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SIMULATION MODELING BY ENTERPRISE RESOURCES PLANNING IMPLEMENTATION IN MEDIUM SIZED CORPORATION

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ABSTRACT
Enterprise Resource Planning (ERP) is the systems for moving data from application to application without reentry by integration of applications as a methodology for the seamless integration of all the information flowing through the company. This study applied the ERP systems to construction materials management process and quantified the resulting benefits by the variation in productivity. This paper investigated the business processes involved in construction materials management by mapping out the whole process, and illustrated how ERP systems can increase the productivity based on simulation of two model in construction materials management systems, one non-integrated and the other ERP implemented system. The transformation from a non-automated system to an ERP implemented automated system were performed to illustrate individual task improvements through four steps in application, internal and external integration, and automation. An ERP system shortens procurement cycle through automating most of the repeated transactions and reducing manpower to perform the tasks by up to 80%.

KEYWORDS
Enterprise Resource Planning , Materials Management, Integration, Simulation

1. ENTERPRISE RESOURCES PLANNING

1.1 ERP Systems

ERP (Enterprise Resource Planning) is the systems for the seamless integration of all the information flowing through the company such as finances, accounting, human resources, supply chain, and customer information (Davenport, 1998). The goal of ERP is to support one time entry of information at the point where it is created and to make it available to all the systems that need it throughout the entire organization (Grad, 1999). Application integration is a methodology for moving data from application to application without reentry by integrating those applications. This one common database for the whole enterprise represents the concept of internal integration (Back and Bell, 1995). External integration is connecting the enterprise or organization computer network with computer networks of business partners, clients and suppliers, for information sharing and exchange. Accordingly ERP can

provide integrated working environment in its major business management functions. ERP also enables automation so that any benefits attributable to automation can be credited to ERP. Automation in materials management improves labor productivity (Bell and Stukhart, 1986) by providing good documentation.

1.2 History of ERP Systems

ERP has its origins in manufacturing and production planning systems (Fitzgerald, 1992). The early systems evolved from the 60's, when inventory control was the focus of manufacturing systems. In the 70's, the focus shifted to material requirement planning (MRP) systems (Grad, 1999), which was mainly for the storage and allocation of production materials by comparing inventory to production quantity requirements. The concept of the manufacturing resources planning (MRP II) was developed in 80's as an extension of MRP to include management of materials in production plants, personnel planning and product distribution planning. So while MRP dealt with only forecasting the materials requirement by keeping a check on inventory, MRP II kept track of goods movement to and from production floor, assigned responsibilities to personnel and planned product distribution. MRP II attempted to incorporate accounting, sales, engineering and many other functional areas into its planning strategy. MRP II also used Mainframes, but in conjunction with LAN (Local Area Networks) to input and access information. By utilizing powerful desktop computers and LANs, along with client server applications, data became decentralized. This in turn allowed departmental computing environments to emerge with local control. The benefits of local computing were many: dedicated resources meant much better response times, and departments were able to develop applications that best met their needs (Koss et al, 1998). As the MRP II gave rise to disintegrated applications residing in different departments, the sharing information and resources was needed. To harmonize the functioning of the entire company in the early 90's, MRP II was further extended to cover engineering, finance, human resources, and project management to develop Enterprise Resources Planning (ERP) systems. ERP encompasses the full range of enterprise wide activities involving all resources within the business using WANs (Wide Area Networks), which allow coordination of company activities globally.

1.3 ERP Implementation

The market is showing steady growing and could reach $52 billion by 2002 (ML Payton, 2000). Reasons behind companies implementing ERP are tremendous benefits derived from enterprise integration of processes and applications. A number of benefits can be reaped after ERP implementation (Fryer, 1999), which is following as:

- The information visibility: Any data created at the field level can immediately become available at the form desired by any level of management.
- The business integration: Enterprise wide view of financial data is available for analysis from top-level management at any time.
- Integration of applications residing in different departments
- Other than those, also standardizing processes, flexibility of the ERP system to accommodate change and globalization are some other intangible benefits that are difficult to calculate to determine the return on investment (ROI) from ERP implementation.

On the other hand, ERP implementation can have also following disadvantages:

- Very costly: The cost of implementation can be from few hundred thousand dollars for small companies (Liber and Jaynes, 1995) to a billion dollar for large multinational companies (White et al, 1997). Costs are involved with training users—the expenses are high because workers almost invariably have to learn a new set of processes, not just a new software interface. Cost of consultant has the largest share of total implementation cost (Garner, 1995).
- Delay in return on investment (ROI): Benefits of ERP may not be revealed until after companies have had them running for some time. The 90 percent of ERP implementation efforts are either cost overrun or time overrun, and 35 percent of the implementation is cancelled before being completed (Calogero, 2000).

1.4 ERP Implementation in Construction Industry

ERP systems are being used for construction companies to improve responsiveness in relation to customers, strengthen supply chain partnerships, enhance organizational flexibility, improve decision-making capabilities, reduce project completion time and lower costs (ML Payton, 2000). However, the construction industry has some

uniqueness, which should be taken into consideration by the ERP vendor, since the construction industry is highly fragmented one with specialized segments requiring specialized systems and driven by project (ML Payton, 2000).

2. MATERIAL MANAGEMENT IN CONSTRUCTION

Materials management is the process for planning and controlling of all necessary efforts to ensure that the correct quality and quantity of materials and installed equipments are appropriately specified in a timely manner, are obtained in a reasonable cost, and are available when needed (Business Roundtable, 1982). The material management process combines and integrates the individual functions of materials requirement planning, material takeoff, vendor evaluation and selection, purchasing, expediting, shipping, material receiving, and inventory, and material distribution (Bell and Stukhart, 1987). Other than these, accounting function is also an integral part of a comprehensive materials management system as it relates to transaction document processing (Back and Bell, 1995). The flow charts of materials management system involve as many as 50 steps (Formoso and Revelo, 1999). Those engaged in this complex process has to be coordinated and communicated effectively, accurately and timely both internally and externally within and over organizational boundaries. This dependence on timely information and need to effectively communicate at many organizational levels makes materials management system suitable to be benefited from information technology implementation (Back and Bell, 1995). Engineered materials are materials uniquely assigned a number that those can be identified throughout the life of the project, bulk materials are those manufactured to industry standards and purchased in quantity, and fabricated materials are typically engineered or fabricated per specification (Back and Bell, 1995).

3. INFORMATION TECHNOLOGY IN MATERIAL MANAGEMENT

Material management is a clearly defined task that, when properly planned and executed, provides project management with an invaluable tool to optimize schedules and improve labor productivity (Bell and Stukhart 1987). By the estimation by Business Roundtable Construction Industry Cost Effectiveness (CICE) report, substantial savings have accrued to both the owner and the contractor, which is 6% savings on project craft labor costs (Business Roundtable, 1982).

3.1 Material Management System

Many construction firms have invested in computer based materials management system (MMS), which stores, sort, combine and print data files pertaining to materials requisition, purchasing, vendor evaluation, and warehouse inventories (Bell, 1986). Properly designed MMS can save cost and reduce the cycle schedule significantly in maximizing labor productivity, reducing material surplus, improving vendor relations, optimizing cash flow, and reducing required warehouse space (Bell and Stukhart, 1987). These MMS development efforts have been focused in integrating the materials related functions of quantity takeoff, requisition, purchasing, expediting, transportation, field material control and warehousing. An effective MMS should be linked to design and scheduling systems, since the integration with design ensures that updates of design data are rapidly reflected in the takeoff file to eliminate problems related material availability and surplus. Integration with scheduling systems provide critical automation interface (Elzarka and Bell, 1995). Integrating MMS and scheduling also provides procurement schedule driven by construction. A construction driven procurement schedule effectively prioritizes the procurement activities, reduces project durations, and causes fewer delays in the field (O'Conner et al, 1987).

3.2 Integrated Information Technology

The efforts have been made to integrate MMS with external computer systems to perform functions related to design, project scheduling and cost accounting (Elzarka and Bell, 1995). Prior study by Back (1994) concluded that dramatic improvements in cost and document processing cycle time were made possible through the use of information technology systems. Implemented information technology systems are an integrated database management system (DBMS) and externally integrated electronic data interchange management (EDI). The integrated database management system (DBMS) is an information technology that permits users to organize, store, and manage all electronic data relating to a major activity or area of interest, while allowing users to enter and store data for once and utilized by multiple users and applications (Back and Bell, 1995) and EDI is a direct computer application exchange of business data in standard format, thus eliminating the need for the reentering the

information ("X12/DISA," 1993). These information technology systems implemented in the materials management results in significant benefits quantified by simulation (Back, 1994). Current materials management systems can be enhanced by creating interface links to design and scheduling systems and by adding knowledge based modules that can further automate the material management process (Elzarka and Bell, 1995). In this paper, more advanced information technology management system, ERP (Enterprise Resource Planning) system is introduced and demonstrates quantifying benefit by ERP implementation in materials management.

4. METHODOLOGY

Any process can be defined by a sequence of interrelated tasks with durations and resources, which is required to complete the tasks. A task is defined as a basic element that requires time to perform and materials management process is composed of a set of interrelated tasks and can be modeled as a sequence of such tasks (Halpin and Riggs, 1992). Back (1994) analyzed the implementations of information technology and quantified the benefits of implementation by EDI and DBMS with respect to its affect on task durations and costs based on MicroCYCLONE simulation. This paper analyzes the benefits of ERP implementation in construction material management using quantifying methods applied in prior study by Back (1994). In this paper, a baseline model representing the general system without any integrated technology is compared with ERP implemented model based on MicroCYCLONE simulations, which intends to identify any time improvements between non-integrated system and ERP integrated system in materials management. And the effect of ERP implementation on task durations is analyzed, and then the overall time for a procurement cycle completed is determined.

5. MATERIAL MANAGEMENT MODEL SIMULATION

The baseline four models representing the general system, material requirement planning, purchasing, receiving and accounting are based on the model identified in prior study (Back and Bell, 1995) and it was modified based on feedback from the project manager level in medium sized construction corporate in Indianapolis, Indiana, U.S.A. As a base line system, a list of the 54 tasks used in the simulation model is shown in Table 1.

5.1 Non-Integrated Simulation Model of Material Management

Each cycle of the model represents one complete transaction from distribution of material requisition to making final payment to the vendor as shown in Figures 1 and 2.

- The process was modeled assuming that the summary of material requirement report (MRR) had already been prepared from engineering documents and specification and from the schedule in the planning stage. In the non-integrated model, all tasks were not performed during every pass through the material management process.
- As with any business process, the material management process also has multiple paths of progression, so that "Probability arcs" are associated for such probable occurrence. The transaction documents used to support the transmission of information and data were identified and tracked as flow units in the simulation model.
- As the distribution of material requisition is dependent upon construction schedule, the subsequent start of a transaction does not depend on a deterministic interval, rather it depends on when the material will be required. In order to model this situation, a triangular distribution was assumed.

Material Requisition

In one summary material requirement report, there are many materials for which separate transactions require to be performed. This situation is modeled assuming that one report will generate 15 material requisition, so 15 resources were initialized in QUE 15, "MRR Summary Ready." Tasks from node 16, "Distribute Requisition for Approval" to node 37, "RFQ Ready Issue/Transmit" involve the organization's own resources. Task at node 38, "Vendor RFQ Received/Quote Prepare" is a vendor performed work task, on which the organization has little control. Based on different vendors, as the task duration can vary, a triangular distribution was assumed. With improved communication with the vendors, this task duration can be improved.

Purchasing Process

After the bid is received from the vendors and tabulated at node 40, all work tasks till node 57, "Purchase Order Issued" are performed using organization's own resources. The time after issuance of Purchase Order is expended by the vendors in preparing and shipping the material. This portion of vendor time is not simulated within the model as this time depends on material type and complexity and schedule of the order.

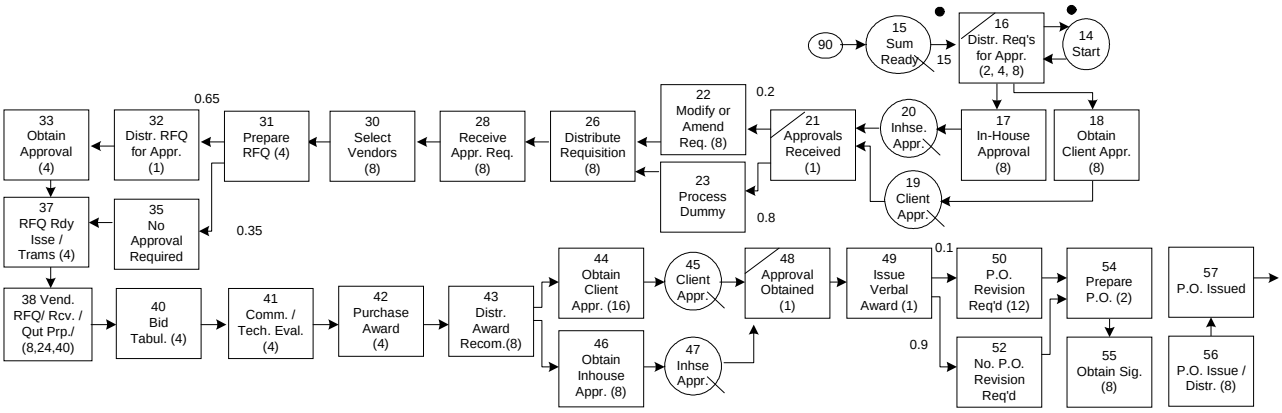

Figure 1: Material Requisition and Purchasing Process

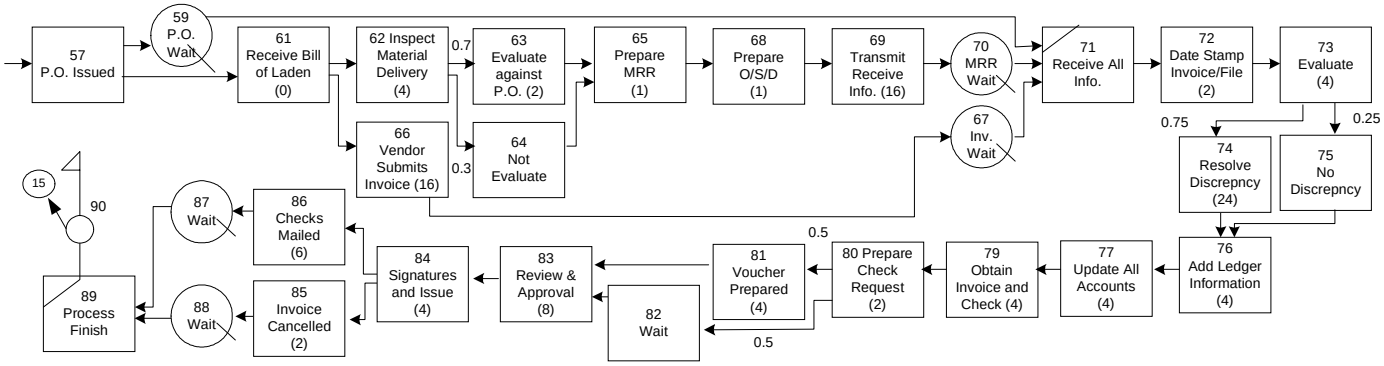

Figure 2: Material Receiving and Accounting Process

Material Receiving

After node 57, the model directly goes to node 61, where the material is received in the field. Material receiving tasks from node 61, "Receive Bill of Laden" to node 69, "Transmit Receive Info" are all performed in the field. At node 71, "Receive All Info," three documents are received a Purchase Order generated at node 57, an invoice send by the vendor of that Purchase Order and the material receiving report from the field.

Accounting Process

These three documents are evaluated at node 73, in order to check for any discrepancies. If the promised material quality and quantity do not match in any of those documents, the discrepancy is recorded. Accounting functions related to a particular material purchase begins from node 76, "Add Ledger Information." At the end of accounting transactions payment is made according to material received. One complete transaction cycle ends at node 90.

5.2 ERP Implemented Simulation Model

This non-integrated simulation model of material management is modified to ERP implemented model based on four distinct steps, which are application integration, internal integration, external integration, and automation. The combination of these four steps represents the ERP implemented model.

Application Integraiton

The first step is the application integration, which enables the data to be communicated among different applications automatically. In case there is integration of accounting and purchasing application, the accounting application updates accounts automatically, when the procurement application completes a purchasing transaction. So the tasks at node 76, "Add Ledger Information," node 77, "Update All Accounts," and node 68, "Checks Mailed (Payment Made)" are all automated and thus the durations are reduced.

Internal Integration

The second improvement to the non-integrated model are applied by internal integration implementing an integrated database management system (DBMS), where the data is stored centrally in an integrated database to allow users to enter and store data for once and utilized by multiple users and applications (Back and Bell, 1995). Any information produced once is stored in the system to be accessed by anyone in the organization who needs it. Before node 16, when the "Summary of Material Requirements" is prepared, it is stored in the system. So the duration of the task at node 16, "Distribute Requisition for Approval" is reduced. For "In house approval" at node 17, the distribution time does not count, because the information for approval is already available in the system. All tasks related to distribution of documents within the organization are benefited from the internal integration. Thus, all task durations such as, "Distribute Requisition" at node 29, "Receive Approved Requisition" at node 32, "Distribute Request for Quotation" (32), "Distribution of Award Recommended" at node 43, "Approval Obtained" at node 46, "Issuing Purchase Order" at node 57, "Transmit/Receive Material Receiving Report" at node 69 become zero, because the documents distributed or transmitted by these tasks are immediately available, when they are created.

External Integration

The third modification is enabled by external integration connecting the internal organizational network systems of business partners by external network. As a result, the task durations related to transfer or distribution of documents like quotations, purchase orders, invoice, shipping notifications etc. between the organization and its business partners become zero. Tasks improved by external integration are obtaining client approval (18), selecting vendor (30), vendor RFQ Received/Quote prepare and Submit (32), client approval for award recommended (44), issuance of purchase order to vendors (57), inspect material delivery (62), resolve discrepancies in invoice, material requirement report and/or purchase order (74) and payment by electronic fund transfer (85). The task durations are reduced dramatically because the transmission of documents or information is instantaneous.

Automation

The forth transformation is made by task duration caused by automation. Many tasks are automated by the applications themselves. Thus, task like "Selecting Vendors" based on past performance at node 30, "Preparation of Request for Quotation" at node 31, "Bid Tabulation" at node 40, "Technical and Commercial Bid Evaluations" at node 41, "Evaluation of Material" received in the field with purchase order at node 63, "Evaluation of PO," "Invoice and Material Receiving Report" at node 73, "Add Ledger Information" at node 76, "Updating All Accounts" at node 77, and making payment by electronic fund transfer with update of accounts are processed by applications.

When creating the model for material management supported by ERP, most of the tasks identified fully automated were assumed to have zero duration. In the final ERP based model, the probabilities were also changed due to reductions in the need for rework, which are 0.1 at Node 22, 0.9 at Node 23, 0.2 at Node 74, and 0.8 at Node 75. There were also some changes in the process like making electronic fund transfer (EFT) while making payments to the vendor. The EFT was enabled by external integration with the vendor either by EDI or the web. After all four transformations, the resulting model can be called an ERP implemented model.

Table 1: Duration of Work Tasks

Tasks	Durations	
	Non-Integrated	ERP Integrated
Material Requirement Planning		
Distribute purchase requisition for approval	2, 4, 8	1, 2, 4
Obtain in-house approval of requisition	8	4
Obtain client approval of requisition	8	4
Approval received	1	0
Modify or amend requisition	8	8
Distribute approved requisition	8	0
Purchasing		
Receive approved requisition from MRP	8	0
Select/prepare listing of prequalified vendors	8	1
Prepare request for quotation (RFQ)	4	0
Distribute RFQ for approval	1	0
Obtain approvals for RFQ	4	2
Issue/transmit RFQ to prequalified vendors	4	0
Vendor receive RFQ / translate material requirements /establish pricing, terms, exceptions / prepare response to RFQ /transmit response to RFQ	40	8, 24, 40
Bid tabulation is prepared	4	1
Commercial/technical evaluation	4	0
Purchasing prepares award recommendation	4	1
Purchasing distribute tabulation/recommend	8	0
Obtain in-house purchasing approval	8	4
Obtain client purchasing approval	16	8
Approval obtained	1	0
Issue verbal award of purchase order	1	0
Revise purchase specification Obtain approval of revised specifications	12	2
Purchasing prepares purchase order	2	0
Obtain approvals signatures for purchasing order	8	0
Issue formal purchase order document Distribute copies of issued purchase order	8	0
Field Material Control		
Receive bills of landing or packing slip	0	0
Inspect material delivery or shipment	4	4
Evaluate against purchase order information	2	0
Prepare material receiving report (MRR)	1	1
Prepare overage/shortage/damage report Transmit reports to all departments	1	0
Account Payable		
Receive all purchase order and MRR info	0	0
Vendor prepares and submits invoice	16	0
Date stamps invoice and files all documents	2	0
Evaluate invoice against P0 and MRR	4	0
Resolve information discrepancies	24	1
Add general ledger and cost code info	4	0
Update all accounts payable registers	4	0
Obtain invoice (payment) approval	4	0
Prepare check request	2	Eliminated
Voucher preparation	4	Eliminated
Obtain signatures for check	4	Eliminated
Checks mailed or transmitted	6	0
Invoice canceled and all registers updated	2	0
Process finish	0	0

5.3 Simulation Findings

Each cycle in both of non-integrated and ERP implemented models represents one complete transaction for a material with a particular material code. The simulation model representing non-integrated materials management system takes 878 hours to complete 50 cycles, complete transactions. The productivity at the end of 50 transactions is 25.63 transactions per day. The ERP supported simulation model takes 178 hours to complete 50 cycles, transactions. The productivity at the end of 50 transactions is 126.5 transactions per day. So a decrease of 79.73% in total time to complete 50 transactions is achieved by implementing ERP in materials management. At the same time a productivity of 126.5 transactions, which is 100 transactions more per day, can be achieved by implementing ERP.

6. CONCLUSION

This paper discussed the ERP systems and its implementation in material management in construction industry. The cost of developing and implementing these systems can be substantial, but the benefits outweigh the costs, particularly when the system is used by the crafts for scheduling their work around bulk material availability (Bell and Stukhart, 1987). An ERP system shortens procurement cycle through automating most of the repeated transactions, and by reducing manpower to perform the tasks. According to the research conducted in this paper, ERP system shortens procurement cycle by 80%. Implementing ERP in the materials management area has measurable benefits in all other areas, which interface with the materials management module.

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