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A Conceptual Design of a Computer-Assisted Procurement Management System as Applied to a Construction Project

by Raul P. Rodriguez*

This paper aims to describe the concept of an information system for construction project management—designed, developed, and installed for the civil works subcontractor (WIPCO being the main contractor) for the Philippines' First Nuclear Power Plant Unit #1. What perhaps distinguishes this model from others that one have encountered in literature dealing with the same area is the component of a computer-assisted materials procurement management system. I shall first describe the general framework of the project management information system and, in the context of this general framework, devote the major part of this paper in describing the general specifications of the procurement management system.

Operating Environment

The construction of the Philippines Nuclear Power Plant Unit #1 (or simply PNPP-1) was formally conceived in 1973. Construction began in 1976. Its original targetted date of commercial operation was December, 1982. Due to a temporary work suspension brought about by a formal investigation of the plant's safety features (such concern sparked by the Three Mile Island incident), estimated completion date is early 1985. When operational, the plant will provide additional capacity in the Luzon grid of 620 megawatts.

PNPP-1 is located on Napot Point, a small promontory on the west coast of the Bataan Peninsula. It is situated on the southern portion of the Municipality of Morong in Bataan Province. To the south of the site is the South China Sea. From Makati, the site is around thirty minutes by helicopter and 2½ hours by land.

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Westinghouse International Projects Company (WIPCO) was contracted to be the supplier and general project manager for the construction of the plant by the government's National Power Corporation, the entity fully responsible for the complete safety and adequacy, quality assurance, and operation of the station. The construction project management function therefore, rests squarely on WIPCO, although in this undertaking, WIPCO has sub-contracted to local firms major portions of the project, the civil works portion being the subject of the systems study. For the whole project to smoothly progress, it is demanded that sub-contractors are efficient in their own share of project management, not a small task considering the size and complexity of the project.

For planning the control of the project, specifically project costs ($ and physicals) and schedules, a Work Breakdown Structure concept was adopted. Direct cost of construction for the project is analyzed into Plant costs, Plant costs divided into Building Costs (i.e., Reactor Bldg., Reactor Auxiliary Bldg., Fuel Handling Bldg., Emergency Diesel Generator Bldg., Turbine Bldg., and Service Bldg.), Building Costs into Work Package Costs and WP Costs into the most basic Identification Number (INO) costs. Please refer to Figure 1 Work Breakdown Structure.

The civil works sub-contractor has preferred to call the smallest work package unit as an "accountable activity" (AA). The AAs are more PERT-chart project activity-related while INOs are designed primarily for cost accumulation purposes. Correspondence between these two types of work packages, however, was established by identifying INOs to AAs to which they belong. Several INOs may be associated with a single AA.

Systems Conceptualization

The final concept of the particular Project Management Information System (PMIS) described in this paper evolved from a series of working papers written by the sub-contractor's Resident Manager and discussions on these ideas by him with the systems development project team (belonging to a computer service bureau. The author was the project team manager in the conceptualization, systems specifications, and early program development phases of the project) of consultants (2), systems analysts (5), and programmers (8). The working papers provided the basic foundation for the subsequent gross management level design of the system which includes specific report formats and the basic man-machine processes. Later discussions refined this gross design and resulted into technical level design which specifies in detail report fields, input documents, file layouts, and computer programs.

There were three major management considerations in the design of the information systems model, namely:

1. The key element in most construction projects is *materials management.* Project management can be thought of as the management of 4 resources, namely labor, materials, equipment, and subcontracts. The management of materials is the more complex of project management systems

which ought to consider the numerous and continual changes in plans, work specifications, schedules, and priorities. Procedures for initiating orders, expediting, delaying, cancelling, or substituting thousands of items still undelivered are an indispensible part of the system.

2. The system should assist, rather than take-over, decision-making made by project managers. The system should simply trigger human judgment. In this case, it is not necessary to reduce decision rules or logic processes used by managers into mathematical formulas for use by the computer, as Operation Research does. On the other hand the system should "interact" as an analytical tool with the managers rather than being just a "housekeeping" administrative tool (referring to the three types of MIS—administrative (e.g., accounting, systems, support, and mainstream). In this sense, the system can be truly classed as a decision support system.

3. While data contained in the various computer master files must be complete and meticulously maintained to permit analyses as needed, the computer system should filter out data so that reports are short and to the point—No massive data print out should ever go to the manager. In fact, *all routine reports are exception reports.*

The Project Management Information Systems (PMIS) Framework

Development of the PMIS began with the specifications of the following computer-based subsystems:

1. *Materials Procurement System (MPS)*—On the basis of accountable activity schedules, bill of materials, ordering lead times, and other inventory parameters, MPS generates a series of weekly and on-request reports that enable the procurement manager to trigger off purchase requisitions and purchase orders, expedite, delay, and be abreast of up-to-date status of the procurement process. The cycle starts with the system generating a "buy list" of materials whose orders ought to be placed so that they arrive on time for use in the respective accountable activities. The status of orders and deliveries is tracked until the materials arrive and are used in accountable activities. MPS is also useful in generating cash disbursements forecasts for materials. MPS shall be discussed at length in the next section of this paper.

2. *Warehouse Reporting System (WRS)*—This system records receipts and issues of materials at plant warehouses and maintains records of the current inventory of materials. Upon issue of materials, the system also activates a charge-out mechanism, costing out materials used for specific accountable activities/INOs.

3. *Cost Monitoring System (CMS)*—CMS monitors expenditures for materials, labor, equipment, and subcontractors for the whole project according to the aforementioned Work Breakdown Structure (WBS),

internally labelled as Chart of Accounts. Reports are generated monthly reflecting expenditures in different levels of the WBS.

4. *Cash Flow System (CFS)*—CFS assists the subcontractor in forecasting drawdowns to be made 6 months ahead from WIPCO. The system also incorporates a budgeting system which generates periodic reports reflecting actual expenditures (in $ and physical) versus estimates for project work packages.

5. *Payroll System (PS)*—This is the usual payroll system generating payslips and costing out labor usages to the INOs.

The linkages among these subsystems can perhaps be best defined by stating common files shared by the subsystems. These are shown in Figure 2.

Interfacing manual processes and management systems have revolved around these computer systems. It is worthwhile now to discuss at some length the dynamics of the interfacing processes since these comprise the entire Project Management Information System in the context of which the Materials Procurement System shall be described, and since the success of such an information system rests not only on a technically sound computer system but on the way these systems are managed, used, and controlled by a human organization.

Referring to Figure 3, the entire PMIS is defined to consist of 3 modules. These are:

1. *The Computer Facilities Management System*—Major components are the computer systems just previously described. The management system integrates all computer and related processes into a single system which will continually maintain and operate. MPS, WRS, CMS, CFS, and PS. The system contains computer operating capability to handle data processing and report generation. Supportive of this is a data entry system. Assistance by a computer company is provided for this module.

2. *The Project Operations Management System*—is directly linked with the computer systems via the information subsystem. Linkages are feed forward flows (data transmission) and feedback flows (report distribution). As users of reports generated by the first module, the functional units comprising this system manages both the information system and on the basis of these information, manage project operations.

3. *The Project Control System*—performs two primary functions: PERT network-based project planning and monitoring and operations coordination. This module can be regarded as a master system as it provides a clearing house (data administrator of sorts) for computer generated information and controls information/data flows through guidelines and manual systems and procedures pertaining to computer-related reports, input data forms, and file maintenance transactions.

The flows in the data/information channels among these systems components are further reflected in Figure 3.

The Materials Procurement System

With the not-too-brief description of the PMIS framework done, I will now discuss in some detail the operational and management concepts of MPS which is the main subject of this paper. I have left out computer systems design aspects since it is the intention of this paper to present the use of the system rather than details of the system's computer design and development.

The man-machine process is triggered off by a computer review of the most major of master files, the Accountable Activity File. This File contains data of the Bill of Materials of AAs and of AAs' start and end date schedules.

Upon inspection of this file, the system selects those AAs whose start dates are such that a review for purchase ought to be made so that materials arrive on time, on the basis of assumed lead times. The computer system generates this Purchase Review 15 days from the date a Pro-Forma Requisition is generated, indicating the time needed to check lead times, prices, sources and make any necessary corrections to the system's data files. Assumed lead times are the following:

R—15 days, to review schedules lead times, and prices of materials soon to be requisitioned.

F—7 days, to finalize a Pro-Forma Requisition into a Final Requisition.

Q—30 days, to finalize a Purchase Order from a Final Requisition.

Li—delivery lead time for material i, from date of PO to the time materials are received.

S—safety allowance of 30 days.

The reader is requested to refer to Figure 4, which depicts the information process between machine ("Computerized Procurement and Inventory Control") and men ("Project Management and Superintendent").

A description of this process follows.

The Man-Machine Interaction

1. Machine outputs the *Purchase Review* after examination of AAs. The Purchase Review lists the prices and lead times of materials to be included in the next Pro-Forma Requisition. For Procurement Management.
2. Using the Purchase Review form, man communicates to machine any revisions to material prices and lead times.
3. Machine then outputs the *Accountable Activities for Revision* which lists the AAs affected by changes in material ordering lead times and prices. For Project Control and Cost Engineering to show effects on overall project schedule and cash requirement.

4. Man inputs back *AAs for Revision*, confirming or correction information.
5. Due to revisions in lead times or AA schedules, machine tells Procurement through this exception report to order listed items now and implement special expediting procedures for these items.
6. Man re-enters this report to indicate it has taken appropriate action. In the absence of this signal, machine will continue to generate this report.
7. *Pro-Forma Requisitions* are then generated by machine listing materials which need to be requisitioned during this reporting period. For Engineering to review quantities required and specifications of any add-ons. For Project Control to add allowances for waste. For Procurement to decide on how much to order or to reserve from free stock.
8. Machine accepts back the Pro-Forma Requisition with additional data from Project Control, Engineering and Procurement.
9. *Final Requisitions* are then output summarizing requisitioned materials according to vendor, material code, and date required. For procurement's use in requesting for quotations.
10. Procurement shall indicate on the form *Data for Purchase Orders* (blank form is machine-generated) its decision on the grouping of requisitioned materials into Purchase Orders, the order quantity, and purchase prices of the materials as well as other PO data. Procurement can have the flexibility of also indicating in this form externally generated (not generated by machine) requisitions for purchase.
11. Machine generates the *Purchase Order.*
12. The exception report *Mismatch in Final Requisition vs. PO* points out to man the difference between quantities requisitioned and quantities ordered by Procurement.
13. Once resolved, Procurement inputs the aforementioned exception report telling machine that all is OK. Otherwise, machine nags.
14. The machine next issues out for Procurement's and Project Control's reference a report on Movements of Open Orders which catalogues all POs according to status and scheduled date of movements. Through this form, Procurement answers machine by indicating actual dates of movements of outstanding POs.
15. With the generation of the *Shipping Date* Reminder, the machine now advises Procurement to nag the suppliers in following up their commitments. This report lists POs with scheduled dates of shipment 14 days from report date.
16. For the second time, machine evaluates effect of changes in AA schedules revisions this time on open POs. The report *Expedite or Delay List* identifies for Procurement those POs which need to be expedited or delayed due to any revision in AA schedule or on account of changes in movement dates.
17. Man cancels the exception report (in which case problem has been resolved) or remains silent (in which case machine will continually spit out the reminder).

18. Machine prints out the *Receiving and Inspection Report* which lists for Procurement and OC/OA inspection materials expected to be received soon.
19. A similar report is the *Warehouse Receiving Report* this time to give notice to Warehouse on materials soon to be received.
20. Procurement and OC/OA Inspection records on the Receiving and Inspection Report the quantities of materials received, date when received, and condition as received. Man feeds this to machine.
21. Warehouse, upon turnover by Procurement, records on the Warehouse Receiving Report the quantities of materials received and the date when received. Report is returned to machine.
22. Upon evaluation of material receipts versus materials ordered, machine reports on *Unplanned Deliveries* advising Procurement and Project Control that the listed materials were delivered in quantities different from the quantities originally ordered.
23. Man responds by deciding on the disposition of the delivery shortage or excess. Once properly acted on, man tells machine to ignore differences or inputs delivery dates of balances in case of short delivery. Otherwise, machine will persist in reminding.
24. Machine indicates, through the report *Delivery on PO's 98% Complete,* PO's which are 98% or more served for the reporting period listing these POs as well as undelivered balances.
25. Man ticks off those POs considered served. The machine reads this and clears these POs from its data files (thereby decongesting data base).
26. As materials are issued, man documents using the *Warehouse Requisition and Issue Slip.* Machine updates materials inventory file on the basis of this.
27. Machines flags issues of reserved materials for AAs other than those for which materials have been reserved.
28. Project Control and Warehouse indicates whether this is authorized or not. In the absence of such indicator, machine will persistently generate the report *Improper Issues of Reserved Stocks.*
29. Machine is informed of AAs which have been substantially completed (say, 95%) and a list of residual work by AA.
30. The computer system then lists closed INOs and lists residual work by AAs.
31. Man then informs the computer system of 100% completed AAs.
32. *A Report Materials Ordered But Not Used* is generated by machine to tell Project Control and OC/OA of materials still in inventory but ordered for a now-completed AA. This is to advise them of a potential deviation from building plans.
33. Project Control either tells the machine "All is OK" or chooses to remain silent, in which case machine will continue to remind man to act on such an exception.

In addition to these printed reports, any of the project management users can inquire into the status of materials or POs by way of on-demand reports.

Such queries can either be answered by printed reports or through computer terminals. Two of such queries (materials by AA allocation and an inventory status request) are depicted in Figure 4.

The successful use of such a system shows that a computer-based system that assists in decision-analysis as well as in decision making need not be sophisticated. In fact it should appear as simple to the user as possible, user friendly as others are wont to say, so the user may "converse" with the computer system.

While the use of the system should be made simple, this simplicity masks a not-too-simple internal computer process of data handling and processing. The computer system has been implemented by maintaining seven masterfiles and many more transaction files. The system was initially run on an IBM 360/65 on a batch mode, then later converted for processing in an interactive HP-3000 minicomputer.

Figure 1
WORK BREAKDOWN STRUCTURE

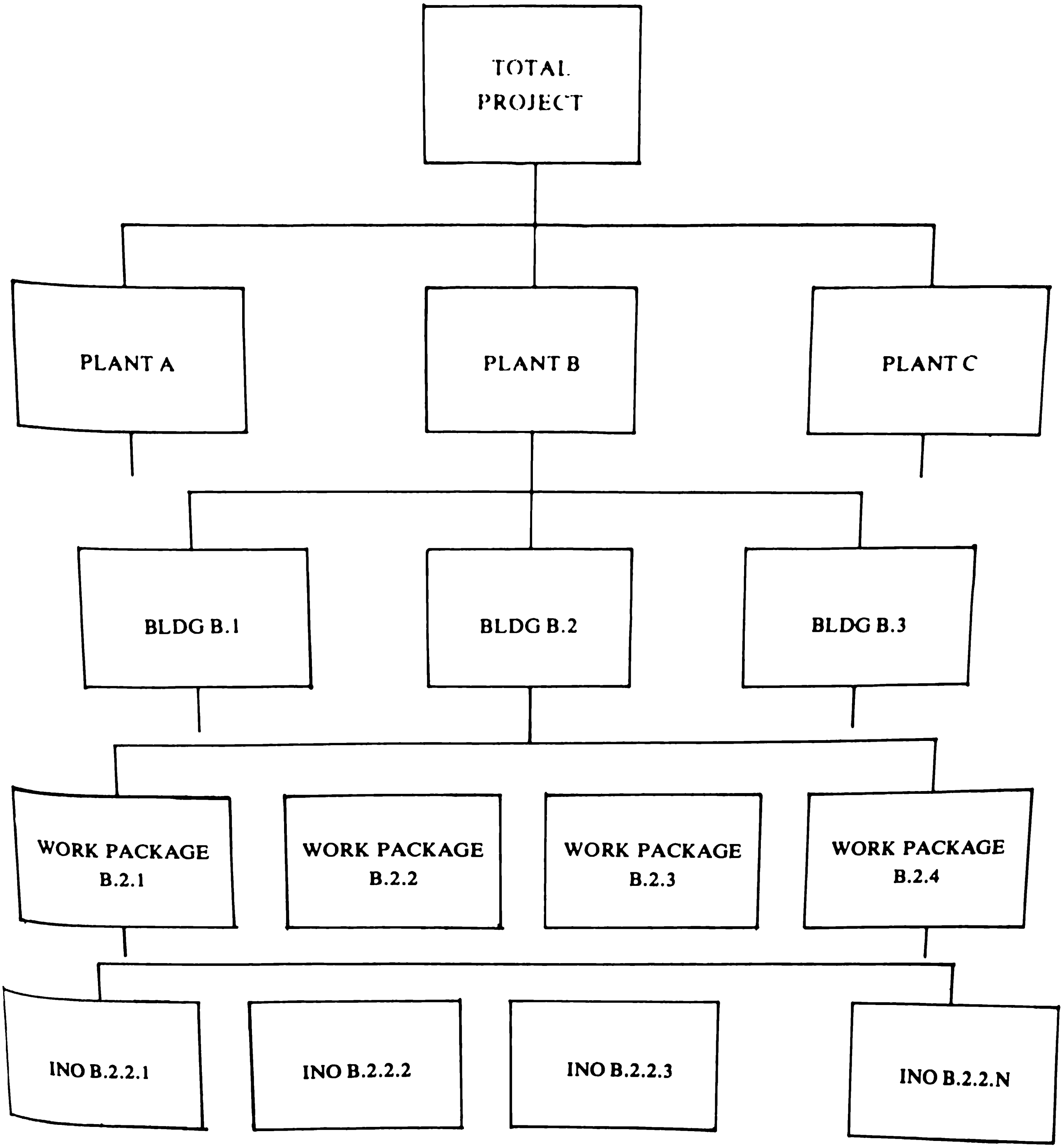

Figure 2

SYSTEM RELATIONSHIPS

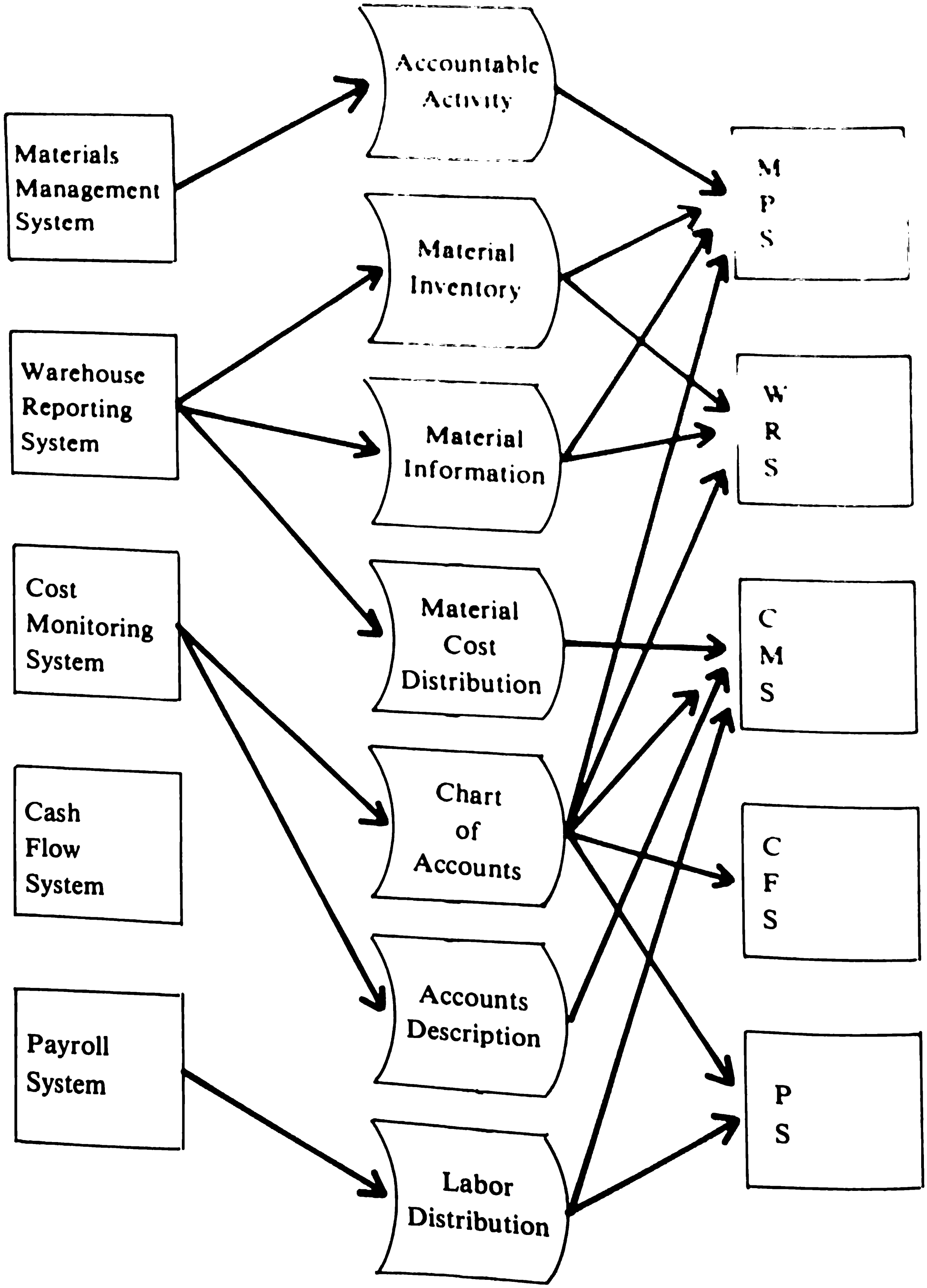

FIGURE 3

PROJECT MANAGEMENT SYSTEMS OVERVIEW

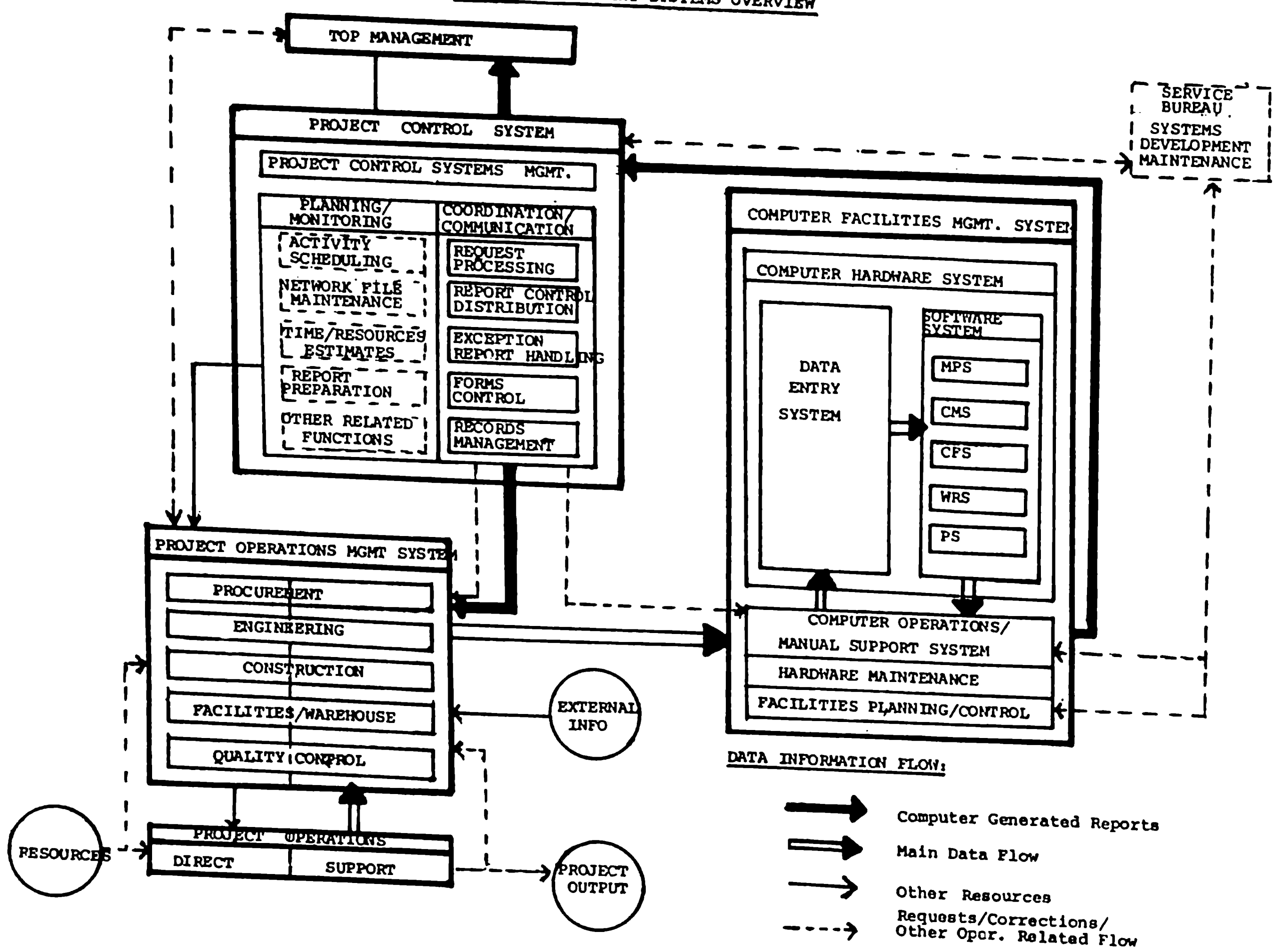

FIGURE - 4

DOCUMENT FLOW DIAGRAM - PROCUREMENT SYSTEM