WHY USE ENACTABLE MODELS OF CONSTRUCTION PROCESSES?

By Geetha Abeysinghe[1] and Dominic Urand[2]

ABSTRACT: Construction is a process-based industry. In such an industry it is important to have a clear understanding of the process. One way to achieve this is by the use of a process model. In a European Community funded research project the business process of a small U.K. construction company was modeled and analyzed. Both visual modeling and enactable modeling techniques were used in this exercise. This paper aims to show how process understanding can be better achieved by a combination of visual models and enactable models. This is supported by examples from the construction company process studied. The tools and techniques used in this exercise are those developed by the collaborators of the project. The visual modeling is done using ProcessWise WorkBench and Role Activity Diagrams. The view of the business process given by the ProcessWise WorkBench models is predominantly process based, whereas Role Activity Diagrams provide a role based view of the process. The enactable modeling is done using RolEnact, a modeling tool that enacts formal specifications of processes.

INTRODUCTION

It is important for a business organization to have a clear perspective of how the organization achieves its objectives and aims. The perspective of the business process can differ at different levels of the organization (e.g., the director's view, the manager's view, and the accountant's view). These views of the business process may differ from one another and to the view given by the organizational documents such as the quality manual.

There is a need for companies to identify and have a better understanding of their processes. Many industry representatives agree that most companies do not know their processes well (Elzinga et al. 1995).

For an industry to survive in a competitive market it must adapt emerging technologies to increase its efficiency. When change becomes necessary, it is essential to establish the best way of making that change and to be able to evaluate the effects before implementing them. All these lead to the necessity of finding better ways of representing a business process. Business process modeling is one way of achieving this end. ''Process modeling'' has come to be associated with a number of ideas that, in general, are all concerned with the dynamic behavior of organizations, businesses, or systems (Snowdon 1994).

The model of the business process should be easy to understand, easy to change, and easy to correct and above all should represent the process correctly. In this paper two kinds of process models are dealt with: visual models and enactable models. Visual models are simple graphical models that are easy to use, easy to change, and easy to understand. Enactable models provide a way of stepping through the process in a logical way and make the process steps clearer by distinguishing one logical path from another.

There are a number of methods and tools available for process modeling today. These vary from formal methods, notations, and visual modeling tools to simulation techniques. In this exercise we use two modeling techniques: visual modeling and enactable modeling. Visual modeling enables the construction of abstract representations using graphical descriptions of the phenomenon being studied (Alabastro et al. 1995). Visual representations are easier to understand than the more formal representations and therefore are more suitable in process elicitation and as a presentation medium. Enactable modeling produces abstract representations of the process studied that enable the modeler to simulate the process activities. Enactable models are useful in process verification and experimentation. They enhance the process knowledge giving the modeler a better understanding of the event sequence. It is the writers' belief that visual models, although easier to understand, are unable to capture all the information relating to the process. The aim of this paper is to show how a combination of a visual model and an enactable model provide better process understanding.

In the second section the need for construction process understanding and the activity of process modeling and its place in the construction industry are briefly discussed. In the third Section the method adopted in modeling the tendering process studied is described. The fourth section describes the different types of user-facing modeling (Abeysinghe and Phalp 1996) methods used in this paper. The use of enactable models is discussed; RolEnact, the modeling paradigm used to produce enactable models, is described in the fifth section. The sixth Section describes the studied tendering process. In the seventh section the usefulness and the insufficiencies of the two models produced are illustrated with examples. The final section presents the conclusions and the observations made from this exercise.

PROCESS MODELING IN CONSTRUCTION INDUSTRY

Alabastro et al. (1995) defined modeling as ''the process of developing and providing an abstraction of reality, i.e., a model.'' When the modeling activity is aimed at describing business processes we term it as ''business process modeling.'' Gruhn (1995) defined a ''business process'' as a set of logically related activities, which are carried out to reach a defined outcome.

Construction is a process based industry (Halpin 1993). The researchers in the forefront of the industry have recognized the importance of modeling and understanding the construction processes to bring improved methods and technology to the industry. In his Peurifoy address Halpin stressed the need to study construction processes, operations, and states:

> . . . the basis for the study of construction lies in the area of process modeling and simulation. Since construction is a process-based industry, we must strive to improve our

[1]Lect., Middlesex Univ., The Burroughs, London NW4 4BT, U.K.; formerly, Postdoctoral Res. Fellow, Declarative Sys. and Software Engrg. Group, Dept. of Electronics and Comp. Sci., Univ. of Southampton, Southampton SO17 1BJ, U.K. E-mail: geetha1@mdx.ac.uk

[2]Information Mgr., P. Trant Ltd., Hollybank House, West St., Hythe, Southampton, SO45 6ZG, U.K.; formerly, Res. Asst., Business Engrg. Group, Dept. of Civ. Envir. Engrg., Univ. of Southampton, Southampton SO17 1BJ, U.K.

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J. Constr. Eng. Manage., 1999, 125(6): 437-447

construction methods and processes. But in order to develop new processes, we must better understand the present processes, which are in place.

As in any other industry the construction market has become very competitive. Clients are looking for more cost-effective methods, and those who can develop more efficient and cost-effective construction processes will dominate the market (Halpin 1993). Innovation is increasingly being recognized as essential to the success of the industry (Laborde and Sanvido 1994). Thus process understanding has become a fundamental necessity for success.

METHOD

In a European Community Esprit Framework 4 funded research project, CORE (COnstruction companies process RE-engineering), the business process of a U.K. based small construction company was studied. [Esprit (European Strategic Program for Research and IT), the new information technologies program, is an integrated program of industrial research and development projects and technology take-up measures (further details can be found at ⟨http://www.cordis.lu/esprit/home.html⟩). During the period 1994–1998, all Community Research and Technology Development activities were carried out under the Esprit Fourth Framework Program (see ⟨http://www.cordis.lu/cordis/02.html⟩ for further details). CORE is a European research project that aims toward a successful business process re-engineering in the construction industry (CORE 1995).] One of the lessons learned during this exercise is that process understanding is better achieved by the use of both visual models and enactable models. The aim of this paper is to present those findings.

This paper contains a real-life case study of the tendering process of a construction company. Visual models of the examples are first produced using the ProcessWise WorkBench, Standard Edition (PWBS) (*ProcessWise* 1995), a graphical modeling tool provided by International Computers Ltd. (available at ⟨http://www.icl.co.uk/cguide/cg5b0002.html⟩). The initial model was developed using the input obtained by the analysis of existing documents and by interviews carried out with the process actors. This initial model also acted as a framework for further knowledge elicitation.

PWBS models give a predominant process view of the business process. The modeling paradigm very closely resembles standard Data Flow Diagrams (DFD), and understandably the modeling is very data intensive. The tool does not enforce a specific modeling method (such as IDEF) by which the notation provided is to be used. This gives the modeler the flexibility to use the notation as suitable for a particular modeling exercise. However, there are certain restrictions imposed on the drawing mechanism as with any drawing tool, which results in models similar to Data Flow Diagrams. PWBS also provides certain built-in static calculation and simulation capabilities, such as cost calculation, volume calculation, and dynamic simulations. These capabilities have not been pursued in this paper.

PWBS models can also provide a partial role view of the business process modeled. This role view is enhanced to give a complete role view of the process by mapping the PWBS models to a subset of Role Activity Diagrams (RADs) (Ould 1995).

The combination of views provided by PWBS and RAD models gives an overall pictorial description of the business process. The PWBS models highlight which processes are dependent on others for resources (or inputs), which are independent, and which are overburdened with too many activities, whereas the RAD models highlight where resources are overused (i.e., which role is overworked and which is idle).

The RAD models also make the transition from the visual model to the enactable model easier. The enactable modeling

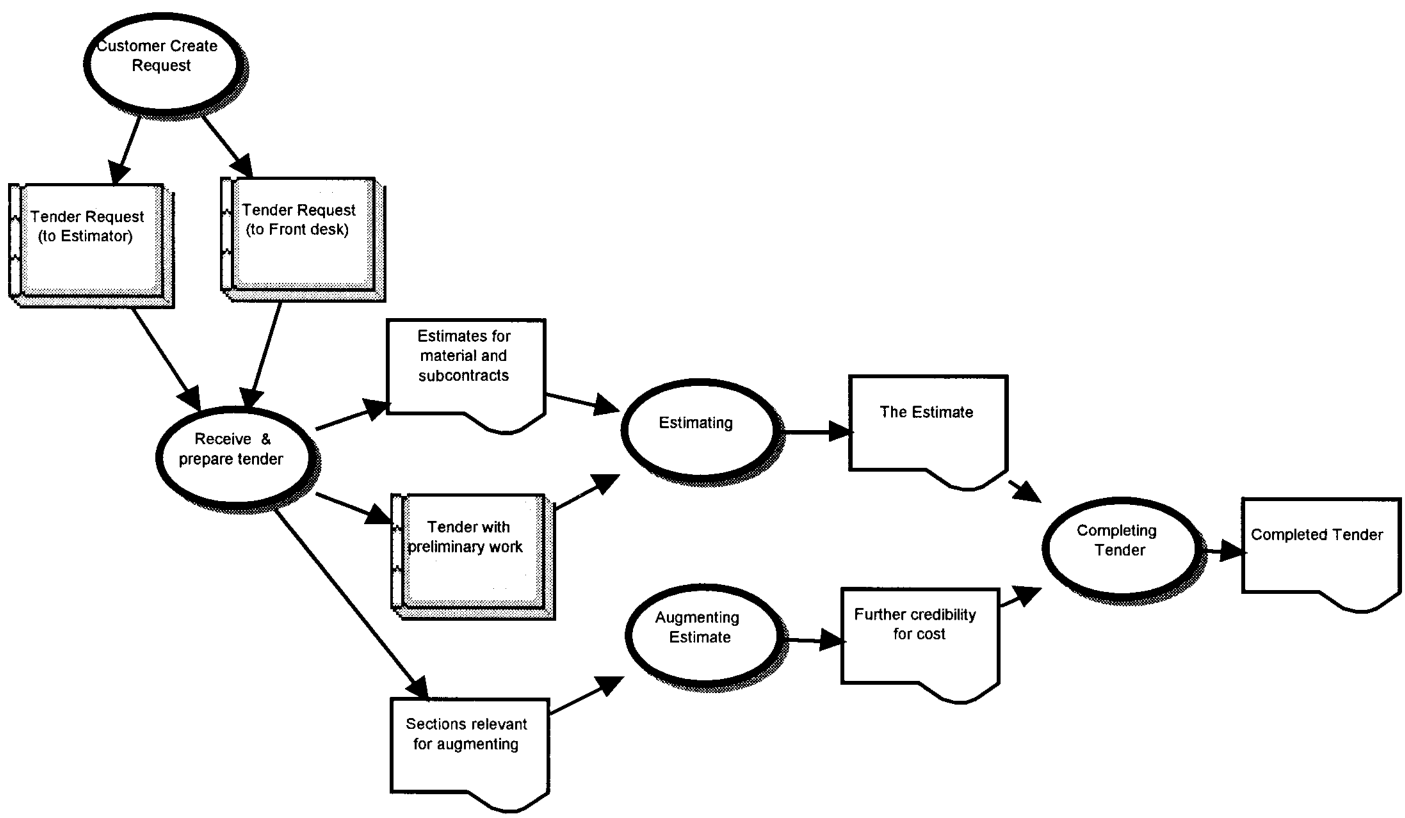

FIG. 1. Top View of Business Process Given in PWBS

J. Constr. Eng. Manage., 1999, 125(6): 437-447

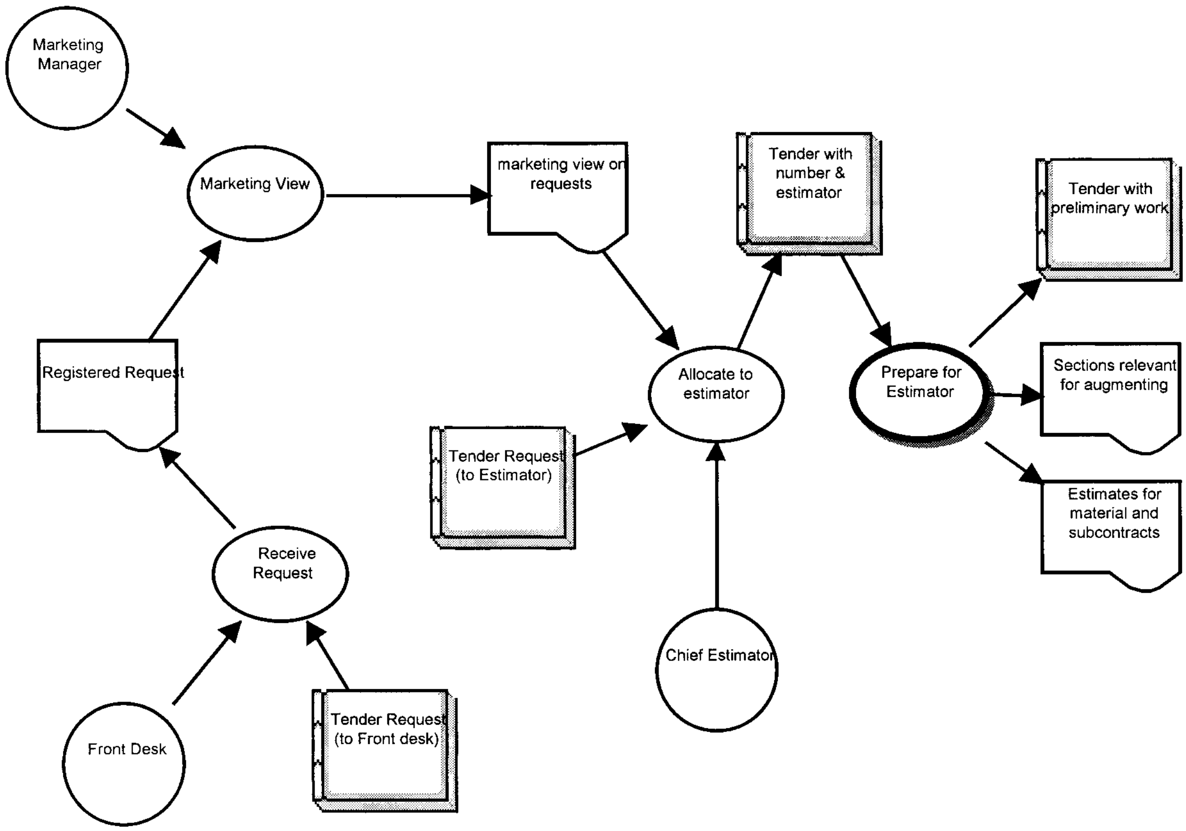

FIG. 2. Expansion of "Receive & Prepare Tender" Process

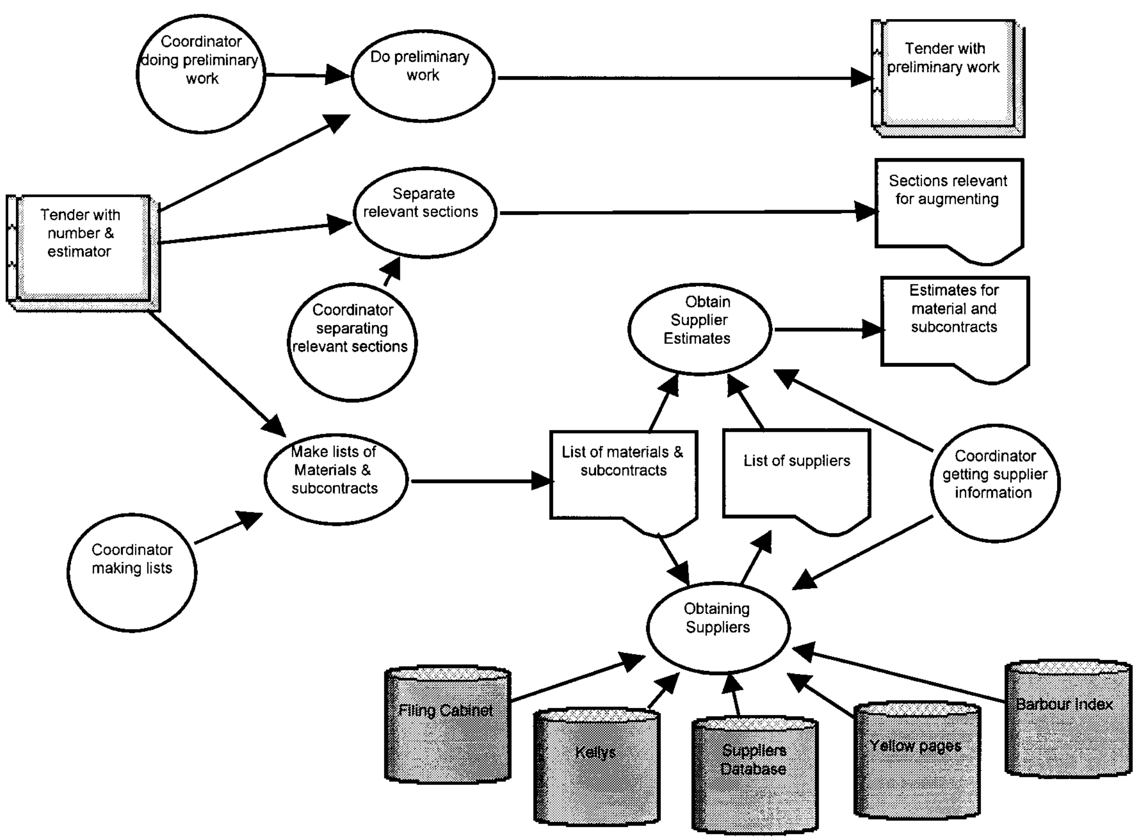

FIG. 3. Expansion of "Prepare for Estimator" Process

J. Constr. Eng. Manage., 1999, 125(6): 437-447

paradigm used is the in-house modeling tool RolEnact (Henderson 1995b; Abeysinghe et al. 1997). RolEnact is based on roles and the activities each role can engage in. Thus the RAD models can in a way be considered as pictorial views of the RolEnact models.

The decision to use these tools was made by their availability and the desire to see how well they can be used for modeling purposes in the construction industry.

USER-FACING MODELS

A process model can be constructed either for a specific audience or for a general one. The models that are aimed at the world at large need to be simple enough to be understood by anyone. Such models are termed as user-facing models (Phalp 1996). In the initial stages of this exercise, visual modeling is used as a knowledge acquisition tool, which uses pictures to facilitate the communication process. These ''pictures'' are used to elicit the experts' representation of reality (Alabastro et al. 1995). An advantage of this exercise of process elicitation is that through the procedure of describing and agreeing on the process, potential opportunities for improvement may be immediately revealed (Elzinga et al. 1995).

Example: Tendering Process in Construction Industry

First, to outline the studied process, the tendering process receives from a customer a request for a tender for a construction project, and then it responds with an estimate of the cost of the project together with supporting documentation.

PWBS

Fig. 1 shows the uppermost view of the tendering process modeled in PWBS. The model is represented as a network of objects: processes, business objects, and roles. The ellipses represent processes. Between the processes are business objects that represent the data or information passing from one process to the next. There are different types of business objects (e.g., the squares represent documents). The arrows indicate the direction of flow.

PWBS models can be hierarchical. A process can be expanded to show more details at a lower level. Such expanded processes are represented with a heavy outline. In Fig. 1 all processes have been further expanded. At the lowest level, the model may resemble a data flow diagram. It is important to decide to what level of detail the process should be modeled. Too much detail can make the model complex and will also restrict the generality of the model.

In Fig. 1, the *Customer Create Request* process represents the customer generating a request for a tender for a particular construction project. A request for a tender from the customer can reach the organization via two routes: directly to an estimator, or by the postal system to the front desk. The *Receive & prepare tender* process receives the request for tender, takes

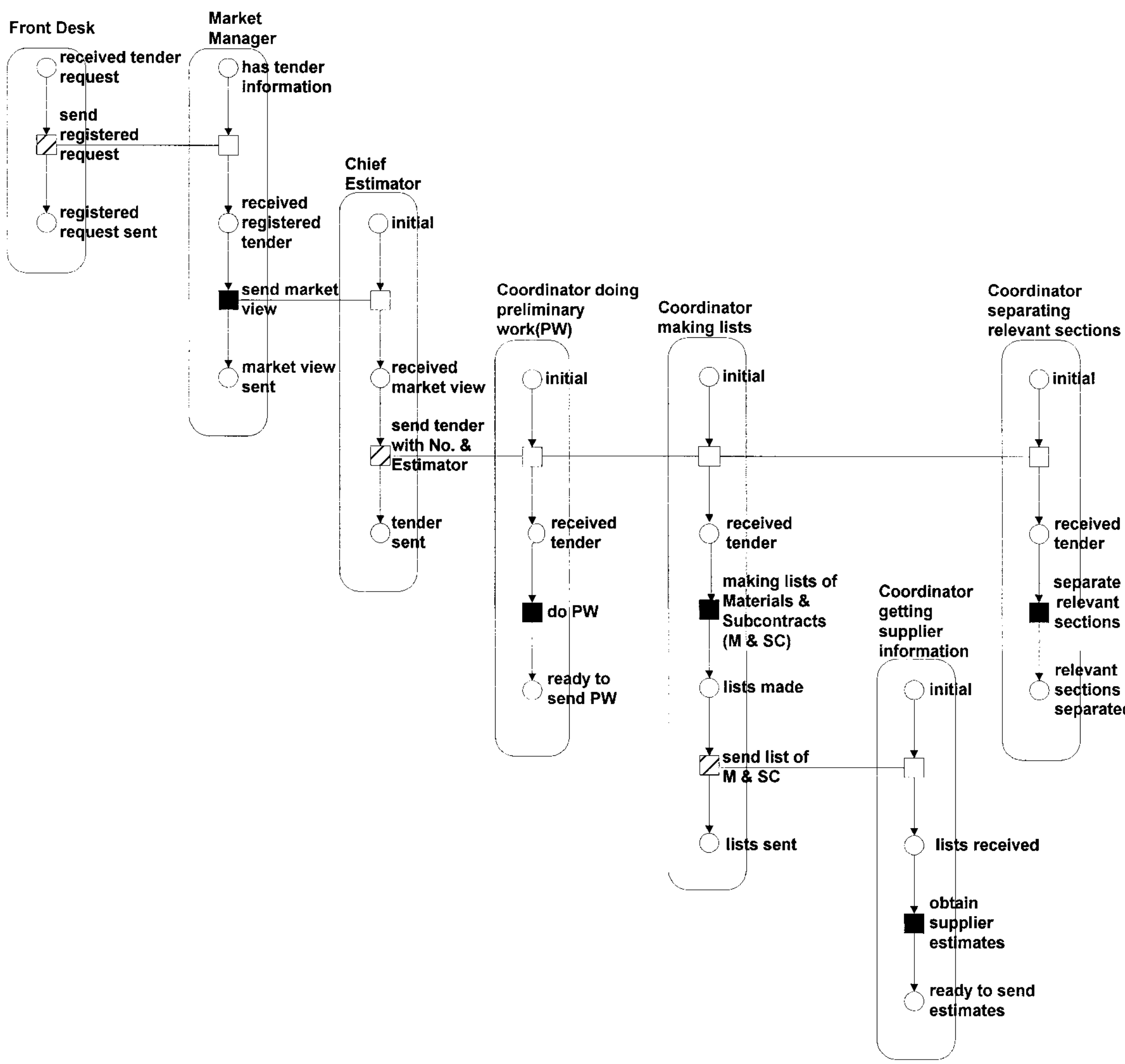

FIG. 4. RAD Model Corresponding to PWBS Models Given in Figs. 2 and 3

J. Constr. Eng. Manage., 1999, 125(6): 437-447

initial decisions on the tender, and plans the development of the reply. The output from this process goes to two processes: *Estimating* and *Augmenting Estimate*. The *Estimating* process estimates the cost of the construction project. The *Augmenting Estimate* process creates the additional material (such as quality plan, health and safety information, insurance certificates, and performance bonds) that does not directly affect the cost estimate but reinforces its credibility. The *Completing Tender* process adjusts the estimate to take account of commercial considerations, gathers together all the material generated earlier into a coherent reply, and submits the reply to the customer.

A part of the tendering process is described in detail by expanding into lower levels. These lower level views will be used to highlight how the weaknesses of the static PWBS models are set off by the strengths of the enactable model.

Fig. 2 shows the expansion of the process *Receive & prepare tender* (shown in Fig. 1). In Fig. 2, circles (linked to processes) represent roles, which perform those processes. These roles may not map onto physical roles in the organization; rather they represent the logical roles of the process.

In Fig. 2 the *Receive Request* process represents the receipt of the request by the company. The request may come to the front desk via the postal system or may come via an employee. Its receipt is registered so that its subsequent progress may be monitored. The *Marketing View* process represents the interactions between the Tendering and Marketing processes. The Marketing Department gives a marketing view on requests indicating whether or not they are commercially important and recommending how they should be handled. The tender is then allocated to an estimator, which may be one person or a team of people depending on the scale of the project, represented by the process *Allocate to estimator*. The *Prepare for Estimator* process represents preliminary work done on the request before it is passed to the estimator. This is normally done by the coordinating estimator, who makes a list of the tasks that are required to generate the reply and sends information to the people who perform these tasks. Fig. 3 shows the details of the *Prepare for Estimator* process.

In Fig. 3, the *Do preliminary work* process carries out the necessary preliminary work before sending the tender request to the estimators. The *Separate relevant sections* process separates the parts of the customer's request. These sections are forwarded to the relevant experts on quality, environment, insurance, performance bonds, health and safety, legal, financial, and construction methods. The *Obtain Supplier Estimates* represents the coordinating estimator and the estimator obtaining estimates for materials and subcontracts from existing or potential suppliers. Two outputs produced, namely, *Estimates for material and subcontracts* and *Tender with preliminary work*, are then input to the *Estimating* process (Fig. 1).

RADs

RADs (Ould 1995) represent a role view of the business process. In process modeling a role is a list of responsibilities assigned to an agent to be followed in a specific order. Such an agent needs to interact with other roles to assist in part of a process (Fereidoon and Warboys 1995). A RAD model is a network of roles interacting with each other.

Fig. 4 shows the RAD model corresponding to PWBS models given in Figs. 2 and 3. Each curvy edged rectangle represents a role. A role is read from top to bottom (i.e., the vertical lines represent control threads). A role has a state represented by a labeled circle. For example, the "Front Desk" (in Fig. 4) when in the state "received tender request" is able to send the registered request to the "Market Manager," who is in a state "has tender information."

An action carried out by a role is represented by a square. An action changes the state of the acting role. An interaction

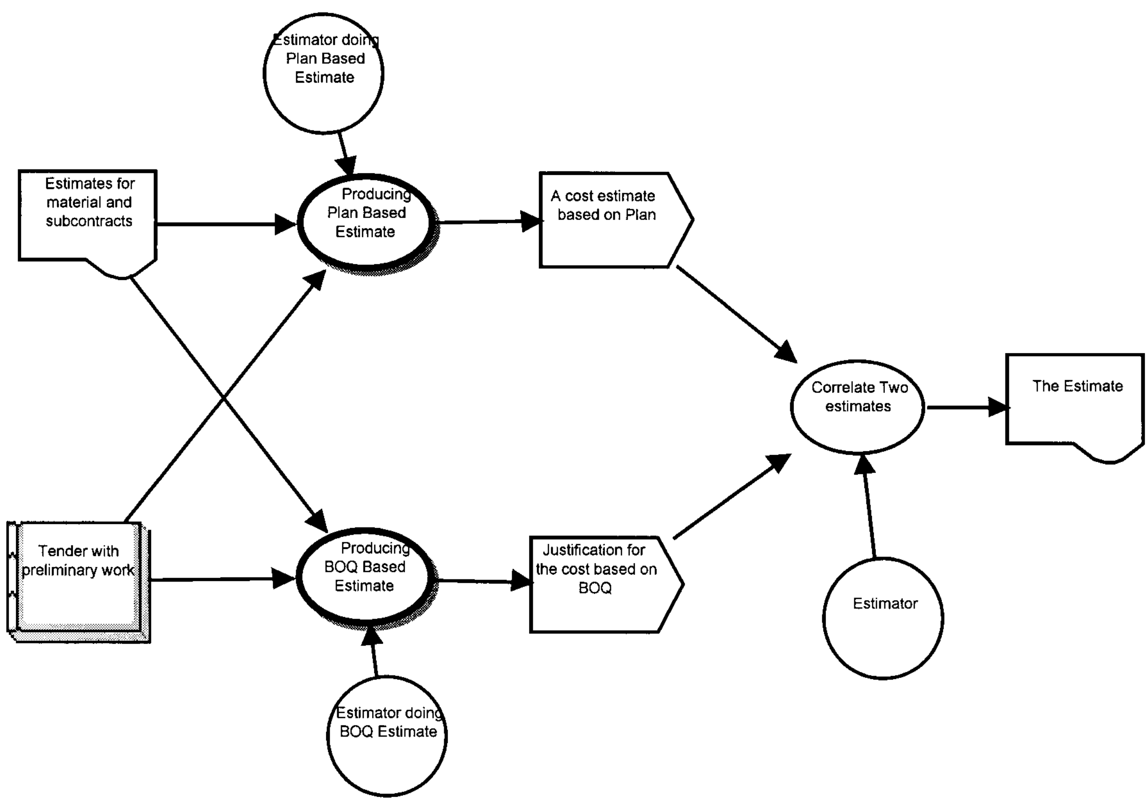

FIG. 5. Expansion of "Estimating" Process

J. Constr. Eng. Manage., 1999, 125(6): 437-447

needs the participation of more than one role. An interaction changes the state of all roles involved. A horizontal line joining the relevant activity squares of the involved roles represents an interaction. The shaded square of an interaction indicates the role that initiates or drives the interaction. For example, in Fig. 4, the interaction ‘‘send market view’’ is initiated by the ‘‘Market Manager’’ by sending the market view to the chief estimator when it is ready.

The RAD models are used as an intermediate between the PWBS and RolEnact. RADs give a good visual representation of a role based view of the model and also give a near enough visual representation of the RolEnact models.

Visual representations of business processes are easier for the layperson to understand and are quicker to use and change. However, their capability of information representation is limited. For example, one of the limitations of the PWBS models is their inability to explicitly represent the logical steps of a process. When there is more than one outward path from a particular process, the PWBS model is incapable of representing the logical sequence of those paths (i.e., whether they are alternative, parallel, or sequential).

Enactable Models

One drawback of most static models is that they do not easily highlight bottlenecks in the process. However, they enable easy identification of roles and processes that are very busy. These drawbacks can be overcome by having an enactable model. For example, bottlenecks can be discerned by logically stepping through the model. Enacting also helps the modeler to obtain confirmation that the model represents reality, or where the purpose of the modeling exercise is process change, whether the modeled change is one that is desired.

RolEnact, a paradigm based on roles and the events that the roles participate in, was chosen for this exercise. RolEnact is a windows based application written in Enact (Henderson 1993, 1995a; Abeysinghe et al. 1997), a hybrid of object oriented and functional languages, used for system and process modeling.

RolEnact

The primitives of RolEnact match those of role based models (Abeysinghe et al. 1997). Processes are described in terms

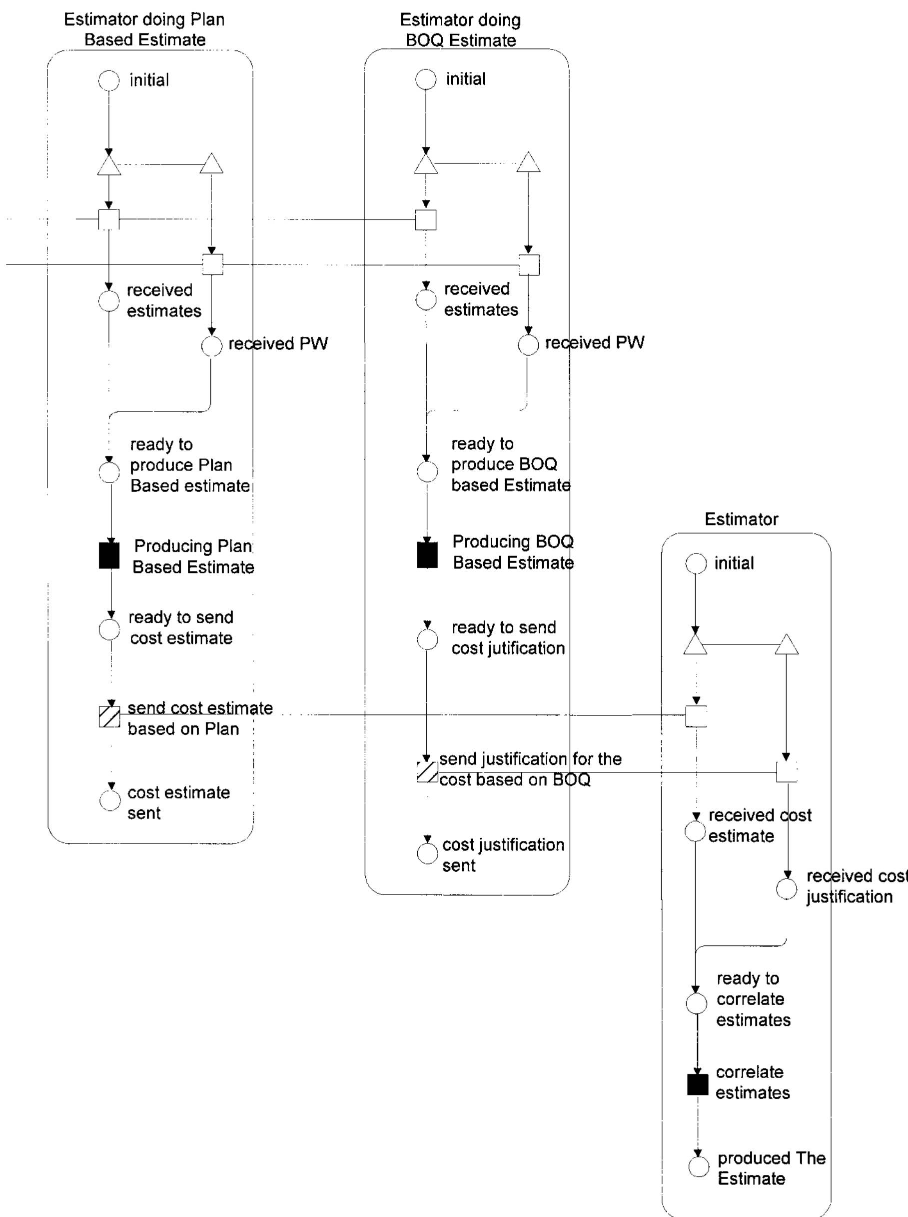

FIG. 6. RAD Model Corresponding to Fig. 9

J. Constr. Eng. Manage., 1999, 125(6): 437-447

of roles, states of the roles, and the activities or events in which each role may take part. It relates closely to RAD diagrams. The difference being that a RAD model represents the types of roles that are in the model, whereas a RolEnact model can simulate scenarios containing the instances of each role type.

In RolEnact, each instance of a role is represented by a separate window. The title bar of the window contains the role name postfixed by a digit. The digit distinguishes each instance of the role. For example, Customer0 and Customer1 are two instances of the customer role. Each window has three distinct parts: (1) A menu displaying a list of events that the role may perform; (2) a text box that displays the current state of the role; and (3) a ‘‘do’’ button. The arrowed events are available to be enacted (i.e., they are allowed to happen) in the current state of the system (Henderson 1993).

The aim is to demonstrate how the weaknesses of the static PWBS models are set off by the strengths of the enactable model. The two models complement each other providing a modeling environment that is better suited to process understanding.

Clarifying Event Sequence

The expansion of the process *Prepare for Estimator* is shown in Fig. 3. As can be seen from the figure, the process has three threads of activity each producing an output. The *Do preliminary work* process produces the *Tender with preliminary work*, the *Separate relevant sections* process produces *Sections relevant for augmenting*, and the *Obtain Supplier Estimates* process produces *Estimates for material and subcontracts*. The model does not explicitly imply in which order each process is carried out in reality (e.g., whether the *Make list of Material & Subcontracts* process follows the *Separate relevant sections* or whether they can be carried out in parallel).

In a RAD model the roles are assumed to act in parallel. For example, the three parallel threads in Fig. 3 mentioned above are represented by three individual roles in Fig. 4, namely, ‘‘Coordinator doing preliminary work,’’ ‘‘Coordinator making lists,’’ and ‘‘Coordinator separating relevant sections.’’ In reality, these three roles may be executed by the same agent in the organization. The RAD model clearly indicates that after receiving tender with number and estimator the three processes, *Do preliminary work*, *Separate relevant sections*, and *Make list of Material & Subcontracts*, can be carried out in parallel.

Fig. 5 shows the PWBS model of the expansion of the *Estimating* process (Fig. 1). Estimating the cost of a construction project is normally done in two ways: one based on a plan of the project, and the other based on a list of deliverables [known as a bill of quantities (BOQ)].

In the *Producing Plan Based Estimate* process a plan for the construction project is developed showing tasks, plant, labor, materials, and subcontracts that are required on the project. A cost estimate is produced based on this plan.

The customer normally provides a BOQ with his/her request or expects the company to produce one. This lists the deliverables (e.g., meters of pipe laid or wall built) that the cus-

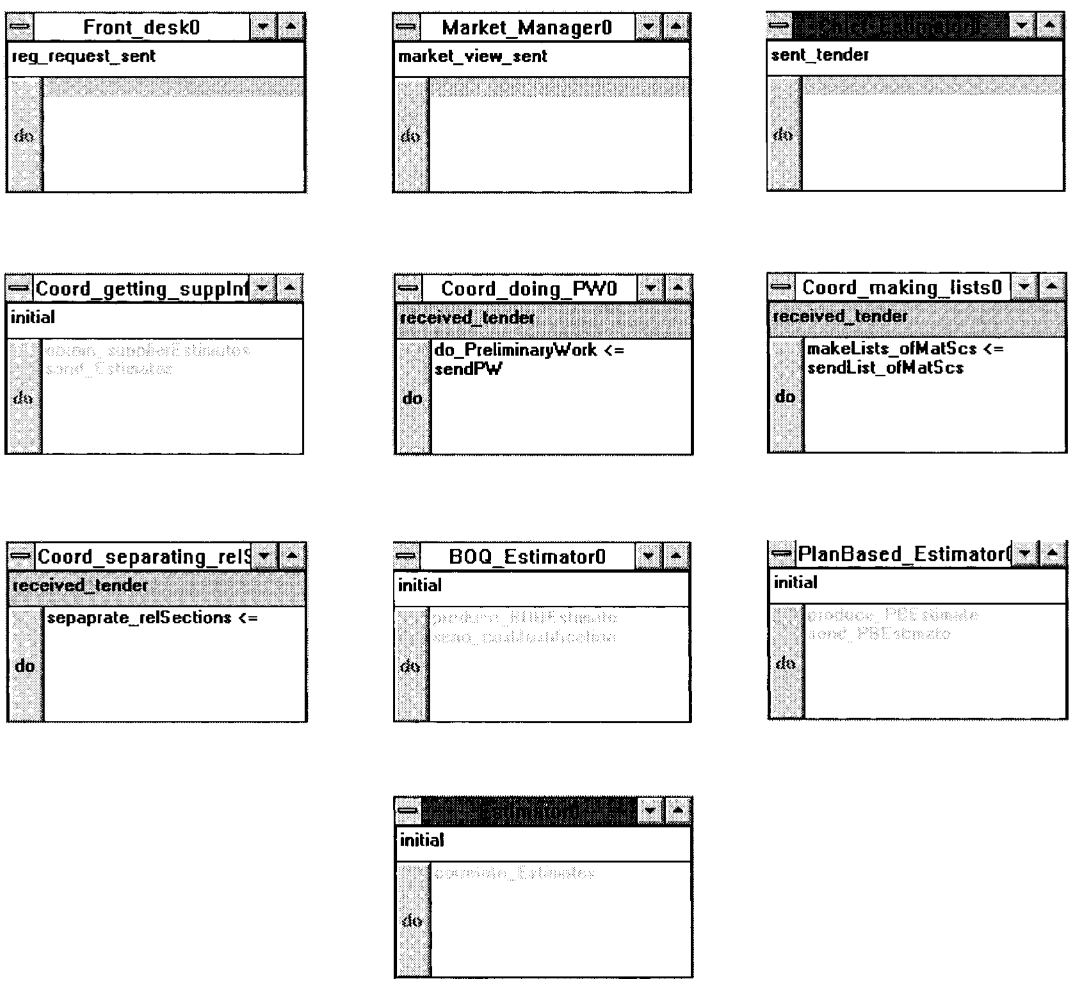

FIG. 7. Snapshot of RolEnact Model Showing State of System after “Chief Estimator” Has Sent Registered Tender Request to Relevant Coordinators

J. Constr. Eng. Manage., 1999, 125(6): 437-447

tomer expects to be generated by the project. The company is expected to justify its cost estimate in terms of this BOQ. The *Producing BOQ Based Estimate* process generates this justification.

The shapshot of the model shown in Fig. 5 indicates that two processes, *Producing Plan Based Estimate* and *Producing BOQ Based Estimate*, require two inputs, *Estimates for material and subcontracts*, and *Tender with preliminary work*. What is not clear is the order in which the inputs are required by each process. Can the two processes start without any input, or can they start with one input and receive the other later? The answer is not apparent, particularly to someone who is unfamiliar with the process. However, when the model was presented to the process actors they agreed that the PWBS model depicts the business process correctly.

The RAD model corresponding to Fig. 5 is shown in Fig. 6. A triangle in a RAD indicates concurrent activity. For example, in Fig. 6 the role *Estimator* has two concurrent threads of activities, each representing a single interaction with another role. The *Estimator* interacting with the role *Estimator doing Plan Based Estimate* and the role *Estimator doing BOQ Estimate*. Each interaction is independent of the other.

In the next stage of our modeling, a RolEnact model is produced that maps onto the RAD models described in Figs. 4 and 6. (The reader will find it easier to understand the scenarios described below by comparing the descriptions with the RAD models given in Figs. 4 and 6.)

Fig. 7 shows the system in the following state: the registered tender request has been sent by the *Chief Estimator* and received by the *Coordinator doing preliminary work*, *Coordinator making lists*, and the *Coordinator separating relevant sections* (Fig. 4). This state is indicated by the state of the *Chief Estimator* role being *sent_tender* and the states of the latter three above-mentioned roles being changed to ‘‘*received tender*.’’

In Fig. 7, the active roles are highlighted by changing the color of their state bar to nonwhite and their event lists being made available. The state bars of the inactive roles are white, and the lists of events are in gray or disabled. We have tried to keep the role names and the action names in the RolEnact model as close as possible to those given in the RAD model. The slight difference in names of the roles and actions are due to the naming convention forced by the Enact language.

In the state of the system represented in Fig. 7, there are three parallel threads of activities that can be carried out. The *Coordinator separating relevant sections* (*Coord_separating_relSecs*) can carry out the action, *separate relevant sections* (*sepaprate_relSections*), separating relevant sections of the tender request to be sent to relevant people (e.g., legal, finance, insurance and bond, environmental and quality). The *Coordinator doing preliminary work* (*Coord_doing_PW*) can now carry out the necessary preliminary work (*do_PreliminaryWork*) before sending the tender request to the estimators. The *Coordinator making lists* (*Coord_making_lists*) can make lists of materials and subcontracts (do *makeLists_ofMSC*).

Now, if the *Coord_doing_PW* enact its possible event, *do_PreliminaryWork*, it will be able to send the preliminary work completed to the Estimator doing Plan Based Estimate (*PlanBased_Estimator*) and the Estimator doing BOQ Estimate (*BOQ_Estimator*) by enacting the next possible event, *sendPW*. The state of the system after the enaction of *sendPW* is shown in Fig. 8. Note that the state of *Coord_doing_PW* is

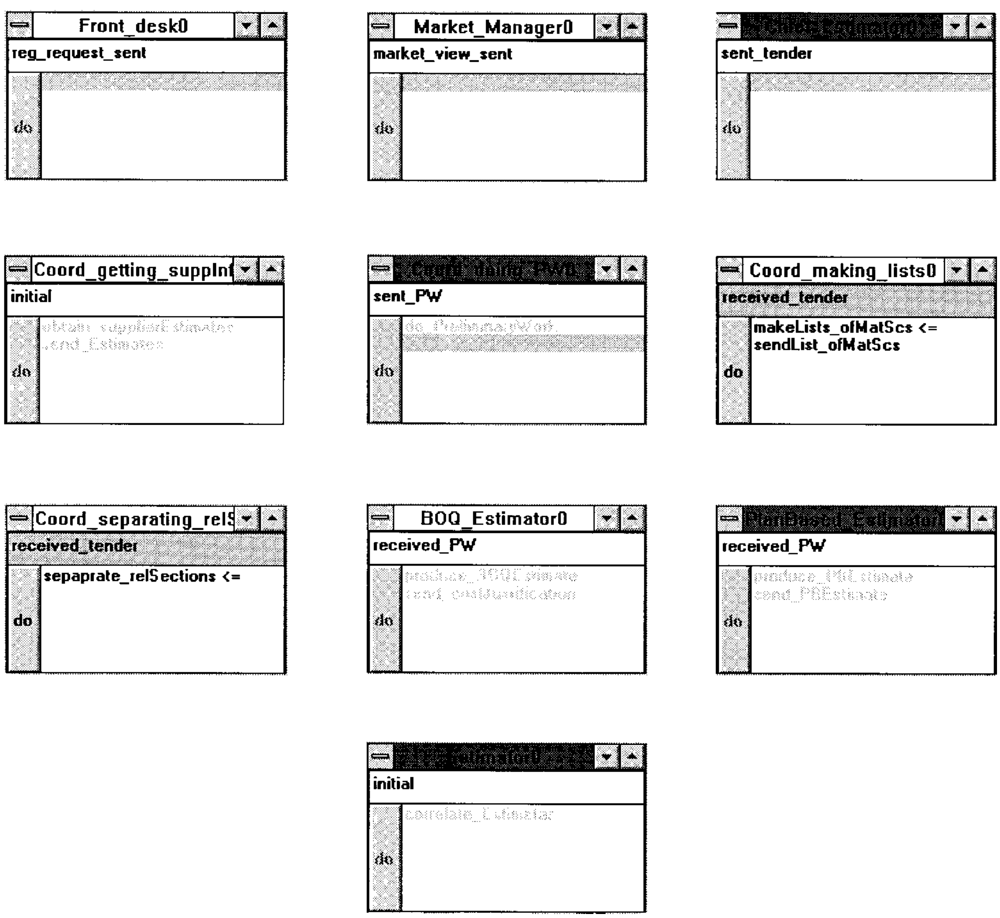

FIG. 8. Snapshot of RolEnact Model Showing State of System after “Coordinator Doing Preliminary Work’’ Has Sent Tender Request with Preliminary Work to Estimators

J. Constr. Eng. Manage., 1999, 125(6): 437-447

now changed to *sent_PW* and the states of the *PlanBased_Estimator* and *BOQ_Estimator* roles have changed to *received_PW*. The event list of *Coord_doing_PW* is now in gray indicating that the role is not active anymore. Only the remaining two Coordinators are active in this state of the system.

Next, let the *Coord_making_lists* enact the event, *makeLists_ofMatScs* (making lists of Materials and Subcontracts in Fig. 4) followed by *sendList_ofMatScs* (sending the lists made to the *Coordinator getting supplier information*). The changed state of the system after the enactment is shown in Fig. 9. The *Coord_making_lists* is now no longer active, and its state is changed to *lists_sent*. The state of the role that received the tender, *Coord_getting_suppInfo*, is changed to *lists_received*.

Coord_getting_suppInfo now can obtain the estimates and send them (*send_Estimates*) to the *PlanBased_Estimator* and the *BOQ_Estimator*. This sequence of events will change the state of the *Coord_getting_suppInfo* to *sent_estimates* and the states of the two above-mentioned estimators to *readyTo_producePBE* and *readyTo_produceBOQ*, respectively. The state of the system at this point is shown in Fig. 10.

When the PWBS models were presented to the users of the process, they agreed that the model represents the business process correctly. But when we presented the equivalent RolEnact model they immediately noted discrepancies.

The RAD model in Fig. 6 indicates the Plan Based Estimator and the BOQ Based Estimator are able to start producing the relevant estimates only after receiving both the tender with the preliminary work and the estimates for materials and subcontracts. As discussed in Section 5, the PWBS model in Fig. 5 does not make the logical flow of activities clear. However, the natural assumption is the scenario depicted by the RAD model. Although there is no notation in the PWBS model that indicates a different scenario, one can assume that all interpretable scenarios may happen. Hence the interpretation of the model may differ depending on the level of knowledge the reader has of the business process. A process actor may consider the model to be correct because that person may consider information not given in the model as common knowledge.

However, in reality, the Plan Based Estimator can start producing the plan based estimate as soon as the tender with the preliminary work is received if he/she so wishes. But he/she can finish the estimate only after receiving the estimates for materials and subcontracts. This fact only came to light when the users stepped through the enactable model. The logical flow of the actions in the process is very clear in the enactable model and does not allow for ambiguity.

Indicating the above-described event sequence in a RAD is difficult. Furthermore, the resulting RAD would be very complex. PWBS does not have the capability of representing such behavior. Thus the RolEnact model has the ability to represent more information easier than the two visual static models. The understanding of the graphical models can be further enhanced by the support of the enactable model.

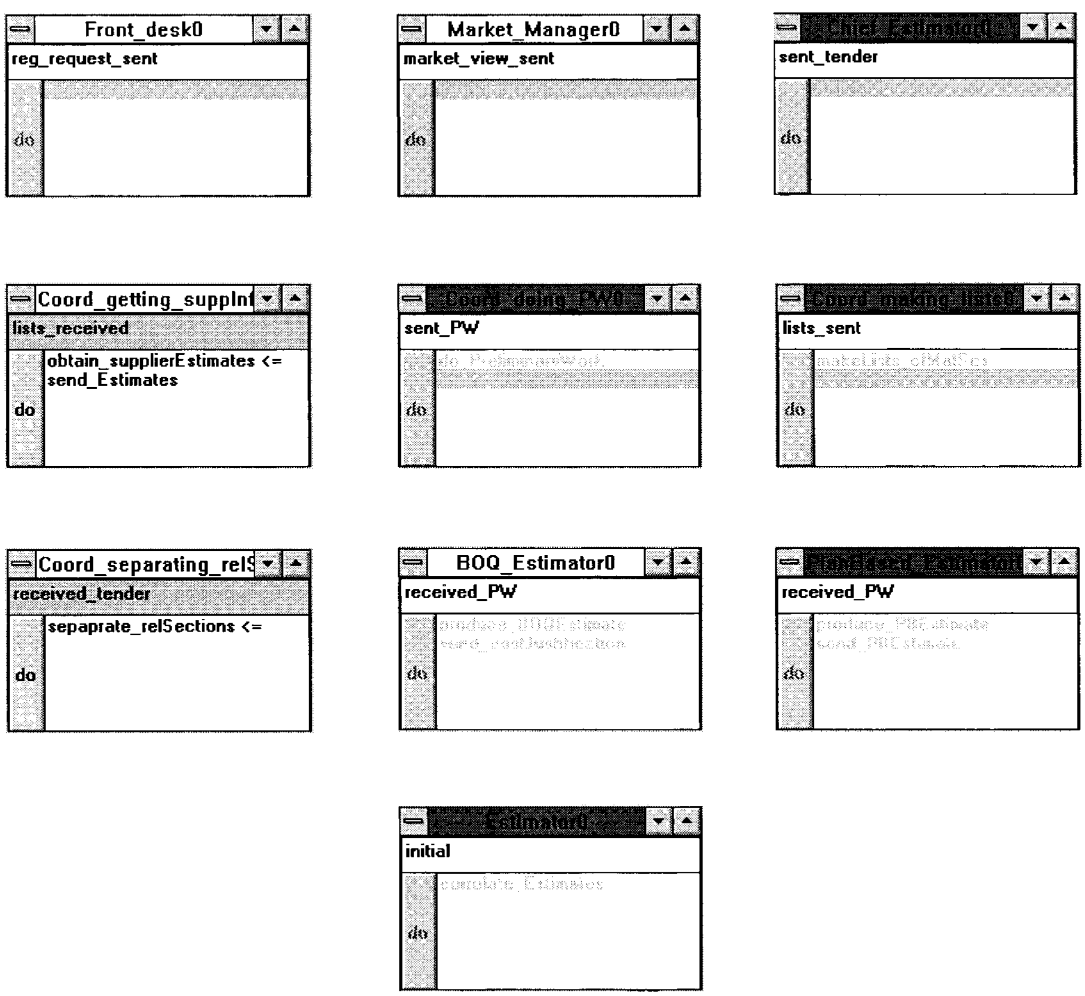

FIG. 9. Snapshot of RolEnact Model Showing State of System after "Coordinator Making Lists" Has Sent List of Materials and Subcontracts to "Coordinator Getting Supplier Information"

J. Constr. Eng. Manage., 1999, 125(6): 437-447

IDENTIFYING BOTTLENECKS AND CRITICAL PROCESSES

The tendering process is an important activity in the construction industry. The process evolves over a number of phases from market research, feasibility studies to cost analysis leading to the collation of the tender document. In each phase many personnel from different departments of the organization contribute toward this final goal. The process needs to be completed within a time limit. A delay in the process can lead to losing the tender, and this may in turn cause considerable loss to the company. The role view given by the RAD models clearly shows which roles are busy or, in other words, which roles have a heavy workload. If such a role is detected, then the situation can be further verified using the enactable model that is capable of clearly showing idle roles that wait for an interaction from another role to continue its business. This can be particularly effective if the roles map on to the process actors.

The different sections pertaining to the tender request such as the legal section, financial section, and the environment section are sent to the appropriate people. The contributions from all those concerned are then sent to the estimator who assimilates them into the tender. For each tender there are one or more critical factors associated with it. For example, an environmental issue overlooked at this stage may cause considerable delay during the construction phase, and this in turn may cause huge unavoidable costs. Therefore, it is essential to make the process efficient, identify the critical processes, and remove any possibility of bottlenecks or unnecessary delays.

Process analysis using simulation offers a vehicle for deciding what processes, methods, and resources should be used and how work processes can be improved or ''optimized'' (Halpin and Huang 1995). There are various tools on the market that provide simulation facilities. STELLA, mainly used in physical sciences, is a complex system that provides a schematic flowcharting environment with simulation facilities. The DISCO program, which is integrated with the CYCLONE modeling system (Gonzalez-Quevedo et al. 1993; Halpin and Huang 1995; Vanegas et al. 1993), provides a graphical modeling and simulation environment for flowcharting and studying the interaction of resources within a construction process. Pictorial simulation, however, is very costly in terms of the man-hours required to develop the modeling input (Halpin and Huang 1995). The key to simulation success is knowing where and when to apply it (Gonzalez-Quevedo et al. 1993). Hence, process understanding should be achieved before any attempt at process simulation.

The aim of our study was not process analysis and therefore did not lead to the identification of critical processes or ''optimization.'' Rather the goal was to achieve better process understanding. RolEnact as presented in this paper does not provide time simulation. Although PWBS provides certain basic static analysis, these techniques were not pursued in this exercise. However, it is clear that the RolEnact model, because of its enactable nature, is able to clearly identify the waiting states and therefore will support such a study if undertaken.

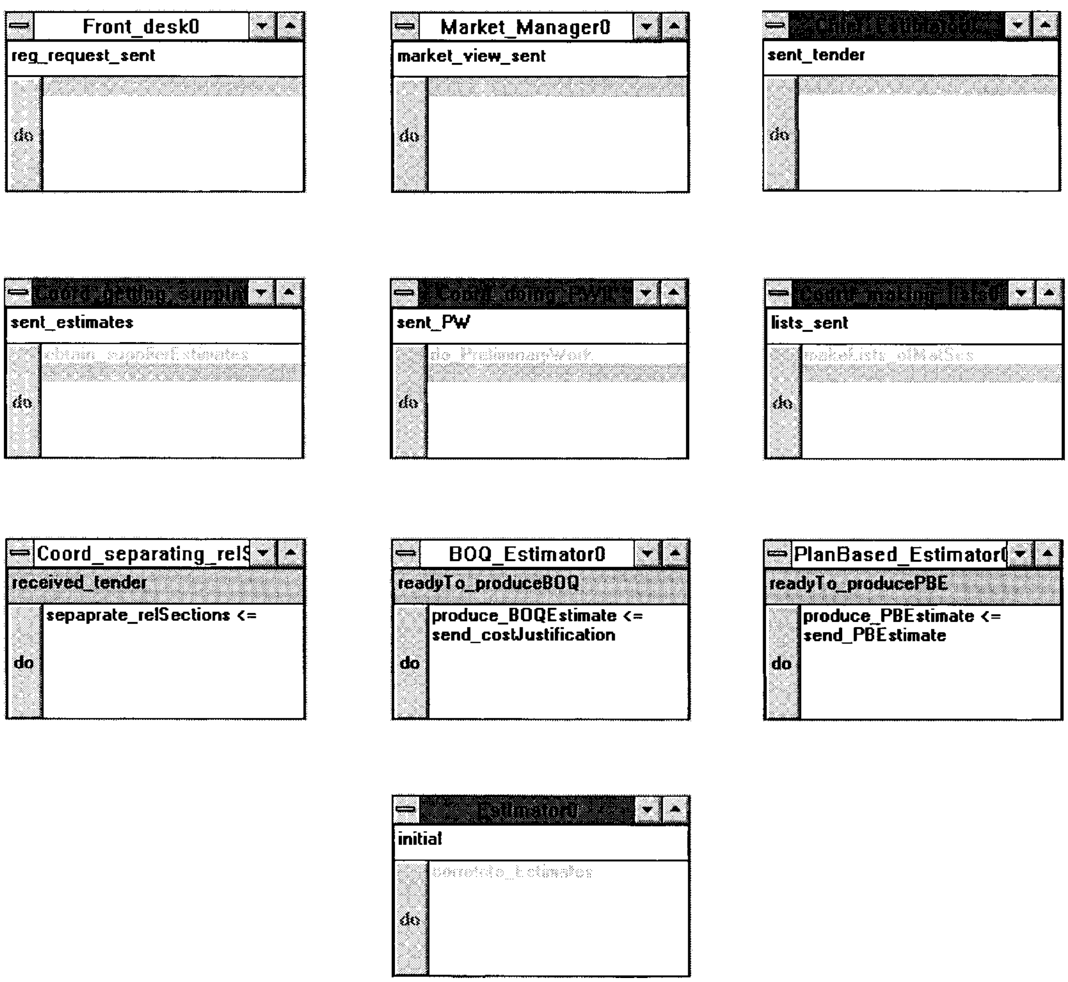

FIG. 10. Snapshot of RolEnact Model Showing State of System after ''Coordinating Getting Supplier Information'' Has Sent Supplier Estimates to ''Estimator''

J. Constr. Eng. Manage., 1999, 125(6): 437-447

CONCLUSIONS

Construction is a process based industry (Halpin 1993). Companies strive to improve their construction methods and processes to be more time and cost effective. Many companies are engaged in assessing ways in which their productivity, product quality, and operations can be improved (Elzinga et al. 1995). Whether to improve the current process or to introduce new processes first, the present process should be understood well. The world of construction will inevitably become more complex in the future (Paulson 1995), and this enforces the need to have a complete and correct understanding of the business process of the organization and therefore the benefit of process modeling. Halpin and Huang (1995) emphasized the need for the construction industry to become more process oriented to achieve better efficiency.

We have described the model of part of the tendering process of a small construction company and have shown how the static visual models are incapable of representing all the information pertaining to the process. We have then mapped the visual model to an enactable model, which clearly shows the event sequence, the process steps that occur within the process, and thus a better understanding of the process.

One way of producing process understanding is by visual modeling. When the modeling process requires communicating with either a team of modelers or people knowledgeable in the problem domain, visual representations are extremely helpful (Alabastro et al. 1995). To the participants of the process, the end result of the exercise should be that it gives a better understanding of the process; hence, the mode of presentation should be easy to understand. In this regard a visual representation without many complex notations is more suitable.

There are a number of advantages in investing the modeler's time in producing an enactable model. An enactable model enables the modeler to discern the critical processes and the bottlenecks in the model and to make clear where change is necessary. Change is more effective if made to the critical processes. Whatever the scale of the change is, it incurs some cost. One way of making sure the change benefits the organization is to evaluate its effect using simulations. The visual models are more suitable in this regard due to the ease of use and ease of change. The enactable models can be used to further support the decisions made.

Enactable models also help to note the behavior of the organization that is inconsistent with the quality manual, the discrepancies, duplication of effect, redundancy, usage of human resources, etc. It was possible to identify certain aspects of the business process that were not apparent at a glance in the graphical model.

The conclusion of this exercise is that we cannot represent all the information pertaining to a process model either by a visual model or by an enactable model. It is the modeler's prerogative to decide which is better for a particular purpose. In the writers' experience, a visual model better supports the process of process elicitation, thus making it more suitable in the initial stages of modeling. An enactable model better supports understanding the greater details of the process steps and the interactions between the different participant roles.

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