# Reengineering of Construction Management Process

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**Abstract:** Applying the business process engineering philosophy, this study focuses on developing a construction management process reengineering (CMPR) method to improve the efficiency of construction management. The CMPR method includes four phases, namely, process representation, process transformation, process evaluation, and reengineering activity. Using CMPR, inefficient operations within a construction company working process can not only be identified, but a new rational operation process can also be developed to improve management efficiency. In this way, the competitive ability of a construction company is also increased. This study argues for the need of a new research agenda in construction management in general. This is illustrated by information technology within construction—in particular, by examining the potential application of the reengineering philosophy. The research possibilities are identified and tested based on the implementation of the CMPR method. To some extent, this study establishes a new agenda of process reengineering for future research.

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## Introduction

The phrase ''business process reengineering'' (BPR) first appeared in 1990, raised by Michael Hammer in his paper published in the *Harvard Business Review* called ''Reengineering work: Don't automate, obliterate'' (Hammer 1990). Hammer believes that in the fiercely competitive environment of the 1990s, most businesses adopt measures such as rationalization and automation to improve their organizations. However, neither of these measures was able to truly improve business operations. Many businesses spend millions of dollars to improve or implement new information technology. However, this effort serves only to strengthen the existing false working processes, thus causing the cost of organization to increase, while the improved performance is negligible. To solve these problems, the idea of ''reengineering'' should be advanced as a theory and tool toward business reorganization. In Hammer's article (Hammer and Champy 1993), the key issues of BPR include organizational redesign, process reorganization, and the use of information technology. The fundamental definition of BPR as defined by Hammer is that starting from the very basic issues, reformation of the reengineering process will dramatically improve an organization in terms of its cost, quality, service, and speed. Therefore, improvement and reengineering of the process is a fundamental tenet of BPR.

The construction management process is a necessary procedure in construction companies' execution of their business. An inefficient management process will have a profound impact on a company's management performance. However, most business owners are not able to properly determine a correct process. They fail to establish the system effectively or even to understand whether the system itself is reasonable and effective. These problems result in a redundancy of business operations and are a waste of valuable human and time resources. This can render management ineffective to the degree that those individuals may not know how to improve their predicament.

Computerization is receiving increased awareness in the construction industry and has become the focus of development for many construction companies. However, many business owners fail to properly examine existing management procedures and seek to improve them before implementing computerization. As a result, the structure of computerization is built upon a foundation of a false working procedure. The result is a failure of the management procedure, which precipitates the malfunction of computerization. As is apparent in the above, the prudence and efficiency of a management process have a direct influence on the success of computerization. Thus, if management is better able to evaluate the existing management process and address deficiencies before the implementation of automation or the establishment of a standard operation process, the likelihood of computerization's success will be greatly increased.

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This paper redefines the definition and description each scholar has provided of process reengineering by the following criteria (Davenport and Short 1990; Furey 1993; Harrison and Pratt 1993): ''use of customer satisfaction as the primary target and examination of the information technology and operational process within and between organizations; and use of process analysis as a means to understand process performance and redesign the process in order to reach the target of simplification, cost reduction, and improvement of the service quality.'' To effectively raise management performance in construction companies, it is necessary to begin by researching related processes. Construction companies can start by considering the method of reengineering to improve the quality of management—and thereby their competitiveness. The primary purpose of this study is to use the idea of BPR to develop a construction management process reengineering (CMPR) model. Using CMPR, the major procedural categories of construction company management are systematically identified and defined. Further aims include the formulation of a method for evaluating the construction management process, and establishment of indices for procedural performance to assist managers in realizing the hidden problems of the process and to use the findings as the basis for comparative analysis before and after reengineering. Finally, by the analysis of the current management problems of construction companies and establishment of the delivery of the management information technology system, one can draft and evaluate a reasonable and effective management plan. This study can serve as a basis from which to execute operation procedures, implement computerization, and plan methods of the management procedure.

## Construction Management Process Reengineering

This study pioneers the idea of BPR in the construction industry for management process reengineering by developing a CMPR execution model (Sager 1994). This model includes the following four major steps: (1) process representation; (2) process transformation; (3) process evaluation; and (4) process redesign.

### *Process Representation*

In process reengineering, one of the most difficult and important tasks is to identify and establish a company's process. The current system adopts the method of departmental function that divides up originally related activities. Some construction company managers are employed to manage the company based on their experience and habits. Under these circumstances, it is often difficult, if not impossible, for them to accurately describe the categorized operational process. Therefore, the primary purpose of process representation is to develop a systematic definition for process to assist companies in clarifying and establishing their management process. Two major steps are included in this model.

#### Clarification of Process

From the viewpoint of process, a company's complicated business can be regarded as a systematic composition of business activity functions and a flow of data (Martin 1989). The business functions, as shown in Table 1, serve the purpose of defining the company's range of operation. Closely related company functions and operations can produce highly relevant data, which are a valuable reference when executing other activity functions. Therefore, by conducting an analysis of business functions and their relationship to associated data, this study profiles the function of related activities to further represent and clarify the range of the primary process. Based on these analysis results, managers can better understand the contents of their operations. This study uses the ''data entity/operation function matrix'' method to analyze the relationship between business functions and data subjects to clarify and name a company's procedural categories.

***Development of Data Entity/Operation Function Matrix.*** The business functions are defined based on the organizational structure diagram and the departmental function data. The worksheets and documents regarding interdepartmental activities are collected and categorized according to subject in order to determine the company's data subject. Using construction company A as an example, this study, by analysis of departmental responsibility and function, summarizes the company's business function in seven main categories, listed based on the operational sequence in the first column of Table 1. The functions of each category are also identified and listed in the second column. In addition, the data subjects derived from the formats and types of departmental charts, worksheets, and reports are grouped and listed at the top of the table. The corresponding relations between functions and data are then filled in to complete the matrix. In the table, ''create'' (C) means produce data, ''read'' (R) means read data, ''update'' (U) means renew data, and ''delete'' (D) means delete data.

***Rearrangement of Matrix.*** Because read, update, and delete all use an existing data subject as the target of execution, for existing data, the above actions can also be treated as read. Before rearranging the matrix, then, replace the R, U, and D characters with R. Rearrange the functions column according to the operation sequence of the company and adjust the order of data subjects to allow the C to be represented from the top left to the bottom right.

***Definition of Name of Process.*** According to the matrix after rearrangement, the data subjects are grouped in several nonoverlapping divisional frames. These frames are the clarification of the processes. Then, based on the functional category and characteristics grouped in each divisional frame, the process can be named and the company's operational process category is determined. The eight core management processes of company A are identified and shown in Fig. 1. By the establishment of the matrix, the company can not only set the range of main business function processes, but it can also examine the data delivery process by the relationship between function and data. Using the financial accounting management process and the operation management process as examples, the budget planning function has to refer to read the financial income, financial expenses, and sales data in order to create information regarding the financial budget. Sales data actually belong to a set of data created by the operation management process. The relationship between these two processes is apparent. Likewise, the main data delivery process is established using the same method.

#### Process Selection for Reengineering

To avoid scattering resources and blurring the focus of reengineering, the number of reformation processes should be limited to 10 or less. Before general reengineering is possible, it is necessary to initiate the core reengineering process. The purpose of this step is to identify the prioritized order of process reformations from the processes that have already been established. To choose the appropriate reformation, process evaluation factors must be carefully selected. In addition to choosing factors according to a company's strategic target and the particular emphasis of its man-



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**Table 1.** Data Entity/Operation Function Matrix (Prior to Arrangement)

| | | Data Subjects | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Categories | Functions | Compliance | Bidding | Sales | Construction plan | Contract | Quality | Material | Contractor | Customers | Change order | Construction management | Equipment | Building | Personnel | Financial expense | Financial income | Investment | Organization | Financial budget |
| Business management | Construction marketing | — | — | CRUD | — | — | — | — | — | R | — | — | — | — | — | — | — | — | — | — |
| | Sales forecast | — | R | CRUD | — | R | — | — | — | — | — | — | — | — | — | R | R | CR | — | — |
| | Compliance | CRUD | — | R | — | — | R | R | — | — | R | R | R | — | R | R | R | R | — | — |
| Material management | MRP | — | — | — | RU | — | RU | CRUD | R | — | RU | R | — | — | — | R | R | — | — | — |
| | Purchase | — | — | — | RU | R | R | CRUD | R | — | — | R | CRUD | — | — | CRUD | — | — | — | — |
| | Expediting | — | — | — | RU | — | R | CRUD | R | — | — | R | CRUD | — | — | — | — | — | — | — |
| | Inventory control | — | — | — | RU | — | — | CRUD | — | — | R | R | — | — | — | — | — | — | — | — |
| | Quality control | — | — | — | RU | R | CRUD | RU | R | — | — | CRUD | — | — | — | — | — | — | — | — |
| Construction planning | Cost estimates | — | — | — | CRUD | R | R | R | R | — | CRUD | RU | R | — | R | — | — | — | — | — |
| | Construction scheduling | — | — | — | CRUD | R | — | R | R | — | CRUD | RU | R | — | R | — | — | — | — | — |
| | Construction plan | — | — | — | CRUD | R | R | R | R | — | CRUD | RU | R | — | R | — | — | — | — | — |
| | Productivity management | — | — | — | RU | — | — | — | CRUD | — | — | R | RU | — | CRUD | — | — | — | — | — |
| Construction | Material control | — | — | — | RU | — | — | CRUD | — | — | — | RU | — | — | — | — | — | — | — | — |
| | Progress control | — | — | — | RU | — | RU | RU | RU | R | RU | CRUD | R | — | — | — | — | — | — | — |
| | Safety control | — | — | — | RU | — | — | — | RU | — | RU | CRUD | RU | — | RU | — | — | — | — | — |
| Sales expansion | Bidding/contract | — | CRUD | RU | — | CRUD | — | — | — | CRUD | — | — | — | — | — | — | — | — | — | — |
| | Postsale service | — | — | — | — | R | R | — | RU | CRUD | — | — | — | CRUD | — | — | — | — | — | — |
| | House delivery | — | — | RU | — | R | R | — | — | — | R | — | — | CRUD | — | — | — | — | — | — |
| Financial accounting | Financing plan | — | — | — | — | — | — | — | — | — | — | — | — | — | — | R | R | CRUD | — | R |
| | Loan management | — | — | — | — | — | — | — | — | — | — | — | — | — | — | CRUD | CRUD | CRUD | — | R |
| | Cash flow | — | — | R | — | — | — | — | — | — | — | — | — | — | — | R | R | — | — | CRUD |
| | Payroll management | — | — | — | — | — | — | — | — | — | — | — | — | — | CRUD | CRUD | — | — | R | — |
| | Cost accounting | — | — | R | — | — | — | R | — | — | R | — | R | — | R | CRUD | CRUD | — | — | RU |
| | Budget plan | — | — | R | — | — | — | — | — | — | R | R | — | — | — | R | R | — | — | CRUD |
| | Profit analysis | — | — | CRUD | — | — | — | R | — | — | — | — | R | — | R | R | R | — | — | — |
| Human | Human resources | — | — | — | — | — | — | — | — | — | — | — | — | — | CRUD | — | — | — | CRUD | — |
| | Recruiting | — | — | R | — | — | — | — | — | — | — | — | — | — | CRUD | — | — | — | — | — |
| | Training | — | — | R | — | — | — | — | — | — | — | — | — | — | CRUD | — | — | — | — | — |





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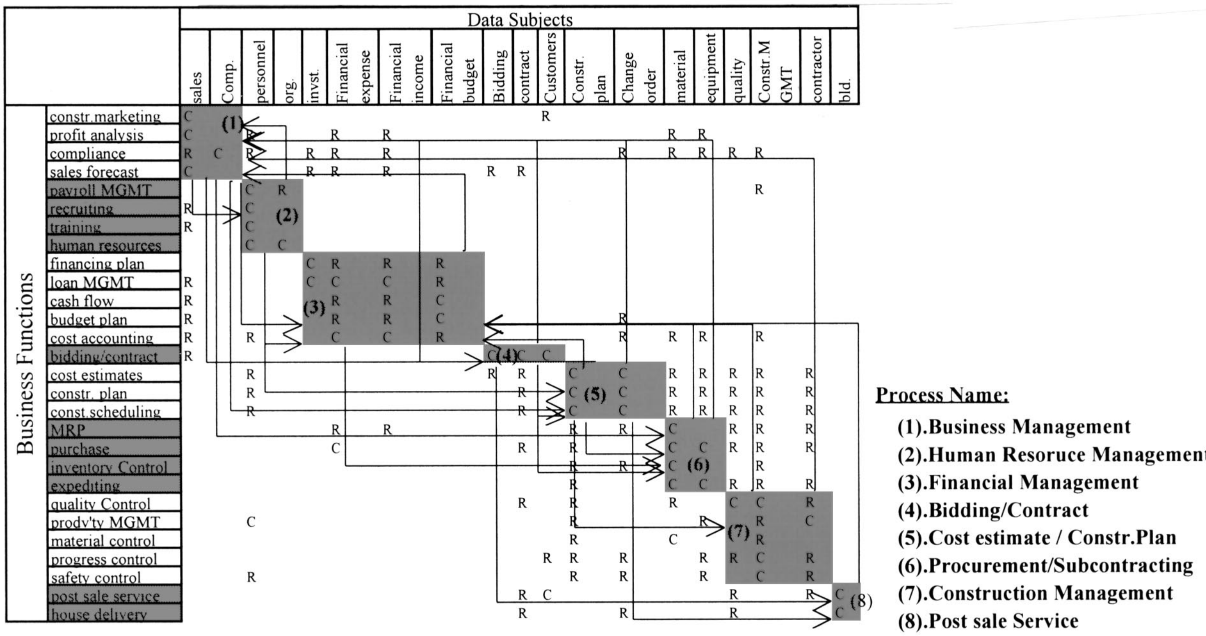


**Fig. 1.** Company A data entity/operation function matrix (postprocess clarification)

agement, this study applies the suggestions raised by Hammer and other scholars (Freiser 1992; Farrell 1994; Hammer and Stanton 1995), while employing urgency, feasibility, importance, timeliness, efficiency, and cost as the six main criteria for process evaluation (Table 2). The relative weight of each of the six criteria is identified using the analytical hierarchy process method. Taking construction company A as an example (a company that has not been previously introduced to the idea of process reengineering), feasibility and cost should be weighted heavily. A numeric model-scoring method (employing a scale of 1–5) is then used to evaluate the score of each criterion, and thereby calculate the weighted score for each process. The priority of the reengineering processes is then identified according to these scores [Eq. (1)]

$$\text{NMS}_k=\sum_{j=1}^{6} AW_i^{*}P_{ki} \quad \text{NMS}_k\text{: process score} \tag{1}$$

where $k$=number of process; $i$=number of criterion; $AW_i$=weight of criterion $i$; and $P_{ki}$=process $k$ score for $i$ criterion.

### Process Transformation

The transformation process is mainly the application of the conducted operational analysis and IDEF0 process modeling. This section presents a sample operational analysis and an IDEF0 diagram describing the procurement/subcontracting process of company A. The primary purpose of the operational analysis is to define the operational category and hierarchical structure of the process. Fig. 2 is the node tree for the example model. The node tree is a graphical overview describing all of the functions that comprise the entire model. The tree is useful in showing the hierarchical relationships that exist between various components of the model.

A process is composed of a series of orderly activities. Hence, before drawing the IDEF0 process diagram, due attention should be paid to the use of the IDEF0 language to explain completely the relationship between operations. The operational relationships used in developing the IDEF0 diagram include the following: (1) input connection (IC); (2) control connection (CC); (3) output mechanism (OM); (4) control feedback (CF); (5) input feedback

**Table 2.** Evaluation Scores of Core Processes for Construction Company A

| | | Processes Name ($P_{ki}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Criteria | Weight ($AW_i$) | Business management | Human resource management | Financial management | Construction bidding /contracts | Cost estimates/ construction planning | Purchase/sub contracting | Construction management | Postsales service |
| Urgency | 0.05 | 2 | 1 | 3 | 3 | 3 | 4 | 4 | 2 |
| Feasibility | 0.36 | 3 | 2 | 3 | 4 | 3 | 4 | 3 | 4 |
| Importance | 0.04 | 1 | 1 | 2 | 5 | 4 | 4 | 4 | 3 |
| Timeliness | 0.09 | 3 | 3 | 3 | 4 | 4 | 3 | 2 | 3 |
| Efficiency | 0.15 | 4 | 2 | 4 | 3 | 4 | 4 | 5 | 3 |
| Cost | 0.31 | 3 | 3 | 3 | 4 | 4 | 3 | 4 | 3 |
| $NMS_k$ | — | 3.02 | 2.31 | 3.12 | 3.83 | 3.59 | 3.6 | 3.62 | 3.3 |
| Order | — | 7 | 8 | 6 | 1 | 4 | 3 | 2 | 5 |



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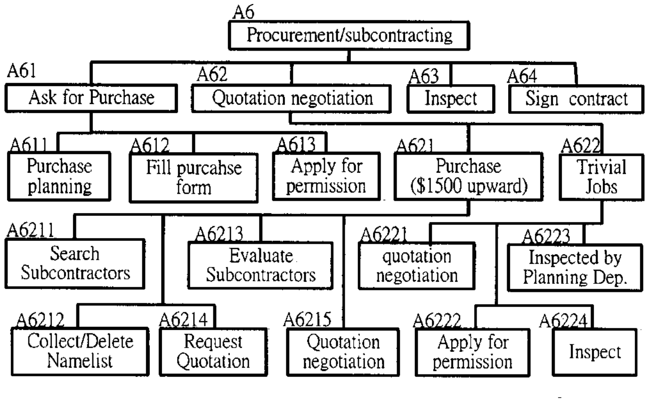


**Fig. 2.** WBS of procurement/subcontracting process for company A

(IF); (6) loop (L); (7) parallel (P); (8) conflict (C); and (9) no relationship (X) (Construction Industry Institute 1993). The reasons for classification for the operational relationship are represented in eight items—namely, use common input data (code 1), need some output to proceed to the next step (code 2), need common equipment (code 3), need common staff (code 4), use common space (code 5), need information feedback (code 6), data effects of the process on the next activity (code 7), and need the decision from the prior step to proceed (code 8). Based on the eight classification reasons, an operational relationship matrix (ORM) is developed to systematically establish the relationships between operations, and is used as a reference for drafting the IDEF0 diagram.

Using the second level of activities identified in Fig. 2 as an example, the development of the IDEF0 diagram for the procurement/subcontracting process is described. As shown in the figure, this diagram is composed of four functions, including ask for purchase, quotation and negotiation, inspect, and sign contract. Fig. 3 is the ORM developed to illustrate the relationships between these four operations. The quotation and negotiation can only be done after the ask for purchase has been completed. According to the IDEF0 operational relationships and classification reasons, the relationship between these two operations is coded as 7, which represents the relationship of IC. Likewise, the remaining relationships between operations are identified and filled in to complete the matrix. Based on the matrix, the example IDEF0 diagram for the procurement/subcontracting process can be drafted as shown in Fig. 4.

## *Process Evaluation*

Reengineering activities focus on improving the outdated and inefficient problems in the process in order to effect the greatest

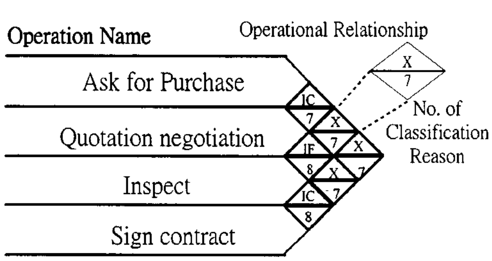


**Fig. 3.** Operation relationship matrix

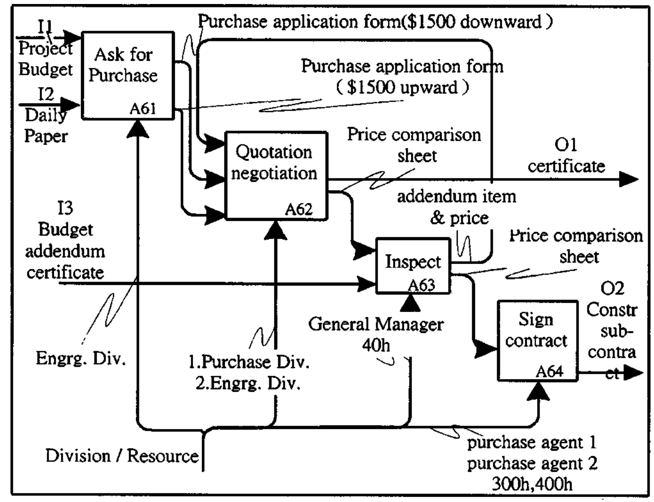


**Fig. 4.** IDEF0 diagram of procurement/subcontracting process

efficiency. Hence, before the reengineering process can commence, the present process must be examined to locate the barriers to the process in order to use them as a basis for process redesign. The process value (PV) is used to evaluate process performance. PV can be viewed from two perspectives—(1) the function each unit of cost can achieve; and (2) the function each unit of time can achieve. The IDEF0 modeling method used in this study emphasizes describing the relationship between process function and cost. The time factor is reflected in the cost; the longer it takes, the higher the cost. Applying this concept, this study focuses on evaluating function and cost to find problematic areas related to these perspectives as a reference point for process reengineering.

### Process Function Evaluation

The primary objective of process reengineering, as defined by this study, is to satisfy customer needs. Hence, to satisfy customer needs, the functional target of the process should be customer oriented. In addition, the attainability of the existing process should be assessed to identify existing problems. Using the quality function deployment method, this study transforms company policy and customer concerns into targets of the process. This study is also the first to develop the target attainability matrix in examining the attainability of the target as an important source for measuring the effectiveness of the process. The main steps of the evaluation process are described as follows.

***Definition of Operational Strategy and Policy of Company.*** A company's operation can be viewed as a serial composition of processes. Each process has targets to achieve. In this framework, it is essential to combine company policy with the targets of each process in order to accomplish the company policy. Before analyzing the process, a company's operation policy must first be defined. Inclusion of policy demands when setting process targets is also essential to the realization of a company's operation policy and its customer needs.

***Identification of Internal and External Customers of Process.*** In the IDEF0 process diagram, the output of the previous process is the input for the next process. This means that the follow-up process will check the result of the preceding process. In this relationship, the successor process customer can be viewed as the direct customer of the precedent process, and consumers



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| Customer Demands / Target components | | | Planning | | | Bidding | | Awarding | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Accurate takeoff quantity | Reasonable purchase schedule | Forecast possible outburst situation | Vendors evaluation standards | Thoroughness/ completeness of bidding content | Perceive market price | Price negotiation skill | establish faultless contract | well controlling of purchase budget | Emphasis degree(p) |
| External | Owner | Purchase quality matching requirements | | 3 | | 5 | 3 | | | 3 | | 5 |
| | Subcontractors | Accurate subcontracting data | 3 | | | | 5 | | | | | 4 |
| | | Reasonable profit | | | | | | 5 | 3 | | 3 | 3 |
| Internal | Purchase unit | Definite purchase schedule | 3 | 5 | 3 | | | | | | | 5 |
| | | Accurate vendor information | | | | 5 | | 1 | | | | 4 |
| | | Clear price quote | 3 | | 1 | | 5 | | | | 5 | 3 |
| | Financial unit | Low purchase cost | 3 | | | | | 5 | 5 | | 5 | 5 |
| | | Vendor with sound financial condition | | | | 5 | | | | | 3 | 3 |
| | Engineering unit | Purchase matches time effectiveness | | 5 | 5 | | | | | 1 | | 5 |
| | | Vendor' s willingness to cooperate | | | | 5 | 3 | | | | | 4 |
| | | Correct quantity of purchase | 5 | 3 | 3 | | | | | | 1 | 5 |
| | | Purchase quality matching requirements | | | | 5 | 3 | | | 3 | | 4 |
| | | Competent and skillful vendors | | | | 5 | 3 | | | 3 | | 4 |
| | | Clear purchase contracts | | | | | | | | 5 | | 3 |
| | | | 76 | 80 | 58 | 120 | 86 | 44 | 34 | 59 | 63 | 620 |
| | | $W_i$ | 12.3 | 12.9 | 9.4 | 19.4 | 13.9 | 7.1 | 5.5 | 9.5 | 4.1 | |

**Fig. 5.** Relative importance weight matrix for procurement/subcontracting process

are the final customers of each process. Direct customers are mainly the parties participating in the process; the final customers, as the acceptors of the final products of the process, are generally referred to as consumers. As this relates to construction companies, owners usually play the role of the final customer. The following are the definitions of internal and external customers. Internal customers are those who actually participate in the process. External customers are the consumers who accept the final products of the process. The objective of this step is to identify the executor of each operation from the mechanism of each operation derived from the IDEF0 process diagram. The executor is the internal customer of the previous operation. Taking the example of the procurement/subcontracting process and employing the IDEF0 flow diagram, the internal and external customers of each process are identified and listed in the first and second columns in Fig. 5.

***Surveying of Customers' Requirements of Process.*** Customers' requirements have to be considered when setting process targets. Based on the internal and external customers identified above, the requirements of each customer are established and shown in the third column of the matrix. Experts' interviews are used to collect customers' requirements in the case of company A for the procurement/subcontracting process.

***Determination of Process Targets.*** Customers' demands must be satisfied by the process. To satiate customers' demands, the process must have the capability to assign human-power and related resources to accomplish the necessary tasks. Hence, this step treats customers' demands of the process as input information to determine the targets of the process. The identification of process targets is described as follows.

1. Determination of the process targets according to customer demand. The process targets deployment (PTD) method developed in this study is used to transform the customer demands into process targets. Taking the example of the procurement/subcontracting process, the targets of the process as shown at the top of the matrix in Fig. 5 are determined based on the PTD analysis.
2. Analysis of the relative importance of process targets. The relative importance of process targets is identified using the relative importance weight evaluation matrix (Fig. 5). In the matrix, customers' demands are listed vertically on the left-hand side, and process targets are listed at the top. Based on the relationship between the two, the corresponding number $r_{ij}$ ($r_{ij}$: 1,3,5) is determined. The higher the value of $r_{ij}$, the more the target elicits customers' demand. Then, considering the emphasis that customers place on each demand, represent it as $p_j$ ($p_j$: 1~5 points) and fill it in on the right-hand side of the matrix. The degree of emphasis is assessed by questionnaires and interviews. Finally, use Eq. (2) to calculate the score of the relative importance ($W_i$) of each process target

$$W_i=\frac{\sum_{j=1}^{m} r_{ij}\times p_j}{\sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij}\times p_j}\times 100 \tag{2}$$

where $W_i$=relative importance weight for process target $i$; $m$=number of customers' demands; $n$=number of process targets; $i=i$th item of process targets; $j=j$th item of customer demands; $r_{ij}$=corresponding rating between $i$th process target and $j$th customer demand ($r_{ij}=1,3,5$); and $p_j$=emphasis degree of $j$th customer demand ($p_j=1\sim5$).

The score of the process target ($W_i$) represents the degree of demand satisfaction that the process target delivers to the customer; the higher the score, the more complete the satisfaction. Using the case of the procurement/subcontracting process as an example, this study conducts interviews with senior managers to complete the relative importance weight evaluation matrix for the company. The score of the relative importance ($W_i$) of each process target is calculated as shown in Fig. 5.

***Analysis of Process Target Achievement.*** A quantitative method is used to calculate the achievement of each process target that the operational functions complete. Fig. 6, the process target achievement matrix (PTAM), illustrates this concept. Taking the case of procurement/subcontracting as an example, the operation items of the IDEF0 process diagram are placed on the left, and the process targets and scores of the relative importance weight ($W_i$) are listed at the top. Based on each process target, the attainability of each operation for each process target $A_{ik}$ ($A_{ik}$: 0~10/10) is evaluated by the senior managers. After completing the $A_{ik}$ evaluation, the operation target attainability, $OA_i$ ($OA_i$: 0~$W_i$), achieved by the process activities can be calculated. The total process attainability ($TA$) of the targets and the degree of contribution ($C_k$) endowed by each operation are also identified. The equations for calculating $OA_i$, $TA$, and $C_k$ are demonstrated as follows:



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| Operation node | Name of Operation | Target components: Planning — Accurate takeoff quantity | Reasonable purchase schedule | Forecast possible outburst situation | Bidding — Vendors evaluation standards | Thoroughness/completeness of bidding content | Awarding — Perceive market price | Price negotiation skill | establish faultless contract | well controlling of purchase budget | contribution of operation(C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wi | 12.3 | 12.9 | 9.4 | 19.4 | 13.9 | 7.1 | 5.5 | 9.5 | 10.2 | |
| A611 | Purchase Planning | 9/10 | 9/10 | | | | | | | | 22.6 |
| A612 | Fill purchase form | | 1/10 | | | | | | | | 1.3 |
| A613 | Apply for permission | | | | | | | | | | 0.0 |
| A6211 | Search Subcontractors | | | | | 1 | | | | | 13.9 |
| A6212 | Collect/Delete Namelist | | | | 3/10 | | | | | | 5.8 |
| A6213 | Evaluate Subcontractors | | | | 7/10 | | | | | | 13.5 |
| A6214 | Request Quotation | | | | | | 8/10 | | | | 5.7 |
| A6215 | Quotation negotiation | | | | | | 2/10 | 5/10 | | 2/10 | 6.2 |
| A6221 | Quotation negotiation (trivial jobs) | | | | | | | 5/10 | | 2/10 | 4.8 |
| A6222 | Apply for permission (trivial jobs) | | | 1 | | | | | | | 9.4 |
| A6223 | Inspected by Planning Div. | | | | | | | | | | 0.0 |
| A6224 | Inspected by Engr. Div. | 1/10 | | | | | | | | | 1.2 |
| A63 | Inspected by G.M. | | | | | | | | | | 0.0 |
| A64 | Sign contract | | | | | | | | 1 | | 9.5 |
| | Target attainability(OA) | 12.3 | 12.9 | 9.4 | 19.4 | 13.9 | 7.1 | 5.5 | 9.5 | 4.1 | 94.1 |

**Fig. 6.** Process target achievement matrix for procurement/subcontracting process

$$OA_i=\sum_{k=1}^{g} W_i\times A_{ik} \tag{3}$$

$$TA=\sum_{i=1}^{n} OA_i \tag{4}$$

$$C_k=\sum_{i=1}^{n} W_i\times A_{ik} \tag{5}$$

where $g$=number of process operations; $n$=number of process targets; $OA_i$=attainability of $i$th process target achieved by the process operations; $A_{ik}$=operation $k$'s attainability of the $i$th process target; $TA$=total attainability of process to the targets ($TA$ $=0\sim100$); and $C_k$=contribution of operation $k$.

$OA_i$, $TA$, and $C_k$ can be used as indices for process evaluation. $OA_i$ represents the process attainability of a certain process target; the higher the number, the more probable the attainability. $TA$ represents the total attainability of the process; the higher the value, the more suitable the operational function related to the process targets. $C_k$ represents the contribution of a certain operation to all process targets; the higher the number, the greater the contribution, which also means that the function is more likely to satisfy customer demand.

## Evaluation of Process Cost

The primary purpose of process cost evaluation is to discuss the cost occurring during process operations and review the process from the perspective of cost to reduce the process operations cost. The process is composed of a series of operations with input/output relationships. Therefore, the cost of the process can be calculated by adding up costs occurring in each operation. Based on this concept, this study adapts the activity based costing (ABC) method to calculate the process cost. The ABC method can clarify the cause and effect relationship between each activity and cost. It also complements the IDEF0 model in proceeding with the cost evaluation process. The steps of calculating the process cost are described as follows.

***Definition of Characteristics of Activity.*** To incorporate cost data into the evaluation of the process, it is necessary to define each activity's suitable characteristics as the reference for evaluation. The activity characteristics are defined based on the results derived from the process function evaluation; therefore, defects inherent in the subjective definitions can be avoided. The types of characteristics sorted by this study include (1) value-added and non-value-added; and (2) primary and secondary.

1. Value-added and non-value-added. An activity producing value that is of use to external customers is called a valued-added activity. The opposite is called a non-value-added activity. For external customers, demand satisfaction is a direct method to produce value. Therefore, this study uses process targets in the PTAM that are of some contribution to the external customer demands to discern whether or not the activity has value-added characteristics. In Fig. 5, regarding the case of the procurement/subcontracting process, the owner's (external customer) demand is quality purchase. The four process targets, namely, reasonable purchase schedule, vendors evaluation standards, thoroughness/completeness of bidding content, and establish faultless contract (the gray shaded items), have a contribution to the owner's demand. It is concluded that the process targets listed in the gray area can satisfy the external customer demands. Then, based on the PTAM as shown in Fig. 6, the six operations that have a contribution to the four process targets are purchase/subcontracting plan development, fill purchase orders, subcontractor search, build/edit subcontractor namelist, subcontractor evaluation, and sign contract. These six activities are defined as value-added, whereas the rest are non-value-added.
2. Primary and secondary. A primary activity is a direct supporting task of the process. The opposite is called a secondary activity. The score of the relative importance weight $W_i$ obtained in Fig. 5 is used to define the primary and secondary targets. The activities supporting the primary targets in Fig. 6 are then selected as primary activities. Referring to the 80/20 principle, this study identifies the activities completing 80% of the process targets and defines them as primary activities. Hence, the process targets are arranged in descending order of $W_i$ scores to find the first 80% of the primary targets. By use of the PTAM, the activities supporting the primary targets are then identified and defined as primary activities.

***Identification of Resources Used by Each Activity.*** The cost of an activity is derived from the use of resources in each activity. This study adopts IDEF0 as the tool to describe the process.



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**Table 3.** Bill of Cost for Procurement/Subcontracting Process

| Node | Name of operation | Value-added | Primary activity | Resource | Resource driver | Resource driver frequency | Resource driver cost[b] | Resource cost[b] | Operation cost[a] | Cost percentage |
|---|---|---|---|---|---|---|---|---|---|---|
| A6 | Purchase subcontract | — | — | — | — | — | — | — | — | — |
| A611 | Purchase planning | N | P | Engineer 3 | Hour | 80 | NT 188/h | 15,040 | 27,712 | 3.7% |
| | | | | Engineer 4 | Hour | 96 | NT 132/h | 12,672 | | |
| A612 | Fill purchase form | N | P | Engineer 3 | Hour | 25 | NT 188/h | 4,700 | 8,660 | 1.2% |
| | | | | Engineer 4 | Hour | 30 | NT 132/h | 3,960 | | |
| A613 | Apply for permission | N | S | General manager | Hour | 40 | NT 800/h | 32,000 | 3,200 | 4.3% |
| A6211 | Search subcontractors | V | P | Purchasing agent 1 | Hour | 15 | NT 236/h | 3,540 | 11,940 | 1.6% |
| | | | | Purchasing agent 2 | Hour | 20 | NT 227/h | 4,540 | | |
| | | | | Engineer 3 | Hour | 10 | NT 188/h | 1,880 | | |
| | | | | Engineer 4 | Hour | 15 | NT 132/h | 1,980 | | |
| A6212 | Collect/delete namelist | V | P | Purchasing agent 1 | Hour | 40 | NT 236/h | 9,440 | 20,790 | 2.8% |
| | | | | Purchasing agent 2 | Hour | 50 | NT 227/h | 11,350 | | |
| A6213 | Evaluate subcontractors | V | P | Purchasing agent 1 | Hour | 100 | NT 236/h | 23,600 | 96,250 | 12.9% |
| | | | | Purchasing agent 2 | Hour | 150 | NT 227/h | 34,050 | | |
| | | | | Engineer 3 | Hour | 100 | NT 188/h | 18,800 | | |
| | | | | Engineer 4 | Hour | 150 | NT 132/h | 19,800 | | |
| A6214 | Request quotation | N | S | Purchasing agent 1 | Hour | 150 | NT 236/h | 35,400 | 67,180 | 9.0% |
| | | | | Purchasing agent 2 | Hour | 140 | NT 227/h | 31,780 | | |
| A6215 | Quotation negotiation | N | P | Purchasing agent 1 | Hour | 300 | NT 236/h | 70,800 | 145,710 | 19.5% |
| | | | | Purchasing agent 2 | Hour | 330 | NT 227/h | 74,910 | | |
| A6221 | Search subcontractors/quotation | N | P | Engineer 3 | Hour | 250 | NT 188/h | 47,000 | 86,600 | 11.6% |
| | | | | Engineer 4 | Hour | 300 | NT 132/h | 39,600 | | |
| A6222 | Apply for permission (trivial jobs) | N | S | Engineer 3 | Hour | 50 | NT 188/h | 9,400 | 17,320 | 2.3% |
| | | | | Engineer 4 | Hour | 60 | NT 132/h | 7,920 | | |
| A6223 | Inspected by planning division | N | S | Planning executive | Hour | 80 | NT 328/h | 26,240 | 26,240 | 3.5% |
| A6224 | Inspected by engineering division | N | P | Superintendent | Hour | 40 | NT 315/h | 12,600 | 12,600 | 1.7% |
| A63 | Inspected by general manager | N | S | General manager | Hour | 40 | NT 800/h | 32,000 | 32,000 | 4.3% |
| A64 | Sign contract | V | P | Purchasing agent 1 | Hour | 300 | NT 236/h | 70,800 | 161,600 | 21.6% |
| | | | | Purchasing agent 2 | Hour | 400 | NT 227/h | 90,800 | | |

Note: V=value-added operation; N=non-value-added operation; P=primary operation; S=secondary operation.
[a]Total operation cost is $746,602.
[b]Cost in U.S. dollars.



Therefore, the total resources used by each activity can be found in the mechanism of each activity of the process diagram. The management process is the major focus of this study. The main purpose of the management process is to provide supporting services for production activities. The cost of resources for supporting services can be classified into five categories—personnel cost, computer equipment cost, office equipment cost, building cost, and other costs. Personnel cost is the main recipient of the resource cost in the management process. Consequently, in the development of the IDEF0 diagram, only human resources in each activity are considered. Hence, this study amortizes the remaining costs into personnel cost according to the cost amortization methods.

***Development of Bill of Costs (BOC).*** The BOC shown in Table 3 is developed based on the data identified above. Through the calculation of the BOC, the cost of each activity is obtained.

***Analysis of Cost Structure of Activities.*** Incorporating the activity cost with its characteristics defined above, Eqs. (6), (7), and (8) are used to calculate the value-added index (VI), primary activity cost index (PI), and process cost index (CI) to determine the executive efficiency of each activity. Process reengineering is conducted based on the indices identified

$$\text{Value-added index (VI)} = \frac{\text{total cost of value-added activities}}{\text{total process cost}} \times 100 \tag{6}$$

$$\text{Primary activity cost index (PI)} = \frac{\text{total cost of primary activities}}{\text{total process cost}} \times 100 \tag{7}$$

$$\text{Process cost index (CI)} = W_v \times \text{VI} + (1 - W_v) \times \text{PI} \tag{8}$$

VI represents the cost efficiency of a certain process that satisfies the external customers' demands. PI depicts the cost efficiency of the process in supporting the primary activities to achieve their targets. CI is used to represent the overall score of the process in terms of costs. $W_v$ is the weight used by managers for weighting VI while conducting the process cost evaluation. The greater the emphasis of increasing the satisfaction of external customers, the higher the $W_v$ value. If a company puts more emphasis on the cost efficiency of internal operations, then a lower weighting ($W_v$) is given.

According to Table 3, the VI of the procurement/subcontracting process for company A is calculated at 38.9. The score of PI is 76.6. In addition, the procurement/subcontracting



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process is the internal operational process of the company. The owner does not directly participate in the operation of this process. The main focus of the process management is internal coordination, and thus the weighting of $W_v$ is 0.4. Using Eq. (8), the CI of the procurement/subcontracting process for company A is calculated and totals 61.52.

## Process Redesign

### Identifying Defects of Process

The analysis results derived from the process evaluation model can be used to identify the major defects of the process. According to the operation target attainability $(OA_i)$, the satisfaction of customers' demands provided by the process and the requirement of adding new activities are identified and determined. Operation contribution $(C_k)$ is an index that measures the contribution of each activity to the process and deletes the redundant activities. The value-added index (VI) is applied to determine the cost efficiency of transforming the process cost into the value of the external customers. The primary activity cost index (PI) examines the cost efficiency of the process in supporting the primary activities to achieve their targets, and forms a basis for process management. In addition, the process value (PV) is a function of process function and cost. Consequently, this study uses the total process attainability (TA) and process cost index (CI) derived from the process evaluation model to calculate the PV. PV is an index to determine whether or not the process reengineering is necessary. TA represents the attainability of the process in terms of effectiveness and emphasizes the achievement of process targets. CI is the efficiency of cost in maneuvering the process. Emphasis is placed on decreasing the process cost. In general, higher effectiveness demands higher cost. Logically, decreasing the cost can also possibly decrease the effectiveness of the process. Thus, for the evaluation of the process value, managers have to trade off between effectiveness and efficiency in consideration of the focus of management and the pursuit of the process value that is most suitable to the company. The PV function is defined as follows:

$$\text{Process value (PV)} = f(\text{TA,CI}) = W^*_{\text{TA}}\text{TA} + W^*_{\text{Cl}}\text{Cl} \tag{9}$$

where $W_{\text{TA}}$=weight of function evaluation; $W_{\text{Cl}}$=weight of cost evaluation; and $W_{\text{TA}} + W_{\text{Cl}} = 1$.

In Eq. (9), $W_{\text{TA}}$ and $W_{\text{Cl}}$ are used to assist managers in determining the weights of functional effectiveness and cost efficiency. Construction company A, considering that effectiveness and efficiency are of equal importance, sets the weights of $W_{\text{TA}}$ and $W_{\text{CI}}$ at 0.5 each. Based on the results of the function and cost evaluation, the PV of procurement/subcontracting for the company is calculated and totals 77.8.

From the functional evaluation results, the procurement process has a lower level of $OA_i$ in terms of purchase budget control (Fig. 6). The reason is that in the current process, the functions of all activities are not able to pinpoint and deal with a circumstance in which the purchase budget exceeds the execution budget. The low process value of the procurement/subcontracting process is due to the fact that the cost evaluation is too low. This is caused by the fact that this process has more non-value-added and secondary activities. In other words, the main bottleneck of the process is the failure to transform the cost to the target value as demanded by the owners. It is important to seek strategies for improvement of this specific problem.

### Design of New Process

The principles of process redesign are identified and established based on the problems discovered in the process evaluation model. According to the characteristics of the model, the following five rules of process redesign have been developed:

1. In the conduct of process reengineering for processes that are undervalued, the medium and high value processes should proceed with improvement and strengthen the performance of management.
2. Design of new activities for operation targets that have a lower $OA_i$ score in order to satisfy the demand for that operational target.
3. Consideration of teamwork to consolidate activities for those activities with a lower $C_k$ value in order to decrease the flow of documents and reports between activities and thereby increase both time and the cost efficiency of the process.
4. For those processes with a lower value-added evaluation, primary consideration should be given to the deletion of non-value-added activities with high cost, or reconsideration of new composition activities to match the existing skill level of management and information technology. Effort should be made to decrease the cost of non-value-added activities.
5. For those processes with a lower evaluation score for primary activities, consideration should be given to deleting secondary activities with a high cost or integrating all secondary activities into one independent process to decrease the cost of secondary activities.

Using the case of the procurement/subcontracting process as an example, it is apparent that the value of the process is still at a level acceptable to management. Hence, the reengineering of the procurement/subcontracting process for the company to achieve the increase in process efficiency can be considered as follows:

1. For the problem of the process having a lower $OA_i$ in terms of purchase budget control, this study suggests that the company should develop an integrated computer system for cost estimates and procurement/subcontracting. Through computerization of the purchasing schedule and budget, an automatic comparison can be made between the actual purchase price and the budget; it can also be used as a basis for budget control. Computerization can increase the TA of the procurement/subcontracting process and reduce the repetition of activities. Furthermore, using computerized systems, the current use of materials on the site can be reflected and purchase suggestions can be made.
2. By inspection of the results of the process evaluation, it is discovered that compliance activities have no contribution to the procurement/subcontracting process; in fact, they belong to the non-value-added and secondary activity categories. From the point of view of decentralization, deleting the compliance activities in the purchase process is of aid to the efficiency execution and cost reduction of the process. However, it should be cautioned that human errors might occur during such a deletion.
3. According to the suggestions made in items 1 and 2, this study believes that construction company A can apply information technology as an appropriate management system of procurement/subcontracting. Furthermore, it can use related data, such as purchase categories, quantities, unit prices, vendor's information, and purchase schedules, as provided by computers as the basis for procurement/subcontracting. Therefore, suggestions made using the problems discovered during process evaluation are used as points of reference to discern whether or not an automatic management system is





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suitable to a company's needs. Using the same process as an example, the process is shown to be weak, in that there are too many compliance, non-value-added, and secondary activities. Hence, in order to reduce compliance activities, a computerized system must provide functions that give the precise purchase category, quantity, and schedule information data. Moreover, to lower the cost of non-value-added and secondary activities, the management system should have related functions that provide price inquiry, price comparison, price negotiation, and vendor information.

In consideration of the above suggestions, this study believes that company A should develop a computerized system that includes functions such as planning the procurement/subcontracting schedule, providing market price data, controlling the budget, and recording the quantity of construction. The system should also be able to provide correct timing and quantity of procurement/subcontracting in order to reduce compliance activities and decrease the cost of non-value-added and secondary activities executed manually. In addition, budget execution can be controlled by checking the completed quantity of construction to make up for the deficiency of budget control in the process.

## Conclusion

Due to the fact that at present the BPR lacks the actual method and steps of execution, this study focuses on the crucial stages of process analysis and redesignation in reengineering to establish the construction management process reengineering model. Through the four major steps of process representation, process transformation, process evaluation, and process redesign integrated with suggestions for process definition, process selection, operation analysis, process description, process evaluation, and process reengineering as well as methods of execution, this study provides construction companies with a valuable reference for internal management process reengineering. With the development of the CMPR model, this study establishes a new research area for process reengineering in the construction industry and serves as a basis from which business managers can execute operation procedures, implement computerization, and plan methods of management procedures for companies.

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