1)	4 days	24/08/1998	27/08/1998
4	Mech./Elec. (Section 1)	2 days	27/08/1998	28/08/1998
5	Con'c (Section 1)	1 day	31/08/1998	31/08/1998
6	Con'c_After Curing (Section 1)	3 days	14/09/1998	16/09/1998

## (b) Test data 2

ID	Task	Duration	Start Date	Finish Date
1	Section 1	21 days	20/08/1998	16/09/1998
2	Formwork (Section 1)	5 days	20/08/1998	26/08/1998
3	Setting Out (F.W_S1)	0.5 days	20/08/1998	20/08/1998
4	Fixing Form Work (F.W_S1)	4 days	20/08/1998	25/08/1998
5	Water Proofing (F.W_S1)	0.5 days	26/08/1998	26/08/1998
6	Inspection Formwork (F.W_S1)	0.5 days	26/08/1998	26/08/1998
7	Rebar (Section 1)	4 days	24/08/1998	27/08/1998
8	Bar Bending/Cutting (Rebar_S1)	2 days	24/08/1998	25/08/1998
9	Assembling Cages (Rebar_S1)	2 days	25/08/1998	26/08/1998
10	Lifting/Positioning (Rebar_S1)	2 days	25/08/1998	26/08/1998
11	Insert Spacer blocks (Rebar_S1)	1 day	27/08/1998	27/08/1998
12	Inspection Rebar (Rebar_S1)	0.5 days	27/08/1998	27/08/1998
13	Mech./Elec. (Section 1)	2 days	27/08/1998	28/08/1998
14	Mark out Powers/Lights/Comm./Other outlets (M/E_S1)	0.5 days	27/08/1998	27/08/1998
15	Install Conduits/Trunking (M/E_S1)	2 days	27/08/1998	28/08/1998
16	Insert Openings in Slab/Beams (M/E_S1)	1 day	28/08/1998	28/08/1998
17	Inspection M/E (M/E_S1)	0.5 days	28/08/1998	28/08/1998
18	Con'c (Section 1)	1 day	31/08/1998	31/08/1998
19	Con'c Pouring/Vibrating (Con._S1)	1 day	31/08/1998	31/08/1998
20	Make Test Cylinders (Con._S1)	0.5 days	31/08/1998	31/08/1998
21	Test of Cylinders (Con._S1)	0.5 days	31/08/1998	31/08/1998
22	Inspection Con'c pouring (Con._S1)	1 day	31/08/1998	31/08/1998
23	Con'c_After Curing (Section 1)	3 days	14/09/1998	16/09/1998
24	Stripping Formwork / Inspect honey combs/deflects (Con._S1)	2 days	14/09/1998	15/09/1998
25	Rectification of deflect (Con._S1)	3 days	14/09/1998	16/09/1998
26	Inspection Con'c _after curing (Con._S1)	1 day	16/09/1998	16/09/1998

(Note: Rest of test data is available in Appendix II)

Resource information is also one of the essential components in the establishment of the settlement of project plan. In this study, WCSM does not incorporate material control and cost analysis. However, resource information can be input to WCSM display with the related tasks. One unit of resource was assumed as 100 percent in the system. For example, in Table 4.2, test data was assumed as 50 labourers required in this period of project. Thus, input users have to input the data as 5,000 percent. Other resources have also been similarly assigned.

Table 4.2 Resource Information for Test1 and 2

ID	Name	Max. Unit	Std. Rate	Ovt. Rate
1	Labours	5,000%	\$12.00/hr	\$15.00/hr
2	Carpenters	2,200%	\$20.00/hr	\$25.00/hr
3	Surveyors	600%	\$30.00/hr	\$37.00/hr
4	Formwork Foreman	300%	\$30.00/hr	\$40.00/hr
5	Bar benders	1,400%	\$12.00/hr	\$15.00/hr
6	Steel Fixers	1,400%	\$12.00/hr	\$15.00/hr
7	Rebar Foreman	300%	\$30.00/hr	\$40.00/hr
8	Tower Crane Operators	400%	\$50.00/hr	\$55.00/hr
9	Speacers	1,200%	\$12.00/hr	\$15.00/hr
10	M&E Foreman	300%	\$30.00/hr	\$40.00/hr
11	M&E Skilled Workers	800%	\$20.00/hr	\$25.00/hr
12	Vibrators	800%	\$12.00/hr	\$15.00/hr
13	Ready Mixed Con'c	500%	\$12.00/hr	\$15.00/hr
14	Pump Car	400%	\$30.00/hr	\$35.00/hr
15	Con'c Foreman	300%	\$30.00/hr	\$40.00/hr

### 4.1.2 Assumptions and Variables

In this study WCSM is mainly designed for schedule control. The system has been specially developed for Web and mobile computing background. A few assumptions are required to measure time performance of WCSM. These assumptions are listed below:

- ☐ The connection of wireless devices are reliable
- ☐ All users are familiar with Internet-based working conditions.
- ☐ All users are trained for WCSM working environment and how to use the system.
- ☐ Weather conditions and resource information was regenerated for the test as field information was not available.

Internet security and connection technology of mobile device is an important sector, but that is not an issue for these tests.

The test was performed to simulate and measure the time efficiency after progress of works at site was affected by heavy rain in afternoon of 24 August 1998. The project manager decided that construction activity had to be halted. He then modifies the construction project schedule. The modified schedule for test 1 and test 2 are shown below in Table 4.3

Table 4.3 Modified Test data for Section1 (due to weather condition on 24 Aug 98)  
(a) Modified test data 1

ID	Task	Duration	Start Date	Finish Date
1	Section 1	23 days	20/08/1998	18/09/1998
2	Formwork (Section 1)	7.5 days	20/08/1998	31/08/1998
3	Rebar (Section 1)	7.5 days	24/08/1998	2/09/1998
4	Mech./Elec. (Section 1)	2 days	31/08/1998	2/09/1998
5	Con'c (Section 1)	1 day	2/09/1998	3/09/1998
6	Con'c_After Curing (Section 1)	3 days	16/09/1998	18/09/1998

(b) Modified test data 2

ID	Task	Duration	Start Date	Finish Date
1	Section 1	21 days	20/08/1998	16/09/1998
2	Formwork (Section 1)	6 days	20/08/1998	27/08/1998 0
3	Setting Out (F.W_S1)	0.5 days	20/08/1998	20/08/1998
4	Fixing Form Work (F.W_S1)	5 days	20/08/1998	26/08/1998
5	Water Proofing (F.W_S1)	1 day	27/08/1998	27/08/1998
6	Inspection Formwork (F.W_S1)	0.5 days	27/08/1998	27/08/1998
7	Rebar (Section 1)	4 days	24/08/1998	27/08/1998
8	Bar Bending/Cutting (Rebar_S1)	3 days	24/08/1998	26/08/1998
9	Assembling Cages (Rebar_S1)	2 days	25/08/1998	26/08/1998
10	Lifting/Positioning (Rebar_S1)	2 days	25/08/1998	26/08/1998
11	Insert Spacer blocks (Rebar_S1)	1 day	27/08/1998	27/08/1998
12	Inspection Rebar (Rebar_S1)	0.5 days	27/08/1998	27/08/1998
13	Mech./Elec. (Section 1)	2 days	27/08/1998	28/08/1998
14	Mark out Powers/Lights/Comm./Other outlets (M/E_S1)	0.5 days	27/08/1998	27/08/1998
15	Install Conduits/Trunking (M/E_S1)	2 days	27/08/1998	28/08/1998
16	Insert Openings in Slab/Beams (M/E_S1)	1 day	28/08/1998	28/08/1998
17	Inspection M/E (M/E_S1)	0.5 days	28/08/1998	28/08/1998
18	Con'c (Section 1)	1 day	31/08/1998	31/08/1998
19	Con'c Pouring/Vibrating (Con._S1)	1 day	31/08/1998	31/08/1998
20	Make Test Cylinders (Con._S1)	0.5 days	31/08/1998	31/08/1998
21	Test of Cylinders (Con._S1)	0.5 days	31/08/1998	31/08/1998
22	Inspection Con'c pouring (Con._S1)	1 day	31/08/1998	31/08/1998
23	Con'c_After Curing (Section 1)	3 days	14/09/1998	16/09/1998
24	Stripping Formwork / Inspect honey combs/deflects (Con._S1)	2 days	14/09/1998	15/09/1998
25	Rectification of deflect (Con._S1)	3 days	14/09/1998	16/09/1998
26	Inspection Con'c _after curing (Con._S1)	1 day	16/09/1998	16/09/1998

(Note: Rest of test data is available in Appendix II)

The above information is shown only for section 1. Other modified sections are included in Appendix II. The differences between the two tables 4.1 and 4.3 are in the number of modified tasks. For example ID number 4 Fixing formwork in data 2 had to be increased by one more day from that in the original plan. The duration of ID number 2 and 3 in

Table 4.3 (a) and ID number 4, 5, 6 and 8 in Table 4.3 (b) for Section 1 has to be modified from the original schedule due to weather conditions. A similar exercise was also required for sections 2 and 3.

## 4.2 Test for Establishment of Initial Information

### 4.2.1 Input General Information

In general, the majority of WCSM virtual tests were carried out to measure the time taken for data input and its modifications. Table AI-3 gives an outline of tests conducted. Measured time will be compared with MS Project and Micro Planner to analyse time efficiency.

The first stage of this user group is the input of general information, such as general construction information and registration of site engineers, into the system. Prior to the use of system, every new user has to generate an ID and password from the first screen, such as that in Figure 4.2 (a), (<http://61.41.128.184/WCSM/index.html>). This enables WCSM to recognise users and to provide suitable content for different user access. This test involved two cases shown in Table 4.4.

Once the user access is authorised a site map content will come up on the screen as shown in Figure 4.2.(b). This initial access stage would require the user to input information about the project, such as construction site and site engineer information, see Figure 4.2 (c) and (d).

Table 4.4 Number of Users of WCSM

	Case 1		Case 2	
	Site Engineer	Project Manager	Site Engineer	Project Manager
Test 1	3	1	3	*5
Test 2	3	1	3	*5

\*5: this amount of user is required to establish initial information



Figure 4.2 General Information Input stage by Project manager

## 4.2.2 Input Resources and Tasks Information

At this stage, most of the time will be spent to establish a construction plan for the project. The contents of resources, such as that listed in Table 4.2, will be filled into the screen on Figure 4.3. Each resource has its own identification, name, maximum units available and standard as well as overtime rates. In a similar way task information can be input. Each task has its own ID, name, related engineer, duration, predecessors, and resource requirement as shown in Figure 4.4. These are the important stages in the input modes of the WCSM. Input information will be shared in real time as soon as any user stores

information into DB (DataBase). Once saved information will be immediately available to other users.

The information is directly related to the engineer's daily task list. These data will be used when server performs calculations and distributes tasks to each site engineer. In order to complete input stage project planners will perform a check back on the project schedule. WCSM can increase the number of input users. These users can share the information between them in real time. The objective of sharing input information in this system is to reduce the total input time.

WCSM  
Web-based Construction Site Management System

Log Out

Site Selection Input Information  
Map Project Viewers  
Site Information  
Site Engineer's Information  
Resources Information  
Tasks Information

Resource Information

ID: 1  
Name: Labour  
Unit max: 4800 %  
Rate standard: 12 A \$/hr  
Rate Overtime: 15 A \$/hr  
Note: General skilled workers

Save Delete

ID	Resources Name	Max. Units(%)	Std. Units(%)	Ovt. Units(%)
1	Labour	4800	12-Australia	15-Australia
General skilled workers				

Figure 4.3 Input Resources Information

The screenshot displays the 'WCSM Engineer's Information' web application. The browser window shows the address 'http://61.41.128.184/wcsm/wcsm\_task\_information.asp?id=1'. The page features a navigation menu on the right with links: Log Out, Input Information, Project Viewers, Site Information, Site Engineer's Information, Resources Information, and Tasks Information. The main content area is titled 'Tasks Information' and contains a form with the following fields: Task ID (3), Task name (Setting out (F.W\_S1)), Engineer (enginner1), Durations (0.5 days), Start Date (20/8/1998), Finish Date (20/8/1998), and Predecessors (a table with columns Task ID, Task Name, and Type). The WCSM logo is visible at the top left of the page.

Figure 4.4 Input Tasks Information

## 4.3 Test for Updating Schedule

### 4.3.1 Download Task Information

Once the stage of input information is completed, the mobile users (site engineers) will be able to access WCSM through wireless network. In order to connect the system, user has to key in their own ID and password shown in Figure 4.5. Once wireless device's user connects to the system, server will move to the second page of transmission as shown in Figure 4.6, which is the daily tasks list for the site engineer.

Suggested method of access in the case of wireless ISP is that the user save daily task information page and then fills in the results of tasks later. The other connection method is to use wireless intranet that does have any connection costs. Wireless intranet will cost more to install the equipment entire construction area. The second method was used in both tests. It was assumed that the mobile users do one download and one upload everyday.



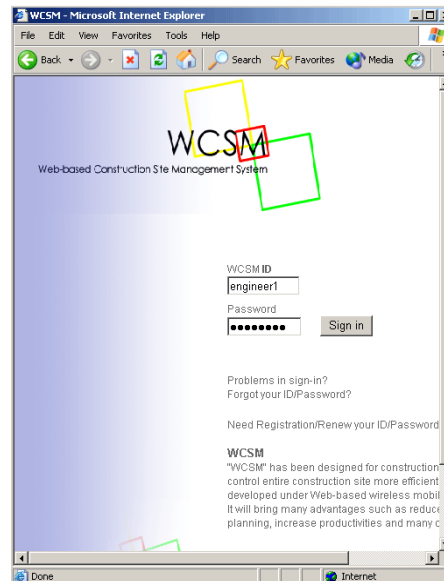
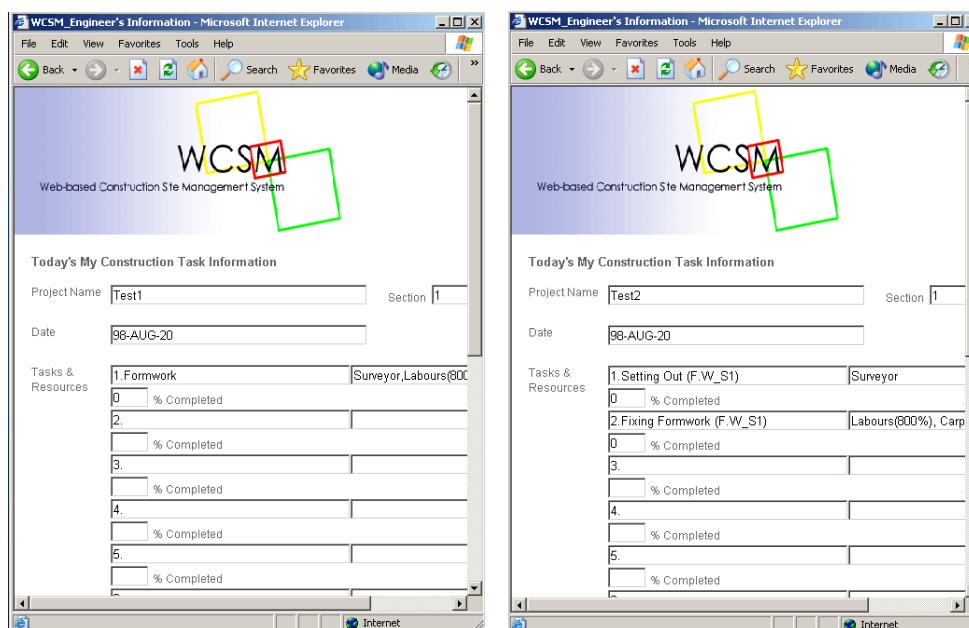


Figure 4.5 WCSM Screen Shot for PDA Log-in



(a) Test 1

(b) Test 2

Figure 4.6 Daily Tasks Download by Wireless Device

### 4.3.2 Upload Daily Task Information

The master project schedule will be updated as soon as daily tasks information is uploaded by the site engineers. Figure 4.7 shows the upload screen for Test1 and 2. This is a straight forward input stage for the user as most of the information is entered as a percentage of completion of each task. Upon completion of the daily tasks input the user

will click on the “Report” icon as shown in Figure 4.7 (c). Once the data transmission is complete, server will immediately rearrange the schedule according to uploaded information.

From a project manager’s is point of view, he/she can monitor the construction process easily by reviewing Gantt charts. Figure 4.8 (a) and (b) shows that section 1 of test 1. Figure, (c) and (d) are the results after the modification of the schedule. The focus of this is on ID number 2, which is formwork (section1). In the original schedule, it took 5days (start on 20<sup>th</sup> August 1998 and finish on 26<sup>th</sup> August 1998). When the heavy rain scenario was introduced on the 24<sup>th</sup> August 1998, site engineers had to cancel (0 percent of completion) or record an incomplete (less than 100 percent of completion) task. In the test, site engineer makes a decision to upload the result as 50% complete for formwork. In order to complete this task, one more day (new completion date: 27<sup>th</sup> August 1998) is required, see Figure 4.8 (c) and (d). These rearrangement procedures are automatically performed by WCSM. This automatic function is the major difference between WCSM and the other current applications.

More detail tasks were involved in test 2. These can also be easily viewed on a Gantt chart, that is shown in Figure 4.9 (a) and (b). In the same Figure, (c) and (d) reflect the schedule after modification.

WCSM  
Web-based Construction Site Management System

Today's My Construction Task Information

Project Name: Test1 Section: 1

Date: 98-AUG-20

Tasks & Resources

Task ID	Task Name	Resources	% Completed
1	Formwork	Surveyor, Labours(800)	100
2			
3			
4			
5			

WCSM  
Web-based Construction Site Management System

Today's My Construction Task Information

Project Name: Test2 Section: 1

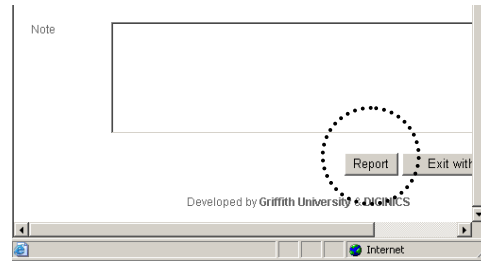
Date: 98-AUG-20

Tasks & Resources

Task ID	Task Name	Resources	% Completed
1	Setting Out (F.W_S1)	Surveyor	100
2	Fixing Formwork (F.W_S1)	Labours(800%), Carp	100
3			
4			
5			

(a) Test 1

(b) Test 2



(c) Bottom of Upload Page Screen for Test 1 and 2

Figure 4.7 Daily Tasks Upload by Wireless Device User

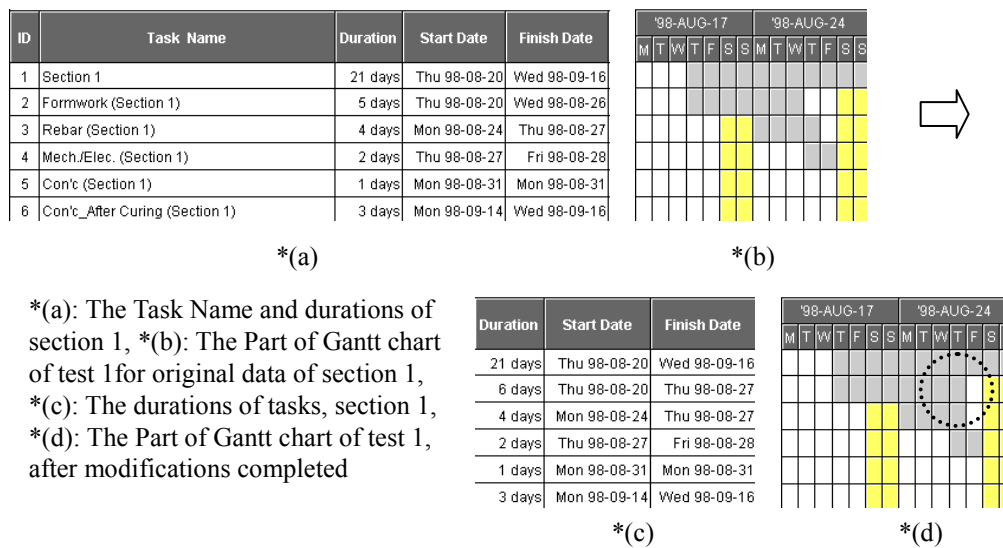
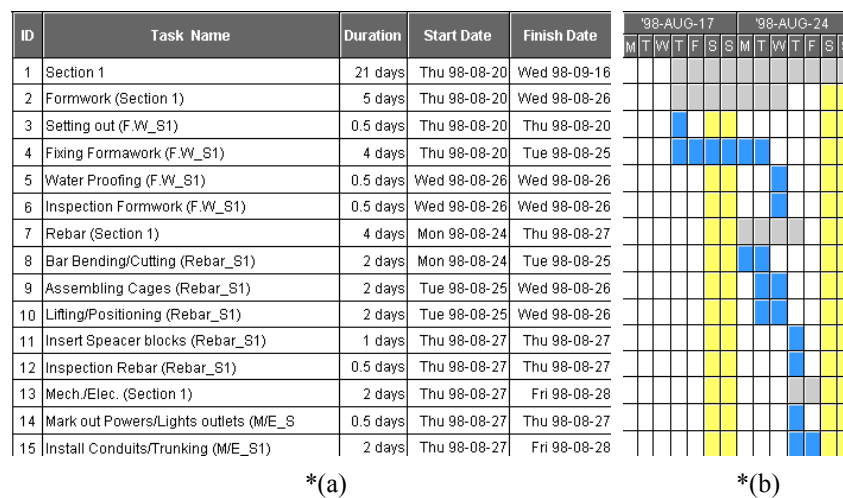


Figure 4.8 Viewer Mode of WCSM: The Comparison of Gantt Charts (Comparison of schedule change (Test 1))



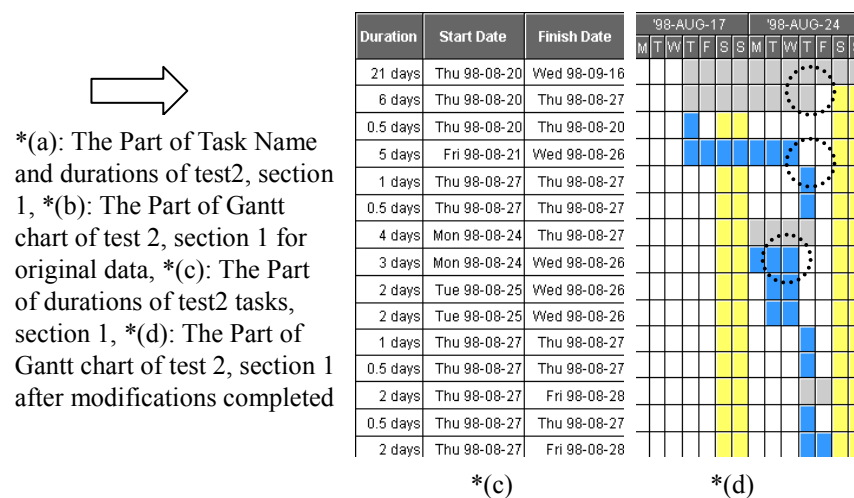


Figure 4.9 Viewer Mode of WCSM: The Comparison of Gantt Charts  
(Comparison of schedule change (Test 2))

## 4.4 Results and Discussion

The two tests that were conducted focused on time efficiency in data handling. Tests were also done on current applications, such as Microsoft Project and Micro Planner, to compare the performances. WCSM had a major advantage in that it does not require the project manager to do manual scheduling inputs, when construction schedule is changed. Other current applications require that modification must be done manually by project manager.

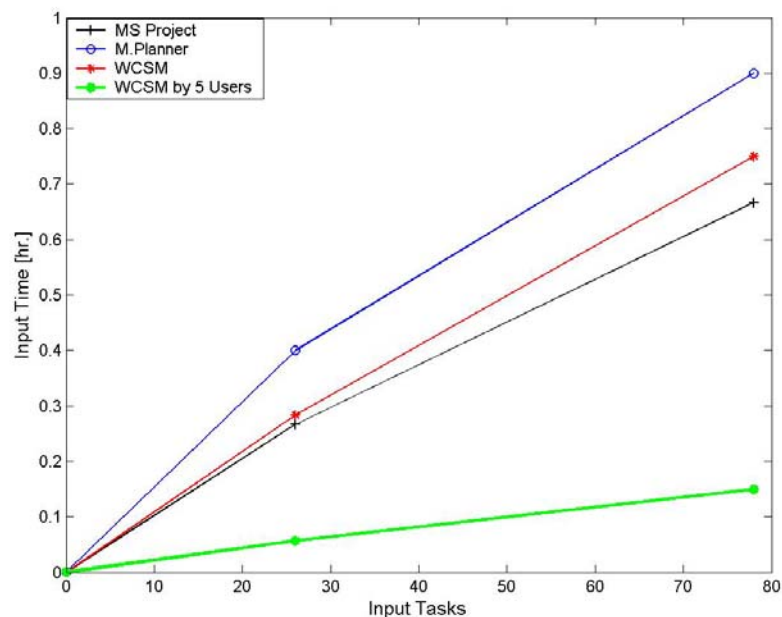
Each site engineer of WCSM reports to server through their portable device. The connection method was described in section 4.3.1. Both connection methods (wireless ISP and internal wireless network) have advantages and disadvantages. When the system used wireless ISP method, company takes into account for the cost of connection of each device, but this method has low system set up costs. The use of internal wireless network has huge advantage in very low maintenance cost and no connection fees. However, it requires a lot of initial system set up costs. The tests in this study were performed on mobile users using the later method.

WCSM can maintain an accurate time record of log-in and out for mobile and other users. Thus, all the time measurement of mobile users can easily be obtained from the WCSM database.

### 4.4.1 Input Time Analysis

WCSM has been developed for multi-user environment. The advantage of this will have to be taken into consideration in the tests. However, the results of measured time were the sum of total operation time from users. Therefore, this cannot be considered as an advantage to WCSM in the comparisons with other applications.

The time consumption of each engineer displayed in Figure 4.10 is the measured input time for three different applications for five different input users. It can be seen that the input time for WCSM (Test1: 0.28 hr. and Test2: 0.75 hr.) is quicker than Micro Planner (Test1: 0.4 hr. and Test2: 0.9 hr.). In this single user time measurement, Microsoft Project (Test1: 0.27 hr. and Test2: 0.67 hr.) has a marginally better performance compared to single input user operation of WCSM in establishing the initial schedule. However, WCSM can reduce input time dramatically when initial information is established by 5 different input users (Test1: 0.06 hr. and Test2: 0.15 hr.). The major step forward in WCSM is that it has been designed for multi users.

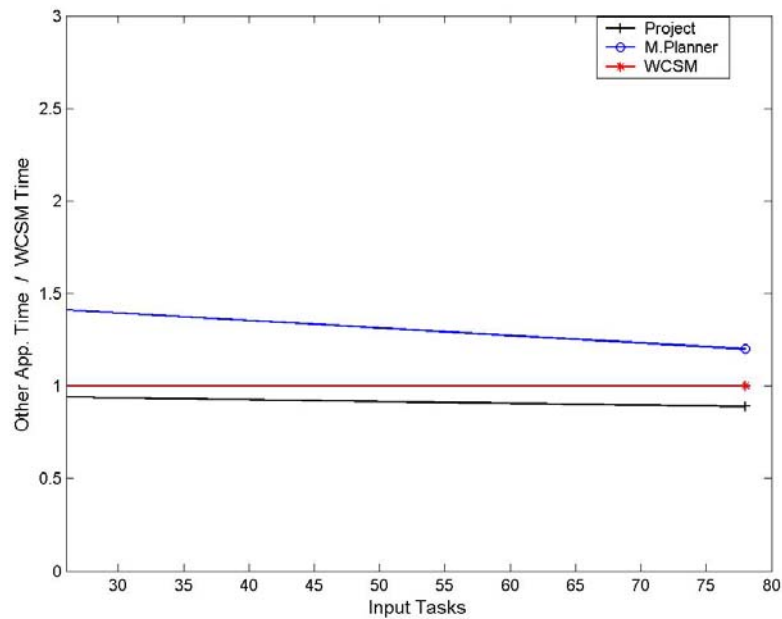


\*Input task 26 indicates Test1 and 78 indicates Test2

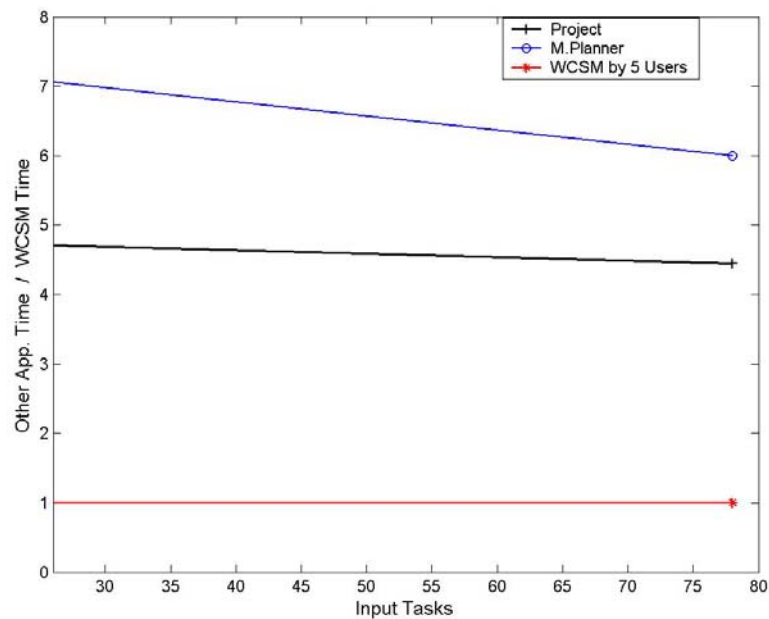
Figure 4.10 Input Time Measurements

Figure 4.11 shows the comparison of input speed ratio among the three applications. This comparison includes two cases, for WCSM single and multi input user environment (see Figure 4.11 (a) and (b)). Figure 4.11 (a) indicates that MS Project with a ratio of 0.94 ~

0.98 is marginally efficient than WCSM. However, in the case of multi-user interface in Figure 4.11 (b), the total input time of WCSM is much smaller than MS Project (4.4 ~ 4.7) and M. Planner (6 ~ 7.6). In other words, the input speed of WCSM is approximately 4.5 and 6.8 times faster than MS Project and M. Planner respectively when WCSM is operated in the multi-user interface.



(a) WCSM (Single User)



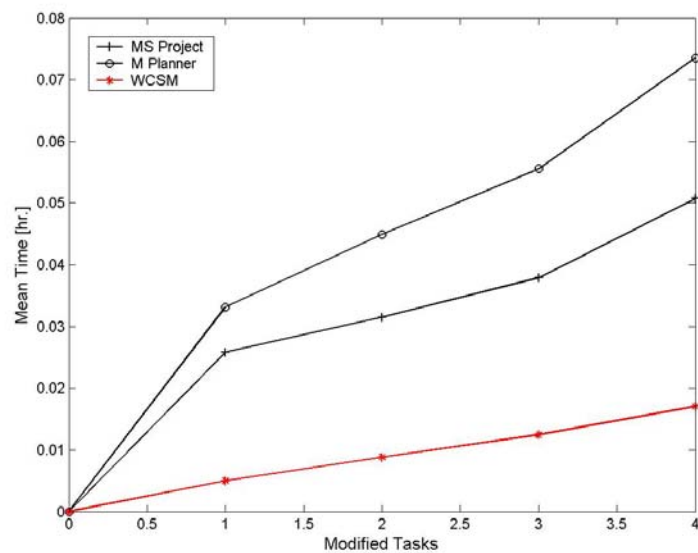
(b) WCSM (Multi user)

Figure 4.11 Ratio Comparisons for Input Time

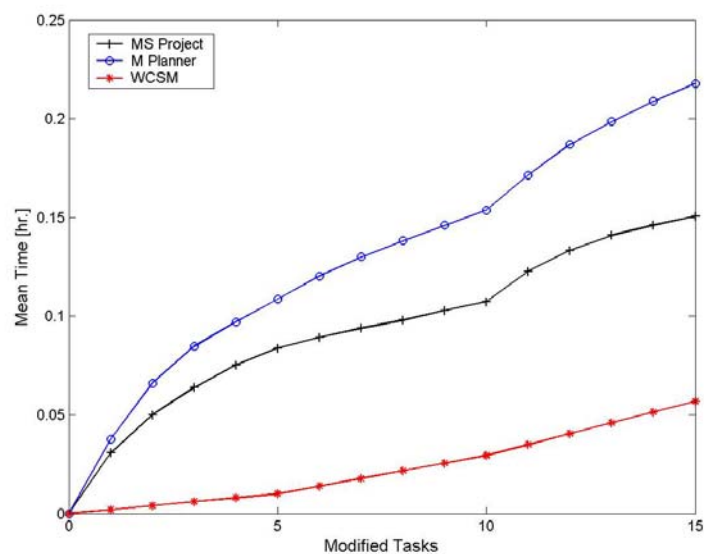
#### 4.4.2 Time Analysis for Schedule Modification

Between 4 and 15 tasks were modified from the original schedule in the first and second test respectively. WCSM did not require modification of initial plan by project manager, these were updated automatically.

Figure 4.12 shows the cumulative time measurements for rescheduling as measured during each test. In the first test, 0.017 hour of WCSM, 0.051 hour of MS Project and 0.074 hour of Micro Planner were taken to modify the initial plan. This shows that modifications are handled in MS project faster than Micro Planner, but both are much slower than WCSM.



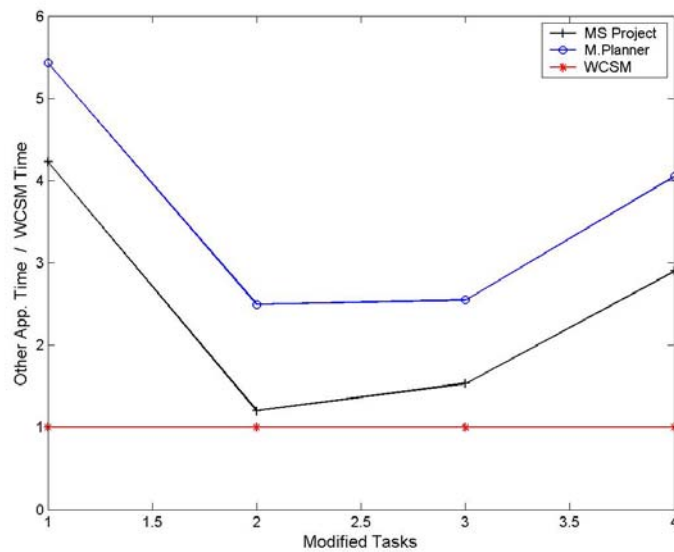
(a) Test 1



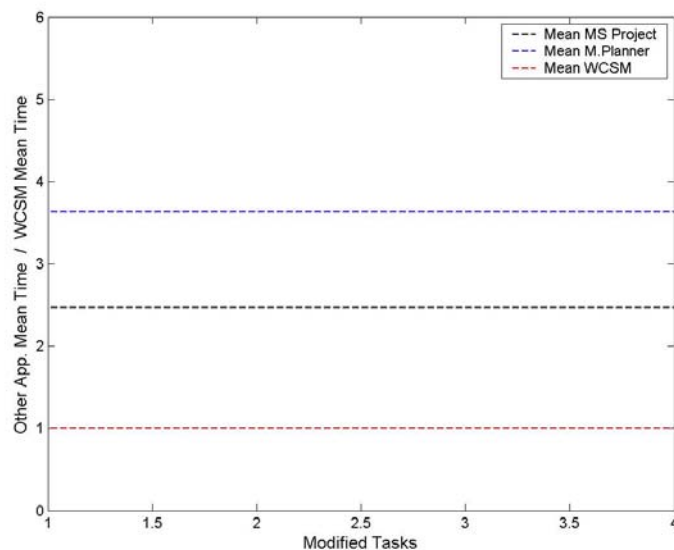
(b) Test2

Figure 4.12 Modification Time Measurements

The modification speeds are compared as ratios in Figure 4.13 (Test 1) and 4.14 (Test 2). Both tests (Figure 4.13(a) and Figure 4.14(a)) show that other applications take more time to modify the first few tasks, as the project manager needs to study and make decisions. WCSM does the rescheduling automatically as soon as the mobile user update information into WCSM.



(a) Ratio Comparisons

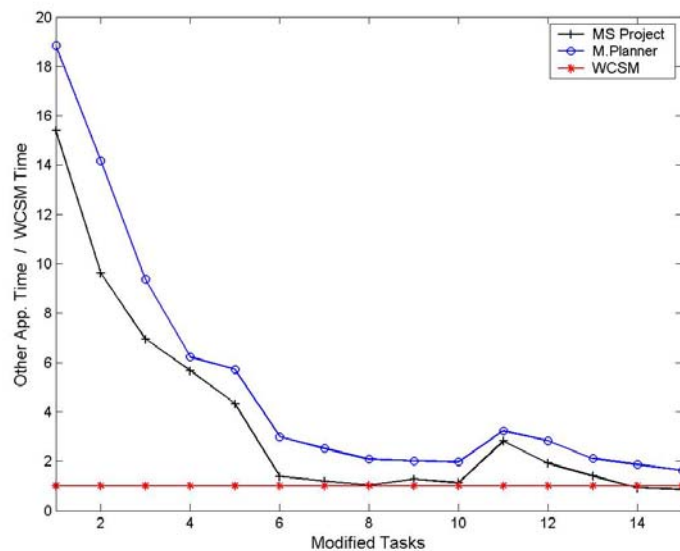


(b) Mean Ratio Comparison

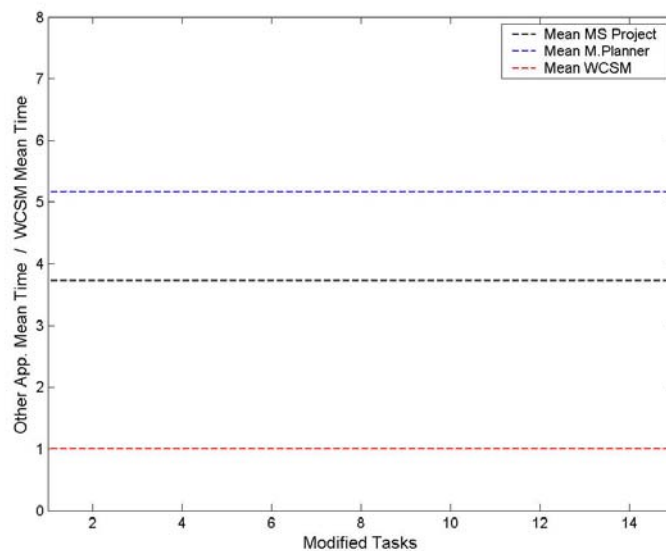
Figure 4.13 Ratio Comparisons for Input Time (Test1)



From the mean ratios comparison in Figure 4.13(b) and 4.14(b), it can be seen that WCSM is 2.5 times to 3.7 times faster than MS Project and 3.6 times to 5 times faster than Micro Planner.



(a) Ratio Comparisons

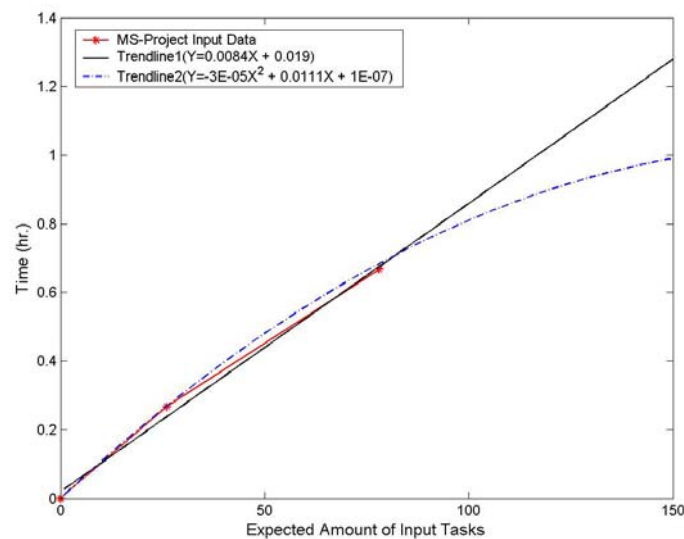


(b) Mean Ratio Comparison

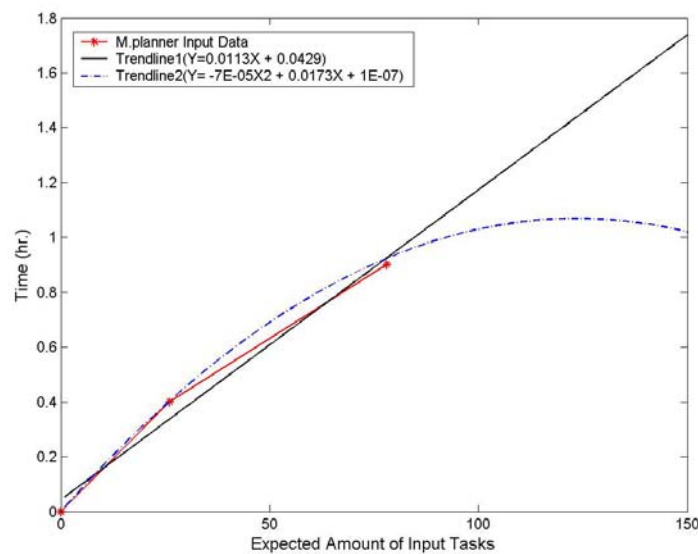
Figure 4.14 Modification Time Measurements (Test2)

### 4.4.3 Time Prediction for Large Amount of Data

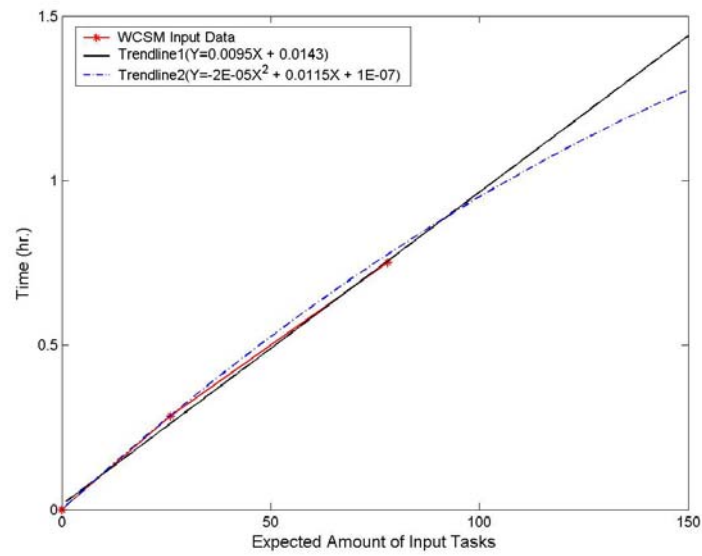
Trendline was generated based on cumulative times for a number of input tasks and modified tasks from the second test. The reason for taking second test data only is because the amount of data in the first test was too small to generate it. Trendline was obtained with best fits from logarithmic, polynomial, power, and exponential type for each results data. The generated trendlines were very similar in the scale of small number of tasks, but it begins to show up different shape of curve when tasks increased, such as input tasks from 78 to 150 in Figure 4.15 (b). Based on these trendlines operation time for processing large amount of project information can be predicted.



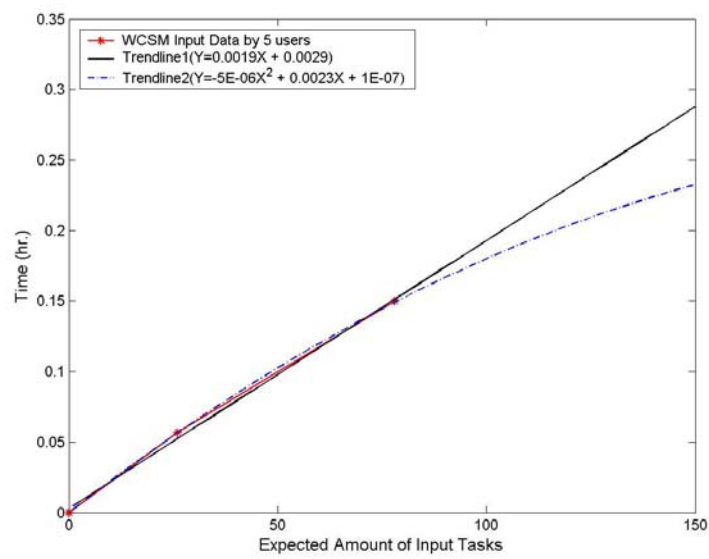
(a) Microsoft Project



(c) Micro Planner



(c) WCSM



(d) WCSM by 5 Input Users

Figure 4.15 Trendline of Input Data

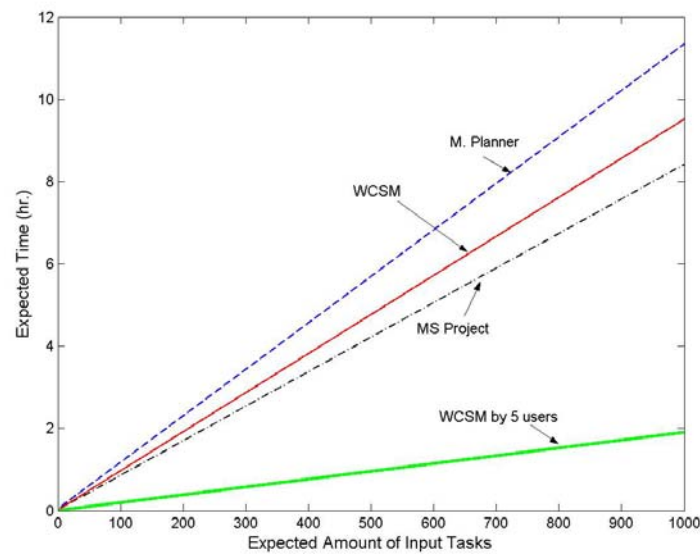
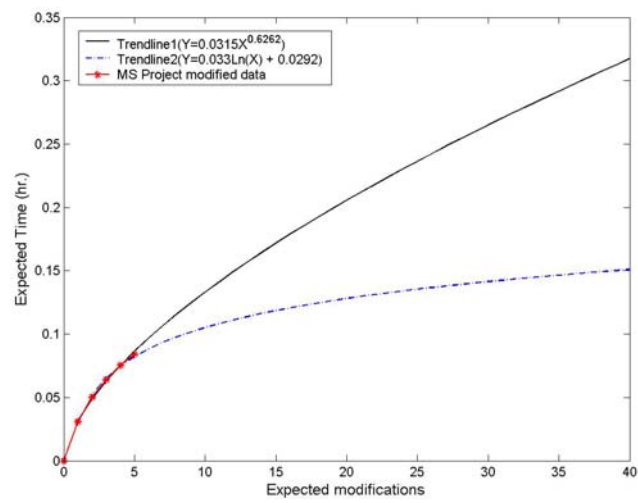


Figure 4.16 Predicted Time for Large Data Input

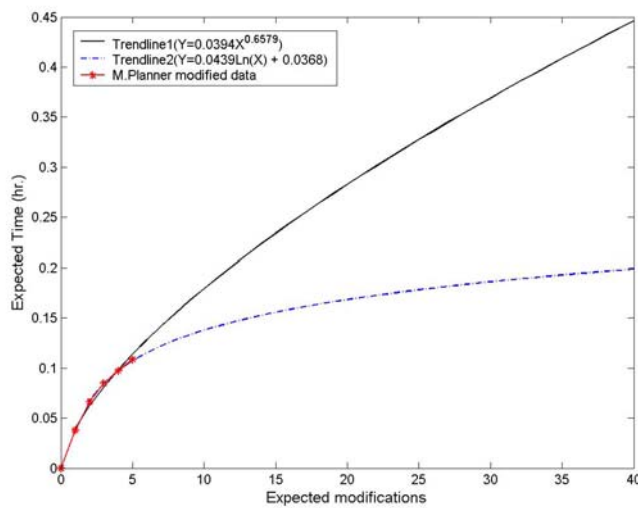
Using the best trendline from Figure 4.15, the expected time for large amount of data input for each applications were plotted in Figure 4.16. The summary of predictions is as follows:

- 500 input tasks will take Microsoft Project: 4.22 hrs., Micro Planner: 5.69 hrs., WCSM: 4.76 hrs and WCSM by multi-user interface: 0.95 hrs.
- 1000 input tasks will take Microsoft Project: 8.42 hrs., Micro Planner: 11.34 hrs., WCSM: 9.51 hrs and WCSM by multi-user interface: 1.9 hrs.

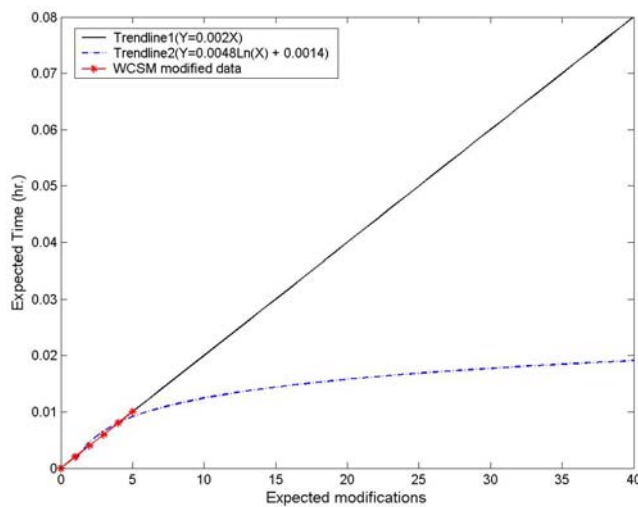
In single-user interface, Microsoft Project was about 11% more efficient than WCSM in information input. However, under multi-user environment, WCSM can reduce the project data input time from 4.4 up to 6.0 times.



(a) Microsoft Project



(b) Micro Planner



(c) WCSM

Figure 4.17 Trendline for Data Modification

In a similar way, Figure 4.17 shows a plot of the trendline for data modification. Using the trendlines the predictions for large data modification were plotted in Figure 4.18. The summary of predictions is as follows:

- 50 modification tasks will take Microsoft Project: 0.37 hrs., Micro Planner: 0.52 hrs. and WCSM: 0.1 hrs.
- 100 modification tasks will take Microsoft Project: 0.56 hrs., Micro Planner: 0.82 hrs. and WCSM: 0.2 hrs.

Even in single-user interface, WCSM was 2.8 and 4.1 times quicker than Microsoft Project and Micro Planner respectively.

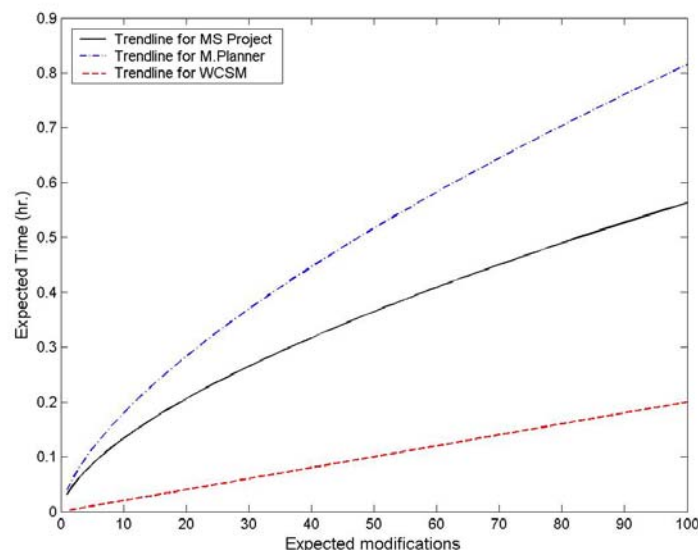


Figure 4.18 Predictions for Large Data Modifications

## 4.5 Summary

In this chapter, analysis and results of two tests comparing WCSM to MS Project and Micro Planner were discussed. The discussion about initial input and modification time analysis showed the efficiency of WCSM compared to the other current applications. The results dramatically favoured WCSM when large amount of input and modification data is involved in a project.

WCSM is built on by Web technology, which makes multi-user interface possible. Once user has registered into WCSM DB (Data Base) as a project manager, WCSM will

provide the most up to date information in real time. The unique feature of WCSM is automatic schedule updating in real time. The principle behind this is that updating tasks are performed individually by wireless device users in real time. The results of updated plan can be monitored by the project manager and shared by others. Normal applications on the other hand would require time to modify the original plan whenever a change or disruption occurs on site.

The performance comparison of WCSM showed that project information set up time can be reduced by as 4.4 ~ 6.0 times and modification time can be reduced by 2.8 ~ 4.1 times when compared to Microsoft Project and Micro Planner.

# Chapter 5

## Conclusion

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A Web-based Construction Site Management system called WCSM, has been developed taking advantage of current Information technology. WCSM has been designed for the Web and mobile computing technologies of today. Mobile computing solutions enable instantaneous transferring of the information from work filed to office. The system provides daily tasks for each site engineer and reports back the daily progress results. The project schedules are automatically updated. The main objective of this study was to develop a model of WCSM to improve the efficiency of work environment in managing a construction jobsite.

From the construction site's management point of view, in order to complete a project within time and budget, a lot of information has to be communicated efficiently and accurately. In order to perform construction job schedule management effectively a well designed computer application is essential.

Some mobile computing solutions have been proposed in the past decade. Mobile computers have been used as personal computers to download big files of information in the field. But at present data transfer from portable device is not efficient when compared to a wired network condition. Thus, any information used by handheld device has to have simple format of contents and small file size. The main reason for the implementation of mobile computing solution in the real field is that user can access and share information quickly and easily.



## **5.1 Conclusions of Research**

In this MPhil research program, a web-based management tool for construction site, has been developed. The focus was on integrating wireless mobile devices for use in construction sites. The WCSM that was developed during the study, automates the modification of project plan once the initial master project plan has been established. The system was evaluated and was found to be reliable and more efficient than the existing applications. Based on this research, the following conclusions can be drawn:

1. The importance of IT in construction was confirmed. Current status of IT in construction industry and the various proposed IT solutions by researchers were reviewed. Internet Technology has become one of the potential tools if it is applied appropriately in construction projects. Many construction companies still hesitate to establish IS for their construction projects, mainly due to the potential initial investment that is required.
2. A construction site management system (WCSM) has been developed making use of existing IT technology. The structure of WCSM is a combination of wired and wireless web technology. Each component of structure is upgradeable in line with technology advance. WCSM can transfer data faster as wireless network technology improved. WCSM does not have any geographical limitations to monitor project progress.
3. The initial information and details of the project are first uploaded by the project manager. The system is then ready to be operated by site engineers (mobile device users). Each site engineer can access WCSM through wireless network to obtain daily tasks. During the construction the scheduled tasks may be delayed for several reasons. As every site engineer reports progress, WCSM will automatically update the overall project schedules. In order to efficiently use the system, project manager needs to provide a detail break down of the project schedule. WCSM saves time and cost in project management as it eliminates the need for manual input from the project manager, during project implementation.

## **5.2 Recommendations for Future Research**

WCSM has been developed integrating mobile solutions, for construction jobsite schedule management. This management system can be considered to be part of ERP (Enterprise Resource Planning) system. Most of the existing ERP is for the manufacturing industry to improve the efficiency of project management and to reduce unnecessary project cost. The reason for the slow adoption in the construction industry is due to the uniqueness of projects and the large variations between projects. WCSM, the system that is developed in this study has addressed part of the problem involving management tasks. However, further developments are required to incorporate resource management, material control and equipment control etc.

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# Appendix I

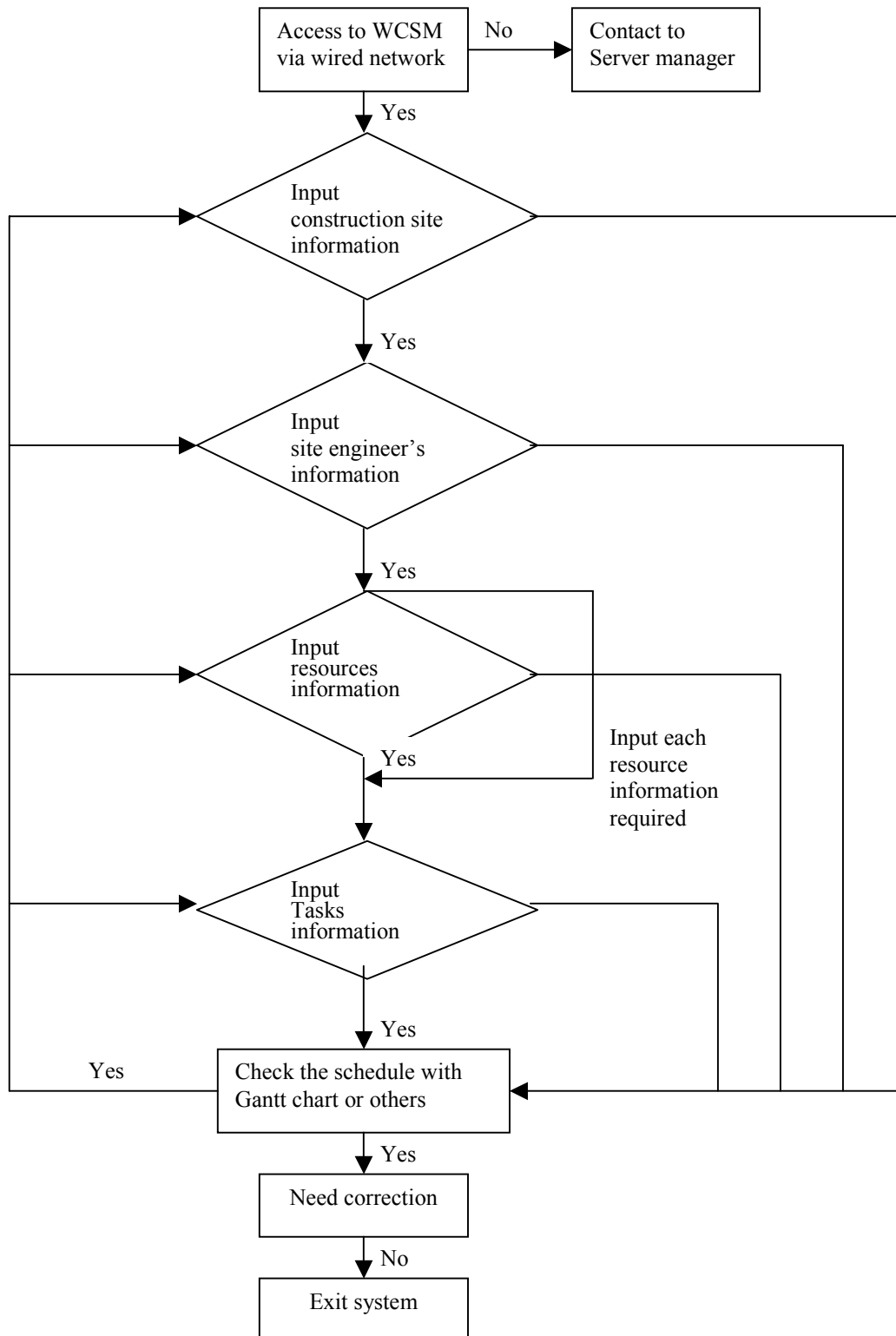


Figure AI-1 WCSM Server Flowchart for PC's Users

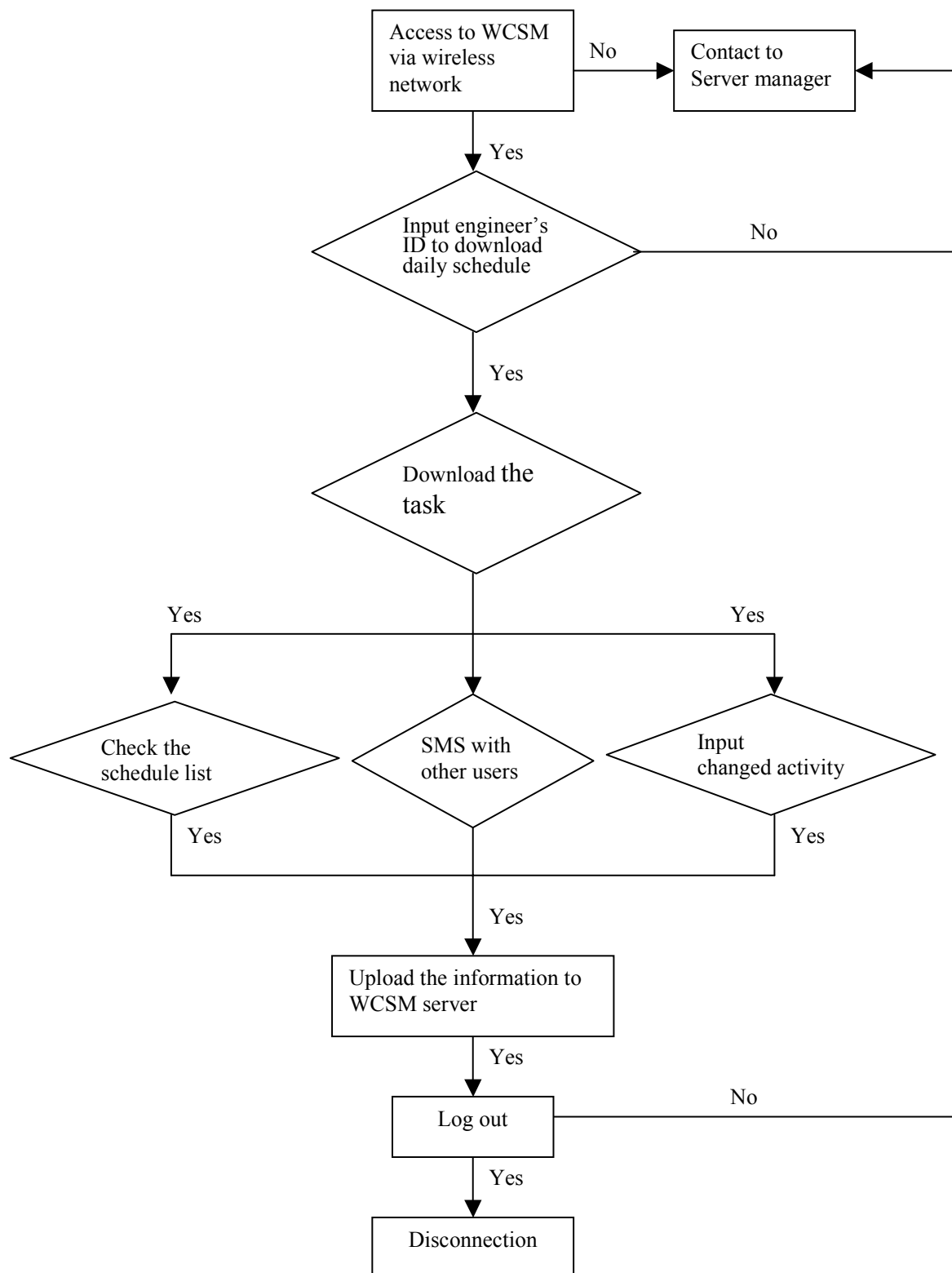


Figure AI-2 WCSM Server Flowchart for Mobile Device's Users



Table AI-I. Outline of Tests Conducting

	Measuring operation time
	WCSM
1. Input general data (See section 4.2.1)	Yes
↓	
2. Input resource data (See section 4.2.2)	Yes
↓	
→ 3. Supplying daily task to site engineers (See section 4.3.1)	
↓	
4. Reports from site engineers (See section 4.3.2)	Yes
↓	
5. Updating entire project information (See section 4.3.2)	Yes
↓	
End of test	
6. End of tests	

# Appendix II



Figure AII-1. Sketch of Korean Industrial Bank headquarter Project in Seoul, Korea (July 1996 ~ April 2001).

Table AII-1. Test1 data

1	Section 1	21 days	20/08/1998	16/09/1998
2	Formwork (Section 1)	5 days	20/08/1998	26/08/1998
3	Rebar (Section 1)	4 days	24/08/1998	27/08/1998
4	Mech./Elec. (Section 1)	2 days	27/08/1998	28/08/1998
5	Con'c (Section 1)	1 day	31/08/1998	31/08/1998
6	Con'c_After Curing (Section 1)	3 days	14/09/1998	16/09/1998
7	Section 2	21 days	20/08/1998	16/09/1998
8	Formwork (Section 2)	5 days	20/08/1998	26/08/1998
9	Rebar (Section 2)	4 days	24/08/1998	27/08/1998
10	Mech./Elec. (Section 2)	2 days	27/08/1998	28/08/1998
11	Con'c (Section 2)	1 day	31/08/1998	31/08/1998
12	Con'c_After Curing (Section 2)	3 days	14/09/1998	16/09/1998
13	Section 3	12 days	20/08/1998	4/09/1998
14	Formwork (Section 3)	4 days	20/08/1998	25/08/1998
15	Rebar (Section 3)	3 days	21/08/1998	25/08/1998
16	Mech./Elec. (Section 3)	1 day	26/08/1998	26/08/1998
17	Con'c (Section 3)	1 day	27/08/1998	27/08/1998
18	Con'c_After Curing (Section 3)	2 days	3/09/1998	4/09/1998

Table AII-2. Test2 data

1	Section 1	21 days	20/08/1998	16/09/1998
2	Formwork (Section 1)	5 days	20/08/1998	26/08/1998
3	Setting Out (F.W_S1)	0.5 days	20/08/1998	20/08/1998
4	Fixing Form Work (F.W_S1)	4 days	20/08/1998	25/08/1998
5	Water Proofing (F.W_S1)	0.5 days	26/08/1998	26/08/1998
6	Inspection Formwork (F.W_S1)	0.5 days	26/08/1998	26/08/1998
7	Rebar (Section 1)	4 days	24/08/1998	27/08/1998
8	Bar Bending/Cutting (Rebar_S1)	2 days	24/08/1998	25/08/1998
9	Assembling Cages (Rebar_S1)	2 days	25/08/1998	26/08/1998
10	Lifting/Positioning (Rebar_S1)	2 days	25/08/1998	26/08/1998
11	Insert Spacer blocks (Rebar_S1)	1 day	27/08/1998	27/08/1998
12	Inspection Rebar (Rebar_S1)	0.5 days	27/08/1998	27/08/1998
13	Mech./Elec. (Section 1)	2 days	27/08/1998	28/08/1998
14	Mark out Powers/Lights/Comm./Other outlets (M/E_S1)	0.5 days	27/08/1998	27/08/1998
15	Install Conduits/Trunking (M/E_S1)	2 days	27/08/1998	28/08/1998
16	Insert Openings in Slab/Beams (M/E_S1)	1 day	28/08/1998	28/08/1998
17	Inspection M/E (M/E_S1)	0.5 days	28/08/1998	28/08/1998
18	Con'c (Section 1)	1 day	31/08/1998	31/08/1998
19	Con'c Pouring/Vibrating (Con._S1)	1 day	31/08/1998	31/08/1998
20	Make Test Cylinders (Con._S1)	0.5 days	31/08/1998	31/08/1998
21	Test of Cylinders (Con._S1)	0.5 days	31/08/1998	31/08/1998
22	Inspection Con'c pouring (Con._S1)	1 day	31/08/1998	31/08/1998
23	Con'c_After Curing (Section 1)	3 days	14/09/1998	16/09/1998
24	Stripping Formwork / Inspect honey combs/deflects (Con._S1)	2 days	14/09/1998	15/09/1998
25	Rectification of deflect (Con._S1)	3 days	14/09/1998	16/09/1998
26	Inspection Con'c _after curing (Con._S1)	1 day	16/09/1998	16/09/1998
27	Section 2	21 days	20/08/1998	16/09/1998
28	Formwork (Section 2)	5 days	20/08/1998	26/08/1998
29	Setting Out (F.W_S2)	0.5 days	20/08/1998	20/08/1998
30	Fixing Form Work (F.W_S2)	4 days	20/08/1998	25/08/1998
31	Water Proofing (F.W_S2)	0.5 days	26/08/1998	26/08/1998
32	Inspection Formwork (F.W_S2)	0.5 days	26/08/1998	26/08/1998
33	Rebar (Section 2)	4 days	24/08/1998	27/08/1998
34	Bar Bending/Cutting (Rebar_S2)	2 days	24/08/1998	25/08/1998
35	Assembling Cages (Rebar_S2)	2 days	25/08/1998	26/08/1998
36	Lifting/Positioning (Rebar_S2)	2 days	25/08/1998	26/08/1998
37	Insert Spacer blocks (Rebar_S2)	1 day	27/08/1998	27/08/1998
38	Inspection Rebar (Rebar_S2)	0.5 days	27/08/1998	27/08/1998
39	Mech./Elec. (Section 2)	2 days	27/08/1998	28/08/1998
40	Mark out Powers/Lights/Comm./Other outlets (M/E_S2)	0.5 days	27/08/1998	27/08/1998
41	Install Conduits/Trunking (M/E_S2)	2 days	27/08/1998	28/08/1998
42	Insert Openings in Slab/Beams (M/E_S2)	1 day	28/08/1998	28/08/1998
43	Inspection M/E (M/E_S2)	0.5 days	28/08/1998	28/08/1998
44	Con'c (Section 2)	1 day	31/08/1998	31/08/1998
45	Con'c Pouring/Vibrating (Con._S2)	1 day	31/08/1998	31/08/1998
46	Make Test Cylinders (Con._S2)	0.5 days	31/08/1998	31/08/1998
47	Test of Cylinders (Con._S2)	0.5 days	31/08/1998	31/08/1998

48	Inspection Con'c pouring (Con._S2)	1 day	31/08/1998	31/08/1998
49	Con'c_After Curing (Section 2)	3 days	14/09/1998	16/09/1998
50	Stripping Formwork / Inspect honey combs/deflects (Con._S2)	2 days	14/09/1998	15/09/1998
51	Rectification of deflect (Con._S2)	3 days	14/09/1998	16/09/1998
52	Inspection Con'c _after curing (Con._S2)	1 day	16/09/1998	16/09/1998
53	Section 3	12 days	20/08/1998	4/09/1998 0
54	Formwork (Section 3)	4 days	20/08/1998	25/08/1998
55	Setting Out (F.W_S3)	0.5 days	20/08/1998	20/08/1998
56	Fixing Form Work (F.W_S3)	3 days	20/08/1998	24/08/1998
57	Water Proofing (F.W_S3)	0.5 days	25/08/1998	25/08/1998
58	Inspection Formwork (F.W_S3)	0.5 days	25/08/1998	25/08/1998
59	Rebar (Section 3)	3 days	21/08/1998	25/08/1998
60	Bar Bending/Cutting (Rebar_S3)	1.5 days	21/08/1998	24/08/1998
61	Assembling Cages (Rebar_S3)	2 days	21/08/1998	24/08/1998
62	Lifting/Positioning (Rebar_S3)	3 days	21/08/1998	25/08/1998
63	Insert Spacer blocks (Rebar_S3)	1 day	25/08/1998	25/08/1998
64	Inspection Rebar (Rebar_S3)	0.5 days	25/08/1998	25/08/1998
65	Mech./Elec. (Section 3)	1 day	26/08/1998	26/08/1998
66	Mark out Powers/Lights/Comm./Other outlets (M/E_S3)	0.5 days	26/08/1998	26/08/1998
67	Install Conduits/Trunking (M/E_S3)	1 day	26/08/1998	26/08/1998
68	Insert Openings in Slab/Beams (M/E_S3)	1 day	26/08/1998	26/08/1998
69	Inspection M/E (M/E_S3)	0.5 days	26/08/1998	26/08/1998
70	Con'c (Section 3)	1 day	27/08/1998	27/08/1998
71	Con'c Pouring/Vibrating (Con._S3)	1 day	27/08/1998	27/08/1998
72	Make Test Cylinders (Con._S3)	0.5 days	27/08/1998	27/08/1998
73	Test of Cylinders (Con._S3)	0.5 days	27/08/1998	27/08/1998
74	Inspection Con'c pouring (Con._S3)	1 day	27/08/1998	27/08/1998
75	Con'c_After Curing (Section 3)	2 days	3/09/1998	4/09/1998
76	Stripping Formwork / Inspect honey combs/deflects (Con._S3)	2 days	3/09/1998	4/09/1998
77	Rectification of deflect (Con._S3)	2 days	3/09/1998	4/09/1998
78	Inspection Con'c _after curing (Con. _S3)	1 day	4/09/1998	4/09/1998

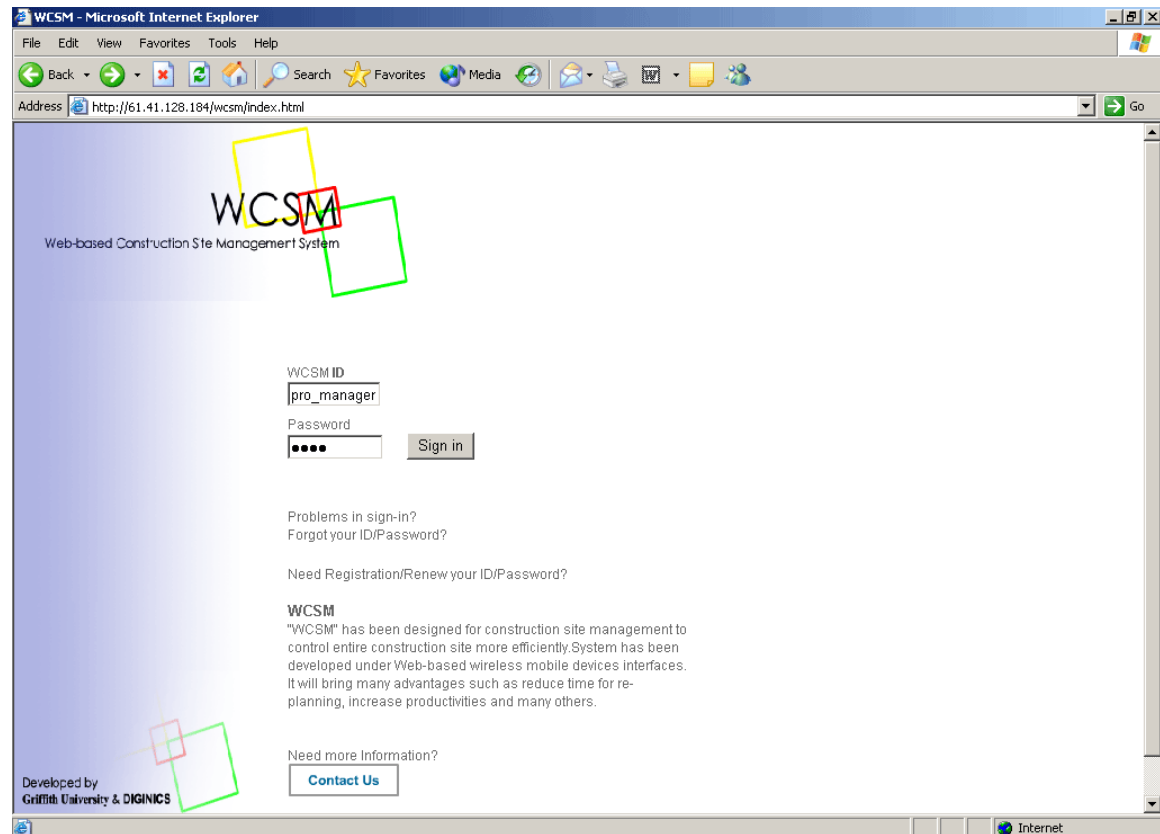


Figure A II-2 WCSM Screen Shot for Project manager Log-in

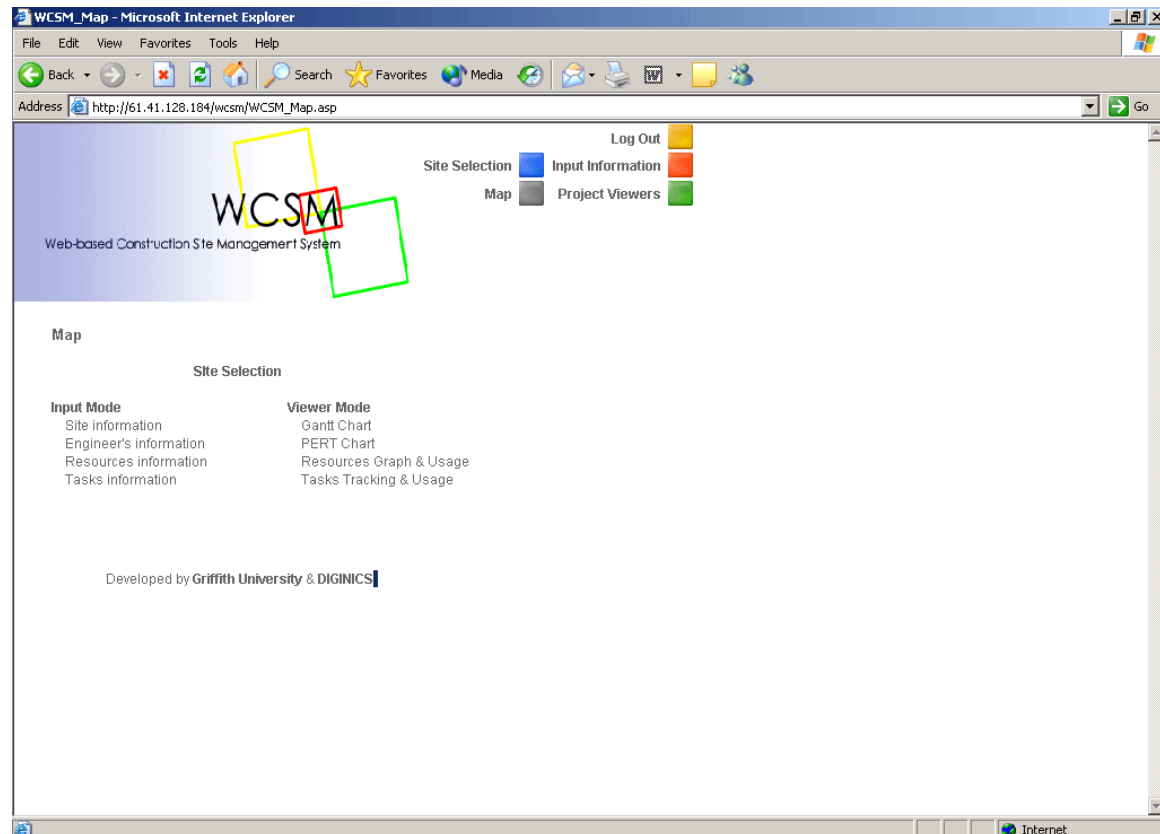


Figure A II-3 WCSM Screen Shot for Site Map

The screenshot shows the WCSM (Web-based Construction Site Management) system interface in Microsoft Internet Explorer. The browser address bar shows the URL: [http://61.41.128.184/wcsm/WCSM\\_input\\_mode.asp](http://61.41.128.184/wcsm/WCSM_input_mode.asp). The page features a header with the WCSM logo and a navigation menu on the right. The main content area is titled "Construction Site Information" and contains a form for entering project details. The form fields are as follows:

Field	Value
ProjectID	WCSM Test1
Project name	Test1
Site location	N/A
Expected duration	20 days
Start date	20/8/1998
Finish date	16/9/1998
Scope	WCSM test1

At the bottom of the form, there are two buttons: "Save" and "Exit without Save". The status bar at the bottom of the browser window shows "Internet".

Figure A II-4 WCSM Screen Shot for Input mode of Construction Site Information (Test1)

The screenshot shows the WCSM (Web-based Construction Site Management) system interface in Microsoft Internet Explorer. The browser address bar shows the URL: [http://61.41.128.184/wcsm/WCSM\\_input\\_mode.asp](http://61.41.128.184/wcsm/WCSM_input_mode.asp). The page features a header with the WCSM logo and a navigation menu on the right. The main content area is titled "Construction Site Information" and contains a form for entering project details. The form fields are as follows:

Field	Value
ProjectID	WCSM Test2
Project name	Test2
Site location	N/A
Expected duration	20 days
Start date	20/8/1998
Finish date	16/9/1998
Scope	WCSM Test2

At the bottom of the form, there are two buttons: "Save" and "Exit without Save". The status bar at the bottom of the browser window shows "Done".

Figure A II-5 WCSM Screen Shot for Input mode of Construction Site Information (Test2)

WCSM  
Web-based Construction Site Management System

Site Selection ☒ Input Information ☐  
Map ☐ Project Viewers ☐  
Site Information ☐  
Site Engineer's Information ☒  
Resources Information ☐  
Tasks Information ☐

Log Out

**Site Engineer's Information**

ID:   
 PASSWORD:   
 NAME:   
 SECTION:   
 TASK:   
 Site:

Input Engineer On  
 engineer1 - engineer - engineer1 - Section1 - Supervising section1 area  
 engineer2 - engineer - engineer2 - Section2 - Supervising section2  
 engineer3 - engineer - engineer3 - Section3 - Supervising section3  
 pro\_manager - wcsm - project manager - 0 - manager

Figure A II-6. WCSM Screen Shot for Input mode of Site Engineers Information

WCSM  
Web-based Construction Site Management System

Site Selection ☒ Input Information ☐  
Map ☐ Project Viewers ☐  
Site Information ☐  
Site Engineer's Information ☐  
Resources Information ☒  
Tasks Information ☐

Log Out

**Resource Information**

ID:   
 Name:   
 Unit max:  %  
 Rate standard:  A \$/hr.  
 Rate Overtime:  A \$/hr.  
 Note:

ID	Resources Name	Max. Units(%)	Std. Units(%)	Ovt. Units(%)
Input Resource On				
1	Labour	4800	12-Australia	15-Australia
4800	Labour	4800	12-Australia	15-Australia

Figure A II-7. WCSM Screen Shot for Input mode of Resources Information

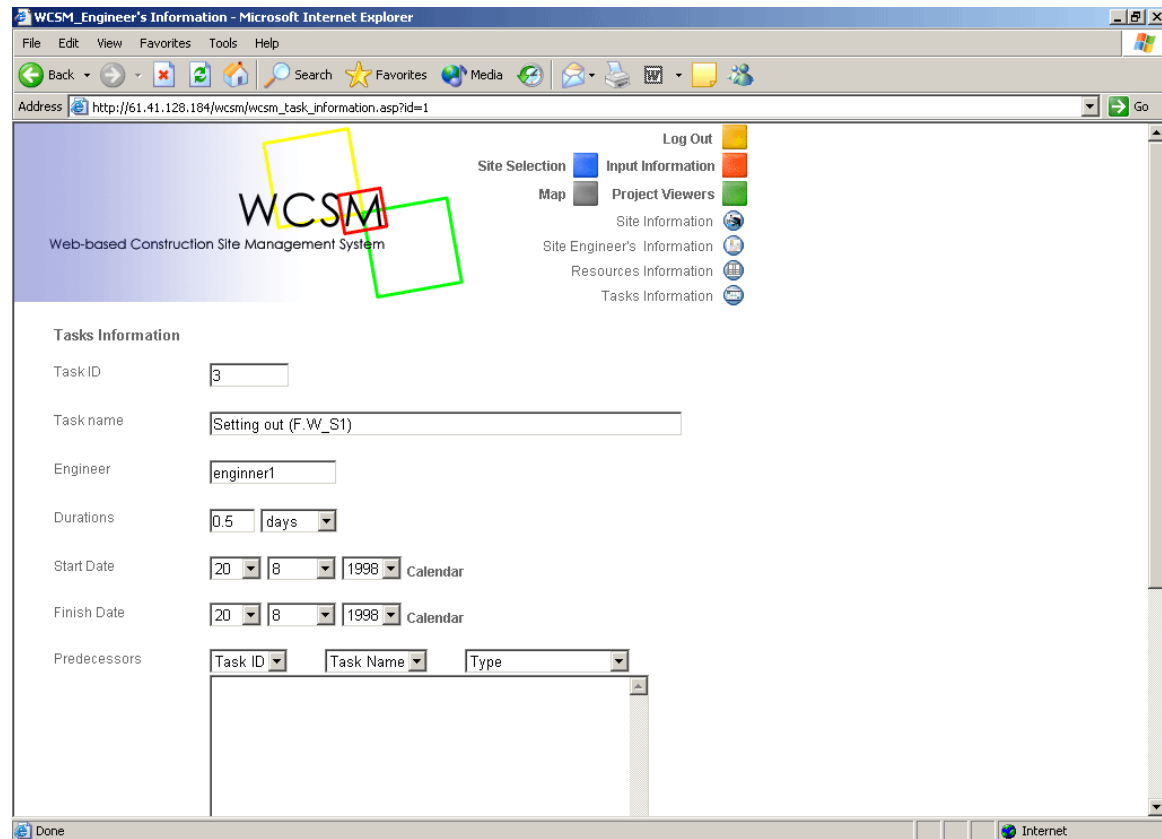


Figure A II-8. WCSM Screen Shot for Input mode of Tasks Information

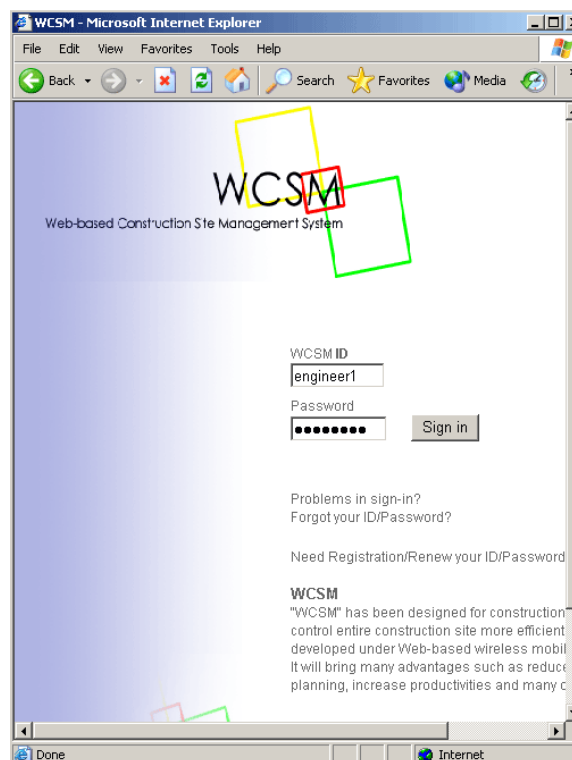


Figure A II-9. WCSM Screen Shot for PDA Log-in



The screenshot shows the WCSM web application in a Microsoft Internet Explorer browser window. The page title is "WCSM\_Engineer's Information - Microsoft Internet Explorer". The browser's address bar shows the URL "http://localhost:8080/WCSM/". The page features a header with the WCSM logo and the text "Web-based Construction Site Management System". Below the header, there is a section titled "Today's My Construction Task Information". This section contains a form with the following fields: "Project Name" (Test1), "Section" (1), "Date" (98-AUG-20), and a table for "Tasks & Resources". The table has two columns: "Task" and "Resource". The first row shows "1. Formwork" and "Surveyor, Labours (800%)". The second row shows "2." and an empty resource field. The third row shows "3." and an empty resource field. The fourth row shows "4." and an empty resource field. The fifth row shows "5." and an empty resource field. The sixth row shows "6." and an empty resource field. Each row has a "% Completed" checkbox next to the task name.

Task	Resource
1. Formwork	Surveyor, Labours (800%)
2.	
3.	
4.	
5.	
6.	

Figure A II-10. WCSM Screen Shot for PDA Daily Task Download (Test1)

The screenshot shows the WCSM web application in a Microsoft Internet Explorer browser window. The page title is "WCSM\_Engineer's Information - Microsoft Internet Explorer". The browser's address bar shows the URL "http://localhost:8080/WCSM/". The page features a header with the WCSM logo and the text "Web-based Construction Site Management System". Below the header, there is a section titled "Today's My Construction Task Information". This section contains a form with the following fields: "Project Name" (Test2), "Section" (1), "Date" (98-AUG-20), and a table for "Tasks & Resources". The table has two columns: "Task" and "Resource". The first row shows "1. Setting Out (F.W\_S1)" and "Surveyor". The second row shows "2. Fixing Formwork (F.W\_S1)" and "Labours (800%), Carp". The third row shows "3." and an empty resource field. The fourth row shows "4." and an empty resource field. The fifth row shows "5." and an empty resource field. The sixth row shows "6." and an empty resource field. Each row has a "% Completed" checkbox next to the task name.

Task	Resource
1. Setting Out (F.W_S1)	Surveyor
2. Fixing Formwork (F.W_S1)	Labours (800%), Carp
3.	
4.	
5.	
6.	

Figure A II-11. WCSM Screen Shot for PDA Daily Task Download (Test2)

WCSM  
Web-based Construction Site Management System

Today's My Construction Task Information

Project Name: Test1 Section: 1

Date: 98-AUG-20

Tasks & Resources	Resources
1. Formwork	Surveyor, Labours(800)
100 % Completed	
2.	
% Completed	
3.	
% Completed	
4.	
% Completed	
5.	
% Completed	

Figure A II-12. WCSM Screen Shot for PDA Daily Task Upload (Test1)

WCSM  
Web-based Construction Site Management System

Today's My Construction Task Information

Project Name: Test2 Section: 1

Date: 98-AUG-20

Tasks & Resources	Resources
1. Setting Out (F.W_S1)	Surveyor
100 % Completed	
2. Fixing Formwork (F.W_S1)	Labours(800%), Carp
100 % Completed	
3.	
% Completed	
4.	
% Completed	
5.	
% Completed	

Figure A II-13. WCSM Screen Shot for PDA Daily Task Upload (Test2)

WCSM\_Engineer's Information - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites Media

5.  % Completed

6.  % Completed

7.  % Completed

8.  % Completed

9.  % Completed

10.  % Completed

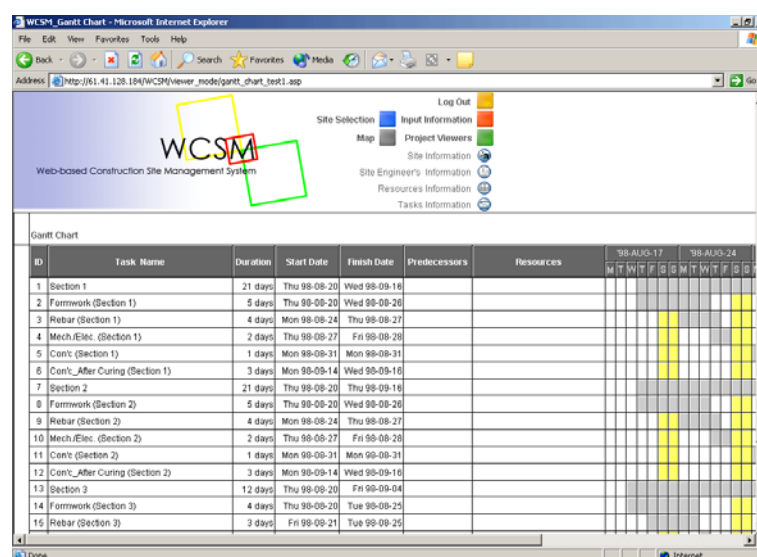
Note

Developed by Griffith University & DIGINICS

Internet

Figure A II-14. WCSM Screen Shot (Lower Part) for PDA Daily Task Upload (Test1&2)

WCSM displays Gantt chart in the same web-page, which include Gantt charts AII-15, 16, 17 and 18. In addition to that the specific location of the above mentioned Gantt chart is indicated by map number.



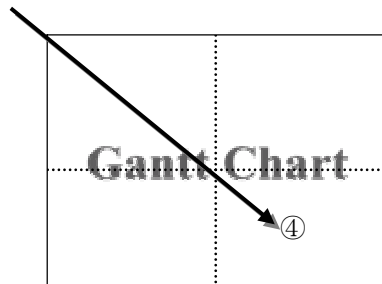
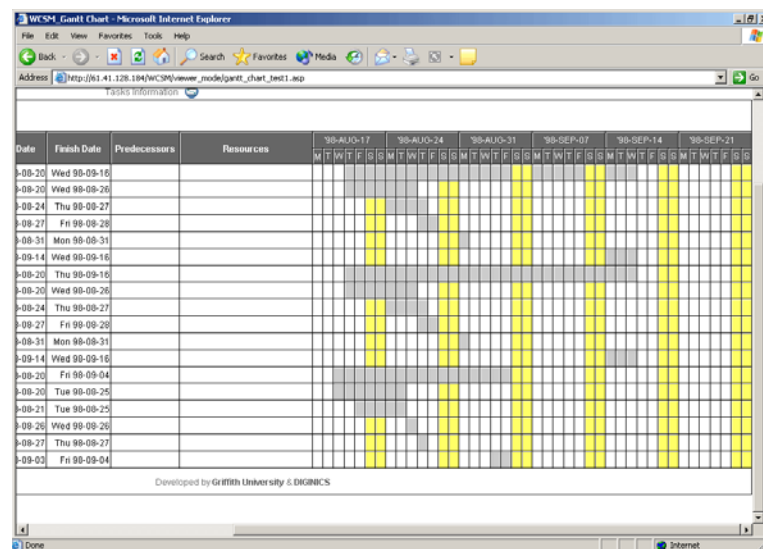
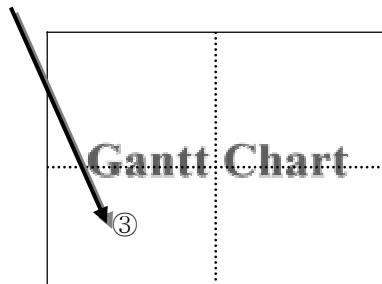
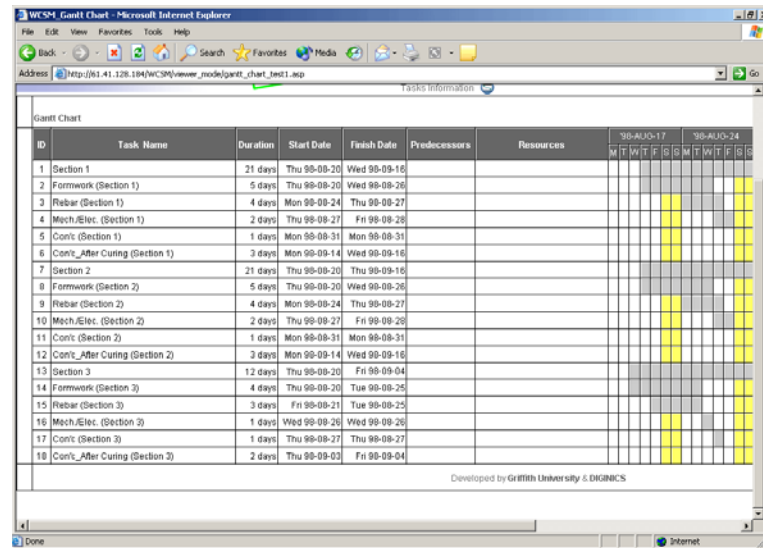
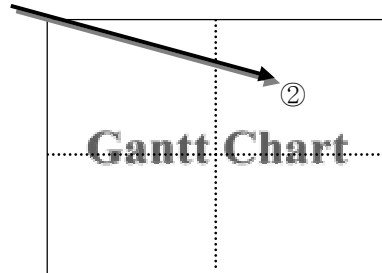
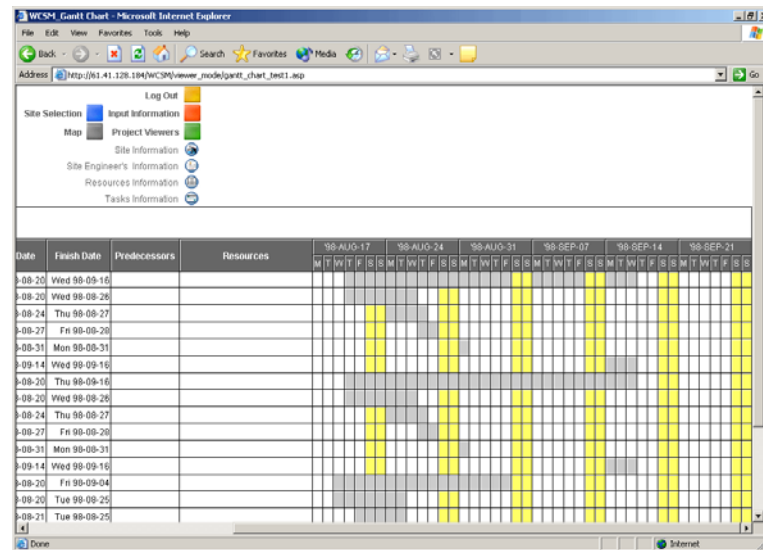
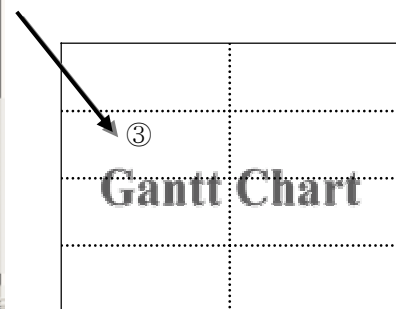
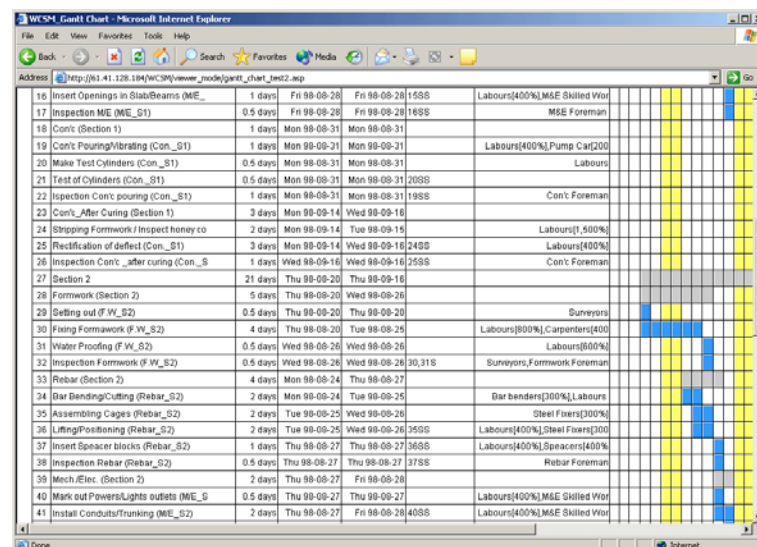
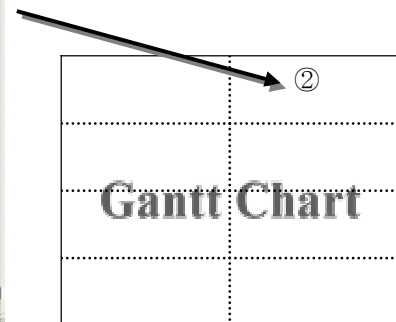
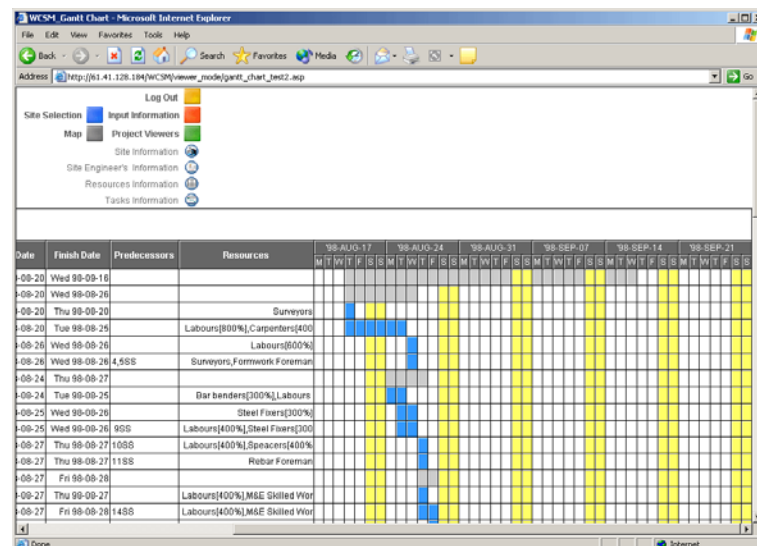
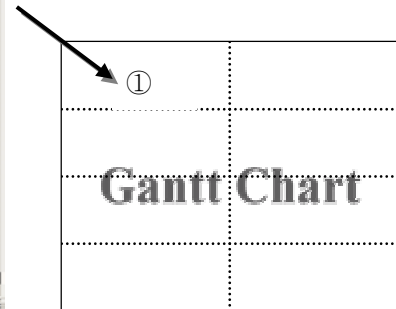
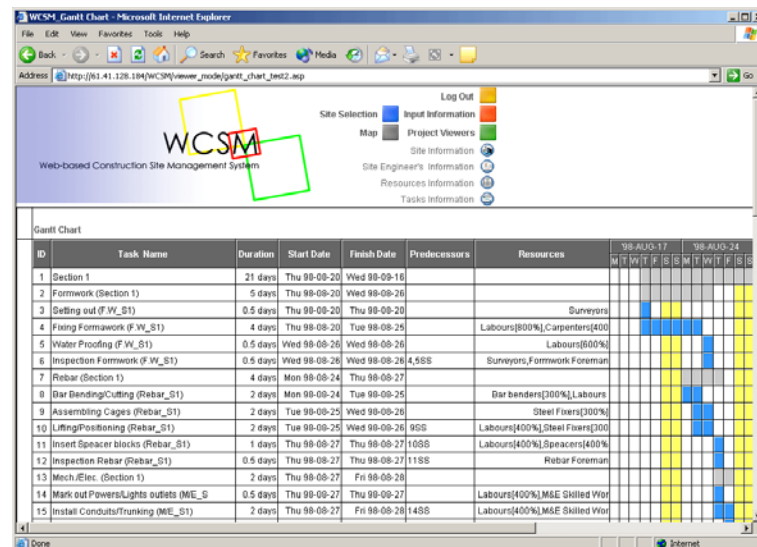
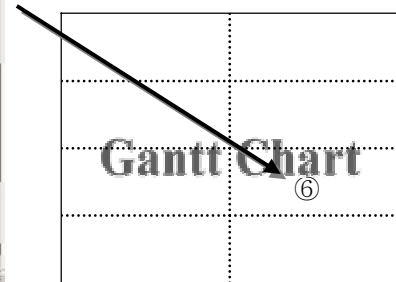
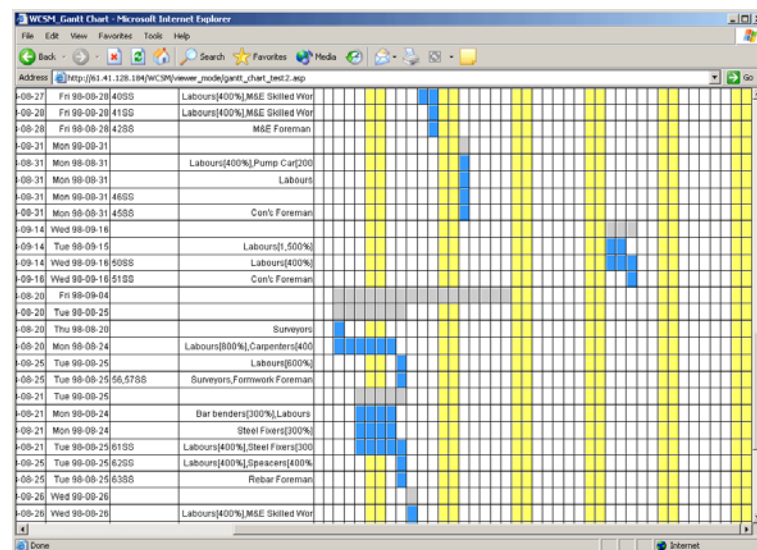
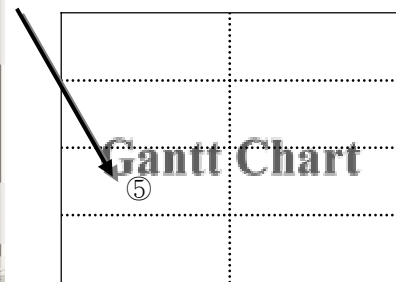
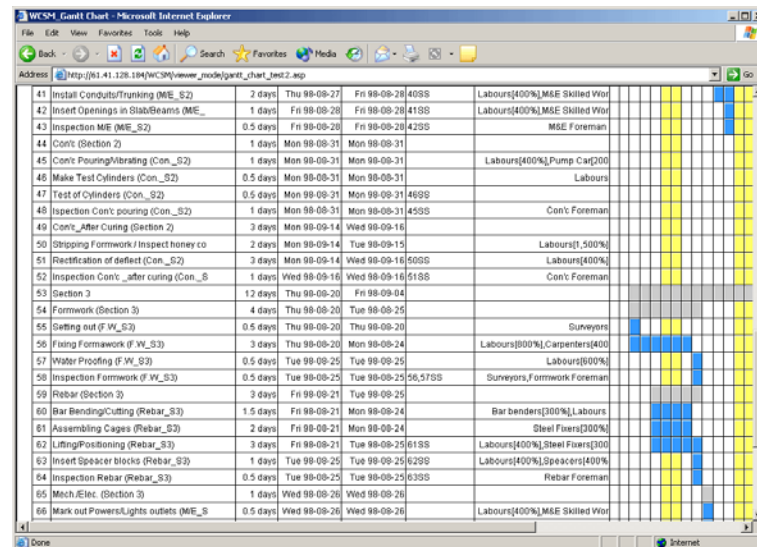
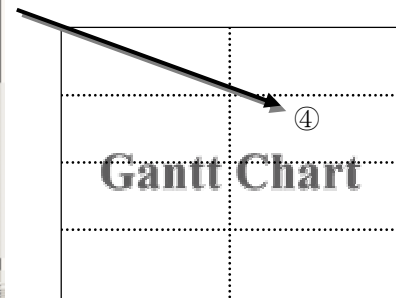
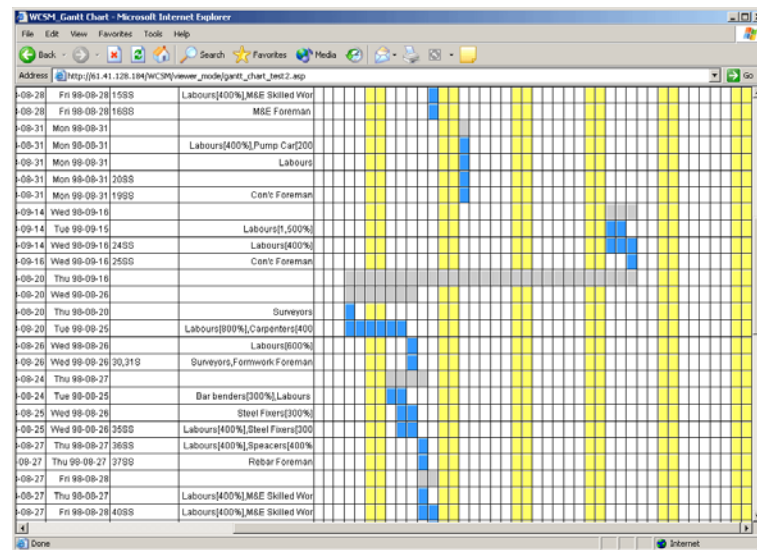


Figure A II-15. WCSM Gantt Chart for Original Plan (Test1)





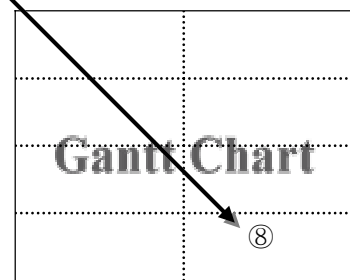
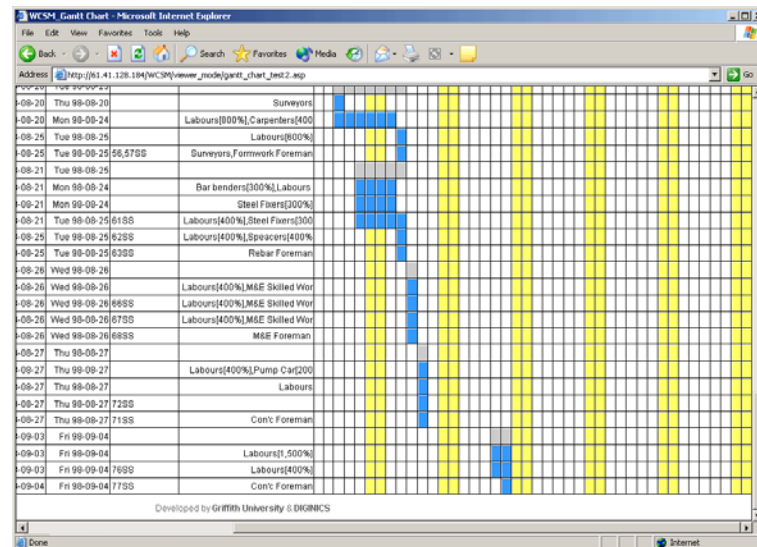
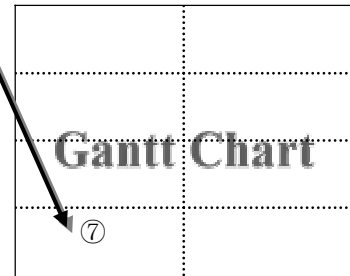
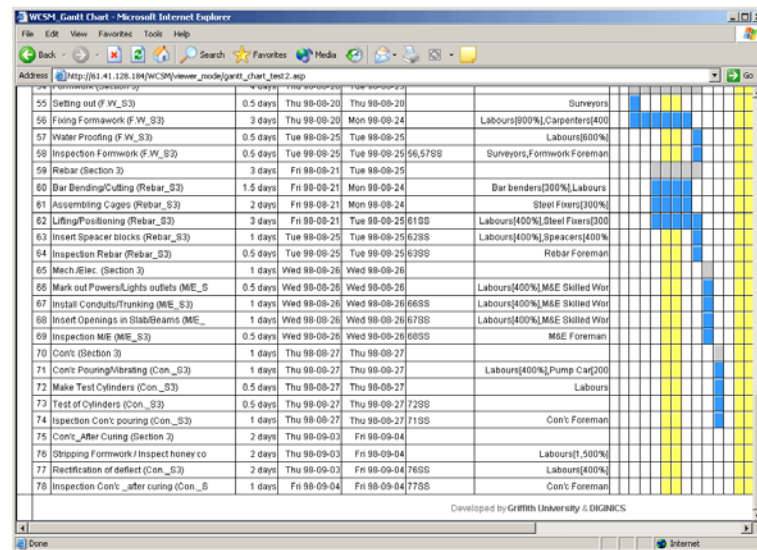
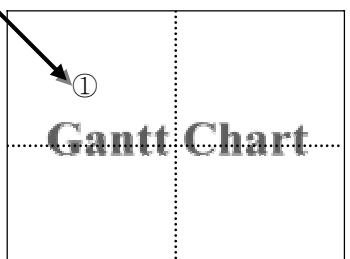
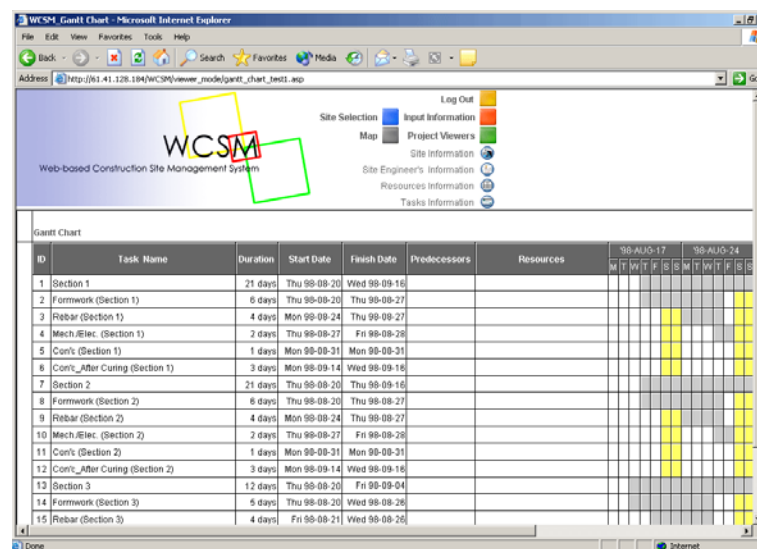


Figure A II-16 WCSM Gantt Chart for Original Plan (Test2)





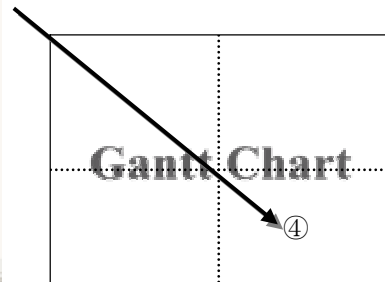
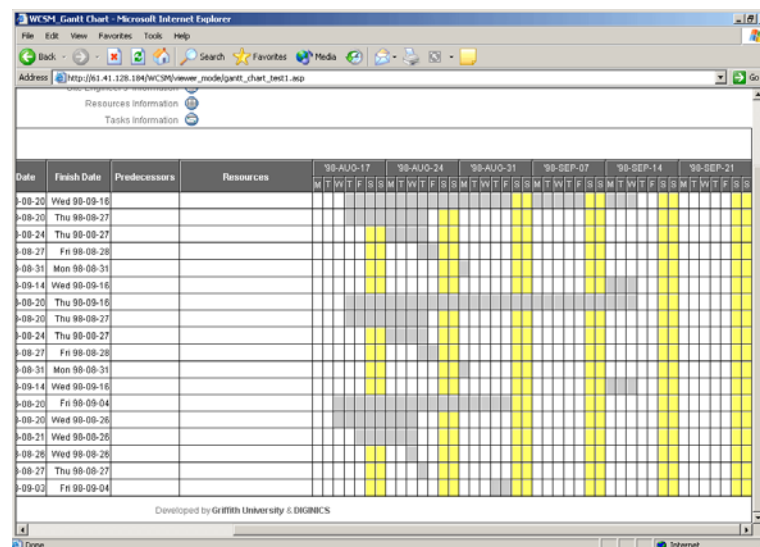
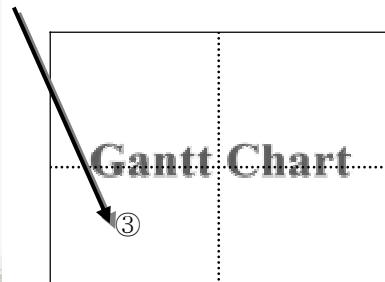
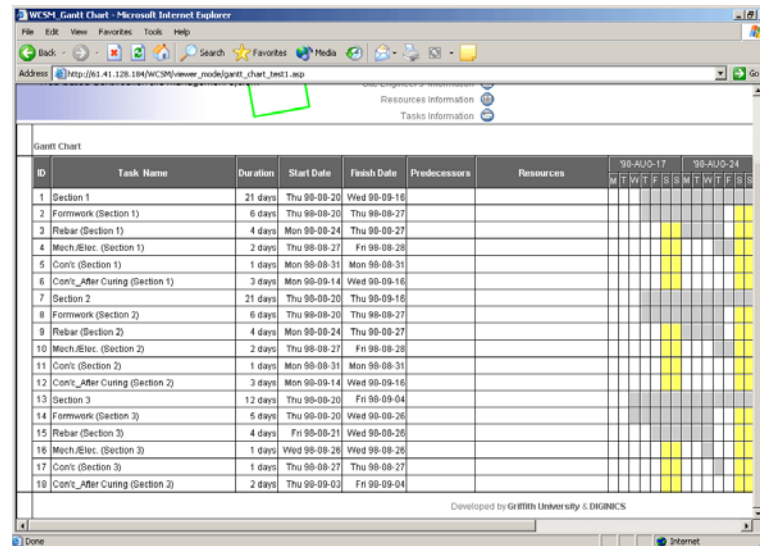
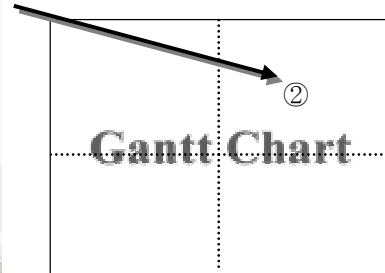
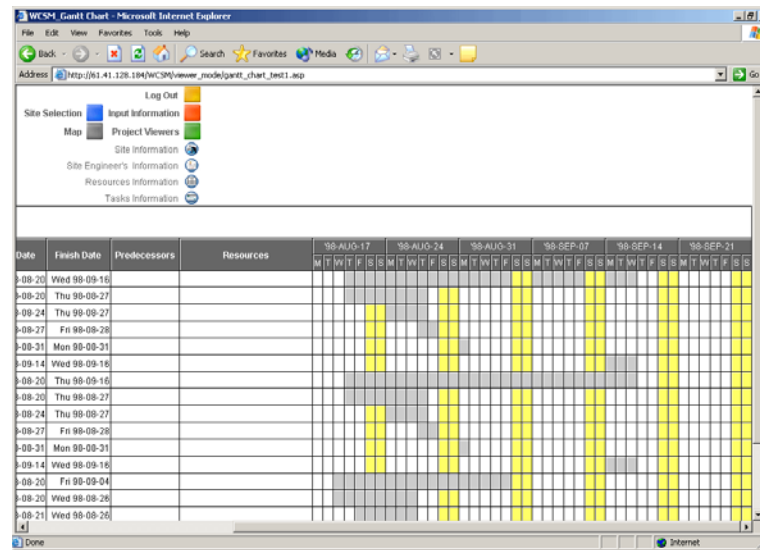
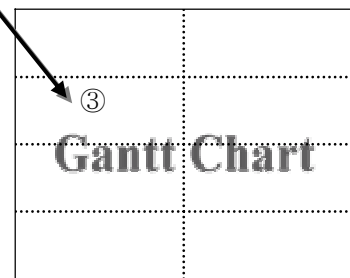
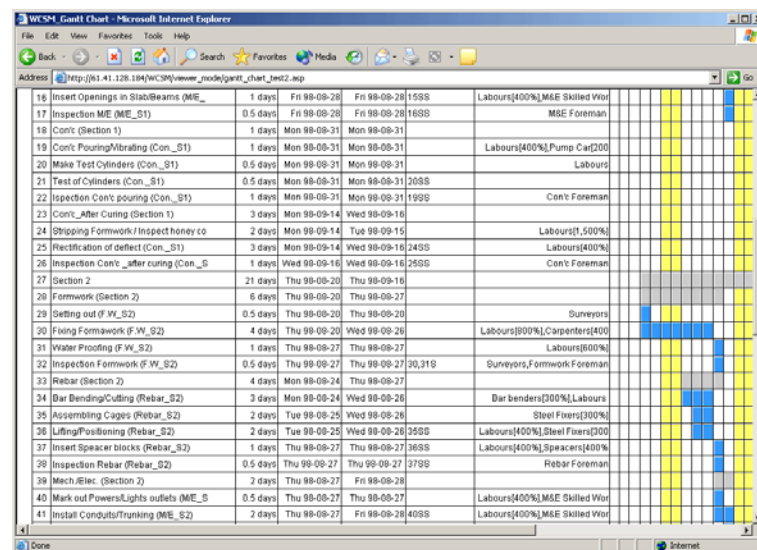
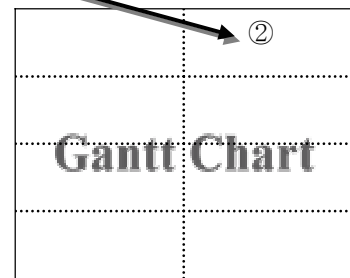
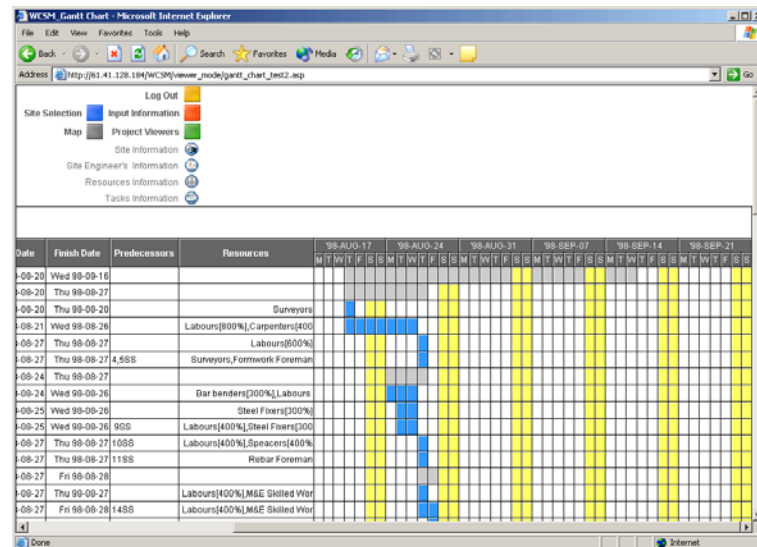
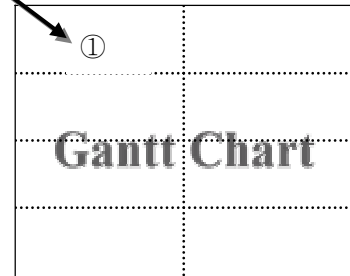
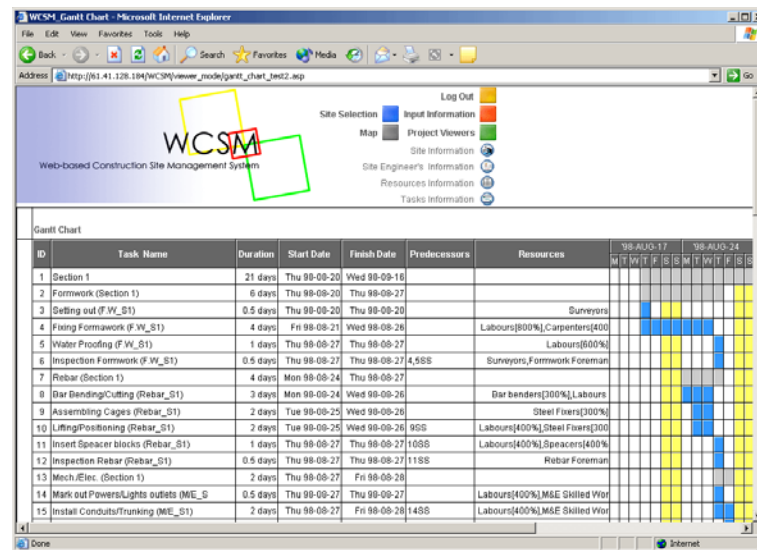
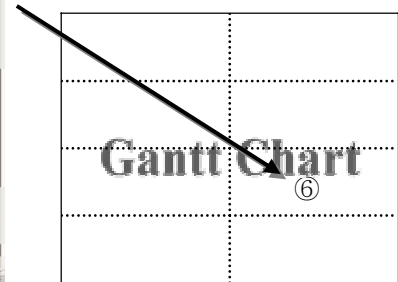
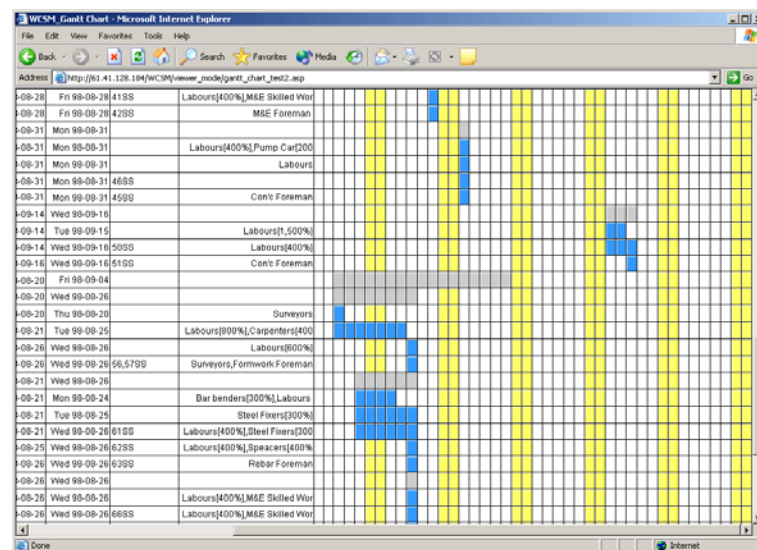
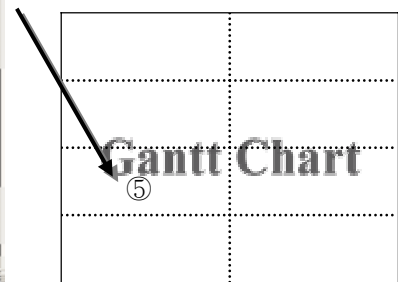
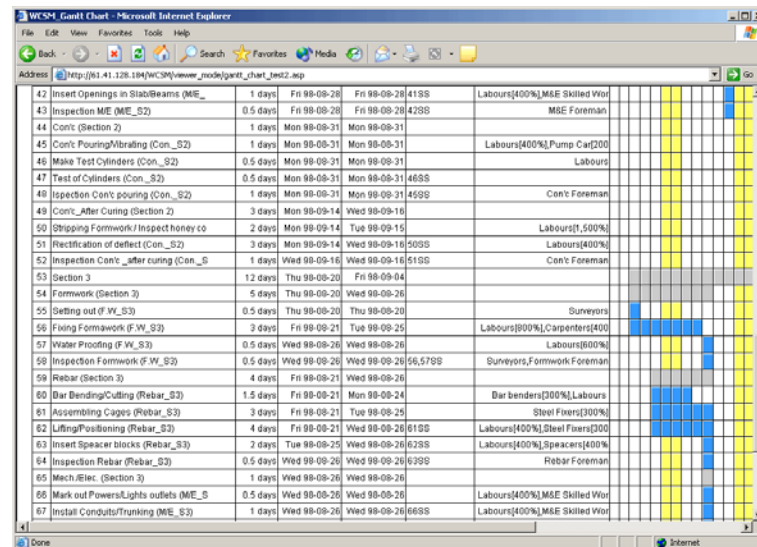
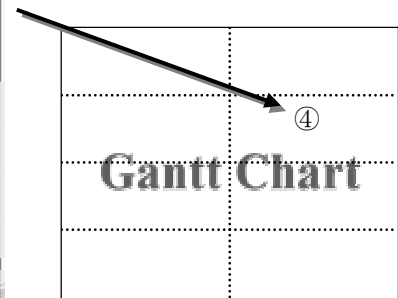
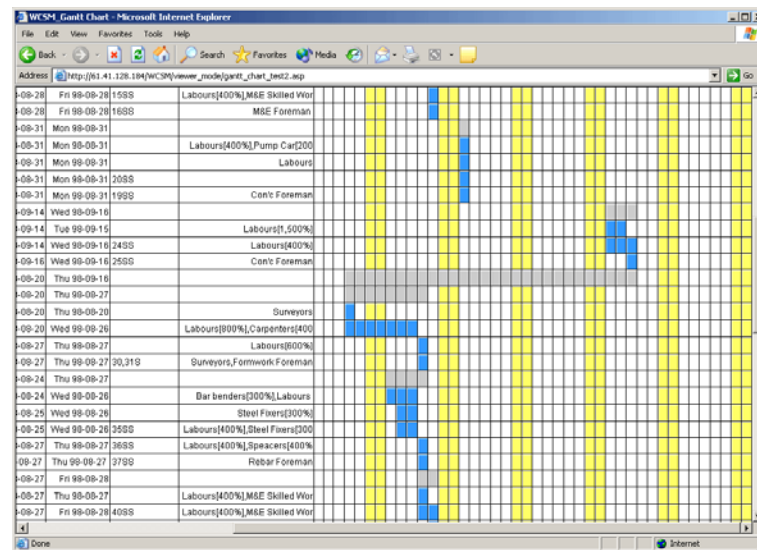


Figure A II-17 WCSM Gantt Chart for modified Plan (Test1)







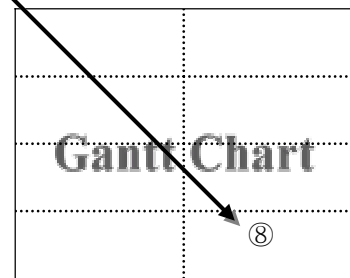
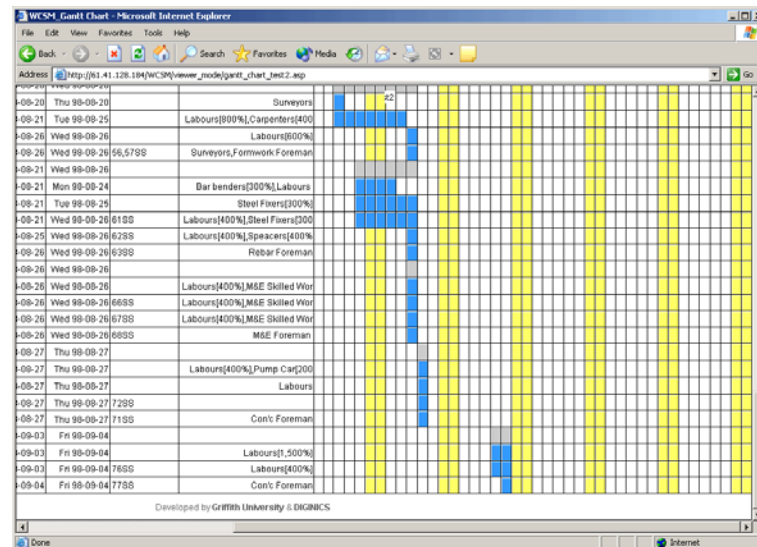
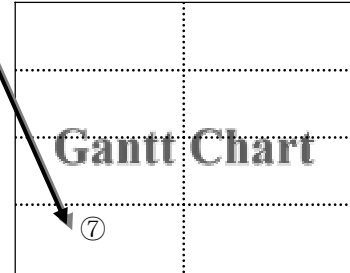
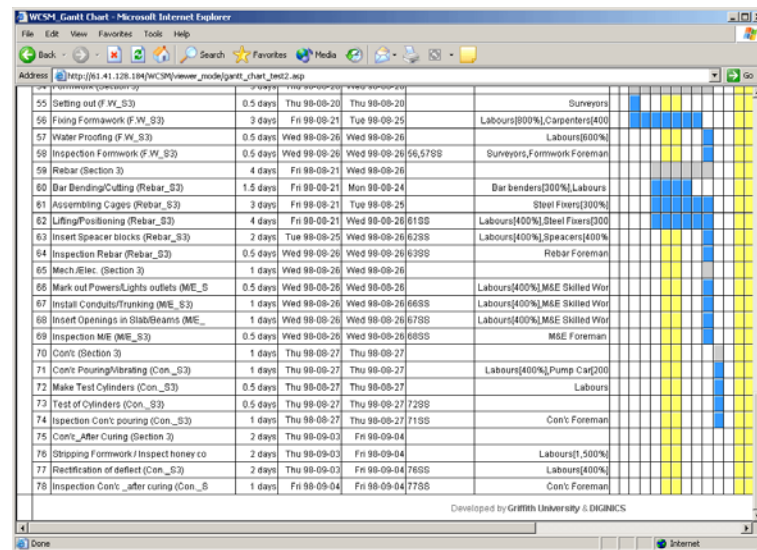


Figure A II-18 WSCM Gantt Chart for modified Plan (Test2)