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A METHODOLOGY FOR INTEGRATING BUSINESS PROCESS AND INFORMATION INFRASTRUCTURE MODELS

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ABSTRACT

Many organizations today undertake Business Process Reengineering (BPR) and information infrastructure (i.e., network hardware, communications, and applications infrastructure) modernization efforts to drastically reduce costs and improve performance. While these efforts would appear to be mutually supportive and complementary in nature, they are rarely conducted jointly. Although it is known that changes to one of these two facets of the organization can produce significant impacts on the other, analysts and decision-makers have had only limited support for predicting the impacts of change to one or both of these two facets of the enterprise. BPR efforts are generally conducted using business process simulation tools. Information infrastructure modernization efforts are generally conducted using network simulation tools. What is lacking is an integrated method and the automated environment for studying the impacts of change to one of these two aspects of the enterprise on the other. This paper presents a simulation-based methodology enabling simultaneous consideration of changes to core business processes and the infrastructure mechanisms that support those processes.

1. INTRODUCTION

Many organizations today undertake Business Process Reengineering (BPR) and information infrastructure (II) modernization efforts to drastically reduce costs and improve performance. While these efforts would appear to be complementary, they are rarely conducted jointly. That is, although it might make sense to conduct BPR and II modernization efforts in a highly coordinated fashion, there has been little success to date in making the attempt. The importance of coordinating such efforts is obvious. Making changes to the logic and structure of a business process may introduce new requirements on the supporting infrastructure. Likewise, making changes to the network hardware, communications, and application infrastructure can have dramatic impacts on business process performance.

Although it is known that changing one of these two facets of the organization can produce significant impacts on the other, analysts and decision-makers have limited support for predicting the impacts of change. There are stand-alone methods and tools to assist with reengineering business processes. There are also stand-alone tools to help communication engineers analyze alternative hardware, software, and network configurations. What is missing is the ability to bridge these two analysis domains to determine new infrastructure requirements arising through changes to the business process. Similarly, there is little support for translating the impacts of infrastructure change on the processes the infrastructure is intended to support.

Without effective change impact analysis methods and tools there is an enormous risk that proposed infrastructure designs will have little benefit, or possibly even severely detrimental cost and/or performance impacts. Likewise, proposed business process changes, considered outside the context of their potential impact on the supporting II, may be equally fraught with risk. Lacking the means to integrate business process and II models, decision-makers are forced to rely on intuition and personal experience while committing the organization to massive process infrastructure change.

In this paper, we present a simulation-based methodology for change impact assessment enabling simultaneous consideration of changes to core business processes and the infrastructure mechanisms that support those processes. We call this methodology the BPR-II methodology. We also present preliminary findings from exploring the use of commercial off-the-shelf (COTS) business process modeling, process simulation, and network simulation tools to provide automated support for the methodology. Together, the BPR-II methodology and an accompanying automated support environment provide the ability to seamlessly link models of the business process models with models and supporting infrastructure. These models may then be used to conduct rapid, realistic cost/benefit studies of alternative process and infrastructure design concepts before they are implemented.

2. CHANGE IMPACT ASSESSMENT

The BPR-II methodology provide a holistic approach for BPR and II modernization analysis. Three model types (business process, application, and network models) are used to represent objects and relations that correspond to real world elements (e.g., network topology models representing actual computer and communications hardware). In addition to the three model types, there are physical and conceptual relationships and constraints between objects of different model types. For example, business process **X** requires application **Y**, application **Y** is only available on machines **M1** and **M2**, etc. These relationships and constraints are also represented in the BPR-II methodology.

Changes made within a model type can be analyzed within that model type to determine cost, cycle time, manpower implications, and so forth. However, because of interdependencies between the model types, they cannot be treated as though they are independent. It thus becomes necessary to somehow integrate the models to support more reliable analyses (See Figure 1).

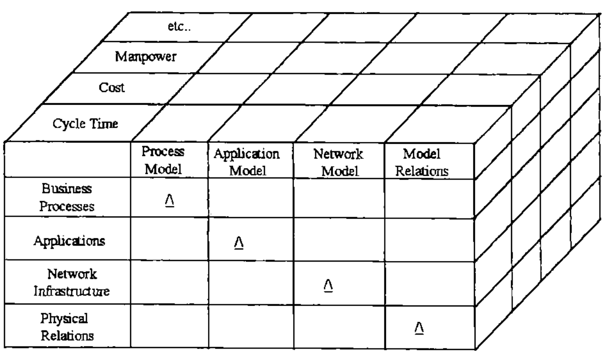

Figure 1. Dimensions of the Physical World Represented through Models

Table 1 shows three dimensions of the change impact analysis support by the BPR-II methodology. Delta symbols (Δ) in the table indicate areas of change. Question marks (?) represent the dependent variables of the analysis; i.e., the areas an analyst would be responsible for investigating in a change situation. For each situation and model type, the only independent variable that is modified is the model itself. For example, in Situation 1, we may wish to propose changes to the structure of one or more business processes. The analyst then determines the resulting impacts (model, performance, cost, and manpower) on the other three model types, as well as business process performance, cost, and manpower impacts.

Table 1. Change Types and their Unknown Impacts

	Situation		
Infrastructure Dimension	**1**	**2**	**3**
Business process	Δ	?	?
Applications	?	Δ	?
Network H/W and Comm	?	?	Δ

Thus, the methodology supports impact assessments of changes to business process structure and logic, application process change, network hardware and communications infrastructure change (e.g., topology changes, parameter set changes), changes in relationships or constraints (referred to above as inter-model mappings), and so forth. Listing and organizing proposed changes by the type of change involved helps the modeler/analyst isolate the changes that need to be made to the models, and devise an appropriate analysis strategy. For example, if the network hardware and communications infrastructure is the only aspect to be changed, and if an ambient traffic file representing the typical traffic generated by the existing business processes is available, there is no need to develop any process models. The analyst can simply elect to "run" the ambient traffic file on the proposed topology. By understanding the possible set of changes that may be considered and their implications, the methodology can be tailored to meet the more narrowly scoped analysis requirements. The following list briefly describes some of the change types that may be considered.

I. Changes in the business process model (e.g., eliminating artifacts of the process).

II. Changes in the application model (e.g., replace application).

III. Changes in the network computing strategies (e.g., centralized to distributed).

IV. Changes in the network hardware and communications infrastructure (e.g., routing, bandwidth)

V. Changes in physical or conceptual relationships among system components (e.g., machine used for an activity, applications residing on a machine).

Developing a methodological framework involved defining the procedures, techniques, heuristics, and languages of expression needed to analyze, predict, and quantify the impacts change for different situations. The use of simulation tools as part of the methodology was motivated by the need for mechanisms to help determine the impacts of shared resources and of probabilistic situations.

3. BPR-II METHODOLOGY

The IDEF3 Process Description Capture [Mayer 92] method serves as the key mechanism for process knowledge capture and organization in the BPR-II methodology. IDEF3 process descriptions are used to capture a definition of the process at the business, application, and network processing levels and to directly generate the structure and logic of simulation models reflecting these levels.

3.1 IDEF3 Method Overview

IDEF3 is a scenario-driven process flow modeling method designed to capture descriptions of the precedence and causality relations between situations and events in a form that is natural to domain experts. IDEF3 provides a structured method for expressing knowledge about the "behavioral" aspects of an existing or proposed system. IDEF3 helps structure user descriptions of enterprise processes in a way that facilitates the construction of analysis and design models.

Two modeling modes exist within IDEF3: process flow descriptions and object state transition descriptions. Process flow descriptions are intended to capture knowledge of "how things work" in an organization; object state transition descriptions summarize the transitions an object may undergo during a particular process. Both descriptions contain units of information that form the basic units of an IDEF3 description.

IDEF3 uses the "scenario" as the basic organizing structure for establishing the focus and boundaries for the process description. The basic syntactic unit of IDEF3 graphical descriptions is the Unit of Behavior (UOB) box, which represents a real world process. Each UOB is described in terms of other UOBs (called a decomposition) and in terms of a set of participating objects and their relations (called a UOB elaboration). UOBs are connected to one other via junctions and links. Junctions provide the semantic facilities for expressing synchronous and asynchronous behavior among a network of UOBs. There are three types of IDEF3 links: 1) temporal precedence, 2) object flow, and 3) relational. Relational links are provided to permit constraint capture not accommodated by the default semantics of the precedence and object flow links. Figure 2 presents an example IDEF3 diagram.

IDEF3 based descriptions are used to automatically generate WITNESS™ simulation code in the target language using ProSim™, an intelligent simulation modeling tool developed at KBSI (Benjamin et al. 93, Padmanaban et al. 95). This description-driven approach significantly reduces the time and effort involved in simulation model development.

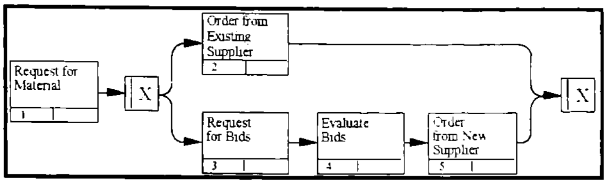

Figure 2. Example of a Process Flow Diagram

The IDEF3 method provides the foundation for acquiring and documenting process knowledge at the business, application, and network processing levels. This task is one of several included in the BPR-II methodological framework. The following section expands on how IDEF3 is used and describes the additional tasks involved in the methodology.

3.2 BPR-II Change Impact Analysis Steps

Developing a methodological framework involves defining the procedures, techniques, heuristics, and languages of expression needed to analyze, predict, and quantify the impacts change. In this section we describe the methodology developed to analyze the impacts of change depicted in Table 1. In general, the following steps are applied.

I. Establish the boundaries of the domain.

II. Catalog domain assets, their relevant performance characteristics, and their fixed and variable costs. Six general categories of assets are listed as part of the domain: computer and communications equipment (e.g., computers, communication links, routers), applications, data sets, employees, sites, and facilities.

III. Capture information about network layout, topology, and performance characteristics.

IV. Catalog and define AS-IS domain business processes using IDEF3.

V. For each application that interfaces directly with the user and that is required to satisfy a business process, model (as a decomposition) the steps that the application performs. This constitutes a process description of the application.

VI. For each step of the application process that requires the use of a remote application or database (i.e., involving distributed processing and/or delay), model the communication process required. Model remote application processes as a decomposition.

VII. Classify and label all UOBs in the resulting IDEF3 descriptions. For convenience, the lower right-hand corner of the IDEF3 UOB box is used for a UOB classification label. Classification categories are as follows:

A. *Scenario (SCN):* UOBs with decompositions, where all child UOBs are classified as involving manual activity (MAN), man-machine interaction (MMI), or local application processing (L_APP).

B. *Manual (MAN):* UOBs involving manual activity and whose decompositions, if they exist, are comprised of UOBs involving manual activity only.

C. *Man-Machine Interaction (MMI):* UOBs involving man-machine interaction and whose decompositions are comprised of both manually accomplished UOBs and local application processes (L_APP UOBs).

D. *Process Data (P_DATA):* UOBs involving Central Processing Unit (CPU) activity.

E. *Transport Message (T_MSG):* UOBs involving message transport (data transmission) across communication lines.

F. *Local Application (L_APP):* UOBs involving local application processing and whose decompositions are comprised of UOBs involving Central Processing Unit (CPU) delay (P_DATA), possible message transport (T_MSG), and possible remote application processing (R_APP).

G. *Remote Application (R_APP):* UOBs that involve remote application processing and whose decompositions are comprised of UOBs involving CPU delay (P_DATA), possible message transport (T_MSG), and potentially additional remote application processing (R_APP).

IX. For UOBs involving message transport (T_MSG), specify source and destination nodes and a unique message identifier distinguishing messages originating from that UOB. For UOBs involving CPU delay (P_DATA), local application processing (L_APP), and remote application processing (R_APP), specify the node where processing occurs. For the leftmost UOB in the decomposition of a parent UOB labeled as involving local or remote application processing (L_APP or R_APP), specify the event type (i.e., interarrival time or message received) that triggers an activation. For activations triggered by messages, specify the message identifier that initiates the activation.

X. Use data developed in steps II through VIII to develop specifications for network and business process simulation models.

XI. Develop or collect baseline performance data for the AS-IS. This may be accomplished by developing and validating simulation models of the AS-IS or through instrumentation of the AS-IS process (e.g., statistics from workflow manager, application program monitors, network managers and monitoring devices, etc.).

XII. Identify and classify the set of proposed changes to the AS-IS. Collect cost data associated with the proposed changes.

XIII. Design the set of simulation experiments to analyze the impact of proposed changes. Using the experiment design, perform the following steps:

A. Develop and run TO-BE simulation models of the network. Collect simulated utilization rates and total processing time statistics for activations spanning the start of the leftmost UOB through the completion of the rightmost UOB in the decomposition of each L_APP UOB. Plug the resulting cycle-time distribution values into the simulation data specification for each L_APP UOB.

B. Develop and run TO-BE simulation models representative of the business process level using the values obtained from the network level simulation. Collect simulated utilization rates and processing times.

XIV. Analyze simulation results.

XV. Calculate costs from actual and simulated process performance data.

XVI. Contrast the AS-IS and each candidate TO-BE configuration in terms of their respective cycle-time, manpower, and cost implications. Prepare high-level business case.

4. INTEGRATING BUSINESS, APPLICATION, AND NETWORK LEVEL SIMULATION MODELS

The most significant element of automated support required of a BPR-II environment is that which integrates process models at the business, application, and network levels. This integration is accomplished by recognizing that network simulation models are designed to model traffic flows. That traffic is generated by the business processes that operate applications, which in turn operate on the network. Network simulation models do not include any graphical mechanisms to explicitly represent applications or their corresponding traffic-generating business processes. Nevertheless, network simulation modelers begin by understanding and later implicitly representing those processes in the network simulation model.

Since business and application processes are not graphically represented in network simulation models, those who are not intimately familiar with network simulation modeling are largely unable to visualize how network processes operate or how they relate to business-level views of the process. This graphical limitation of network simulation models also prevents all but well-trained network analysts from developing and using network simulation models.

The graphical limitation of network simulation was overcome in two ways. First, by using IDEF3 to develop an explicit graphical representation of business, application, and network processes, it is easy for people to see what is happening at any level of the process. Second, the methodology creates an explicit link between the business process level and the network processing level by defining the application process in the context of the business process. The result is a single, integrated model. This strategy not only provides high visibility to the uninitiated but enables one to program the network simulation model directly from the process description. More specifically, in COMNET III, UOBs involved in the decomposition of an L-APP UOB define the command set and sequence for an application source at the node where the application resides. Additional application sources are similarly defined for each R_APP UOB in the hierarchy. Since the entire hierarchy below an L_APP UOB represents a linear process, the L_APP application source run length represents the end-to-end delay that will be experienced by the end user. This value, once obtained, can be used in the L_APP UOB as part of the specification for developing a business process-level simulation model.

To support the BPR-II methodology, we developed a prototype BPR-II environment that integrates tools supporting IDEF3 with simulation tools. The BPR-II environment integrates KBSI's ProSim™ IDEF3 process modeling tool with two simulation tools: WITNESS® by AT&T ISTEL™ and COMNET III™, by CACI Products Company. WITNESS and COMNET III are both discrete event simulation tools. WITNESS has a user interface tailored primarily for those involved in modeling and simulating manufacturing processes. WITNESS also provides an experiment management utility enabling users to design and manage simulation experiments. COMNET III has a user interface that is tailored for network simulation. COMNET III provides an extensive library of objects with default characteristics (or parameter sets) representative of typical network hardware and communications equipment. The BPR-II environment was developed using Microsoft® application development and database tools.

The BPR-II prototype consists of four main modules: the business case notebook (BCN), the situation modeling environment, an experiment manager, and a business case analyzer. The role of the business case notebook is twofold: 1) to capture a description of the domain including a characterization of the assets included in the domain, and 2) to maintain static and variable cost information with which to perform business case analyses. The situation modeling environment guides users through the series of modeling and simulation steps required for analysis. The experiment supports the user in designing a set of simulation experiments to be applied within the environment. By applying this module, users can help ensure the reliability of simulation-generated data and its interpretation. The business case analyzer is used to generate graphical and tabular displays contrasting the cost and cycle-time implications of alternative configurations.

5. EXAMPLE

Consider a simple example of a network that includes three nodes connected by three communication links. That is, assume that the network topology is drawn in the shape of a triangle with nodes resting at each corner and communication links defining the edges of the triangle.

One modeling situation of interest involves altering the supporting network hardware and communications infrastructure while leaving the business process unchanged. The resulting models may reflect contingency situations or business decisions aimed at achieving savings (e.g., wartime loss of dedicated communication lines or satellite uplinks). A second situation involves leaving the supporting network hardware and communications infrastructure unchanged while introducing a reengineered business process. Each analysis situation provides cost and cycle-time information that can be displayed through the Business Case Analyzer for side-by-side comparison.

Since we have already developed a description of the network topology through the BCN, we can now turn our attention toward defining the business process(es) supported by the II. The top portion of Figure 3 illustrates one such process. The process depicted involves data retrieval from a remote site, such as an engineer using a local application to assemble product data distributed across multiple nodes in the network. It should be obvious, even in this simple process description, that changes in infrastructure performance directly impact the user. Likewise, it is clear that the structure of the process and its activation can directly impact the infrastructure.

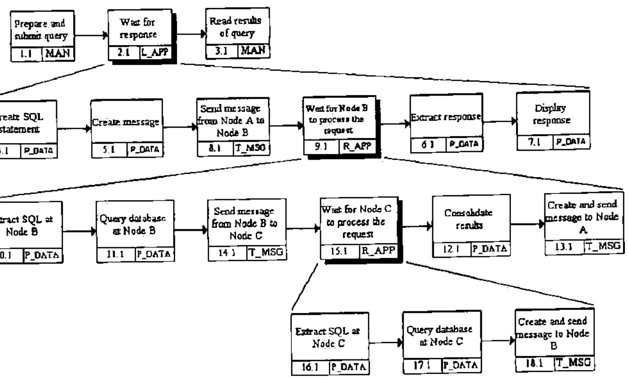

Figure 3. Example Business Process

Further definition of this process is developed through process decomposition or detailing. Using the multiple viewpoint feature of IDEF3, each decomposition level assumes a different viewpoint corresponding to the key agent of the process at that level. For example, at the highest level, the viewpoint assumed is that of the user. From the user's viewpoint, a manual activity is accomplished after which he must wait for a local application to respond with the requested data. The local application process is detailed as a decomposition of the L_APP UOB. At this level, the viewpoint assumed is not that of the user. Rather, the viewpoint assumed is that of the local application. Thus, the local application performs a series of activities until it must wait for a remote application to respond. The remote application process is detailed, in turn, as a decomposition of the R_APP UOB. At this level, the viewpoint assumed is that of the remote application. If each of the decompositions were expanded in place, a serial network process would be revealed representing a query originating with the user at Node A passing to Node B. All the data required is not available at Node B prompting a query to Node C. Node C responds with data to Node B. The data at Node B and that coming from Node C is then assembled at Node B and shipped to Node A and presented to the user.

The decomposition of each L_APP and R_APP UOB represents the sequence of commands executed at corresponding nodes of the network. This process model may be used to program a model of the network topology with the set of commands that are executed by individual nodes, including the sequence in which they are executed. In fact, this is exactly what the BPR-II prototype does. By doing so, the network model is not only configured to run simulations, but is explicitly tied to the current or proposed definition of the business process. Unlike typical network models, those generated by the BPR-II system provide a convenient graphical representation of the application and network process integrated with the business process.

Figure 4 is a picture of the COMNET III model generated from the process description above coupled with the domain assets information provided to the BPR-II repository.[1] As can be seen, three computers were specified with the names Node A, Node B, and Node C. Three communication links (Link 1, Link 2, and Link 3) are connected to the nodes. Traffic is generated on the network model topology using application sources. Three traffic (application) sources are depicted. Each application source is prefaced by the label L_APP or R_APP and the name of the corresponding UOB in the IDEF3 description whose decomposition defines the segment of the process accomplished at the node to which the application source is connected.

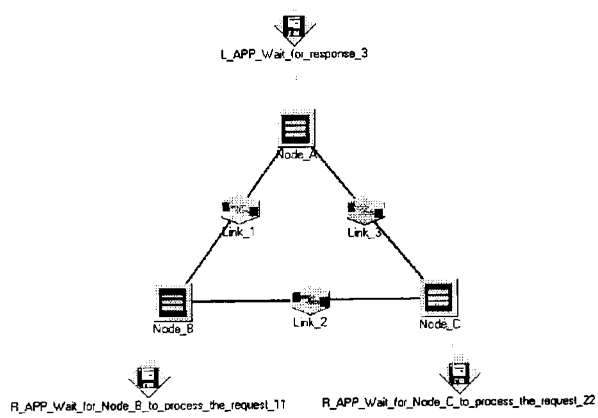

Figure 4. COMNET III Model of AS-IS network

Defining the AS-IS situation provides a baseline against which to compare alternative TO-BE configurations. Rather than defining the entire TO-BE situation from scratch, the BPR-II environment allows the user to describe the set of changes involved in realizing the proposed situation. A number of possible changes may be involved in transitioning from the AS-IS to a given TO-BE situation.

For demonstration purposes, we chose to examine the impacts of removing Link 1. In the physical world, removal of a link might correspond to a business decision aimed at reducing costs or a contingency situation in which the line is destroyed. By removing this link, it should be noted that the previously defined process must query Node B using Links 3 and 2 in place of Link 1. The response from Node B will also require traversing Links 3 and 2 in place of Link 1. Only changes to the network topology affects the network model. By regen-

[1] COMNET III model icons are placed on the screen using an algorithm permitting rapid manual adjustment. The model shown was organized into the shape of a triangle after initial placement of the icons on the screen.

erating a COMNET III model from the information in the BPR-II repository for the TO-BE situation, we generated the model depicted in Figure 5.

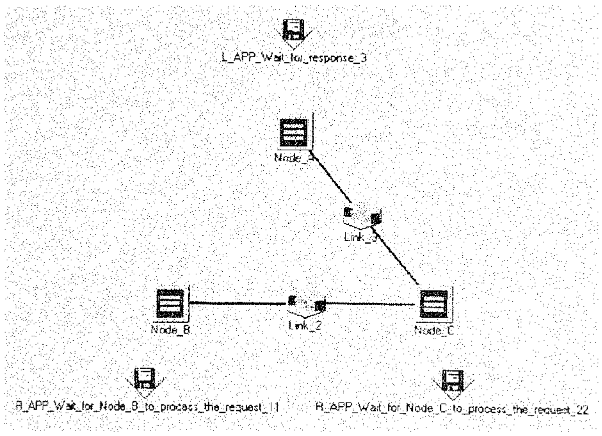

Figure 5. COMNET III Model without Link 1

Similarly, there may be structural changes in the network model that arise through changes in the process. Suppose, for example, that the data set residing at Node C is moved to Node B's database. The resulting process would not require Node B to issue a query to Node C. The bottom two levels of the IDEF3 process description would be changed by eliminating the T_MSG UOB, the R_APP UOB, and the R_APP UOBs' decomposition (Figure 3). Furthermore, the application source attached to Node C would not be generated in the corresponding COMNET III model.

Each of the resulting COMNET III models are used, in turn, to populate the corresponding L_APP UOBs in the IDEF3 process description with the appropriate simulation results. The IDEF3 process descriptions corresponding to each situation are then used to generate a WITNESS simulation model. WITNESS simulation produces cycle time and utilization rate statistics for each situation. (Figure 6.)

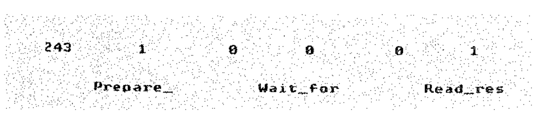

Figure 6. WITNESS Model

Cost and simulated cycle-time performance data is collected and stored in the BPR-II repository. This data may then be used to conduct comparative analyses of alternative situations. The business case analyzer component of BPR-II is intended for this purpose.

The costs associated with each of the three simulated situations described above may be displayed to the analyst using the data in the repository. Figure 7 illustrates how the BPR-II prototype presents this information in a graphical fashion that shows contributing costs by type (e.g., employee move cost, asset change cost) and total costs for each situation.

Tabular and graphical representations of the cycle times associated with process activations for each situation are similarly depicted (Figure 8).

The BPR-II prototype demonstrates the feasibility of using current technology to rapidly analyze the impacts of II change on the business processes it supports, and vice versa. A robust BPR-II system would be capable of integrating business process and II models to perform simple and/or sophisticated "What-If" analyses. AS-IS models required as a baseline for analysis could be maintained semi-automatically by integrating them with sources of information about the assets comprising the domain. Using a BPR-II system, analysts, managers, and decision-makers would have significantly improved visibility of the constraints governing how business is done and how it is supported by the underlying network hardware and communications infrastructure. Finally, with a BPR-II capability, users could more rapidly and reliably generate the data needed for high-level business case development.

Situation	Employee Move Cost	Asset Change Cost	Total Cost
AsIs	$0.00	$0.00	
To Be Alternative 1	$5,000.00	$300.00	$5,300.00
To Be Alternative 2	$0.00	$450.00	$450.00

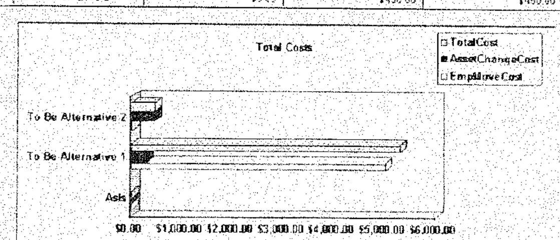

Figure 7. Cost Comparison among Situations

Situation	Domain	Time in System (sec)
AsIs	Domain 1	89.567
To Be Alternetive 1	Domain 1	98.813
To Be Alternetive 2	Domain 1	87.964

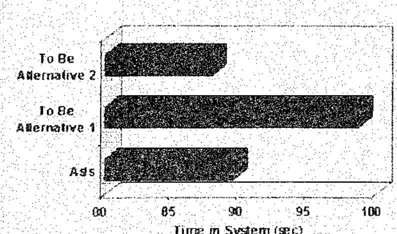

Figure 8. Time Comparison among Situations

6. SUMMARY

There is clearly a strong need for a robust BPR-II capability. Both the commercial and defense sectors stand to gain tremendous benefits from such technology. As illustrated through the effort described in this paper, it is clear that business process models can be integrated explicitly with models of the supporting network hardware and communications infrastructure. Furthermore, doing so provides an effective means for rapidly acquiring a realistic, quantitative assessment of the impacts of proposed change. These assessments can be used to support the development of a business case or to facilitate contingency analyses.

Central to this capability is an effective methodology that provides increased management visibility and "What-If" analysis capability. A key element of this methodology is the provision for effective automated support which appears to be available with current COTS tools.

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