Project-Oriented Business Process Reengineering for Professional Construction Management

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Abstract: This paper focuses on developing a "Project-Oriented Business Process Reengineering Model for PCM" (hereafter called Reengineering model)", which can be applied by Professional Construction Management (PCM) enterprises, when dealing with changing and high knowledge demanding projects. By using this Reengineering model, PCM enterprises can quickly revise their existing service process to meet various goals of specific projects. This Reengineering model is constructed based on both Single-Loop and Double-Loop Knowledge Management (KM) learning concept, and business process reengineering (BPR) tools. This model helps PCM quickly identify and quantify the service and performance gaps, and redesign existing service process. "Construction Cost Change Estimation Process" is used as a case study to validate this reengineering model, which can be a concrete instrument for PCM to reengineer service process, in order to ensure the process meet service demand of a project prior to implementation. Development of this reengineering model provides new input to the research of project-oriented business process reengineering.

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1. Introduction

Professional Construction Management (PCM) is a professional management practice consisting of an array of services applied to construction projects and programs through the planning, design, construction and post construction phases for the purpose of achieving project objectives including the management of quality, cost, time and scope.

Due to the PCM service process are highly complicated with low organizational operation feature and have a strong demand for knowledge and experience feedback [1]. Therefore, before a project start, PCM is often based on the owner's needs reconfigure the company's current operation and process in order to establish project-oriented workflow for each project. For elevating customer service satisfaction, PCM needs to understand three aspects: first, the combination of project-oriented workflow provided by project operation process and its knowledge; second, how the current implementation performance works; third, service process established by the needs of customers, as above three aspects will be the current concerned topic before PCM performs the project-oriented process.

In response to the above-mentioned PCM service characteristics and changes in project requirements, the main subjects of this paper aims to analyze, how to integrate both major theories, Business Process Reengineering (BPR) (Michael Hammer [2]) and Knowledge Management (KM)[3], and adopt to enhance PCM process efficiency and service performance are the main subjects of this paper.

This paper focuses on "customer needs" as the main axis, exploring PCM Business Process Reengineering, thereby establishing "Project-Oriented Process Reengineering Model for PCM", implementing customer needs to PCM operation process and effectively strengthening operation performance of PCM, in order to enhance customer satisfaction and achieve long-term business development. The main subject of this paper includes the following three points:

1. Evaluate PCM project management process: from the perspective of project service demand, this paper establishes a process analysis model to evaluate knowledge-based PCM process and the demand gap between project owner and project manager.
2. Apply KM theory to establish a process reengineering model: applying KM to carry out knowledge production operation in response to a project demand, integrating learning method, reengineering process theory, and establishing reference model to PCM for implementing reengineering process.
3. Enhance operation performance of project management process: from the perspective of service demand, evaluating process efficiency, effectiveness and the process value of project management reengineering is to provide

continuous improvement evaluation before project execution.

2. Knowledge Model

2.1 Concept of KM loop learning

Mark W. McElory and Joseph M. Firestone proposed a KM-oriented BPR model is shown in *Fig. 1*. [4] The model contains single-loop learning to reduce the performance gap which is defined as 'cyclical processes which send feedback and achievements to the organization knowledge base utilizing the established general or specific knowledge in the organization knowledge base, and carry out proper adjustments for relevant activities based on the new knowledge produced by special incidents and demands of activities' [Argyris and Schön][5]. If the process can not satisfy customer service needed, and then double-loop learning model and the Knowledge Life Cycle (KLC) concept will be employed to enhance the performance gaps. which is defined as 'a cyclical process which sends feedback and achievements to the organization knowledge base utilizing the problems accrued in the business processes to solve and revise the established general or specific knowledge in the organization knowledge base, and carries out proper adjustments for relevant activities.'

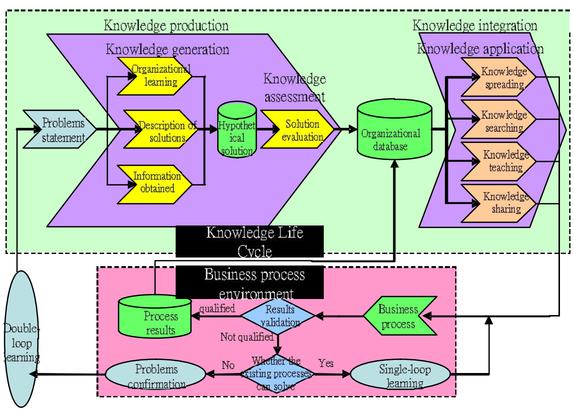

Fig. 1 Conceptual Model of KM-oriented BPR

2.2 Description of the Project-Oriented BPR model

Based on PCM demand, this study develops Project-Oriented BPR model, which focuses 'KLC loop learning' and BPR concepts and practices after a careful review of general BPR models in the literature [6][7]. Its basic scheme is shown in *Fig. 2*. The model encompasses five main processes, including determining the process targets, process representation, process evaluation, process design and process validation.

(1) Determining the process targets: this stage is focusing on project process related to customer point of view. In accordance with customer demands, the quantitative weight is given to 'process target components' in order to provide the improvement basis to process reengineering.

(2) Process representation: This study thoroughly reviews and analyzes processes already execute by PCM. The components of process representation, e.g. operation roles and activities, related documents and knowledge, are progressively assessed and depicted in the context of PCM firm.

(3) Process Evaluation: Process performance must be assessed and diagnosed before changing. The crux that obstructs the operation process should be identified in order to serve as the basis of process redesign. At this stage, the analytical work is divided into two parts, i.e., 'analysis for gap of performance' and 'analysis for gap of service'. The development of matrix operational analysis is to quantify the contribution benefit of 'activities' and 'knowledge ' to ' process target components', as important reference to draft process reengineering policy.

(4) Process Design: KM single-loop and double-loop learning concept are involved according to process evaluation result, and with the learning outcomes table, gradually strengthening the process performance with improve the knowledge information. In order to redeem the process service gap, the operation activities and supporting knowledge should be accrued or redeveloped.

(5) Process validation: Performance of the process before and after reengineering should be further inspected and validated after process is redesigned. The process performance is evaluated according to the process efficiency and costs. Should the execution performance of designed process not improve significantly than the original one, this process should cycle back to the process design step.

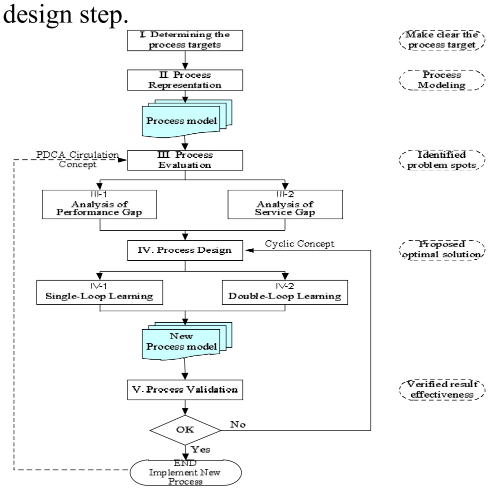

Fig. 2. Project-Oriented BPR model

Base on the Project-Oriented BPR model, PCM may implement process reengineering and adjust in a flexible manner to satisfy project demands at a particular point in time in accordance with the engineering management PDCA (Plan-Do-Check-Action) circulation concept. Finally, this paper selects a medium-sized PCM firm which capitalizes at about 2.2 million USD with 52 employees and mainly undertakes planning, design, and turnkey construction of general building project, and chose its 'construction cost change estimation process' as a process reengineering case study.

3. Implementation and application of the KM-oriented BPR model

3.1 Determining the process targets

This stage must first draft the process target according to "project customer demand". The relative importance of target components is obtained by utilizing "the relative importance weight matrix"[8]. The corresponding number r_{ij} is determined based on the relationship between project customer demands and project target components. The higher the pi value, the greater customer attention the demand elicits. *Eq. (1)* is used to calculate the score of relative importance (w_j) of each project target component.

$$w_j = \frac{\sum_{i=1}^{m} r_{ij} \times p_i}{\sum_{j=1}^{n} \sum_{i=1}^{m} r_{ij} \times p_i} \times 100 \qquad \ldots\ldots\ldots\ldots\ldots(1)$$

where：

w_j = relative importance weight for project target component j
m = number of project customer demands
n = number of project target components
r_{ij} = corresponding rating between the j^{-th} target component and i^{-th} customers' demand, r_{ij} = 0~5
p_i = degree of emphasis of the i^{-th} customers' demand, p_i = 1~5

3.2 Process representation

Process representation expresses the process as the modeling type in order to facilitate follow-up assessment and analysis activities.

This paper applies UML [9] method to show the main function and process activities. In addition, this study combines process knowledge features, by proposed Martin J. Eppler [10], including external knowledge to which the process implementation should refer (knowledge about the process), procedural knowledge generated during process implementation (knowledge within the process), and outcome knowledge produced during process implementation (knowledge derived from the process), leading to the existing operation process and process knowledge model as shown in *Fig. 3*.

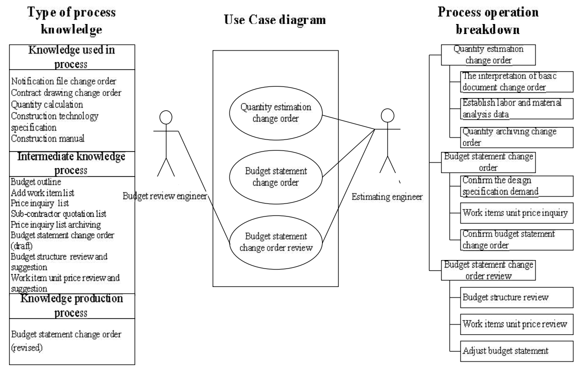

Fig.3 The model of construction cost change estimation process before reengineering

3.3 Process Evaluation

3.3.1 Analyzing Target Component Achievement

The target component achievement matrix (*Table 1*) is utilized to calculate the degree of achievement of each target completed by the PCM existing process. Operation subjects are placed on the left and target components and relative importance scores (wj) are listed at the top.

The mutual relationship amongst each is investigated, and expected contribution degree value *Aij(Aij：0.0~1.0)* and actual value *aij (aij=0.0~Aij)* of each operation subject inserted into corresponding positions. Values utilizing *Eq. (2)–Eq. (10)* are then calculated and used to complete table1.

Table 1 Target component achievement matrix

Operation activities \ Target components		The change order of document record must be easily inquired	Determine the accuracy of change order drawing	Standardized labor and material item analysis	Quantity calculating must be accurate	Correctly used construction manual	Sub-contractor price inquiry must be fast and effective	Work items unit price must able to reflect the construction cost	Budget statement templating	Standardized coding system	Reduce conflict between new and old budget information	Automation review process	The historical case data must be easily compared	Meet owner's budget demand	Confidential budget statement	Operation contribution degree (expected/actual)	Operation performance gap
Relative importance weight for project target component Wi		4.9	2.9	7.9	9.4	4.3	7.3	9.4	8.1	2.9	11.2	6.3	8.6	13.8	2.9		
DP 321-1 The interpretation of basic document change order	Expected	0.7	0.5													4.9	0.8
	Actual	0.6	0.4													4.1	
DP 321-2 Establish labor and material analysis data	Expected			0.4		0.2			0.2	0.3	0.3					9.9	4.6
	Actual			0.1		0.2			0.1	0.2	0.2					5.3	
DP 321-3 Quantity archiving change order	Expected		0.3		0.7	0.6			0.2							11.7	3.1
	Actual		0.3		0.5	0.5			0.1							8.5	
DP 322-1 Confirm the design specification demand	Expected	0.2	0.2	0.2												3.1	1.1
	Actual	0.2	0.1	0.1												2.1	
DP 322-2 Work items unit price inquiry	Expected			0.2		0.2		0.6								8.1	5.5
	Actual			0.2		0.2		0.1								2.6	
DP 322-3 Confirm budget statement change order	Expected								0.5	0.3		0.5				8.1	2.9
	Actual								0.3	0.3		0.3				5.2	
DP 323-1 Budget structure review	Expected										0.2	0.1		0.4	0.2	9.0	3.9
	Actual										0.1	0.1		0.2	0.2	5.1	
DP 323-2 Work items unit price review	Expected							0.2			0.2	0.1		[illegible]	0.2	[illegible]	2.1
	Actual							0.1			0.1	0.1		[illegible]	0.2	[illegible]	
DP 323-3 Adjust budget statement	Expected	0.1			0.3			0.2		0.3		0.1		0.6	0.6	16.[illegible]	5.6
	Actual	0.1			0.1			0.1		0.3		0.1		0.4	[illegible]	11.1	
Expected achievement value of target component EAj		4.9	2.9	6.3	9.4	4.3		9.4	7.3	2.6	7.8	5.0		13.8	2.9	**76.7**	**23.3**
Actual achievement value of target component Raj		4.4	2.3	2.4	5.6	3.9		2.8	4.1	2.3	4.5	3.8		[illegible]	2.9	**47.2**	**29.5**
Operation target service gap wj - EAj		0.0	0.0	1.6	0.0	0.0	7.3	0.0	0.8	0.3	3.4	1.3	[illegible]	[illegible]	0.0		
Operation target performance gap EAj - Raj		0.5	0.6	3.9	3.8	0.4	0.0	6.6	3.2	0.3	3.3	1.2	0.0	5.0	0.0		

$$CE_i = \sum_{j=1}^{n} A_{ij} \times w_j \quad \ldots\ldots(2)$$

$$CR_i = \sum_{j=1}^{n} a_{ij} \times w_j \quad \ldots\ldots(3)$$

$$EA_j = w_j \times \sum_{i=1}^{m} A_{ij} \quad \ldots\ldots(4)$$

$$Ra_j = w_j \times \sum_{i=1}^{m} a_{ij} \quad \ldots\ldots(5)$$

$$G_i = \sum_{j=1}^{n}(A_{ij} - a_{ij}) \times w_j = CE_i - CR_i \cdots (6)$$

$$TEA = \sum_{j=1}^{n} EA_j = \sum_{i=1}^{m} CE_i \quad \ldots..(7)$$

$$TR_a = \sum_{j=1}^{n} Ra_j \cdots\cdots(8)$$

$$G_{sv} = 100 - TEA \ldots\ldots(9)$$

$$G_{pf} = TEA - TR_a \ldots.(10)$$

Table 1 shows the TEA value is 76.7 and the TRa value is 47.2, giving a performance gap in process Gpf of 29.5, this result indicats that the process can be improved and strengthened using single-loop learning.

If the calculated TEA value is 76.7 (full mark is 100), so that Gsv is 23.3. This result indicates that the present process which contains the operation subject can only serve 3/4 of the target components at most. This is defined as the research process has considerably to be reengineering utilizing double-loop learning.

3.3.2 Analyzing Performance Gap

This stage establishes a 'knowledge subject contribution degree accessing matrix', investigates the relationship between data knowledge and process performance. It helps the important knowledge which influences the process service performance with regard to the reference of process improvement.

Step1 Assess Knowledge Demand Intensity of the Operation Subject

This paper evaluates the demand degree of knowledge for each operation subject in the process according to the six factors of 'characteristics of process with knowledge' that Martin J. Eppler addresses, including: external dependency, operation variability, operational innovation, knowledge volatility, output autonomy, and skill obtaining difficulty. The larger the KIIi (0.0~1.0)value indicates greater knowledge demand for an operation subject which implicitly indicates the greater the importance of 'knowledge subject' for an operation subject.

Step2 Establish the Assessment Method of Contribution Degree of Knowledge Subject to a Target Component

This step aims to analyze the contribution degree of 'knowledge used in process' and 'intermediate knowledge in process" to target components in the process. This paper has developed the 'target achievement matrix of knowledge subject process' (as shown in Table 2) to analyze and verify relationships among 'target component', 'operation subject' and 'knowledge subject' in order to serve as a reference for drafting an appropriate process reengineering policy.

where：

Aij = expected achievement value of the jth target component contributed by the ith operation subject, Aij=0.0~1.0, $\sum_{i=1}^{m} A_{ij} \leq 1.0$

fi = efficiency of the ith operation subject, $0 \leq f_i \leq 1$, *fi = fKi + fRi + fAi + fIi; fKi, fRi, fAi, fIi* are the operation efficiency functions of the ith operation subject for knowledge, role, function and control aspects, respectively; when knowledge subject is considered as target component, f_i can be expressed as $f_i(x_1, x_2, \cdots, x_q, f_{Ri}, f_{Ai}, f_{Ii})$

EA_j = expected achievement value of the *j*th target component

K_{ik} = demand degree of the k^{th} knowledge subject for the i^{th} operation subject, $K_{ik} = 0.0 \sim 1.0$, $\sum_{k=1}^{q} K_{ik} \leq 1.0$

KF_k = contribution degree of the k^{th} knowledge subject to target component, $k = 1 \sim q$

KII_i = indicator of strength for knowledge demand of the i^{th} operation subject, $0 \leq KII_i \leq 1$

TEA = total expected achievement value of all target components, $TEA = 0 \sim 100$

TK = total expected achievement value of knowledge subject to all target components, $0 \leq TK \leq TEA$

w_j = relative importance weight of target component *j*

x^k = indicator of completion of the k^{th} knowledge subject, assuming that degree of contribution degrees for the operation subjects of each knowledge subject are independent, $0 \leq x_k \leq 1$; when expected contribution degree of knowledge subject to individual target component is considered, indicator of completion x_k is set as 1.0

The contribution degree of the k^{th} knowledge subject to target component can be obtained through arranging *Eq.(11)* to *Eq. (12)*:

$$KF_{q\times 1} = K^T_{q\times m} \cdot F_{m\times n} \cdot I_{n\times 1} \quad \ldots..(11)$$

$$KF_{q\times 1} = \left[KF_1, KF_2, \cdots, KF_k, \cdots, KF_q\right]^T_{1\times q} \quad \ldots..(12)$$

$$K_{m\times q} = \begin{bmatrix} KII_1K_{11} & \cdots & KII_1K_{1k} & \cdots & KII_1K_{1q} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ KII_iK_{i1} & \cdots & KII_iK_{ik} & \cdots & KII_iK_{iq} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ KII_mK_{m1} & \cdots & KII_mK_{mk} & \cdots & KII_mK_{mq} \end{bmatrix}_{m\times q}$$

$$F_{m\times n}=\begin{bmatrix} w_1A_{11} & \cdots & w_jA_{1j} & \cdots & w_nA_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ w_1A_{i1} & \cdots & w_jA_{ij} & \cdots & w_nA_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ w_1A_{m1} & \cdots & w_jA_{mj} & \cdots & w_nA_{mn} \end{bmatrix}_{m\times n}$$

$$I_{n\times1}=[1,\cdots,1,\cdots,1]^T_{n\times1}$$

The analysis result shows three knowledge subjects, of which contribution degree of construction cost change estimation process is greater than 5.0: contract drawing change order, price inquiry list achieving, and budget statement change order (draft). According to knowledge subjects with larger contribution degree, if the quality content and efficiency of knowledge can be enhanced in the future process reengineering, then the service gap and performance gap of process can be effectively enhanced.

Table 2 Target achievement matrix of knowledge subject

Indicator of strength for knowledge demands	Knowledge subject **1**	…	Knowledge subject ***k***	…	Knowledge subject ***q***	**Knowledge subjects** / **Target components** / **Operation subjects**	Target component **1**	…	Target component ***j***	…	Target component ***n***
						Relative importance weight for target components	w_1	…	w_j	…	w_n
	x_1	…	x_k	…	x_q	Indicator of manage completion of knowledge subjects					
KII_1	K_{11}	…	K_{1k}	…	K_{1q}	Operation subject **1** (f_1)	A_{11}	…	A_{1j}	…	A_{1n}
:	:	:	:	:	:	:	:	:	:	:	:
KII_i	K_{i1}	…	K_{ik}	…	K_{iq}	Operation subject ***i*** (f_i)	A_{i1}	…	A_{ij}	…	A_{in}
:	:	:	:	:	:	:	:	:	:	:	:
KII_m	K_{m1}	…	K_{m3}	…	K_{mq}	Operation subject ***m*** (f_m)	A_{m1}	…	A_{mj}	…	A_{mn}
		…		…		Expected achievement value of target components	EA_1	…	EA_j	…	EA_n
TK	KF_1	…	KF_k	…	KF_q	Contribution degree of knowledge subjects to target component					TEA

3.3.3 Analyzing Service Gap

This paper defines a target component that is unable to be served by the process or which has a poor service state as 'service gap in the process'. Based on the analysis result of target component achievement matrix (*Table 1*), the element of target component achievement gap is defined as relative importance weight of target component minus (-) expected achievement value of target component(*wj-EAj*).Table 1 shows three major service gap of construction cost change estimation process before reengineering, including historical case data must be easily compared, sub-contractor price inquiry must be fast and effective, and reduce conflict between new and old budget information, refer to the rule of 80/20 to explore the following problems of service gaps as bellow:

1. The arrangement and audit process of budget statement change order lack of historical case data to refer. Therefore, budget information generated by the process should have feedback mechanism to serve as a reference for similar problems in the future.
2. A symmetric information of industry supply chain or inadequate cooperation reliability and confidential business information often reduce the willingness of sub-contractor to provide the actual price when conducting price inquiry. Therefore, relationship and communication with the sub-contractor should be strengthened to establish good partnership.
3. Regarding the budget cost alteration, whether over new or existing work items, the calculation of unit price and original budget estimate is often overlapping or having work items neglected. Therefore, budget alteration should be strengthened to enhance the quality of budget statement change order.

3.4 Process Design

This stage integrates the concept map of Knowledge Management (KM) learning loop proposed by Argyris/Schön and Popper with the conceptual model of KMCI knowledge life cycle (KLC) shown in Figure 1, which specifically applies KM double-loop learning concept to conducting process reengineering. As learned in the preceding process stage of performance gap and service gap analysis, the operation subject that causes lower target component achievement should be enhanced through single-loop learning model. The service gaps, which cannot be achieved via existing process, can be explored and enhanced through KM double-loop learning model. The process operation and knowledge subjects that should be added or modified are analyzed and verified through single-loop and double-loop learning.

3.4.1 Performance Gap in the Process – Single-loop Learning

This stage aimed to obtain target components which have greater performance gap through target component achievement matrix (Table 1) Referring to the concept of KM singe-loop learning proposed by Argyris/Schön and Popper and according to operation subjects which serve to every performance gap, process reengineering design is conducted through analyzed information used to deliberate how to improve project service target as a precondition, and explores how to add or enhance the quality of knowledge information.

Take the performance gap of 'work items unit price must reflect the construction cost' as an example, the operations which have contribution to target component are operation activities: unit price inquiry, unit price review, and adjust budget statement change order, respectively. In which, the gap between expected contribution degree and actual contribution degree (*Aij/aij*) of work item unit price inquiry is the largest, while knowledge demand intensity of adjust budget statement change order is the highest (0.73). This result indicates that although work item unit price inquiry operation is obtained based on quality demand of construction technique specification and construction manual, and sub-contractor quotation and price inquiry list archiving, however, adjust budget statement change order operation often need to consider owner's budget and work items unit price unable to reflect the construction cost. Therefore, in order to conveniently adjust budget change order to fully control market condition, this paper proposes to newly establish market condition analysis in inquiry process as a reference for budget review engineer in budget adjusting. Based on the principal of the abovementioned analysis, this paper uses single-loop learning analysis for major performance gap in the process, which results in the finding shown in *Table 3*.

Table 3 The demand performance gap result of single-loop learning efficiency process

Performance gap	Related operation (Fi)	Improvement recommendation	Increase of knowledge data
Standardized labor and material item analysis (3.9)	Establish labor and material analysis data (0.68) Work items unit price inquiry (0.63) Confirm the design specification demand (0.63)	Accelerate the labor and material analysis efficiency, have prompt control on product specification and the requirements of specification during price inquiry, after price inquiry it's highly recommended to establish "Standard Labor and Material Analysis Record" for future sales execution as reference.	*Standardized labor and material item analysis
Quantity calculating must be accurate (3.8)	Quantify archiving change order (0.45) Adjust budget statement (0.73)	For eliminate quantity archiving change order mistake(s) and prevent budget statement adjustment missing the adjusted quantity, after finalized left-sided-line listing two operations, it's highly recommended to add "New and old budget review form" to avoid budget statement adjustment and blueprint have inconsistent quantity.	*New and old budget review form
Work items unit price reflect the construction cost (6.6)	Inquire work items unit price (0.63) Review items unit price (0.53) Adjust budget statement (0.73)	For facilitate the adjustment of budget statement concludes current market condition, it's highly recommended to have well-organized the received quotation(s) during the process of price inquiry, but also establish the "current market condition analysis" as convenient reference for budget audit engineer to adjust the budget.	*Current market condition analysis
Meet owner's budget demand (5.5)	Review budget structure (0.62) Adjust budget statement (0.73)	At times budget statement adjustment fallen into the dilemma between quality and price; therefore, in regard to material specification and market price evaluation, it's highly recommended to add "recommendation for adjust the budget" content for the owner as decision application and eliminate the condition of return for correction.	* Recommendation for adjust the budget

3.4.2 Service Gap in the Process – Double-loop Learning

This stage executes double-loop learning for reengineering operation subject and derives knowledge application from the abovementioned 'knowledge production process' operation showing in Fig.1. According to service gap analysis showing in table1, three major service gaps was obtained including historical case data must be easily compared, sub-contractor price inquiry must be fast and effective, and reduce conflicts between new and old budget information.

Table 4 shows the performance of service gap result in double-loop learning process. For Sub-contractor price inquiry must be fast and effective

(7.3) as the instance. The detail of double-loop learning process is described below.

1. Knowledge generation : At times in price inquiry because of asymmetric info from industry supply chain or reflected by other factors, e.g. business confidential agreement, lack of trust in collaboration, etc. between these sub-contractors, it lower down their willingness to offer the actual business to business price. Therefore, for unit price inquiry, it's recommendable to create "sub-contractor data", "standard labor and material analysis" and "current market condition analysis" data, plus the newly added "price inquiry knowledge evaluation and maintenance" operation.
2. Knowledge integration：The knowledge created in knowledge generation step which can be categorized as collective data into sub-contractor database, standard labor and material database, historical market condition database. Hence, in "sub-contractor database," besides those existing sub-contractor contact list, it's far more important to maintain with establish good business partnership to understand those sub-contractors' current and future business development guideline will elevate unit price inquiry operation with speedy efficiency; for "standard labor and material database", it is focus on accumulating the advanced technology, latest method, new material as standard labor and material analysis for facilitate the making of next budget statement to be fast but in accuracy. Lastly, the "historical market condition database" transforms the records of price inquiry result and its correlated factors of market condition during price inquiry into knowledge, not only provides the next price inquiry and negotiation as reference, it can be added the "cases comparisons analysis" in future implementation and it would be a better resource for budget statement audit. According to the accumulation of database knowledge, it greatly facilitates the budget statement audit and its adjustment basis.

Table 4 The demand performance of service gap result in double-loop learning process

Problem statement		Reduce conflict between new and old budget info	Sub-contractor price inquiry must be fast and effective	The historical case data must be easily compared
Knowledge generation	Knowledge generation	Budget structure review Work items unit price review	Work items unit price inquiry	Adjust budget statement
	Preparing knowledge	*New and old budget assessment form	* Sub-contractor data *standardized labor and material item analysis *Market condition analysis	Budget statement change order (revised)
	Knowledge assessment	Adjust budget statement	Price inquiry and knowledge evaluation and maintenance	Historical data record
Knowledge integration	Organizational knowledge	Organized common budget data and conflict data as "Budget assessment experience database"	* Sub-contractor database * Standardized labor and material item analysis database *Market condition database	*Project cost cases database
	Knowledge diffusion	* Assessment of data conflict	Establish labor and material analysis data Work items unit price inquiry Work items unit price review * Cases comparison and analysis	* Selecting historical data Budget structure review
Increase of knowledge data		*New and old budget assessment form * Budget assessment experience (Database)	* Sub-contractor data (Database) *Standardized labor and material item analysis (Database) *Market condition analysis (Database)	* Project cost cases (Database) * Cases comparison and analysis
Increase of process operation		* Assessment of data conflict	* Price inquiry and knowledge evaluation and maintenance * Cases comparison and analysis	* Selecting historical data * Historical data record

3.4.3 Establishing the New Process Model

After the performance gap of single-loop learning efficiency process and the service gap of double-loop learning process, it helps to gain with the reengineering procedure of the recommendable knowledge information, total in seven, and the newly increased procedure operation, total in five, shown in Table 4 .

As concrete form to represent previous newly added data and facilitate the practical application(s) for the enterprise procedure; Studies explore the interactive social of actual participant and the required Information Technology (IT) of knowledge process content, altogether add into the execution procedure requirements to achieve the new integrated viewpoints of e-EPC diagram same as *Fig. 4* shown [11].

3.5Process validation

After the procedure has been reengineered, it requires implement to the assessment on the new process "efficiency" and "cost", then cross-compared current process to confirm the validity of reengineering process.

3.5.1Evaluating New Target Component Achievement

In regard of evaluating operation implementation performance of newly cost estimate change order after reengineering, the estimation result shown as *Table 5* indicates, the Target Expected Achievement (TEA) rose from the original 76.7 to 95.4 and effectively make up the service gap of current process. Besides, the Real Expectation of Target component (*TRa*) rose from the original 47.2 to 84.8 and it reveals the enhancement of knowledge information application have effectively elevated the execution efficiency.

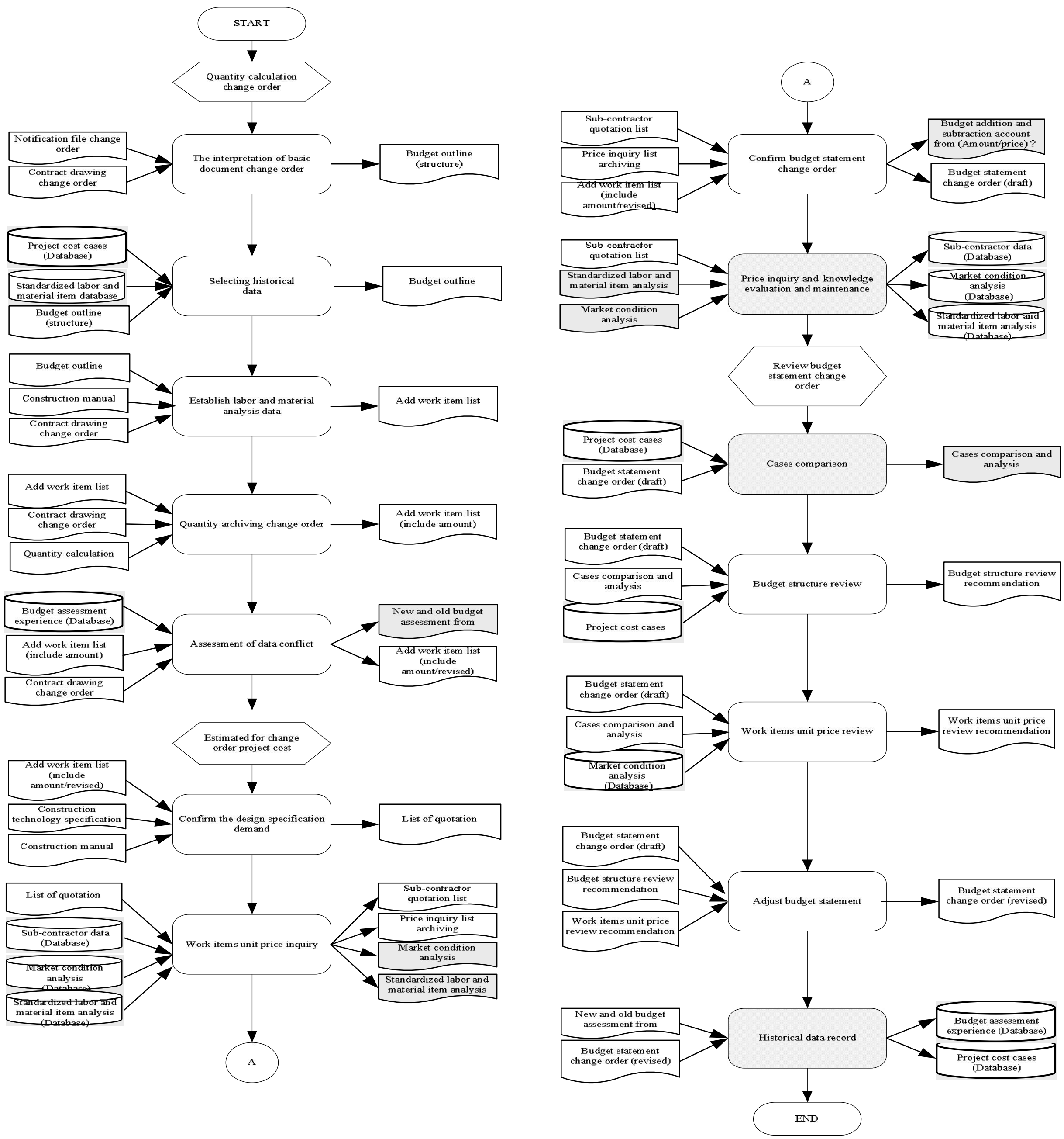

Figure 4 The procedure of cost estimate change order after reengineering e-EPC diagram

Table 5 Target component achievement matrix of cost estimate change order process

Target Components Process / Subject Operation Process		Document record change order easily inquired	Determine the accuracy of change order drawing	Standardized labor and material item analysis	Quantity calculating must be accurate	Correctly used construction manual	Sub-contractor price inquiry must be fast and effective	Work items unit price reflect the construction cost	Budget statement template	Standardized coding system	Reduce conflict between new and old budget info	Automation review process	The historical case data must be easily compared	Meet owner's demand	Confidential budget statement	Operation contribution degree value (Expected/Real)	Gap between expected and Real contribution degree value (*Gi*)
The importance of component		4.9	2.9	7.9	9.4	4.3	7.3	9.4	8.1	2.9	11.2	6.3	8.6	13.8	2.9		
The interpretation of basic document change order	Expected	0.7	0.5													4.9	0.8
	Actual	0.6	0.4													4.1	
Selecting historical data	Expected			0.1	0.2		0.1				0.1		0.1	0.1		6.8	0.0
	Actual			0.1	0.2		0.1				0.1		0.1	0.1		6.8	
Establish labor and material analysis data	Expected			0.2		0.2			0.2	0.3	0.3					8.3	1.4
	Actual			0.2		0.2			0.2	0.2	0.2					6.9	
Quantity archiving change order	Expected		0.3		0.2	0.6			0.2							7.0	2.2
	Actual		0.3		0.1	0.5			0.1							4.8	
Assessment of data conflict	Expected				0.4						0.2					6.0	0.0
	Actual				0.4						0.2					6.0	
Confirm the design specification demand	Expected	0.2	0.2	0.1												2.4	0.3
	Actual	0.2	0.1	0.1												2.1	
Work items unit price inquiry	Expected			0.1		0.2		0.2								3.5	0.9
	Actual			0.1		0.2		0.1								2.6	
Confirm budget statement change order	Expected								0.5	0.3		0.5				8.1	1.3
	Actual								0.5	0.3		0.3				6.8	
Price inquiry and knowledge evaluation and maintenance	Expected			0.3			0.5	0.4					0.2			11.5	1.6
	Actual			0.3			0.4	0.4					0.1			9.9	
Cases comparison	Expected												0.4	0.3		7.6	0.0
	Actual												0.4	0.3		7.6	
Budget structure review	Expected										0.2	0.1		0.1	0.2	4.8	0.0
	Actual										0.2	0.1		0.1	0.2	4.8	
Work items unit price review	Expected							0.2			0.2	0.1		0.1	0.2	6.7	0.0
	Actual							0.2			0.2	0.1		0.1	0.2	6.7	
Adjust budget statement	Expected	0.1						0.2		0.3		0.1		0.3	0.6	9.8	1.4
	Actual	0.1						0.2		0.3		0.1		0.2	0.6	8.4	
Historical data record	Expected			0.2	0.2		0.3						0.3			8.2	0.8
	Actual			0.1	0.2		0.3						0.3			7.4	
Expect Achievement of Target Components (EAj_j)		4.9	2.9	7.9	9.4	4.3	6.6	9.4	7.3	2.6	11.2	5	8.6	12.4	2.9	**95.4**	4.6
Real achievement of target components (RAj_j)		4.4	2.3	7.1	8.5	3.9	5.8	8.5	6.5	2.3	10.1	3.8	7.7	11	2.9	**84.8**	10.6

Table 6 Cost structure form of construction cost change estimation process after reengineering

Operation subject	Resource	Unit	Quantity	Unit price	Resource cost	Cost percentage
The interpretation of basic document change order	Budget Estimation engineer	Person/day	3	100	300	6.2%
Selecting historical data	Budget Estimation engineer	Person/day	1	100	100	2.1%
Establish labor and material analysis data	Budget Estimation engineer	Person/day	5	100	500	10.3%
Quantity archiving change order	Budget Estimation engineer	Person/day	2	100	200	4.1%
Inspection of nuclear conflict	Budget Estimation engineer	Person/day	2	100	200	4.1%
Confirm the design specification demand	Budget Estimation engineer	Person/day	3	100	300	6.2%
Work items unit price inquiry	Budget Estimation engineer	Person/day	5	100	500	10.3%
Confirm budget statement change order	Budget Estimation engineer	Person/day	8	100	800	16.5%
Price inquiry and knowledge evaluation and maintenance	Budget Estimation engineer	Person/day	2	100	200	4.1%
Cases comparison and analysis	Budget review engineer	Person/day	1	125	125	2.6%
Budget structure review	Budget review engineer	Person/day	4	125	500	10.3%
Work items unit price review	Budget review engineer	Person/day	3	125	375	7.7%
Adjust budget statement	Budget Estimation engineer	Person/day	5	100	500	10.3%
Historical data record	Budget review engineer	Person/day	2	125	250	5.2%
TOTAL			46		4850	

3.5.2 Analyzing Process Cost Structure

Study applies Activity Based Costing (ABC) as cost calculation to clarify the process structural cost.[12] The cost structure form of new process in shown in Table 6. Concentrate on confirming its reengineering result via process performance evaluation, the process performance shall apply "process cost" to process assessment and its process cost can be valued by below two methods: (1) the unit cost achievement function; (2) the unit time achievement function. In considering the time factor, which can be reflected on the operation cost, e.g. the longer working hours reflects higher cost. In addition, "efficiency" and "cost" are correlated like cause and effect; it's also never easy to expect the reengineering result can achieve the efficiency elevation with lower cost; therefore, this paper focuses on the relationship of process functions description and its cost. Meanwhile, it applies the process Target Expected Achievement (TEA) to represent the process "efficiency", and to discuss its correlation between its process Total Cost (TC) and here recommends to apply *Eq.(12)* to calculate the "Execution Efficiency of Unit Cost" to be defined as process value and as the basis to evaluate the process reengineering performance. When the new process value is higher than current process value that means the process reengineering result fits for the demands.

$$\text{Process Value} = \frac{\text{Target Expected Achievement (TEA)}}{\text{Total Cost (TC)}} \quad \ldots(12)$$

The reengineering results have respectively proceeded the analysis of current process and new process operation performance, it is found the process target expected achievement have obvious growth from original 76.7 to 95.4. The reengineering result proceeds the process total cost analysis form original 4725 to after 4850. Though the new process overall cost have risen condition, Analyzing operation efficiency and process costs before and after reengineering shows a PV evaluation (before 76.7/4725= 0.0162＜after 95.4/4850=0.0197). i.e. the new process unit cost performance have better result than the current process; therefore, the reengineering process result can be accepted.

4. Conclusion

This paper uses the highly demanded project characteristic of Professional Construction Management (PCM) as study background, applies the single-loop and double-loop learning concept applications into the fundamental process analysis and reengineering process, to construct the model of "Project-Oriented Process Reengineering for Professional Construction Management" then utilizes "Cost Estimate Change Order Process" as real case study. This Project-Oriented BPR model gains the process value of labor cost after reengineering with its efficiently raise up to 20%, and this model has been verified as operational. This paper concludes research results as follows:

1. This paper incorporates "Enterprise Process Reengineering" and "Knowledge Management Learning", then establish "Project-Oriented Process Reengineering for Professional Construction Management" to have prompt react to meet with inside and outside customers' needs, whereas it has been tested by process execution inside the professional construction management enterprise, it can be applied before the actual practice of the process to ensure meeting with customer targets and it verifies the reengineering model can greatly elevate the process efficiency and its service gap.
2. This paper first establishes "Knowledge Subject Process Target Achievement Matrix" and "The Contribution Degree of Process Target to Knowledge Subject" mathematical model, it has successfully resolved the efficiency gap within the highly demanded knowledge interpretation, and it can be act as assessment of the contribution degree of process target to knowledge subject hence for realizing the highlighted reengineering knowledge subject, and provide as the highlighted knowledge subject during reengineering.
3. This paper utilizes knowledge management single-loop and double-loop learning concept as the connected bridge as the contact of enterprise process and knowledge management, it applies Knowledge Management Construction International (KMCI) as analysis of the process efficiency and its service problems, and incorporates with the single-loop and double-loop learning performance result list to clarify the required knowledge and works in solving out process efficiency problems, then achieve the effective improvements as the fundaments for raise the creativity and ability of enterprises.
4. This paper applies the Target Estimated Achievement (TEA) to represent the process "efficiency", and discusses the process value from the unit labor cost creates; this process value index not only provides the process reengineer to evaluate the performance result after process reengineering, but also acts for management team to perform continuous improvements decision basis.

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