# PROJECT-INFORMATION-MANAGEMENT-SYSTEMS DEPLOYED IN ANTICIPATION OF DISPUTES ON MULTI-CONTRACT, NON-TRADITIONAL INFRASTRUCTURE PROCUREMENT

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## Abstract

'West Kowloon Expressway' is one of the airport core programme of projects (ACP) of the Government of Hong Kong. This paper reviews the concerns of the Client for the ACP and how these were translated into requirements for a project-information-management-system (PIMS).

Deployment of a PIMS was a mandatory requirement on the construction phase of this project. The paper describes the approach taken to satisfy the Employer's requirements. It includes comments on the impact of information technology on the IT-innocent site personnel. It provides an analysis of the project information accrued within the PIMS and suggests lessons to be learned for a future deployment.

A paradigm is proposed under the premise that decision support systems must be good ergonomic fit to the construction manager's requirement for a timely supply of comprehensive information: that is taken to mean 'immediately understood without further interpretation'. Data, on it's own, does not meet this need because it is not presented in a context that makes it informative.

**Keywords***:* construction; project-management, information management-systems.

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## INTRODUCTION

On October 11, 1989, at the eleventh hour of Hong Kong's hundred year history under British Administration, just before handing the administration of the Territory to the People's Republic of China, the Government of Hong Kong announced a programme of intertwined projects of great complexity and staggering scale. The ambition was to re-engineer Hong Kong's air and port trans-shipment capabilities, to make it the focal point of industrialising Southern China [1]. The air-transshipment part, is called the airport-core-programme of projects (ACP). It is a complicated, multi-project programme of interrelated projects. Stated simply, it is the construction of a world-class international airport upon a

site reclaimed from the sea, plus the road and rail infrastructure needed to link the airport with the centre of the densely-populated urban area of Hong Kong. This infrastructure is also built upon on freshly reclaimed land, it includes elevated structures, and passes through tunnels, and over a large suspension bridge, as well as several other world-class bridges. The airport itself is dramatic but the infrastructure connecting it to the centre of the urban area is, in itself, slightly the larger part of the ACP.

The degree of interrelationship among the ACP's many participants and contracts is extreme. The cost, US$ 20.3 billion in money-of-the-day terms, makes it by far the largest infrastructure entity ever under-taken in Hong Kong and a member of the world-class of mega-projects. The funding requirements are sufficiently large as to have an effect on fiscal planning for Hong Kong. It has been a concern to the Government of the People's Republic of China. In these circumstances, the decisions to be made by the Client are so important, so influential, that they make it essential that the Client is involved throughout the project life-cycle. Foremost among these decisions was the adoption of a strategy to avoid any increase in cost, particularly uncertain costs due to litigation arising from construction disputes.

## ASSIGNMENT OF THE ACP PROJECTS TO WORKS AGENTS

From the outset, the Government organised itself to take a hands-on approach to the project management of the ACP. A high-level executive body within the Government, called Airport Development Steering COMmittee (ADSCOM), takes the Client-decisions. International Bechtel Inc (IBI) were appointed by the Secretary for Works to be the Client's project management advisor. IBI work in concert with Government staff to form a multi-discipline project management office called the New Airport Co-ordination Office (NAPCO). ADSCOM assigned the responsibility for procuring the ACP projects to four organisations, the Works Agents, who are closely inter-related with the Government and share the same sentient views (Figure 1). The Highways Department was assigned the West Kowloon Expressway and other roadworks in the ACP.

### Information management imposed upon the Works Agents

The Client's over-riding need to mitigate risk gave rise to greater control than previously mandated on public works. The Client did not demand the use of information technology to protect his interests but his concerns were indirectly passed to the Works Agents who reacted by dictating operational constraints to be applied by the managers of the ACP projects.

Statements in the project control documents issued by NAPCO and in the formal Agreement between the Government of Hong Kong and International Bechtel Inc show what was to be provided i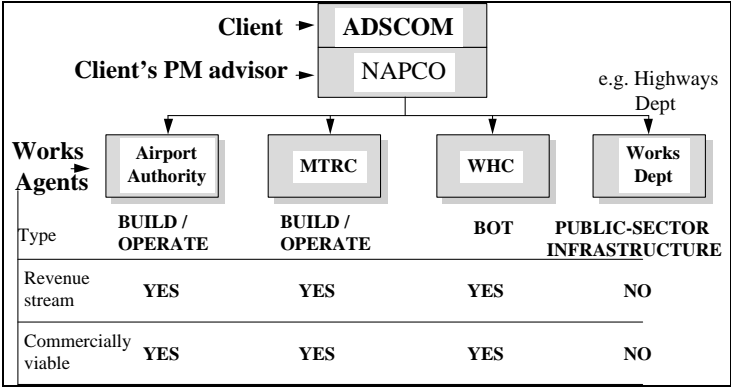n the way of information management *to meet the information needs of the Client*. What is not made evident in these documents is the underlying concern of the Client and it's advisors on how best to avoid cost increases, particularly those caused by contractual disputes. Capped budgets for ACP projects were introduced and, wherever possible,



| | Airport Authority | MTRC | WHC | Works Dept |
|---|---|---|---|---|
| Type | BUILD / OPERATE | BUILD / OPERATE | BOT | PUBLIC-SECTOR INFRASTRUCTURE |
| Revenue stream | YES | YES | YES | NO |
| Commercially viable | YES | YES | YES | NO |

**Figure 1  Assignment of ACP projects.**

contracts were on a lump-sum, fixed price basis. The Client required a series of arrangements that avoided the risk of cost over-run, or placed it with others who were able to accept it in return for a premium.

A form of contract, the ACP Model Form of Contract, was drafted by the Client's legal team to set out the terms to achieve a much greater assignment of risk to the Contractor. Among several radical changes to the traditional form of procurement, the ACP contract required that the Employer must make the key decisions on cost, time, quality and other fundamental issues. The contract set out an innovative time-limited process for the resolution of disputes.

Similar project control procedures were imposed on the Works Agents and their consultants though the instructions in the Hong Kong Core Programme ~ Project Procedures. These set out the requirements for controlling costs and the schedule-of-work; for timely reporting, including cost-trends, changes, bringing up to date progress, and a standardised format for reporting to NAPCO.

## Dispute resolution

Notable among the Client's requirements reflected in the ACP Model Form of Contract, are those to do with 'dispute resolution and claims settlement'. Under the terms of GCC Clause 92, the Contractor could lose the right to claim unless he formally notified the Employers Representative within a limited period of time. Equally prompt action was required of the Employers Representative. In both cases, written arguments based on documentary evidence were necessary. If the issue could not be settled within the period of time stated in the contract then it would be placed in the hands of a mediator who also required all the documentary evidence on the matter within a limited period of time. GCC Clause 92 provided a mechanism in which disputes would be resolved quickly, however the process depended on two things. Retention of all relevant documents and their rapid retrieval.

Lawyers drafting the ACP Form of Contract were troubled by reports of arbitration and litigation in the US where information technology had been deployed for document discovery with considerable effect on the outcome of the case. This became a local phenomena with the arbitration of a dispute on behalf of the Parkview Development Co in the late 1980's. Luk and Wong [2] describe the use of database and scanning technologies when preparing for the case and it's further use during the hearing. They understate it's over-whelming impact, "If the opponent is not using such a computer information system they could be at a great disadvantage due to the high speed and great detail that could be achieved in accessing the relevant information by the party that is using the system". The Client was aware that it's time-limited process for dispute resolution depended on rapid retrieval of *all* documents relevant to the issue. It was also assumed that Contractors would be quick to see IT-based document management systems as a cost-effective weapon to win money through contractual claims.

## Client's requirements for information management

In 1992, the Secretary for Works called for a study leading to recommendations on how to deploy information technology to the Client's advantage on the ACP projects [3]. The perception of a lack of commonplace expertise in information technology in the Hong Kong construction industry, particularly on the construction sites, whilst unproved, was generally accepted without question. Two pragmatic initiatives were recommended and urgently implemented. One, to enable fast 'discovery' in the event of a dispute, a mandatory instruction dictated a common 'good practice' for the filing and referencing of the documents produced throughout the construction process. It was based upon a flexible

but rational, hierarchical breakdown structure of construction documentation. Two, a project information management system was recommended for use on the construction sites of the ACP projects to assist in the settlement of contractual disputes.

As a result of this initiative, the Client's requirements for the deployment of information technology in support construction management was to meet two needs. One, it had to support the traditional project-management tasks of planning, monitoring, reporting and control of baselines of scope, cost, time and quality; along with trend forecasting and change-control mechanisms. Two, the management of documents in a manner that would track issues, provide fast retrieval of relevant documents, and support the time-limited dispute resolution process written into the ACP contracts. How this was to be done was left to the discretion of the Works Agents.

## THE HIGHWAYS DEPARTMENT APPROACH TO PIMS

The Highways Department approach is described by English [4].

. . .management of construction contracts will be assigned to the consultants who carried out the engineering designs and contract preparation, . . . . project management functions and accountability for the projects rests with . . .the Director of Highways who fulfills the role of the Employer under the terms of the contracts. . . . . small teams of independent construction management consultants [will] . . . support the Director. . . .in the construction stage of the projects and are intended to be the "eyes and ears" of the Employer at the construction site level. . . .the consultants . . .will . . .gather information from whatever sources, . . .provide . . .reports, . . .review and report on the actions of the Contractor and the Engineer. . . .[This will] achieve . . . integration . . . of staff into the Employer's organisation and thereby avoid . . .further tiers of control within an already multi-tiered ACP management structure.
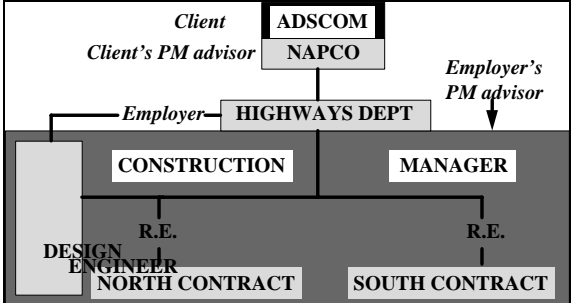


**Figure 2  Organisation structure on WKE.**

Figure 2 shows the organisation structure. The Construction Manager is a site-based project management advisor to the Employer, for the purposes of decision support to aid the Employer's participation as defined in the ACP Model Form of Contract. The PIMS is supplied by the Construction Manager as part of his role as the Employer's 'eyes and ears'. The traditional channels of communication remain intact - the Construction Manager taps into these to fulfill his novel role.

On the subject of information technology English had this to say,

. . . A computerised project information management system (PIMS) is being developed which will encompass all parties involved in the various aspects of construction management. . .A requirement to adopt this technology *has not* [my italics] been incorporated into the construction contracts although the contractors are an integral part of the . . .information process. . . .It . . .will provide a much greater level of direct construction management of the project than has been . . .possible. Information will be available throughout the organisation the instant it is entered into the system instead of . . .days or weeks . . .as has been the case.

| Feature | Detail | Provided in the WKE PIMS? |
|---|---|---|
| Correspondence register | **Include matters which have a material impact on the project**, including cost, time-schedule, quality, safety, environmental impact. | **YES.** includes all documents as electronic images *i.e. retains data in the context of a document.* |
| Documents register | **Include issued documents**, including drawings, revisions | **YES.** But drawings not held electronically. |
| Budgets | **Include matters-of-fact about cost**, including forecasts, variations, use of provisional sums, time extensions. | **YES.** Held as data in a register i.e. a database. With pre-formatted reports. |
| Checklists | **Exception reporting on Actions and/or time defined procedures**, including QA for management control | **NO.** Due to user resistance and lack of universal access |
| Action Lists | **Include a Register of action requests/reactions** with audit trail of the resulting process. | **YES.** It is an additional feature of the Correspondence Register and acts like a 'flag' attached to a document. |
| Standard Forms | **Include a Style library** and proformas for **EDI** | **YES.** But not used because data is not contextural to be useful. |
| Non-conformance register | Capture matters-of-fact about materials, workmanship and obligations | **YES.** But only under the cover of a document. |

**Table 1  The desired features for Highways Department PIMS**

Features of English's model PIMS are listed in Table 1, however in the briefing document, which appoints a consultant to the role of Construction Manager, the specification for the PIMS is made generic to suit a wider range of proposals. Table 2 lists the WKE PIMS specification to be met by the Construction Manager.

## The West Kowloon Expressway [5]

This ACP highway project, managed by the Highways Department, connects the third immersed tube highway crossing of Victoria Harbour to a new highway at the back of Kowloon which leads to the new airport at Chep Lap Kok and also to a new road to China. It has two parts: a North contract which includes construction of 2.7 km of continuous, dual 3-lane viaduct; and a South contract for the construction of the largest and most complicated road interchange in Hong Kong. These constructions are on new reclamation but are made more complicated by the close proximity of the airport rapid transit railway which is being constructed at the same time: in some instances on the same site. The project will cost US$ 301.54 million. Each contract is autonomous, with separate Supervision-in-Chief on behalf of the Employer. The Construction Manager watches over the contractors and supervisor-in-chief, deploying a PIMS to provide a means of

| Feature | Provided in the WKE PIMS? |
|---|---|
| "Provide readily available project information, with document control, accessible to all participants, subject to restrictions on the dissemination of confidential data;" | **YES.** Data held within context i.e.,as whole documents from all participating organisations. *NB secure documents are encrypted.* |
| "assist in avoiding delay in transmitting instructions, decisions and information;" | **YES.** Instant communication to all participant organisations. NB and beyond via e-mail systems. |
| "provide an audit trail of actions and responses for all contract management purposes:" | **YES.** But it is NOT a default action and it is NOT favourably received. |
| "discipline adherence to control procedures:" | **NA.** in effect ad hoc procedures ruled. |
| "provide systematic acquisition of project management data." | **PART YES** In the context of data held within documents and in the cost database but NOT 'time data'. |
| "preparing a project cost control plan and cost management system as an integral part of the PIMS;" | **YES.** Held as data in a register i.e., a database. With preformatted reports. |

**Table 2  PIMS specification given to the WKE Construction Manager**

| Contract No. | HY/92/17 | HY/92/18 |
|---|---|---|
| Name | Kowloon Expressway North Section | Kowloon Expressway Sorth Section |
| Description | Viaduct and Rail Link | Road Interchange and Rail Tunnel |
| Type of Contract | Lump Sum | Lump Sum |
| Level of Risk | High | High |
| Start | 2-Aug-93 | 31-Aug-93 |
| Finish | 4-Jan-97 | 1-Apr-97 |
| Duration (Days) | 1,232 | 1,291 |
| Contract Value | US$ 165.64 million | US$ 135.90 million |
| Main Contractor | Kumagai Gumi (HK) Ltd / Maeda Corp / China Road & Bridge Corp Joint Venture | AOKI Corp |
| Nos. of Sub-Contractors | 30 | 26 |
| Nos. of Site Supervision | 150 | 150 |
| Nos. of Site Workers | 700 | 600 |
| % of skilled orkers | 64% | 60% |
| % of imported labour | 7% | 15% |
| Nos. of Drawings | 700 - 1000 | 500-2000 |
| Nos of PIMS registered documents | 11,000 | 22,000 |
| Nos of PIMS shared documents | 15,000 | 15,000 |
| Nos. of Claims | 171 | 513 |
| Nos of Site Instructions (inc drawings issued) | 1,100 | 900 |
| Nos of Variation Orders | inc in above | inc in above |
| Nos (all) Adjustments | inc in above | inc in above |

**Table 4  Comparison between the WKE contracts.**

monitoring this differentiated and sentient group of participants.    The degree of differentiation and sentience is indicated on Table 3.

## Configuration of the WKE PIMS.

The PIMS implemented by the Construction Management organisation serves the participants shown in Figure 2.  The system configuration is shown in Figure 3.  There are 53 terminals clustered around 1 PIMS main server which is accessed by 70 users. Dedicated data-lines link the main server to three other servers which contain replicated data.  This system uses readily available proven technology purchased off-the-shelf from

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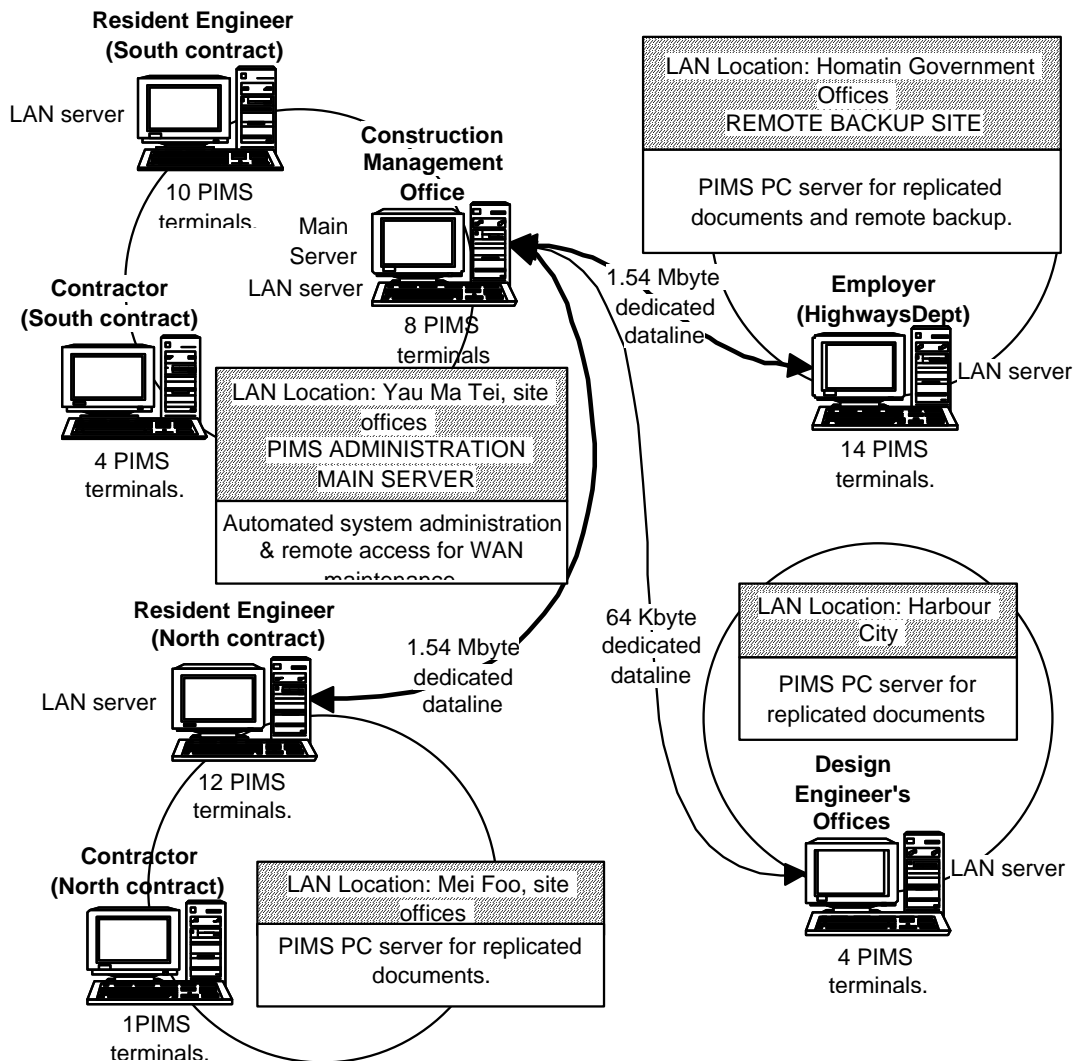**Table 3  Comparison between the WKE contracts.**

**Figure 3  WKE PIMS configuration**

retailers. Terminals, LAN servers and PIMS servers are 80486/50 MHz machines, but the PIMS servers have 6-8 Gbyte memory. The remote back-up server, located in the Highways Office, is for daily back-up of the database. PIMS software is listed on Table 4.

The focus of the PIMS is the AZEUS IPMS[TM] software which is an information management software developed in Hong Kong for the ACP projects but intended as a new product to be marketed in the construction industry. Using a proprietary software on a construction project usually causes problems due to the software not matching the functional need. This dilemma is avoided on the West Kowloon Expressway by using a product already developed but able to be further developed according to specifications written by the Construction Manager. This has lead to modification of the database, the user interface, and the reports so they better suit the circumstances. This is important. At the outset of construction, data-flow, styles, format and process are not known. The PIMS must suit standards and processes as they are created, this is done as work patterns develop among the participants in the process. If not, the users are forced to conform to the system. A situation that causes dissatisfaction and resistance to the technology, if not failure of the system as a whole. Being supportive to daily working practice is a major factor in winning confidence in the system and it's administrators. If they are perceived as critically reviewing daily working practice or hindering work, then users are un-cooperative.

| Item | Purpose |
|---|---|
| Novell Netware™ 3.12 | network management, file transfer, net and printing support |
| Microsoft Windows™ 3.1 | PC operating system |
| AZEUS IPMS™ 4.22 | integrated project information managen |
| WordPerfect OFFICE™3.1 | e-mail |
| Microsoft Word™ 6.0 | wordprocessing |
| WordPerfect for Windows™5.2 | wordprocessing |
| Lotus 123™/Excel™ | spreadsheets |
| ORACLE™ | RDBMS |
| Archserve™ | automated backup |
| SmartUPS™ | uninterupted power supply manager |
| CloseUp™ | remote access for system maintenance |
| Shiva Dial-In™ | remote access to terminals |

**Table 5  WKE PIMS software**

## Functions of the WKE PIMS

Structured data, such as costs or dates, are recorded on registers which are held within the database. Reports are generated from that data in a traditional manner. In other respects the WKE PIMS does not follow the stereotype for a project management information system. The approach has been to capture information and, where-ever possible, to retain it as data held in the context it had when captured, i.e., as electronic images of all mailed documents of whatever format. Aspects of the captured items are profiled and in some cases; such as costs, or extensions-of-time, pieces of data are manually transposed to an electronic register which is the front-end of a database. This data is formatted and therefore eligible for further processing. Other data sources, such as the details shown on drawings or materials testing records, are not retained within the system but their distribution and evolution is tracked. These three approaches to data management are shown on Figure 4. They are described in terms of 'control *(of mail)*', 'processing *(of selected data)*', and 'tracking' *(of evolving information)*.

The distribution of PIMS information is controlled by the mail mechanisms. It is instantaneous and has an audit trail. The data is presented as information-in-context, such as a 'mail' document or an attachment to the mail. Figure 4 describes the nature of data management within the WKE PIMS. A system based wholly on a database approach would satisfy the data processing element of the PIMS but could not match the other aspects of WKE PIMS functionality.

## USE OF THE WKE PIMS

### Acceptance and skills

At the outset, the participants in the project had very little knowledge of information technology. Because of the sparse technology skills available, the Construction Manager was assigned full responsibility to implement and administer the PIMS specified by the Employer (Table 2). The consultant appointed to this task had prior experience of applied information technology for the project management of large engineering works. However, this had been a database approach wholly reliant on formatted data. On the WKE, the
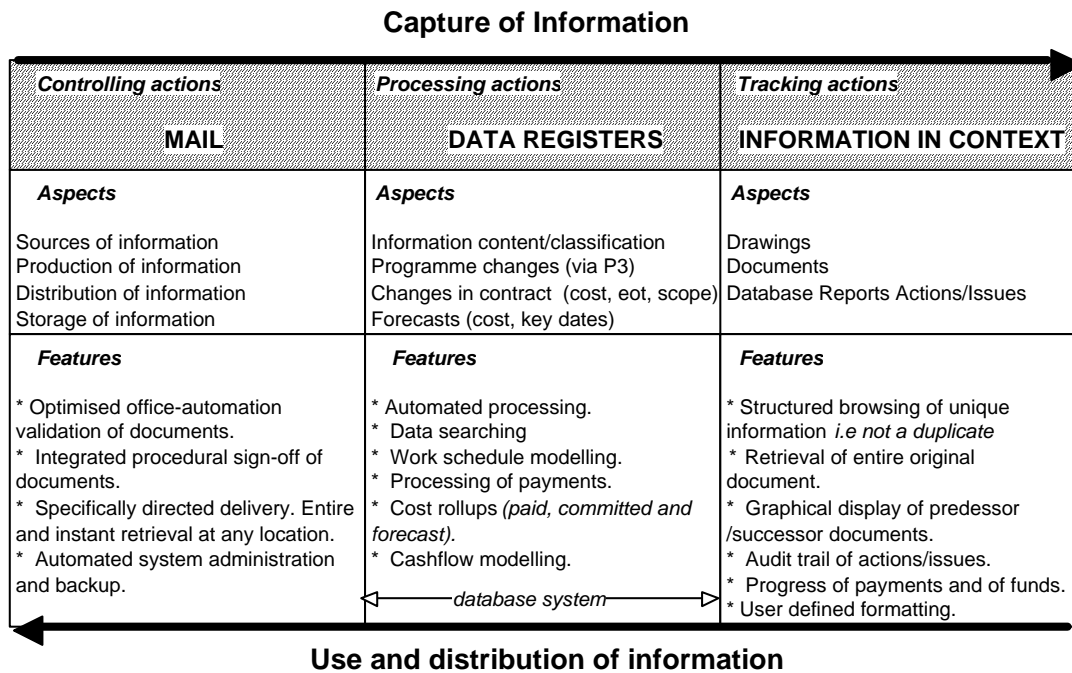
**Capture of Information**

| Controlling actions | Processing actions | Tracking actions |
|---|---|---|
| **MAIL** | **DATA REGISTERS** | **INFORMATION IN CONTEXT** |
| *Aspects* | *Aspects* | *Aspects* |
| Sources of information<br>Production of information<br>Distribution of information<br>Storage of information | Information content/classification<br>Programme changes (via P3)<br>Changes in contract (cost, eot, scope)<br>Forecasts (cost, key dates) | Drawings<br>Documents<br>Database Reports Actions/Issues |
| *Features* | *Features* | *Features* |
| * Optimised office-automation validation of documents.<br>* Integrated procedural sign-off of documents.<br>* Specifically directed delivery. Entire and instant retrieval at any location.<br>* Automated system administration and backup. | * Automated processing.<br>* Data searching<br>* Work schedule modelling.<br>* Processing of payments.<br>* Cost rollups *(paid, committed and forecast).*<br>* Cashflow modelling.<br><br>←——*database system*——→ | * Structured browsing of unique information *i.e not a duplicate*<br>* Retrieval of entire original document.<br>* Graphical display of predessor /successor documents.<br>* Audit trail of actions/issues.<br>* Progress of payments and of funds.<br>* User defined formatting. |

**Use and distribution of information**

**Figure 4  Functions of the WKE PIMS.**

Construction Manager faced a formidable learning curve: they took up the appointment at the same time as the contractors commenced the construction.  There was no opportunity for setting up the systems in advance.

The users of the PIMS were professional engineering staff who were keyboard illiterate.  They were resistant to a change in the methods of information management, stating a variety of reasons to oppose the implementation of the PIMS.  Their opposition can be classified as: techno-phobia; perceived threats to their autonomy; suspicious of critical review of their performance; un-cooperative about procedural constraints not of their own devising; and, in their opinion, the system was introduced too late - they had commenced operations using manual practices and it took about a year for the PIMS to come fully on-stream.

*Training and acceptance*

Opposition occurring at a high level in the participants' organisation could only be overcome by commitment from the Employer, strong system support and continual user training.  Group training sessions were not sensitive to individual perceptions of the PIMS.  Training was one-on-one and on-the-job, it focused on a user's immediate need-to-know, and enabled them to become quickly productive.  The efficiency of the PIMS has meant a more effective use of clerical staff, with no more needed than in the case of a manual system, but it is an advantage if they are better educated than usual.

Attrition of staff through the life of the project has required a continual training effort.  It is estimated that 300% of the management and administrative staff have been trained.  User acceptance is broadly indicated by the rate of document registration shown in the graphs on Figure 5.

Reluctance to use the PIMS is evident on the North Contract.  In general it has been noted that once a user can find about eighty percent of the documents on the PIMS in the order of eighty percent of the time, then use of PIMS becomes unquestioned.  This four-fifths heuristic shows the importance of striving for total document registration as early as possible - preferably on day one of the project.  It also explains the agreement reached in
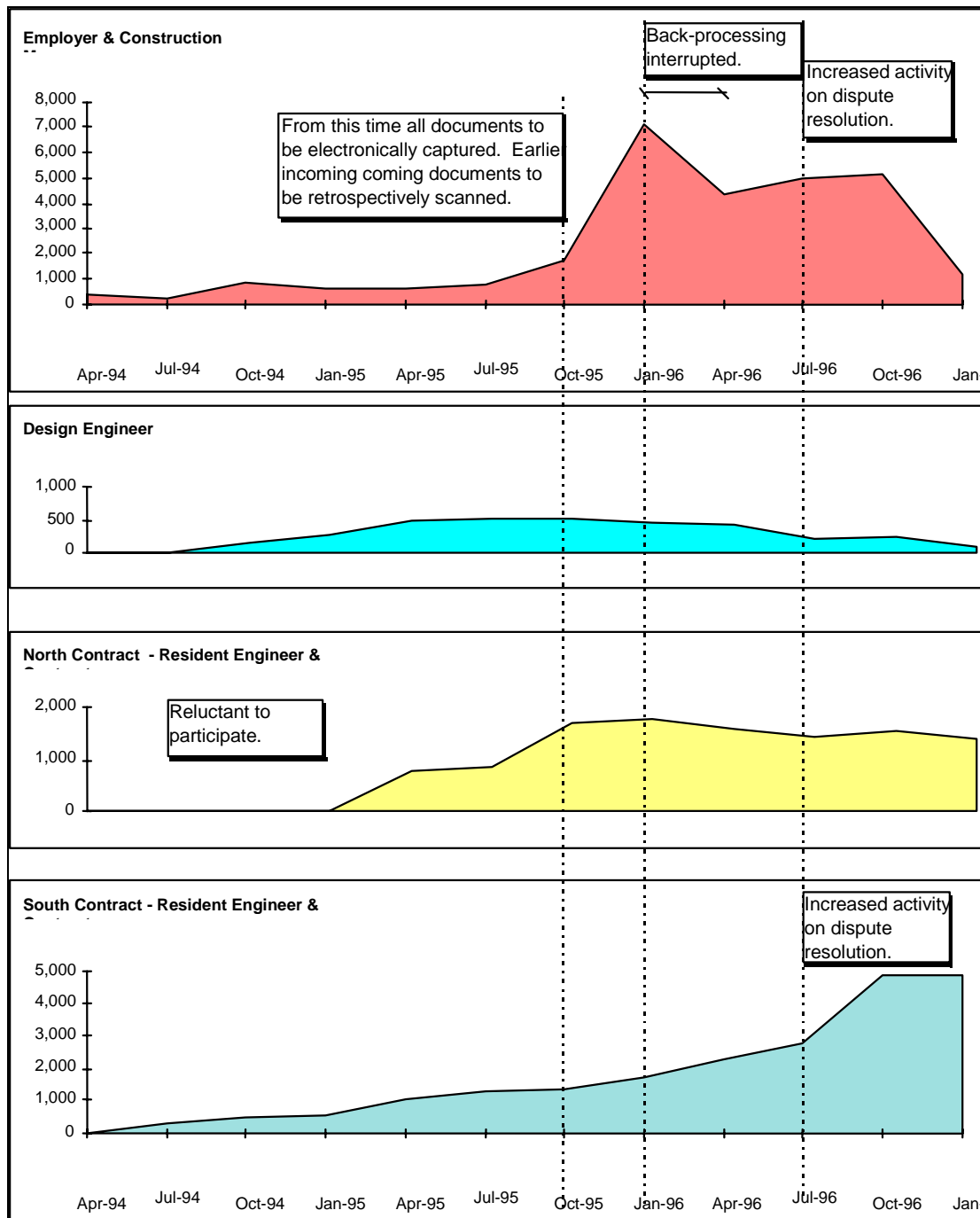
**Figure 5  Rate at which documents have been registered on the WKE PIMS**

July 1995 to capture scanned images of all physical documents plus their attachments and to do similar to those held in the filing cabinets and not yet registered in PIMS

The register of cost changes provides an audit trail of cost variations and their apportionment to different sources of funds.  Benefit from this effort will be enjoyed by the Employer at the end of the contract.  The Construction Manager has maintained the cost register by extracting data from mail documents and recording it in the cost register. Contractors interim payments can be calculated using PIMS however the Quantity Surveyors have used traditional spreadsheet methods.  The Construction Manager has intervened and processed the payments on the PIMS as a parallel, checking action.

Work scheduling is done outside of the PIMS, but key dates, milestones and time targets are recorded on a database register. This has been done by the Construction Manager. The facility has not been used by the other participants and is unlikely to have much benefit other than providing a reconciliation of changes to key dates and the achievement of milestones.

Issue management is now being used to thread together documents relevant to the matters-of-fact regarding any issue under consideration. A graphical display of the trail, similar to a pert network, shows documents, their attributes, and the links to predecessors/successors.

Action management was requested by the Employer as a means of achieving quality- assurance on site. The professionals resisted this concept. They regarded it as an intrusion and did not permit any systematic review of actions in-hand.

## CONCLUSIONS

The traditional approach to implementation and use of a PIMS on construction projects has been to use database technologies to process formatted data which can be aggregated or algorithmically processed to provide an overview and progress reports. These are used to assist in the planning, monitoring, and control of change. It is suggested that this is of limited value: it's usefulness is restricted to the project control staff who are expert in interpreting the data presented. These systems are not presenting information, they merely provide processed data that requires further interpretation.

The traditional approach is an inadequate methodology for construction decision support - especially when dealing with disputes. It is suggested that decision support systems must be provided which are a good ergonomic fit to the construction manager's requirement for a timely supply of comprehensive information: 'information' is taken to mean 'immediately understood without further interpretation. Data, on it's own, does not meet this need because it is not presented in a context that makes it informative. This is the approach of the WKE PIMS, it captures data in it's original context: usually this is a dialogue contained within documents. Profiles of the attributes of these documents allows database technology to be used in search and retrieval operations, thereby meeting the need for timely presentation of archived information. Electronic images of the documents retained within the database enhance this effect and permit a group to share the pool of retained information. A lesson learned from the WKE PIMS is that a group of differentiated and highly sentient participants can successfully share a pool of information to mutual benefit. During a dispute, transparency of the matters-of-fact greatly assists early resolution. In a partnering agreement, sharing the pool of information fosters increased co-operation and trust between the participants.

A recent cost analysis of the total expenditure on the WKE PIMS calculates that the cost of capturing or producing information was: US$50.40 per 'mail' document; US$40.50 per 'data-register' document; and US$ 92.20 per 'information-in context' document. Of these costs; 79% of the mail cost is for the administrative effort needed to process the transaction. For data-register documents the administrative overhead is 83%, and 94% for information-in-context. These administrative costs are required in any case, hence the differential cost for the PIMS was US$10.50 for mail, and US$5.25 for data register and information-in-context documents. The WKE PIMS differential cost for the IT was 0.5% of the project value.

The Client for the ACP wanted the Works Agents to take a pro-active stance in the early settlement of disputes and to avoid cost overruns. Construction Information Technology was advised as a worthwhile investment to help achieve these objectives. The contracts are approaching substantial completion, 603 claims have been received, of these:

163 are resolved, and the rest are in various stages of settlement.  So far there has not been escalation into disputes.  Mediation or arbitration has not been needed.  The 0.5% of the project value invested in the IT has been used in the settling of claims and valuations totaling in excess of US$ 50 million (contractors assessment). WKE PIMS has not been needed for the purposes of discovery in support of litigation. The Client's objective of avoiding disputes has been met.

There is no evidence that the PIMS was a significant factor in the avoidance of disputes or the satisfactory settlement of claims, or of it's effectiveness for post-construction discovery.  However, all the participants agree that it is an approach worth adopting in future, providing the technology and support is in place before the contractors begin work.  For that reason it is recommended that a PIMS is established as part of a 'head-start' mobilisation programme.

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