Towards a smart project management information system*

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The focus in this work is on the creation of a new generation project management information system, which the authors have dubbed: Smart Project Management Information System (SPMIS). As the projects and their environments get more complex, subject to uncertainty, time and money pressures, the need for a really helpful and smart system to support the decision making and manage project information systematically, is accentuated. SPMIS will need to be flexible in accepting information sets, be instantaneous in terms of response, be comprehensive in terms of the range of functions which it can support and be intelligent in terms of analysis and overview of information sets held throughout the project life cycle. A review of the current systems shows that none has the range or capabilities sought. The SPMIS has been defined in a practical and objective manner. A review of the possibilities that the current systems' engineering techniques could offer has been included followed by a discussion on the need for setting up a project-specific information and integration model. Also, a 'centralised control' strategy has been advocated covering the entire core information transactions over the project life cycle. The SPMIS will be a future tool for proactive objective-focused management of the project. Its underlying design philosophy is based on creating conditions for synergy and for management of projects to achieve or exceed quite specific target values for stipulated objective functions such as project net present value or profitability index. © 1998 Elsevier Science Ltd and IPMA. All rights reserved

Introduction

This paper focuses on definition and conceptual development of a smart project management information system (SPMIS). The word 'smart' has been used to distinguish these type of systems from the current generation project management information systems (PMIS). The SPMIS will need to be flexible to respond to a myriad of demands placed on it by project teams during the life of a project; possess a capability to combine both 'hard' and 'soft' systems analysis; and provide a basis for automation and integration of all project processes over its life cycle including planning, design, procurement and construction management

processes. An idealised project management information system has been defined and used as a bench mark for comparison and ranking of the current generation PMIS systems. The evaluation of the current PMIS systems vis-à-vis the bench mark system shows that none of the current systems has the capabilities defined for the SPMIS. An overview of the computer/IT technologies available has been carried out with the specific aim of addressing the need for execution of project management functions in an holistic manner. Through this review it has been shown that all elements of technology for developing a SPMIS are currently available, provided a project-specific information modelling system is adopted. It has been shown that a 'product model' of a project can be defined and used as the basis for information integration and process automation over the project life cycle.

Project management information systems

The authors define a project management information system as a system which supports and facilitates the delivery of any project, particularly those which are

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complex, subject to uncertainty, and under market, time and money pressures, or otherwise difficult to manage. The main capability requirements of a PMIS should be:

1. Systematic modelling, recording, storing, validating, retrieval and general management of information and data related to the life cycle management of a project, as well as direction, management and real time control of key information furnished to project teams, using an integrated structure;

2. Integrating information across the entire project life cycle, from feasibility study through to execution and finalisation (excluding the operation phase), and supporting newer concepts of project delivery, such as *concurrent construction*[1].

3. Processing and reporting, or alerting capabilities, as the case may be, in order to highlight the status of a given project at any point in its life, or measure the impact of a decision affecting the project as a whole, or foreshadow adverse patterns which might affect the achievement of project goals, and so on. Therefore both computational and evaluative capabilities must be built into the system.

4. Proactivity facilitation. In the context of concurrent construction *proactivity* has a specific meaning, as it refers to the real time management of the project in such a way that specific target values set for certain objective functions at the outset can be met or exceeded. Examples of such objective functions include captial and operating costs, total life cycle cost per unit output, cost/worth ratio, internal rate of return and profitibility index. The project management must also respond to the less tangible targets set, including aspects of operability, safety and quality. While a more detailed coverage of this style of project management is outside the scope of this paper, it must be noted that the main requirement is to have a capability for continuous assessment and reassessment of the project decisions to see if value addition is being achieved and if changes made to the project can be objectively justified. (Refer to Jaafari[1], for a more detailed discussion of proactive life cycle project management).

5. Inter-operability and compatibility. In a typical multidiscipline project the PMIS must be fully interfaced with other systems used on the project, e.g. to link with, and import data from, the CAD model of the project. Because of the need to exercise centralised control over the management of the entire project information sets, the PMIS must act as the governing system, making information selectively available to other systems or teams.

As can be seen, the above statement broadly defines a smart PMIS. It will have the potential to act as a unifying system throughout the life of a project, 'remembering' the project information from the preceding stages, including target values and criteria set for objective functions, logic and other important arguments used to make certain decisions, limitations imposed by the environmental, social, safety, quality and other considerations and so on. Also, it will be furnishing a capability to 'vet' any change or addition by any party against all the target values, rules and or criteria already established for the project and held within the system.

The need for PM systems

The authors subscribe fully to the view that project management (PM) systems do not deliver projects, project teams do. However, PM systems are necessary to furnish information to project teams charged with the task of achieving project goals, also providing 'real time' performance feedback of where the project is in relation to the target values set for objective functions, and where it ought to be. One essential requirement for the PMIS is to furnish information in real time. That is to be able to provide more or less instantaneous response to any question or query entered, and to have multiple capabilities to cope with disjointed and seemingly unrelated pieces of information or queries. This is because of the dynamic nature of today's projects, influenced by not only internal and external uncertainties, but also the necessity to integrate information, teams and plans, and accelerate performance. Laufer *et al.*[2] likened this to that of: "directing a three ring circus continuously switching acts based on the crowd's response". The three rings are symbolic of the dominant project characteristics in the 1990s, viz.: 'complex, uncertain and quick'. The authors would concur entirely with this metaphor.

To understand the dynamic nature of project management it is interesting to look at what project managers do, as the objective is to provide a PMIS, which supports and facilitates their performance.

> The very effective project managers appear, superficially to be working disjointedly, in paradoxically opposite directions. In reality they are integrating areas widely separated in space and time, in hierarchy and methods, in orientation and philosophy. The simultaneous managers integrate tasks and people but differentiate between them at the same time. They devise and use formal as well as informal procedures. Goals and means in situations like these are not resolved sequentially but rather simultaneously and interactively.[2]

To further illustrate this point the inside story about the Sydney Opera House is worthy of note (see below).

Revealed: the trials of a world wonder

(Geraldine O'Brien, *Sydney Morning Herald*, 29 March, 1997)

It could have become a casino, a children's playground or even, as one commentator suggested, been left as a romantic ruin. When Joern Utzon left the Sydney Opera House project in 1966, everybody had an opinion about what should be done with his part-finished masterpiece. But as revealed in State Government records, released this week, no-one knew how to do whatever it was that ought to be done. According to Ms. Dawn Troy, a consultant for the State Archives, there were neither heroes nor villians in the saga: 'The building was so complex that nobody had real grasp of it. Utzon was the only one with an overview, but even he was going by trial and error'. When left, in a welter of accusation and counter-accusation over rising costs and endless delays, those chosen to complete the task were dogged by the same problems that had beset him. The Publics Works Department project officer, Phil Taylor, wrote in a confidential minute: 'There is a lack of central command and intelligence as to: The situation: What has to be done; What is being done; Who is doing what; Pre-planning; and Who is responsible. There is unbelievable conflict as to the true situation on nearly every issue that arises'. Mr. John Cross, the State Archivist, says: ' People say Australia loves big projects, we love the Harbour Bridge, we're excited about the Olympics. But people built bridges and staged the Olympics before. Nobody has ever built anything like the Opera House. It was

operating on the very edges of technological knowledge. I don't think that country had ever done anything like it before and we may never do anything like it again'.

From the beginning it was unique. Utzon's sketches were the only ones among the 233 entries which did not conform to the design specifications. The first cost estimate was $7 million. It eventually cost $100 million. Utzon was instructed to design the main auditorium as a multi-purpose hall but, after his departure, the ABC wielded its concert-going numbers to ensure it was completed as a concert hall. The removal of the stage machinery already installed cost $2.7 million. The internal reorganisation, eight years into construction, involved a complete redesign of the electrical, air-conditioning and plumbing systems. The glass walls, planned by Utzon to drop in sheer falls from the shells, with plywood mullions, was another source of concern. Ove Arup and Partners, the consulting structural engineers, were converned about the plywood's durability and demanded a testing program. The Public Works Minister, Davis Hughes, concerned about the delays, refused to allow Utzon to test prototypes. Besides, Ralph Symonds, the only company which could produce the plywood, was in the hands of receivers. The Monty Pythonesque aspects of the drama are impossible to miss in a 1968 opinion from the Public Works Department's legal officer, who wrote that not only was Symonds insolvent but the timber had to come from Borneo, where some local wars and guerilla activities were in progress. As Ove Arup reported in 1969, the scheme would 'use glass in a way never before attempted and our initial contacts with the glass industry have not always been met by an enthusiastic response. Some manufacturers... will have no part in it'. The recriminations go on, in some quarters, to this day. But at Bennelong point a masterpiece was finally completed. Flawed it might be, but as Ove Arup said in 1965: 'the thing we wanted built was Utzon's Opera House'. Arup was referring to the unanticipated cost blow-out, but he could well have included all the tensions, heartache, disappointments and triumphs which are part of that wondrous floating sculpture. Such a work, Arup said, 'costs that amount... and would from the beginning, only nobody knew it then'. Had it been known, ' the Opera House would probably never have been built. The fact that it wasn't known, and that clients and public were completely misled by the first so-called estimate, was one of the unusual circumstances that made this miracle possible'.

The importance of having an efficient PMIS to support the management of a project has also been highlighted by Harrison[3], viz.:

All project managers must be backed up by effective systems, as it is impossible to manage a complex entity, such as a project, without planning, budgeting, analysis, and control systems to assist the manager in his function. If he does not have this back up, his planning and budgeting will be too slow, and they will not be used to help him organize and control his work. Without a good information system, he cannot really control his project, as he will not know until too late what is really happening, must spend a lot of his most valuable and scarcest resources, his time, on simple supervision and the collection of information, and any information he does get will be inevitably out of date.

Idealised PMIS

Assuming there would be no technological limitation, what would be the shape and functions of an ideal PMIS? The authors believe that the best way to define an idealised PMIS is to outline what such a system is supposed to do. *Table 1* displays a series of PM functions which could be effectively supported by provision of an ideal system. Up to 25 typical PM functions (*Table 1*), are presented and explained detailing their typical deliverables and the way they are applied.

These PM functions are commonly used to manage most sizeable projects.

The underlying thesis is that all these functions can be accommodated within a unified PMIS system. This assumption will be challenged later in this paper, but for the moment assume that it can be done. It must be noted that in attempting to define an idealised PMIS, the authors want to: (1) define a bench mark system for the study and ranking of a sample of current PMIS systems; and (2) develop generic capability requirements and specifications so that work can proceed on the development of the smart PMIS.

Review of current PM systems

The review of current systems and other studies (see for example, Churcher *et al.*[4]), confirm that essentially there are two types of systems in use currently in industry:

1. Those systems which have been developed in-house as proprietary systems, and are not generally available to outsiders; and
2. Those which are either commercially developed and marketed or developed as part of research projects at universities and research institutions.

As might be expected, the systems sampled for the purpose of this study are of the latter type. Altogether 24 systems have been sampled, of which 12 are commercially available and the rest (which the authors call prototype systems), are still in the developmental stage (*Table 2*). There is no significance surrounding the number of systems selected, except to ensure that there are functional variations between the systems. The review is based on published information, i.e. journal papers and information sourced from the World Wide Web (see *Table 2*). The sample is neither exhaustive nor representative. It is perceived that the sample represents the best available PMIS systems in accordance with the authors' definition of a PMIS. However, it is acknowledged that there may be some proprietary (in-house) systems used by large PM or owner or contractor organisations which may be based on a different technology or have a different format and processing architecture. Since no information is available publicly, the authors could not consider them in the review.

Further, it must be noted that the term 'PMIS' may be too all-encompassing to be used on some of the selected systems, since the originators of these systems did not intend that they be used to furnish support across such a comprehensive range of functions. The authors have used their own discretion to select those systems to fall partially or totally, under the definition of a PMIS. The purpose of the review of this sample is primarily to see whether or not there is need for developing a new PMIS system (SPMIS) or whether any of the available systems can be further developed to respond to the needs already identified in this paper. The authors have exercised caution in the review and analysis of information on the publicly-known systems, i.e. to ensure that the bias in the selection of the sampled systems is taken into account when generalising the findings.

251

Table 1 Definition of typical PM functions and deliverables

Number	PM function	Deliverables	Application and methods
1	Project start-up	Start-up schedule	Responsibility chart, defining roles and responsibilities, and time scale
		Start-up report	Review current stage to launch the next
2	Proposal and initiation	Organizational chart	Responsibility chart, showing work elements and organizational units
		Multimedia/digitized video meetings workshop	Workshop, defining objectives and scope of client, preliminary plans, estimates, milestone plan— representing logical network, responsibility chart
		Project definition report	A handbook for management, design, and executive teams, which defines what the owner expects to achieve, project's expected life cycle cost and value, trade-offs, delivery strategy
3	Feasibility study	Milestone plan and responsibility chart	A plan to pin-point steps of study through interim and final reports, meeting, data collection, etc.
		Timetable and budget	Spreadsheet like, to enable options to be sufficiently explored optimally
4	Design and appraisal	Design plan	Milestone plan measuring progress and monitoring performance of design achievements
		Project manual	Results of design and appraisal in a document which explains how the owner's requirements are to be delivered
5	Initiation launch and meetings	Multimedia/digitized video meetings workshop	Workshop consisting of plans for current stage, preliminary estimates, management and control plans
6	Resource management	Milestone plans and responsibility charts	Assigning work to people
		Scheduled bar charts and networks	Resource allocation and scheduling of resources
7	(a) Implementation planning	Responsibility chart	Defining roles and responsibilities for each of the team members
	Planning and scheduling activities	Scheduling plan	Milestone of activities within the work-package
	(b) Authorising work	Work content & duration chart	Estimates of the work-packages
		Master plan	Authorising work for inclusion of master plan
		Work-to-lists chart	Spreadsheet like or responsibility chart indicating a list of activities to which a person is assigned
	(c) Representing the activity schedule	Responsibility or bar chart	Schedule of activities making up the work-package
		Estimating sheets	Calculation of work content & schedule of activities in work-package
		Nested networks or bar charts	Showing activities of work-package
	(d) Representing the programs	Program chart/table	Activity schedules representing a program for a particular person, such as the client
8	Allocating work	Work-to-lists chart	Responsibility chart or spreadsheet indicating a list of activities to which a person is assigned
		Marshaling list	Lists of all materials required
9	Project control	S-curves & earn value reports	Using earn value techniques
		Turn-around reports	Reporting any deviations against planned
		Reports on cost & duration	% Completion report for a work-package
		Change control forms	Controlling changes in scope, calculating cost of change, defining change
		What-if scenario reports	Forecasting what-if scenarios analyses
10	Post completion review	Report review	Success & failures & lessons learned for feedback on future projects
		Final costs & benefits report	Feedback to the estimating process of future projects
		Technical achievement report	Feedback to the design of future projects
11	Quality management	Quality plan document	As part of the project definition report, providing quality assurance procedures, monitoring & personnel to ensure objectives of quality are met
12	Value engineering	Value engineering plan	As an integral part of the management of the project to achieve maximum value for money over the project life cycle management
13	Risk management	Probability distributions	Monte Carlo simulation for risk analyses
		Risk tracking forms	Recording relevant information for risks identified
		Risk monitoring reports	Monitoring & determining the reduction of risks over a regular basis
14	Safety management	Digitised video & timetable for meetings	Safety training for personnel
15	Cost management	Proposal estimate & report	For pre-proposal & initiation
		Budget estimate & report	For proposal & initiation
		Sanction estimate & report	For design & appraisal
		Control estimate & report	For implementation planning
		Tender estimate & report	For tender preparation
		Cash flows & cost profiles	Predicting the expenditure of money for project

16	Time management	Time schedule bar or gant charts, estimating sheets, & networks	Schedule design & construction programs, highlighting key client decision milestones, estimate work contents & duration, identify monitoring & updating dates
17	Stakeholders' management	Stakeholders' management plan, implementation, monitoring and control	Refers mainly to those with a direct stake in the project, either as a shareholder, a financier or a government instrumentality, and involves preparation of a management strategy & control plan, communications' charts, reporting and monitoring against pre-agreed agenda
18	External relations' management	Media and public relations' management plan, implementation, monitoring and control	Preparation of a management strategy & control plan, communications' charts, reporting and monitoring against pre-agreed agenda, to promote, inform and align members of the public and the media with the goals and community benefits of the projects, measures taken to mitigate the impacts on the communities affected and other relevant issues
19	Integrated information management & control	Total project management information	The requirement that all the information related to the PM functions must be integrated and managed in a disciplined and thorough manner
20	Inter-systems' communication	To exchange relevant information with other project systems	The need to exchange information electronically with other project information systems, such as CAD files, structural design files
21	Documentation management	To ensure that all project documents are managed systematically	Refers to the information created by the PMIS on systematic registration, storage, maintenance and archival of all project documents, including, labeling, bar coding and physical classification and so on
22	Reporting	Furnishes reports of all types	To satisfy the extensive reporting requirements, particularly those required by the owner and for the real time monitoring of progress, costs, time and budget, as well as alerting of any violations of the project decisions, goals, integrity, implementation strategies and so on

Characteristics of current PM systems

Hardware

Table 2 shows that microcomputers are the preferred hardware for PM software. The trend is moving away from mainframes, and towards the advancing microcomputers, in particular PC's. However, it must be recognised that many in-house systems are based on *work stations* and more powerful computers due to the limitation of microcomputers. Many such systems are perceived to be rather limited in terms of capabilities vis-à-vis requirements on large projects[5]. Thus, the prevalence of microcomputers cannot be taken as an evidence that the hardware requirements should always be microcomputers. However, capabilities of current generation microcomputers are still on the rise, and the authors postulate that a network, based on several linked microcomputers, may well provide all the hardware needs of the future generation PM systems.

Systems interfacing

Most of the commercial systems offer interfacing capabilities of one form or another. Some explicitly create file formats sending them to common application software programs such as spreadsheets and word processors. Some are capable of interfacing with other PM software. For example, PlanView can interface with Microsoft Project, Artemis, Project Manager Workbench and many more. PlanView can also create files in different formats, including ASCII, XLS, WKS, CSV, MPX, and DIF. The prototype systems, on the other hand, appear to rely more on their implementation environments, which may or may not interface with other programs. Normally these systems get around the problem of interfacing by developing a program to communicate with other pertinent software. In the main, however, there is no structural commonality in the data models used to facilitate handshake, transmission, validation, verification and automatic updating to take place in inter-software communication of the above systems.

As far as interoperability and compatibility aspects are concerned the above interfacing capabilities are less relevant, as the aim is to institute full electronic and real time transactions between the systems used on a given project, including PMIS, CAD, construction planning system, HVAC design system (if any), and others. This is the key to improvement of the underlying processes on capital projects.

User-friendliness

Most of the commercial systems studied were found to be relatively user-friendly. This is due in part, to their simplicity in using microcomputers, and because they are normally Windows-based. The prototype systems, however, are perhaps less user-friendly than the commercial systems. Some do not use Windows environment, and this detracts from the ease with which the user can interact with the system.

Project management functions covered

The study shows that most commercial systems cover resource leveling, scheduling, project control and time

Table 2 Description of the PM systems sampled

System number	System's name	System's status	Source (author)	Minimum systems requirements	User friendliness 1—low 2—medium 3—high
1	Viewpoint	Commercial	Archibald[6]	PC, 512 Kb RAM, DOS 2.0	3
2	AMS Time Machine	Commercial	Apte[7]	PC, 256 Kb RAM	3
3	Artemis	Commercial	Weaver[8]	Hewlett Packard 1000 mainframe	2
4	PertMaster	Commercial	Henry[9]	PC, 128 Kb RAM, DOS 2.0	3
5	Qwiknet	Commercial	Davis et al.[10]	PC, 380 Kb RAM, DOS 2.0	3
6	Primavera Project Planner	Commercial	Taleghani et al.[11]	PC, 512 Kb RAM, DOS 2.0	3
7	COBRA	Commercial	http://www.wst.com/products/cobra.html[12]		3
8	PlanView	Commercial	http://www.planview.com/product/pvds.htm[13]		3
9	PROCON	Prototype	Diekmann and Al-Tabtabai[14]		2
10	CASPAR	Prototype	Thompsom et al.[15]	PC, 512 Kb RAM, DOS 2.0	2
11	PMIS	Prototype	Jaafari[16]	PC, 6 Mb RAM, Windows 3.1	2
12	Expert-Risk	Prototype	Kangari and Boyer[17]	Microcomputer	2
13	PROMIS	Prototype	Heck[18]	PC/AT/XT, 512 Kb RAM, DOS 2.0	3
14	'Prototype'	Commercial	Abudayyeh and Rosdorf[19]		2
15	GHOST	Prototype	Navinchandra et al.[20]	Lisp machine	2
16	CONSTRUCTION PLANEX	Prototype	Hendrickson et al.[21]	TI explorer, Knowledgecraft environment	2
17	KNOW-PLAN	Prototype	Morad and Beliveau[22]		2
18	CALLISTO	Prototype	Sathi et al.[23]		2
19	PACES	Prototype	Scott and Yang[24]		3
20	ELSIE	Commercial	Brandon[25]	PC	3
21	OPIS	Prototype	Froese and Paulson[26]	NeXT computer	3
22	COSTAZ	Prototype	Romblon and Rosario[27]		2
23	Superproject Plus	Commercial	Frank[28]	PC, 256 Kb RAM	3
24	CLIENT	Commercial	Hemmett[29]	PC, DOS/UNIX	3

management (*Table 3*). Not all commercial systems have equal capabilities. Also, the basic data modelling used on many is that suited to critical path analysis of projects. This is not surprising as most current generation PM systems were originally developed to do scheduling, and many of these are still used predominantly for this purpose. The evaluation of the sample systems shows that none really fits the description given for a smart or ideal PMIS. In short, many of the 24 systems sampled were found to be excellent systems in performing certain PM functions, for which they have been designed. However, many lack the range or capabilities sought by today's project planner/managers facing many challenges on complex and uncertain projects. Also, and as stated, many of these systems have not been designed to facilitate proactive project management approaches, or even provide integrated evaluation of traditional areas such as cost, time and risks or handle information management, a function which the authors view as an essential integral part of project management.

Point comparison

In order to do a systematic evaluation of the sampled systems the authors decided to use a point comparison approach. In this evaluation no attempt was made to carry out a comparative analysis of the systems within the sample. Instead, they will be compared against the idealised or smart PMIS, whose range of capabilities and functions were already presented in *Table 1*. Below are the points scale the authors have used to evaluate each system against the idealised PMIS:

- a score of 1 shows poor comparison with the idealised PMIS
- a score of 2 shows moderate comparison with the idealised PMIS
- a score of 3 shows high comparison with the idealised PMIS
- a score of 4 has ideal capability.

In assigning a perfect score of 4 to each PM function in *Table 1*, the idealised PMIS's total score will be 100, which is the ideal case. Note that the assumption is that SPMIS is technologically feasible to design and

Table 3 Point comparison of sampled PMIS systems*

System no.	System's name	Total score	Project management function number† 1	2	3	4	5	6	7 (a)	7 (b)	7 (c)	7 (d)	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	100‡
1	Viewpoint							2	2		2			2						3	3				2		3	19
2	AMS							3	2		2									3	3				2		3	18
3	Artemis							2	2		2									3	3				3		2	17
4	PertMaster							2	2		2			1						3	3				1		2	16
5	Qwiknet							2	2		2			3						3	3				1		2	18
6	Primavera							3	3		2			3						3	3				3		3	22
7	COBRA							3	3		3			3						3	2				3	1	3	23
8	PlanView							3	3	1	3		2	3						3	3	1	1		3	1	3	30
9	PROCON																			2	1						1	7
10	CASPAR						1							2				3		3	1				1		1	8
11	PMIS													1				2		2	2			1	2		2	9
12	Expert-Risk						3	2		2			2							3	3				2	1	3	21
13	PROMIS						1	1		1			2							3	2				2		2	14
14	'Prototype'										1										3					1	1	4
15	GHOST																			1	3			1			1	5
16	PLANEX																				3				2		1	6
17	KNOW-PLAN						3	2		2			2							2	2				2	1	2	18
18	CALLISTO			1			2	2		2			3							3	2				2	1	3	23
19	PACES			1			2	1		1		1	1							3	2			1	1		3	19
20	ELSIE					2	1	1		1	1	1	1							3	3			1	2		3	16
21	OPIS						2	2	2	2			2							3	2	2	2		3		2	12
22	COSTAZ						2	2		2	2		2		3					3	3	2	2	3	3	3	3	18
23	Superproject				2		2	2	2	2	2		2							3	3				3		3	18
24	CLIENT																			3	3							39

*A blank entry signifies that the relevant function is not supported by the corresponding system.
†For description relating to each PM function refer to *Table 1*.
‡This is the perfect score derived for the idealized PMIS system.

255

Table 4 Ranking of the PM systems

System name	Total score	Rank
CLIENT	39	1
PlanView	30	2
COBRA	23	3
PACES	23	3
Primavera	22	4
PROMIS	21	5
Viewpoint	19	6
ELSIE	19	6
AMS	18	7
SuperProject plus	18	7
CALLISTO	18	7
Qwiknet	18	7
Artemis	17	8
OPIS	16	9
PertMaster	16	9
'Prototype'	14	10
PMIS	13	11
COSTAZ	12	12
Expert-Risk	9	13
CASPAR	8	14
PROCON	7	15
KNOW-PLAN	6	16
PLANEX	5	17
GHOST	4	18

build; a point which will be considered in the second part of this paper.

Note that there was no assignment of different weights to PM functions to differentiate those which may be perceived to be more critical than others. The reason for this decision is the fact that an ideal system (SPMIS) should have a universal capability in respect of any PM function. It is acknowledged that on a specific project one PM function may assume more importance than others, due to circumstances surrounding that project. However, this is not a valid argument for introducing a bias in the SPMIS system design and capability ranges.

Ranking of PM systems

Table 4 shows the ranking of the systems in accordance with the total points each system scored. *Figure 1* shows the top five systems in the sample. Note the equal ranks for PACES and COBRA. As seen from the total scores' column, the best systems available do not even possess one-half total capability required, meaning that there is a long way to go to produce systems which can respond to the pressing requirements of users in the project industry. Of all the systems looked at, CLIENT scored the highest. It has been claimed to be an integrated multidisciplinary on-line and real time management system[30]. It has the following features: information, documentation, financial, quality, time, claims and process management; electronic mail; audit trails; and security. Relevant parties from remote sites/terminals are brought together as interactive contributors through a central database. The information is distributed in real time to uniquely identified recipients, setting in motion contractual processes, obligations and responses with transactions audited through the system facilities (information supplied by Hemmett[29,30]).

It is not surprising to see that typically, numerous software packages are used on a given project to aid with the delivery of the PM functions. This practice

has many inefficiencies and drawbacks. Firstly, there will be multiple data entries; each using their own data modelling and structure. Second, there will be difficulties in co-ordination of information across these software packages. In fact, the probability of a blunder in data entries increases with an increase in the number of systems used. Third, there will be no integrated (compounded effect) analysis; this is not a desirable situation when judged against the fact on most projects one disturbance will have a compound (chain reaction) effect on many aspects of the project.

There are two ways to respond to the existing disparity between the current PM systems and idealised PMIS, either to take one of the existing systems and try to build it up to the required capabilities, or to start afresh. The authors have decided on the latter, because many of the current systems are not necessarily based on the latest technological advances in computing and IT. Any system developed today must be flexible to accommodate inclusion of a range of emergent IT technologies, as far as possible. A correct system architecture will also be necessary to take advantage of the advances made in the science and art of computing.

Can a SPMIS be built?

In order to explore the feasibility of designing and building a SPMIS the authors have reviewed the status of IT technologies. The question of responsibility for total project information management has been considered and a model put forward, which is in accord with the centralised control strategy. The authors have discussed the suitability of using object-based technologies and have come up with quite specific approach to set up a project model suitable for automation of project life cycle processes and integration of information. As will be seen from the following discussion, the suggested methodology is a pragmatic way of overcoming some of the technological barriers which stand in the way of attaining a SPMIS.

IT outlook

IT is the application of electronic processing, manipulation and transmission of information in all its forms, text, data, graphics and still pictures, voice, moving images and a combination of these. The rapid development of IT will have profound ramifications for project management, particularly in changing the way projects are planned and managed in the near future. As mentioned earlier, capital projects tend to be complex, with hundreds or thousands of activities and tens or hundreds of resources. Effective implementation of IT within projects, as well as the entire industry, would improve the communication processes by an order of magnitude, and would thus benefit the delivery of all phases and functions on projects. More importantly however, it will facilitate automation and integration of all activities over the project's life cycle.

In addition, it will allow for a larger number of options, products and solutions to be considered, appraised and included at minimum time. It will also allow project teams to function more efficiently, particularly under a concurrent construction arrangement. The net result should be significant savings in both
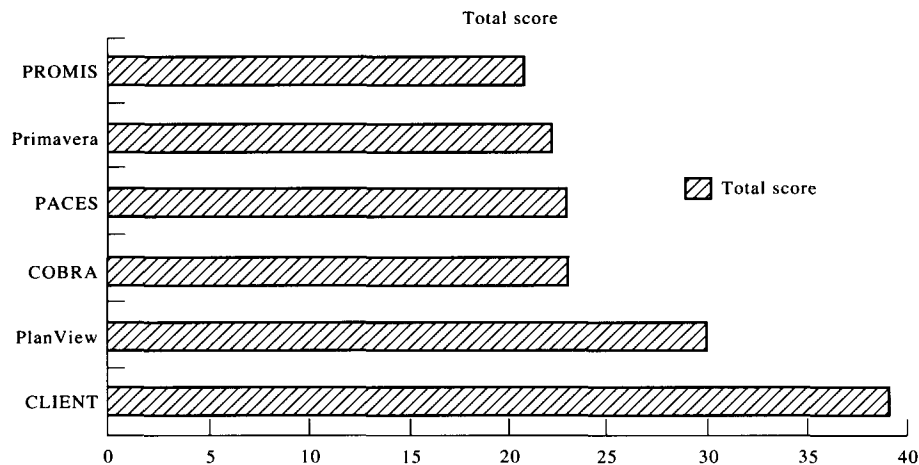
Total score

Figure 1 The top five PM systems in the sample

project time and cost as well as improved realisation of project value and goals. As with all other technologies these benefits will not accrue automatically unless the industry sets in motion processes and means to tap these effectively on projects.

The advent of multimedia communication technologies may well mean a greater variety of input information and interfaces, such as text, data, moving images, and sound or other forms. As an illustration, it is feasible to generate 3D images for the whole or parts of a project, which will allow construction planners to have a better appreciation of the scope of that part, and to come up with an improved construction plan for the same. In turn, the construction planner's output may well contain a simulated and video-animated explanation of the construction process and plan. The people in the field may re-run this video to get a better appreciation of how the works were intended to be constructed. In addition, through the linking of computers it is possible to share multimedia information across a wide geographical area.

Looking over the medium to long horizon, it may become feasible to convey electronically the construction plan to the on-board computers of the relevant construction equipment, and have these programmed accordingly. Certainly research and development will become more focused on man-less computer-driven equipment in the near future, as it will be possible to transfer hazardous and other less desirable work to man-less machines.

The authors believe that, given the current state-of-the-art, only text, data and graphics should be used as means of capturing and analysing the core information on projects; other forms of information, such as voice and moving images, should be seen as offering explanation and training facilitation, and providing auxiliary functions such as clarification of information. Adoption of this strategy is necessary otherwise there will be technological difficulties in the short to medium term, in achieving a practical solution to the development of a SPMIS. This is because multi-media conversion technologies, such as voice recognition and data capture from video images, are still in their infancy.

Project management and information flows

The predominant practice is still based on individual discipline-based designs which are coordianted in a piecemeal fashion, lump sum contracting and multiple sub-contracting. Each party tends to work within its contractual framework and in isolation of the others. The project manager will thus be preoccupied with the administration of the contractual provisions. Professionals under contract to clients define what is needed to be done to fulfill the client's requirements. There is constant data transfer among the various parties and often complexities in data sharing and information flows occur.

It is not uncommon to observe communication breakdowns on projects, as well as misinterpretation of client goals or wrong interpretation of design documents, use of outdated specification on vendors' supplied equipment and systems, errors in project execution plans, transmission of inconsistent information, conflicting data formats and the absence of defined protocols and so on. Project managers more often than not concern themselves with resolution of conflicts. The end facility may or may not turn out to be what the owner or client ordered, depending on the interpretations of the different professionals working under different sets of contracts and contractual arrangements on projects. This style of project execution is under fire but is so entrenched within the industry and the public and private institutions around the world that it will be a long time before one can contemplate its replacement.

Under concurrent construction the role of the project manager is transformed from that of an administrator/coordinator/arbiter of conflicts to the active manager and driver of the project activities to maximise project's net value or satisfy other objective functions[31,32]. The project manager will have to be more technically and technologically oriented than seen today. He should understand the core business of the client as it relates to the project, and should drive the project forward to maximise the stipulated objective functions. This approach requires freeing the project from excessive administration burdens imposed on the project by multi-phase project development and implementation and due to multiple contracting. The legal framework under which projects are executed

must change to ensure that the objectives of the project participants are fully aligned with the objectives of the project, potential for conflicts removed and composite teams are formed to work together in a multi-discipline and integrated team environment to plan and execute project activities. (See Jaafari[1] for more details of concurrent construction). To support such a proactive and goal-driven project management, information flows must be brought under control, not only to reduce incidences of breakdowns and errors, but also to increase focus on objective functions and create synergy among teams.

Information standardisation

In recent years, several moves have been underway to bring the various disciplines involved in the design and implementation of capital projects closer to sharing information between software applications. Initiatives such as the development and implementation of a proposed international standard (ISO 10303-225) for information specifications and interchange, known as 'STEP', are intended to provide common descriptions of product information for a variety of industries. Also recently an alliance, known the Industry Alliance for Interoperability (IAI), has been formed to facilitate and speed up moves to establishing data exchange links between the various systems used in the design and execution phase of projects. IAI's chief focus is the definition of Industry Foundation Classes (IFC), to provide a method for information sharing in the construction industry.

> IFC's will supply a common language for defining a building project. Using object-oriented and component software technologies, IFC's will provide customizable industry-based object definitions that will encapsulate information about building elements as well as design, construction, and management concepts.[33]

> IFC's will conform to STEP Standards. The goal of the IAI is to bring the benefits of interoperable software and intelligent building objects to all players in the

building/construction industry. AEC software vendors will base their software products on the open object technology. That is, these new object-oriented software technologies will supply the incorporation of building industry information into interoperable objects for the building industry that will dramatically increase the sharing of information in the planning, design, construction, and management of buildings.[33]

Responsibility for project information

Broadly, information sets on a capital project consists of the following types: design information; product and process information; and management information. These information types comprise the core of communication content among the various professionals involved in a given project.

The authors found that the project manager should be the appropriate party to assume responsibility for the total information management on projects. A critical function of the SPMIS should be to act as the master system (or control panel), managing information transactions on the project as a whole, and providing real time connections to the discipline-based systems or field construction information systems. The analogy used by Laufer et al.[2] for management of communication on projects is relevant to the author's adoption on this matter, viz.:

> The flow of communication in the successful project resembles traffic in a metropolitan city, heavy with noisy movement of all types of conveyances: bicycles, motorbikes, cars, cabs, trucks, buses, streetcars and trains, going in all directions at a breakneck speed without stopping. It is as though we watch the traffic at the Place Charles de Gaulle (Etoile) in Paris at rush hour at three times the normal speed, seemingly chaotic, but in fact flowing without a hitch, with resolute purposefulness and direction. The effective manager does not act in this tangle as a good traffic officer but more like the top person in the traffic control center of the city responsible for the design, planning, adjustment and
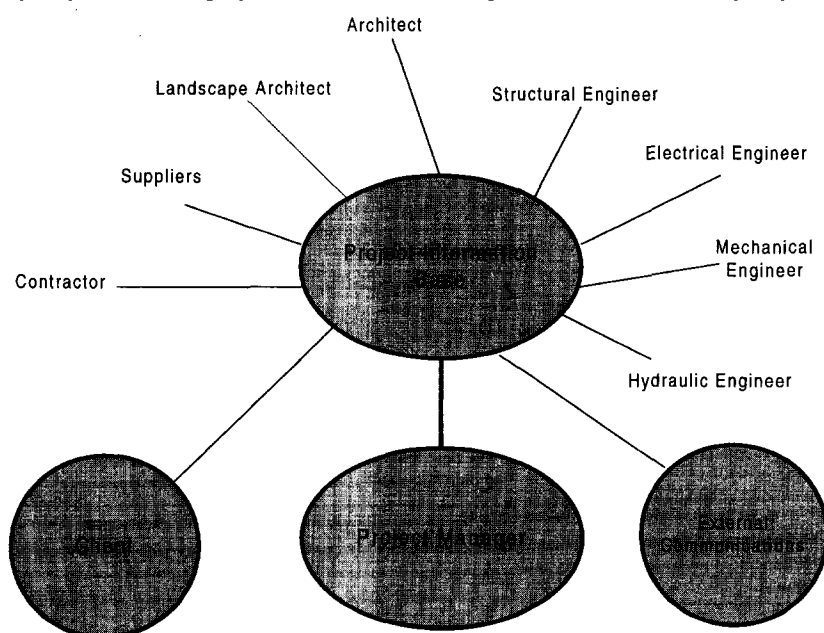

Figure 2 A centralised approach to management of project information

maintenance of the flow in lanes, highways and byways, and monitoring the city's heartbeat operating in concert.

The authors believe that without a control structure, it will be impossible to systematically direct and control the flow of information transactions on projects. *Figure 2* shows the strategy for centralising control over information management on projects; under this strategy both the flow and contents of core information are proactively managed. Also, core information is made available to the various project team members and stakeholders in a manner so as to create synergy and provide conditions to maximise team contributions to project objectives. This strategy is not meant to be stifling the work of the designers or contractors and others. On the contrary, it is meant to streamline the communication process ensuring that the right piece of information will be furnished to the team or party under consideration at the right time and in a correct format to provide conditions to facilitate optimal design and or production results.

Creating a project model

One way to create a structure for communication and integration of the project activities is to establish an information model unique to each project. In setting up a model for the project it may be possible or even desirable to select some or all of the elements from a universally recognisable library of elements. The main distinguishing feature is however that the chosen information model must be able to act as a basis or provide a protocol that is necessary to characterise the project and provide conditions for its successful and proactive life cycle management.

Some authors have explored an approach in which the project model is gradually evolved through linking, — either manually or using machine intelligence, the various computer-based systems used by project participants[34]. The machine recognition approach assumes that individual discipline-based systems will be able to 'talk' to one another in real time, verify information sets received or transmitted between them, using a common protocol to read and decode the information received or requested on an element by elment basis or do the same via a translation software. The input may come at any point, from a project team member, or it may be received from a system within the network of linked systems.

This is where IFCs and STEP will enter the scene. Thus, theoretically, each discipline could carry out its design using a collection of 'intelligent objects' drawn from a library of universally recognised standard objects. Although each discipline would still use discipline-specific objects, these would be understood and automatically related to other objects. The upshot of this approach will be a gradual accumulation of project elements designed and specified by different professionals over a period of time, and without a true integrated team approach. While the use of intelligent objects will no doubt facilitate rapid formation of a project specific model which will be recognisable by all the project participants, it will not necessarily lead to optimum project configuration, as different disciplines

will tend to interpret project objectives differently, and conflict resolution can be quite demanding[34].

A third approach reported in the literature[35, 36] is to have an in-built expert or intelligent system as part of each of the discipline-specific systems, which can act as the information 'gate keeper', to the system to which it is attached. The expert system will use rules to evaluate and validate any information set directed to, or requested from its host system, and only after a proper diagnosis will it allow the transaction to take place. The expert systems are referred to as *intelligent agents* and the whole approach is called the *agent collaborative environment*[35, 36].

With multi-point information entry and 'free-for-all' communication approach on projects there is potential for chaos in information management and creeping in of errors, as well as conflicts among project team members. There are also many points in time and space on projects where faulty lines of communication can occur. Therefore, there is a need to have a disciplined approach to the management of information on projects. There are two sets of information, viz: (1) those which are unique to each discipline, such as estimates of cooling or heating loads used by the heating, ventilation and air conditioning (HVAC) engineer to design the HVAC system; and (2) those which are common to the project as a whole, such as the eventual size, location, type and specifications for the HVAC elements.

Linking of the various seemingly unrelated and discipline-specific systems through the so-called intelligent agents can be very complex, slow, and unnecessarily cumbersome. This explains why the authors have elected to utilise a specific 'product' and or configuration model of the project as the basis of the system design and inter-discipline communication, co-ordination and integration. Also in the case of deliverables which are not physical objects in nature, such as design drawings for a particular part of the project, the product can be defined as the end deliverable, e.g. the completed drawing set. It will be linked to the physical product it relates to.

It is not advisable to allow the project information model to evolve arbitrarily over time from the assembly of disparate sets of information coming from various points or systems, without a direct relation to the selected objective functions and other goals. To allow this to happen is to forego the advantages of running the project proactively in a focused goal seeking manner.

Communication through product models

The authors' research shows that the most effective way of managing information is for responsibility for management of the discipline-specific information to reside within the respective parties; while the project manager presides over the core information. To achieve the required degree of proactive management of the whole project activities the project manager must adopt a 'control centre' strategy for management of core information transactions, i.e. to have all the core information collected, validated, stored and brought under a centralised control with appropriate degree of discipline, authority and security. The authors define the core information on a project as

those information sets which will determine the physical nature of the end facility, its functions, elements, its delivery timing and associated capital and operating cost limits, as well as information related to the management of the external affairs (stakeholders, media, the statutory bodies and so on). Safeguards and management structure considerations must also be built into the system from the outset. This is a key function of the proposed SPMIS. It will be programmed in such a way that it will automatically establish a specific product model of the project interactively at an early stage. Though this may change over time all the changes thereafter will be effected in order to add value to the project or meet specified requirements. Changes are only possible if negotiated with and sanctioned by the project manager.

The other reason why a specific product model of a project is essential stems from the need to integrate information across the project life cycle. As stated already, the proposed SPMIS will have to support proactive management of the project, particularly in respect of the objective functions such as TLCC/unit output, cost/worth ratio and profitibility index. These functions must not only be monitored for the whole project by also for the constituent systems or major parts, to ensure that the decisions made on the design, specification and management of these are also optimum. For example, on a thermal power station, the cooling system is to be considered as a constituent system and the design and construction of this system must be optimised in order to achieve a certain target TLCC per unit cooling load.

In addition to the aforementioned quantitative objective functions the SPMIS must respond to the holisitc management of the soft functions over the life of the project, such as management of OH & S, environmental protection and media and public relations. The SPMIS must be programmed to locate and report violations, particularly those affecting safety, operability, quality and the engineering integrity of the project concept. With the advent of innovative project delivery methods, such as concurrent construction, it will be conceivable that the entire implementation program will be integrated into one phase to save time and maximise the project's net value rather than just achieve time and cost completion targets[1,31,32]. So it is imperative to develop and maintain a specific product model of the project at the outset, and use the same as the vehicle for proactive management and life cycle integration of the entire project activities as the project progresses.

Research shows that the product model will be an effective and powerful structure for integration of the activities of the entire teams, as well as management of core information on projects[37-39]. The authors also believe that there is no need to have a process model also described to parallel the product model, since the focus of the entire project management should be on the end deliverables. Each team responsible for a major part or a system on the project may thus define the relevant process which will fall under its responsibility. An integrated team will include members drawn from the appropriate disciplines, as well as the contractor, the facility user and representation from the relevant statutory authorities and governments. Also, it is imperative to define the process considering the re-

lationship of the work of the teams. For example, a contractor responsible for the execution of a particular line of products situated within the jurisdiction of several teams on a given project may well want to plan and rationalise the use of major resources within the entire scope of his/her contract.

Summary of the approach adopted for SPMIS

1. Define the level of project breakdown into major parts or constitutent systems, followed by division of each part or system into constitutent products. As a guide, one can use the quality management scheme foreshadowed for the project to define its constituent systems, parts, products or deliverables. The point of division is decided considering the acceptance scheme under which works or products are to be delivered;

2. All project participants must be required to use the authorised product model and develop their planning, design or development work around it. Their output will no doubt generate further products, some of which will be discipline-specific. Only the project manager will have the authority to accept or substitute products. Note that each new product, through declared properties assigned to it at the time of creation, will identify itself with one or more products within the model. For example, a pump designed to be installed on specific floor of a machine room will recognise its association with the floor (a new product identifying with an existing product).

3. Although product association is the basis for integration and management of information, the discipline-based designs will be carried out for the project as a whole, as is customary now. This is nececessary to allow application of a proactive value-driven approach to the project development and implementation;

4. The SPMIS will direct and regulate the electronic flow of information between itself (PM) and other systems using the product model as the denominator. Thus request and dispatch of information and other communications will be programmed to operate automatically using the products or objects representing the same as the foundation. However under this system, a particular project participant need not communicate electronically, so long as he/she can return to the PM the products that will relate to his/her scope of work in the prescribed format for inclusion into the project's catalogue of products;

5. All analysis and evaluation of the information sets (of whatever type) held within the SPMIS will be carried out for the whole project or the parts specifically queried (where no inter-dependency exists). In doing the evaluation the SPMIS will automatically check any dependent effect(s) of a particular change. It will be programmed to carry out a holistic analysis even though the user may only be asking the system for a function-specific evaluation.

Because this approach creates a structure of product it lends itself particularly well to object-oriented pro-

gramming. The SPMIS can be programmed to set up a product model of the project using object-oriented programming, and through imported information (e.g. from CAD files), and or interaction with the PM using project definition information as the basis. Thus, a group of objects representing a major part of the project may be linked together. This enables establishing information association between a major part of the project and its respective products. This provides a technique for linking the relevant information throughout project life cycle phases, from concept design through to preliminary and detailed design, construction and start up.

A valid question is how the product model can relate to the work package model of the project. We all know that construction contractors and fabricators prefer to use work packaging as the basis of their information models, since it represents the consumption of resources; i.e. materials and consumables, plant-hours and man-hours. The key to the linkage is the quantity of permanent work contained within a given work package, and the product(s) it relates to, e.g. a part of a reinforced concrete sub-structure could be declared as a product in this instance, and the work package could relate only to the construction of that part. It will be possible to declare a contractor-specific object for each work package, and further decompose it into constituent tasks and resources, and or link it to a sub-contract object. The important point is that this decomposition of work package into tasks and resources is carried out by the contractor to suit his/her operation; it is referenced back to the project's product model, through the product linkage. Each time a query is raised by the SPMIS to the contractor's system regarding consumption of resources to construct a given product, the latter system will simply aggregate the relevant information, note the completion status (i.e. the quantity of work done or percentage points completed), and report back this information to the SPMIS.

Object-oriented systems

The following description given by Abdalla and Yoon[40], will amply convey the underlying concept for object-oriented systems:

> In an object-oriented system, all entries (physical or conceptual) are represented by objects. Each object is an instance of a class. A class describes a set of physical or conceptual objects that have similar properties, constraints, and operations. Each class defines attributes, or a set of data, that define the state of the object, and a set of methods (or procedures) that describes the object's behaviour. Each object has specific values assigned to the attributes defined for its class. Objects that belong to the same class have the same methods, and they behave similarly. Each object encapsulates (hides) its data attributes from other objects, and only shows its behaviour. A class may have several derived classes that may inherit some of its attributes and behaviour (inheritance). A class may have one base class (single inheritance) or several base classes (multiple inheritance). Inheritance, in addition to being a way of organising objects, enables efficient and natural reusability of codes. Messages are the means of invoking the

methods supported by the class of objects a primary way in which objects communicate with each other. An object (sender) communicates with another object (receiver) by sending a message. The receiver object returns a response after a message is received. Messages are generally accompanied by arguments.

Thus, each object has a unique identification code, and contains within it information and program codes which will enable it to interact with other objects through exchanging messages. An object can have defined properties, and through these defined or declared properties it is possible to construct a complex assembly of objects in order to analyse any function. The structures created through assembly of objects may or may not be permanent, and are intended to link objects in order to respond to a certain command (e.g. to estimate project costs or to look into compliance with certain environmental constraints). Objects can be said to be 'intelligent' when the information or codes contained within them enable them to associate with one another according to a particular command. For example, through intelligent objects it is possible to have all HVAC parts of a project recognised and related to one another automatically. The association is created through information and program codes encoded into each object and through object-oriented programming, which will make objects 'talk' to one another.

Execution of PM functions using systems' approach

Both hard systems' and soft systems' approach are relevant to the execution of the PM functions. What is a system's approach, and how it differs from other forms of analysis? Dias *et al.*[41] define a system's approach in terms of its core concept, viz.:

> Interconnectedness of hierarchically arranged concepts. A member of the hierarchy is seen as both a whole and a part, i.e. a holon; this means that each whole is greater in significance than the sum of its parts. In other words, holons display emergent properties. Process loops with interaction and feedback, and the participation of the change agent in the process, leading to learning.

They add:

> One practical manifestation of a systems-based formalisation is diagramming. Two graphical images are often used in systems—a pyramid (signifying hierarchy) and a loop (signifying interaction).

Object-based programming together with systems approach provide a powerful method to create a smart PMIS system. This is because objects can be declared as descendants of others or as an aggregate of a group of objects already declared. The declaration will remain an attribute of the object and in combination can lead to formation of a hierarchical structure among declared objects. By having several attributes declared for a particular object it is possible to support both aggregation and or decomposition hierarchical structures or specialisation structures to suit the situation.

261

The object-oriented programming can support both hard systems, as well as soft systems analysis of project information. For execution of each PM function it will be necessary to define information routing, in terms of a process loop and interconnectedness, so as a clear and function-specific linkage pattern can be created between the relevant interacting objects in order to execute the same. It is possible to write generic programs activated by the relevant command keys, each representing a specific PM function, for creation of these so-called virtual structures of objects. Once activated the SPMIS will be able to scan all objects, and isolate the target objects, establish function specific routing and interconnectedness, and perform the required holistic analysis. A systems' approach implies that there should be function to function links, so as the SPMIS will be able to evaluate the impact that a change has throughout the project in a holistic manner. This is possible using object-based programming.

Accommodation of all functions in a single system

Can a single project management information system be developed to support all PM functions? The answer to this question is yes, provided that all project information sets, regardless of whether these are soft or hard, are contained (and updated) within objects. In a sense, when a function is activated, it will create a real time and unique systems' model of objects, and a particular form of computation or evaluation unique to that function will be executed.

In the case of soft evaluations obviously a soft systems analysis[42], or an expert system type evaluation will take place. It is of course possible to have multiple PM functions each with its own generic program, nestled within the SPMIS, including pre-determined sequential flow on links between them. So long as their coding can recognise the specific objects within the project-specific model, and relate to the information and codes contained within each there is no reason why the SPMIS cannot be the 'motherboard' for all the PM functions. Objects which represent either products or deliverables or both, although specific to each project, must carry both hard and soft information. Hard information will refer to quantities, variances, dimensions and any other data needed to execute the PM functions at a later date. Soft functions will refer to the attributes and conditions, as well as socio–economic factors, such as environmental, safety rules and so on.

Combination of hard functions

Under this heading the authors have explored the possibility of combining and analysing a number of functions in an integrated manner. For example, there is benefit in having data related to project duration, project cost estimation, and risk analysis all combined and analysed. This is because time, and cost are inter-related variables, and risk analysis concerns estimation of the variances of the same variables.

Research[43,44] has highlighted that it is indeed feasible to execute many hard PM functions in combination, using a unified bank of information extracted from the project's objects, provided the critical path

method of scheduling is not used, as the CPM and precedence networks create confusion regarding estimation of project duration, or estimation of the variance of the same. Fortunately, a new compatible and real time (non-network) scheduling method, named: *Time And Priority Scheduling* (TAPAS) method[32,44], can be employed in place of CPM, as it has been designed to respond to the required dynamic and real time scheduling needs on projects. Thus, there should be no major technical barriers to the simultaneous execution of inter-related hard PM functions using a unified bank of information.

Simultaneous execution of soft functions

A review of the literature on soft systems and evaluative techniques show that it is also possible and desirable to link the execution of the relevant soft functions together, and undertake a simultaneous evaluation of the introduced change, where relevant. The authors see the foundation science behind the evaluation of soft functions principally to be the employment of 'reflective practice'. There are a number of ways that computers are used to aid reflective practice; viz.: knowledge-base systems, case-base reasoning and neural networks. In expert systems, knowledge is captured using rules which are then used to evaluate new sets of information. In case-base reasoning, case histories are used to train the machine. The case information could even be generated during the formative stage of a project when many items of information are inputted into the machine. Using developed techniques it is possible to get the computer to compare the 'status' against the pattern discernible from 'stored cases' to identify any deviation. Artificial neural networks are probably the most effective approach to the establishment of case-base reasoning. Dynamic analysis of the information sets is also possible[17].

Proposed SPMIS architecture

Figure 3 shows the conceptual model of the proposed SPMIS. This diagram does not show all PM functions (only showing typical PM functions). It is intended to convey the following broadly stated functional capabilities:

- The system will be programmed to automatically set up a project-specific product model for each project. Interactive communications Windows will allow entry of information sets and rules, relevant to each object, including establishment of the association of objects with one another. Because of the in-built intelligence the SPMIS will assess validity of all information entries at any stage to ensure against blunders or inconsistent information sets. No sophisticated skills will be required other than what is common in the use of Windows-based software.
- There will be 'satellites' of both hard and soft PM function program modules, each of which will, either singly or in combination, create real time temporary structures of objects, execute certain systems' analysis and evaluation and report back to the status of project as far as the function(s) under consideration is concerned.
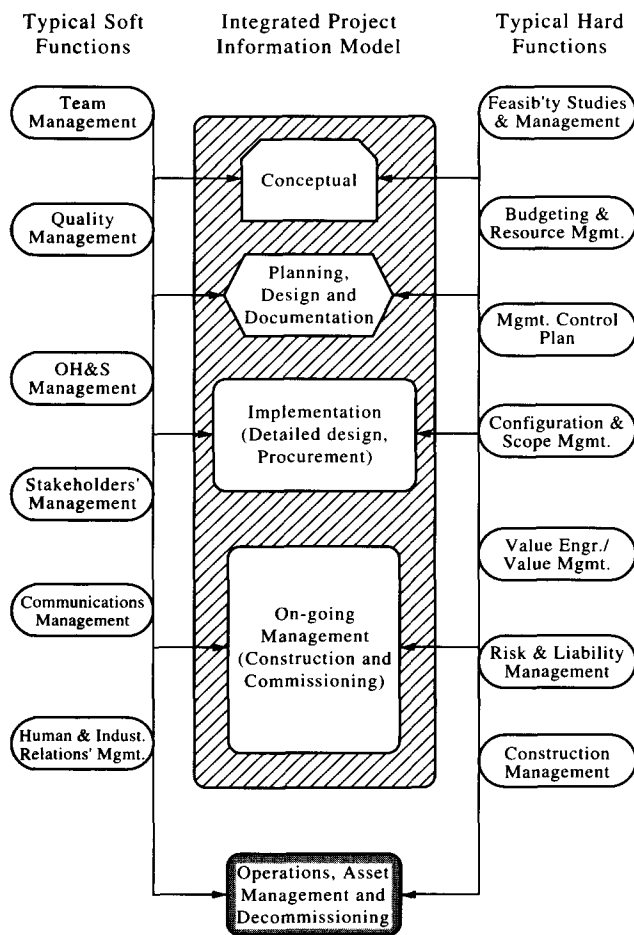
Typical Soft Functions	Integrated Project Information Model	Typical Hard Functions

Figure 3 Broad concept architecture of the SPMIS

- Through linkages of functions to the life cycle phases, it will be possible to get a comprehensive overview of the status of a project at any time in its life, and verify the impact of any change(s). This objective-based approach will open the door for newer forms of project delivery, based on integration of design and construction for project value maximisation, as opposed to the familiar forms of fixed contracting.

- The SPMIS will have no specialised hardware requirements beyond that which will be needed to support the shell on which the SPMIS will run. It is foreshadowed that a powerful PC or a work station with adequate processing and hard disk storage capacity together with multimedia capabilities, to be all that one needs to run the system, though with multiple projects or in the case of a large single project, there could be demand for additional hard disc or other enhancements. A network of computers linking the various computers belonging to other project team members must be established if one is to establish high level electronic transactions capability and real time communications links. However, these are all based on the tested and tried technologies.

Future directions

A detailed case study of a fairly large project ($A84 million construction project, forming part of a $A300 million news printing facility) has been completed. The case study is not intended to shed light on the technological achievability of the computing side of the SPMIS. Rather it is intended to verify the applicability of the SPMIS concept as a whole, and seek conceptual improvement before the development phase commences. The development work on the SPMIS has commenced and it is hoped that a prototype system will be available by the end of the current year.

The focus of the research is on the development of an integrated facility engineering (IFE) system of which the SPMIS is a part. The objective is to develop the proposed IFE system to aid in the automation and integration of the entire life cycle project processes, including definition, design, procurement, construction management and commissioning of facilities.

Conclusions

1. A case was made for the need for a smart project management information system. The main feature of such systems will be their capabilities to assist a goal-driven and focused approach to the development and management of the project, capitalising on opportunities and steering clear of constraints.
2. The SPMIS embraces a holistic view of the project. The main thrust of this system is to encourage a shift from the current adminitration-based and multi-phase project management to a goal-driven proactive practice in which the project manager will preside over the development and implmentation of the project in a single integrated phase;
3. The feasibility of building the SPMIS was explored at some length with the conclusion that the IT and computing technologies were indeed at a stage to support the underlying concept of the SPMIS. The authors' preferred approach is based on a unique project-specific product modelling, using object-oriented programming techniques.
4. The application of systems' approach in solving the project information in order to execute a particular function, or a combination of inter-related functions, was also discussed.

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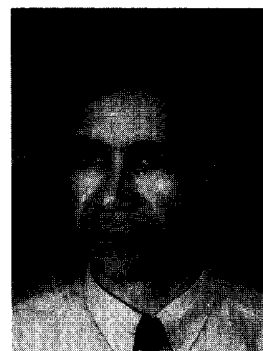
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