

# CONSTRUCTION MANAGEMENT PROCESS REENGINEERING - ORGANIZATIONAL HUMAN RESOURCE PLANNING FOR MULTIPLE PROJECTS

Min-Yuan Cheng<sup>1</sup> Ming-Hsiu Tsai<sup>2</sup>

Department of Construction Engineering, National Taiwan University of Science and Technology

#43,Sec.4,Keelung Rd.,Taipei,106,Taiwan,R.O.C

[myc@hp.ct.ntust.edu.tw](mailto:myc@hp.ct.ntust.edu.tw)

**Abstract:** Applying the business process engineering and organization planning philosophy, this study focuses on the human resource planning for the construction management process reengineering to develop the team-based human resource planning (THRP) method for humanpower allocation, which assists construction companies for scheming, and assaying humanpower allocation alternatives as the construction management process reengineering was performed. The THRP method aims at two purposes; the first is to determine what the maximum project loading of original humanpower could be carried. Also evaluate the sufficient humanpower to meet the optimal project loading in the future.

**Keywords:** human resource planning, business process reengineering (BPR), computer simulation

## 1 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” [1]. The fundamental definition of BPR as defined by Hammer is that starting from the very basic issues by reformation of the reengineering process will dramatically improve an organization in terms of its cost, quality, service, and speed. Moreover, Davenport also addressed that the process redesign, use of information technology, and the reorganization are the three critical objectives of BPR [2]. Therefore, a success of BPR depends not only on process innovation, but also on organizational changes.

Due to smash of organizational functions, new processes are easily suspended by departmental barriers within the function-based organization. Conversely, process execution will be smoother in a team-based organization [2]. A work team is a cross-functional unit which consists of workers from the related departments. In the team-based organization, department barriers will not exist, and resources can collaborate to achieve the process targets. Due to the fundamental difference between team-based and function-based structure, both of the organization and the human resource need to be reorganized to match the redesigned processes.

In addition, as companies growing, the growth of organization is a continuous process; therefore, human resource plans of the future project loading are essential for construction companies.

This study demonstrates a team-based human resource planning (THRP) model to determine the maximum project loading of humanpower, and vice versa, to evaluate the required humanpower for the expected project loadings.

## 2 TEAM-BASED HUMAN RESOURCE PLANNING FOR MULTIPLE PROJECTS

The THRP model consists of four phases to map a company’s processes to the simulation system as shown in Figure 1. Firstly, the new processes model and team-based organization structure are designed in the process reengineering phase. Then, the data preprocessing methods and the simulation algorithms are respectively analyzed and developed. Finally, all results from pervious three phases are integrated in the simulation system. By using the simulation system, the maximal capability of the humanpower, in a work team can be evaluated.

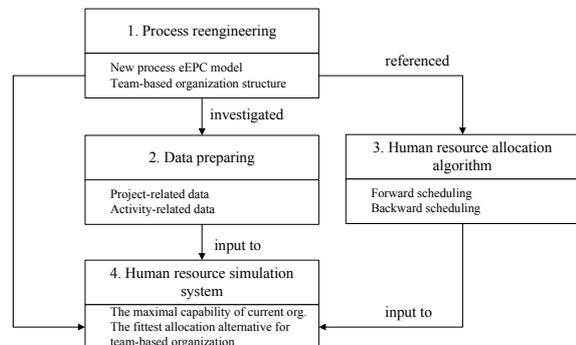


Figure 1. The THRP Model

## 2.1 Process reengineering

In the THRP, the bases of human resource planning are the rational processes and organization structure. Hence, the first phase of the THRP model is applying BPR philosophy to integrate the organizational functions smashed in different departments into independent, rational, and complete new processes. There are two primary purposes in this phase:

**Create original process model:** Using process modeling tools to represent the original management processes. As the existing process model has been done, the assessing and redesigning tasks of BPR can be subsequently executed.

**Redesign a new process model:** Identify the hidden problems of the process and to use the findings as the basis for analysis. A new process model can be drafted in accordance with the analysis of the current management problems of construction companies and establishment of the delivery of the management information technology system.

For these two purposes, this study applies the business process reengineering model addressed by Cheng [4] as shown in Figure 2.

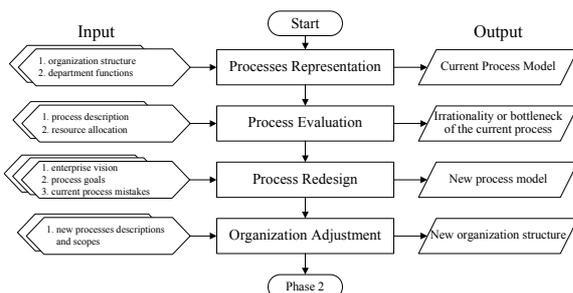


Figure 2. The Stages of Process Reengineering [4]

## 2.2 Data preparing

To simulate the humanpower performance in the processes, information such as activity duration, humanpower requirement, project loadings, etc., need to be preliminarily examined and analyzed. In this study, the required data of humanpower allocation simulation was classified into project variable and process variable. The project variables include (1) Start time of project, (2) Success Ratio of Biding, and (3) Number of Subcontracts.

On the other hand, the values of process variables differ between original processes and new processes due to changes of task contents or operation methods. Hence, the data preparing procedures of original and new process model are different.

### Data preparing of original process variables:

Activity duration with maximal humanpower is an important variable for process simulation. The activity duration is defined as the shortest operation

time with maximal humanpower for an activity. According to the investigated results, the activity duration could be simplified as a linear function of the number of workers in an activity; i.e., activity duration will decrease while more humanpower is assigned, but as workers are more than the maximum, the activity duration is not able to be reduced anymore. The variables of the activity durations can be analyzed as following:

- (1) Expectation and Variance. Summarize the data, and calculate the Expectation and Variance of durations of all activities in the process.
- (2) Goodness-of-fit analysis. The purpose of Goodness-of-fit is to test and verify the fittest probability distribution of duration of an activity. This study used the "Datafit" module in the eM-Plant to verify the fittest function of activity durations.
- (3) Schedulable ranges of processes. The schedulable range of process depicts the process duration from the early-start point of the first activity to the last-finish point of the last activity in the process. Except the bidding/contract process, the early-start points of processes are the same with the finish point of their predecessors. The last-finish points of the processes would be the early-start point plus the summarized durations of all orderly activities within the 95% confidence interval.

### Process variables of new process model

Due to lack of historical data of new process performance, the investigation rules for data of new process variables are necessary. Per investigating features of activities in new processes, three data collection rules are demonstrated as followed.

Rule 1: The duration of activities in the new process can refer to the same activities in the former process, only if there is no change in the new and former process.

Rule 2: Investigate the total operating time of information system to realize the duration of the activities which are fulfilled with the assistance of information systems, such as Estimation Information System (EIS) applied by this study case.

Rule 3: the spending time of the group decision making or of the EIS operation tasks in the new processes is estimated according to the experiences of executives.

## 2.3 Human resource allocation algorithm

The algorithm needs to provide the procedure of activity selection and humanpower assignment for the simulation system with considering the nature of complexity of operation at construction companies. Therefore, the project scheduling techniques under human resource constrains with the objective of minimizing project duration are referred; meanwhile, a proper human resource allocation algorithm stands on the multi-project scheduling with heuristic

procedures for searching approximate optimal allocation.

Forward/backward scheduling technique is the primary allocation algorithm, which evaluate the maximal and minimal humanpower allocation of activities.

#### The Forward Scheduling:

Schedule the activities at their early start times until either available resources or the schedulable activities are exhausted; i.e., each activity whose predecessors are completed and whose resource requirements are met by the currently available resource levels will be taken into the schedulable activity set. Therefore, the maximal resources are possibly assigned to upstream activities to fulfill them as early as possible, and consequently, downstream activities may be accomplished with fewer resources if project duration will not expire.

#### The Backward Scheduling:

Schedule the activities to just be accomplished at the latest finished times; that is, an activity is schedulable at a current decision time if all of its successors have been completed and its resource requirements can be met by the currently available resource levels. Thus, the minimal resources may be assigned to upstream activities while total remaining time is sufficient to complete the project.

This study addressed their corresponding algorithms as following.

#### Forward/backward scheduling algorithms:

##### Input:

- $P_i$  /processes set where  $i= 1,2,3,\dots,n$  |  $n$  is the no. of processes/  
 $Proj_k$  /projects set where  $k= 1,2,3,\dots,\ell$  |  $\ell$  is the no. of projects/  
 $lft_k$  /the last-finish time of  $Proj_k$ /  
 $A_{ijk}$  /activities set where  $j= 1,2,3,\dots,m$  |  $m$  is the no. of activities of  $P_i$  for  $Proj_k$ /  
 $m_{max}^{ij}$  /the maximal humanpower required for  $j$ -th activity of the  $j$ -th process/  
 $m_{min}^{ij}$  /the minimal humanpower required for  $j$ -th activity of the  $j$ -th process/

##### Output:

- $mf_{ijk}$  /the humanpower assigned for  $j$ -th activity of  $P_i$  for  $Proj_k$  by forward scheduling/  
 $mb_{ijk}$  /the humanpower assigned for  $j$ -th activity of  $P_i$  for  $Proj_k$  by backward scheduling/

#### Forward algorithm:

**From**  $X = 1$

**Loop until** ( $X$  .equal to.  $m_{max}^{ij}$ )

**If** ( $A_{ijk}$  is fulfilled by humanpower of  $X$ ) and (the all downstream activities are fulfilled by their minimum humanpower)

and (the  $P_i$  can be accomplished before  $lft_k$ )

**Then**  $mf_{ijk} = X$

**Else**  $X = X + 1$

**End If**

**End Loop**

#### Backward algorithm:

**From**  $X = 1$

**Loop until** ( $X$  .equal to.  $m_{max}^{ij}$ )

**If** ( $A_{ijk}$  is fulfilled by humanpower of  $X$ ) and (the all downstream activities are fulfilled by their maximum humanpower) and (the  $P_i$  can be accomplished before  $lft_k$ )

**Then**  $mb_{ijk} = X$

**Else**  $X = X + 1$

**End If**

**End Loop**

The allocation results of forward/backward scheduling are two extreme scenarios. However, due to constraints of humanpower, the human resource allocation could have conflicts between activities, processes, and projects, so that the enforced idleness owing to the conflicts has to be considered in the THRP model. For identifying the human resource conflicts, an algorithm for checking available humanpower for the scheduling activities is also addressed.

#### 2.4 Human resource simulation system

This study transferred the process context to the mathematical model which is computable to simulate functions of these processes. Therefore, there are six assumptions in the simulation system:

- (1)The property values of projects are all derived from the probability distribution functions.
- (2)Only human resource is considered.
- (3)The sequences of all activities in projects are identified, and the successor can not be started until the predecessor has been finished completely.
- (4) A single humanpower can only be assigned to one activity at the current time.
- (5) The personnel abilities are set equivalent.
- (6) The productivity of an activity is linear functions of humanpower.

Subsequently, this study schemed the development procedure of simulation system preliminarily, where the procedure includes the following steps.

##### Step1. System analysis

This summarizes the results of other three phases and creates the system scenario that guides simulation of every new process of a company. Therefore, process

descriptions and system runtime procedures are two parts of system scenarios.

The process description provides the scenario of process simulation in the system. That is, the description includes process scope, activities, number of team members, and probability distribution function (pdf) of enable event occurrence of one process. In addition, a set of humanpower allocation alternatives should be derived under the limitation of available human resource.

On the other hand, the system runtime procedure describes the mechanism for choosing the fittest human resource allocation from the set of humanpower allocation alternatives, and it also illustrates the mechanism for determining the maximal project loading of humanpower. Figure 3 shows the system runtime schedule.

### Step2. Fitness assessing indexes determination

According to the problems definition, this study uses the “humanpower idleness” index which expresses the efficiency of the human resource to evaluate the fitness of each allocation alternatives. Meanwhile, the simulation progress will not be finished until all the project loadings can not be fully accomplished by the available humanpower.

### Step3. Simulation system creation

This study uses the object-oriented simulation software named “eM-Plant” to simulate the possible allocation alternatives. The tasks in this step include : (1)system objects model creation, (2)objects allocation, (3)object attributes defining and values setting, (4)control method programming, (5)output defining. As they have been done, the relevant objects in the MainFrame module of eM-Plant corresponding to the process model is shown in Figure 4.

### Step4. System test

This research constructed an existing process model additionally, and also simulated it with the simulation model to compare the simulation results with the corresponding parameters in the real existing process. If the errors are acceptable, we can say that the simulation model is correct to represent the real system.

### Step5. System application

As the simulation model has been verified, aiming at new processes, this step applies the model to evaluate the maximal project loading of the existing humanpower, and to create the combinations of humanpower and project loadings, which are references of human resource planning while business achievement of a company is changing in the future.

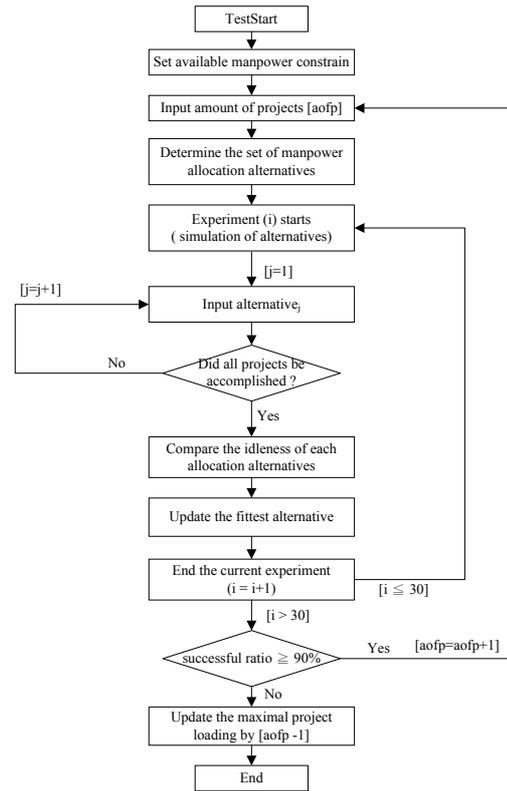


Figure 3. System Runtime Procedure

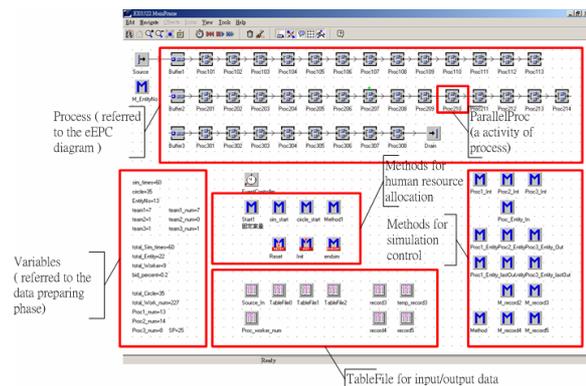


Figure 4. The Objects Allocation in the Simulation Model

## 3 CASE STUDY OF THRP

A real case of construction company “A” with intention of business process reengineering project is illustrated in this section. This study applies the THRP model to assist company “A” with reengineering the project planning process and evaluating the rationality of human resource for the new-designed process.

### 3.1 Process Reengineering Phase

Figure 5 shows the organization structure of company “A”. Due to ineffectiveness of project planning, the manager firstly chose the project planning process for reengineering, where the planning process was executed separately by

bid/contract division, estimate division and purchase division in the engineering department.

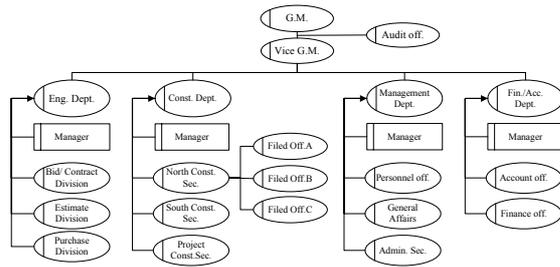


Figure 5. The Organizational Structure of Company "A" before BPR

Based on the functional organization structure of company "A" as shown in Figure 5, a project planning process was entirely executed by the engineering department, but was divided into three functional task divisions. Therefore, the process was separated into three operational categories. As executives have decided to accept the invitation for bidding of a construction project, the planning process will be enabled and be split into (1) bidding/contracting, (2) estimation/budget and (3) purchasing functional tasks, which are executed by their corresponding divisions.

Per discussion and brainstorming with senior managers, this study asserted the hidden problems within the original bidding/contract process as following:

- (1) Only quantities survey was implemented with the computer-aided software while all the other activities were finished manually.
- (2) The job loading was not proportioned to the task divisions due to a various magnitude of construction projects.
- (3) No valid history reference data of material and labor to assist estimators so that the cost estimate didn't correspond with the ruling prices.
- (4) The duration of the document circulation increased unexpectedly because all documentation had to be approved by the managers.

According these four defects, a new process model was then created. In particular, because information can be the "glue" that holds an organizational structure together [3], a cross-functional information system of engineering information system (EIS) was applied. Hence, some activities can be integrated and executed by EIS. Moreover, the approval activities, such as "review bidding examination reports" and "survey quotation tables" which are irrelevant to the objective of process, were superseded, and the decision making activities were also delegated to the decision group. Consequently, the existing bidding/contract process was integrated into a shortened and efficient new process.

Figure 6 shows the team-based organization structure of company A corresponding to the new project planning processes. The primary differences between the former and the team-based structure are the

formations of the decision group and the engineering project teams. The engineering project team, which combines cross-functional skills, is responsible to entire project planning process.

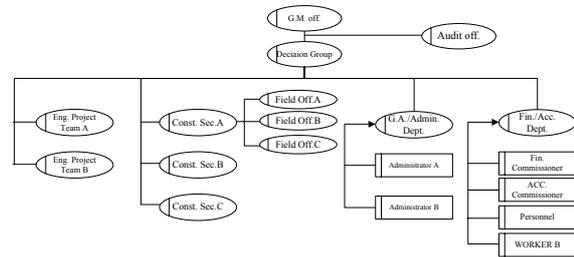


Figure 6. The Organizational Structure of Company "A" after BPR

However, due to lack of teamwork experience, the rational humanpower of a team is difficult to estimate.

### 3.2 Preprocessed Data

In the data preparing phase, the values of project variables and process variables were estimated.

#### Project variables:

- (1) Start time of project. For company "A", projects began irregularly, so "Uniform Distribution" is applicable to characterize the start point of a project. In other words, projects are assumed to be enabled with equal probability in every month.
- (2) Success Ratio of Bidding. By counting the successful times of historical bidding data, the ratio of successful bidding of company "A" is set at "20 %".
- (3) Number of Subcontracts. Based on the historical data of company "A", eight projects had been finished sequentially from May 1999 to October 2000, and the number of subcontracts of each project is counted in the range from 20 to 36 with an average of 25.

#### Process variables

The process variables of both original and new-designed processes were estimated. In the estimated results, activities with their humanpower, probability distribution functions, and durations with up-boundary of 95% confidence interval are evaluated.

### 3.3 Human Resource Simulation

This study takes the "project planning process" of the company "A" as an example in this section. After a model test with the original project planning process, the results of maximal project loading and average humanpower idleness match the real situations. After model test, new-designed project planning process is finally modeled in the eM-Plant system, and evaluated with two criteria: (1) the number of members of engineering project team is a constant of seven, which is total humanpower of the engineering

department; (2) take the number of team members as an independent variable for the maximum project loading, by which the combinations of humanpower and project loading can be estimated. For the first simulation criteria, Figure 7 shows the allocation alternatives.

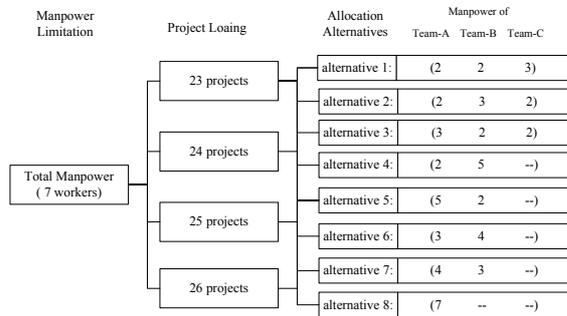


Figure 7. The Humanpower Allocation Alternatives Tree of The Engineering Project Team

With applying the forward scheduling method, the success ratio was always higher than 90% while the project loading was under 25 projects, and it decreased to 83% (less than the threshold of 90%) as the loading increased to 26 projects. Therefore, the maximum project loading of seven members is evaluated 25 projects. Likewise, as the backward scheduling method was applied, the success ratio was always higher than 90% as the project loading was under 40 projects, and it would decrease to 80% as the loading increased to 41 projects. Therefore, the maximum project loading of seven members is 40 projects while the backward scheduling method was applied.

Because the forward scheduling deploys the maximum resource at the beginning of a project to accomplish the process as soon as possible, the capability of humanpower might be limited by the more resource conflicts than that in the backward scheduling method. Therefore, this research speculates that the common project loading is between the two above referenced extreme cases. Based on this corollary, the margin of company A's manpower was adapted to 25 of minimum to 40 of maximum projects.

For the second criteria, we extended the humanpower limitation of the engineering project team up to 15 workers to simulate the possible growth of the organization, and estimate their corresponding capabilities. The simulation results are shown in the Figure 8. From Figure 8, we can find the project loading range of one specific humanpower limitation simulated by the system, which can be a reference for determining whether the project loading matches to the humanpower. Thus, managers could estimate the efficiency or requirement of humanpower based on the number of projects.

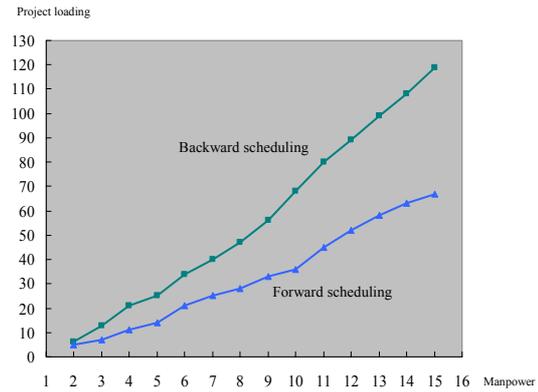


Figure 8. The Humanpower Capability Curves of The New Project Planning Process

#### 4. CONCLUSION

This research addressed the team-based human resource planning model to facilitate human resource allocation for process reengineering. With the THRP model, the maximal project loading of existing humanpower could be evaluated; moreover, the relations between project loading and the maximal humanpower were also created based on the new-designed processes. Finally, the conclusions of this study are addressed as following :

- (1) This study implemented the human resource allocation algorithms of the forward/backward scheduling methods with the eM-Plant simulation system, and the results have been verified that the process model in simulation system is close to the reality.
- (2) The results of the simulation model illustrate the different efficiency of the humanpower operation between the existing and the new processes. This infers that the integration of the cross-functional processes and the human resource caused by the process reengineering would increase the performance of one enterprise.

#### REFERENCES

- [1] Hammer, M., "Reengineering work: Don't automate, obliterate", Harvard Business Review, pp. 104-112, 1990.
- [2] Hammer, M., and Champy, J., Reengineering the corporation—A manifesto for business revolution, HarperCollins, New York, 1993.
- [3] Davenport T.H., Process Innovation, Harvard Business School Press, Boston, MA, 1993.
- [4] Cheng M.Y., Tsai M.H., "Reengineering of Construction Management Process", Journal of Construction Engineering and Management, pp.105-114, 2003.