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PMT: Modeling Enterprise Operations and Organizations

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ABSTRACT

Enterprise environments are complex and multidisciplinary. As the market competition becomes more and more relentless, business companies must keep adapting their current processes to the new needs of the market. During the adaptation process, enterprises may not have any experience with the new business needs. Many enterprise models from different perspectives have been proposed to facilitate this adaption process and reduce risks. However, due to the complexity of the enterprise environment, none of them takes all needed enterprise elements into consideration. A uniform approach that deals with different elements of an enterprise is needed in order to model all elements and analyze their effects on enterprise operations. Inspired by Galbraith's information processing view of organizations and the extant modeling work of project organizations, in this paper we propose a unique model of enterprise called PMT that can be used to analyze enterprise operations and their interactions with market demands. Market demand as an independent variable and enterprise capacity (organization, processes and resources) are modeled computationally and the relations between them are captured. In this paper, the background and the major concepts of the PMT model are introduced and an application example demonstrated to show the effectiveness of the PMT model.

1 Introduction

Enterprise environments are complex and multidisciplinary. Almost everywhere organizations are undergoing rapid and significant changes driven by such pressures as customer expectations, new technologies, and growing global competition. As a result, many business processes within organizations are dynamic and constantly changing. In order to survive in such environments, practitioners are forced to continually revise their business processes to respond quickly to changes. Typically three kinds of scenario can happen in an enterprise. First, an enterprise may look into achieving drastic improvement of its current performance in terms of cost, services and speed. If the business environmental change is drastic, then they need to develop complete new processes to deal with the change. Lack of experience with the new environment forces them to adopt a trial-and-error approach, which can be highly risky and costly. In the middle of 1990s, Business Process Reengineering (BPR) [3] was introduced as a solution to keep enterprises competitive in the changing environment. BPR helps enterprises link its strategic goals to its key processes and targets drastic changes in business processes by focusing on arrangement of processes to improve the efficiency, product quality and reduce cost. There are some methodologies and tools available to help enterprises improve their processes with BPR techniques; however, none of these adequately support the practitioner through all stages in the enterprise evaluation and reengineering. Especially, the current BPR practice pays little attention to the market or client environment in which the enterprise operates. In our research, we attempt to help enterprises make drastic moves in the changing market environment based on organizational theories and computer simulations instead of merely "experience" and "luck". We also attempt to eventually provide sophisticated process knowledge base and library to help enterprises adopt well established processes and organization forms known to be effective.

The second type of business environmental change can be local and dynamic instead of drastic. There are always bottlenecks in different parts of enterprises and detecting these bottlenecks is of high importance. Usually managers are left with no support in analyzing processes and detecting bottlenecks and they completely rely on their own experience. In these cases, managers need to make local changes and they need to predict the change and factor in the impact of the change in the original process planning phase. A computational enterprise model can provide needed support for managers in terms of providing quantitative and qualitative evaluation of enterprise operations. Enterprise managers also need to do quick "fire fighting" once the change or problem is identified. In these cases, managers must quickly find ways to respond to the problem, such as relocating resources, re-routing certain activities or flows of work, and adding new process components. Computational tools are needed to provide process and organization design and analysis support for these managerial activities. In addition such tools can be further developed to provide process monitoring capabilities to track the processes and provide instructions to react to the problems.

Lastly, the business environmental change can also manifest itself as shrinking profit margin and higher labor and technology costs. In these cases, while the business remains the same, companies still have to strive for higher efficiency and effectiveness by upgrading their current practice to a higher level. Again an enterprise management tool is needed to provide process design and management guidelines for managers to analyze the reasons behind shrinking profit margin and react to them.

Our research deals with the above mentioned problems through *enterprise modeling and simulation*. It also creates a potential for *enterprise integration* to make possible true information exchange inside the enterprise and between the enterprise and its clients. In our research, we attempt to address the following three sets of research questions.

What are the key concepts and relations in modern enterprises? What are the intra- and inter-relationships in modern enterprises? How can we maintain a balance between generality and powerfulness of an enterprise model when developing such a model? The concrete problem we face in this research is the lack of sound and complete foundation for the way enterprises should be modeled and analyzed. In this research, we view an enterprise model as a computational representation of the structure, activities, processes, information, resources, people, behavior, goals, and constraints of a business, government, or other enterprises [1]. This model should be abstract enough to make modeling easy and also powerful enough to represent real case scenarios.

How can we embed a modern enterprise in social, political and technological changing environment? With the power of internet, our world is changing every day. Adapting to this continuously changing environment is very important for today's enterprises. Enterprises should adapt their business according to new political situations, social trends and technological advances. For an enterprise model to be effective and reliable, it should take these dimensions into consideration.

How can we model enterprise operations and their relationship with enterprise organization and resources? The core of every enterprise is its operations. To compete in today's market, a modern enterprise should have a clear picture of its operations. Capturing how an enterprise operates in real world and representing it in an abstract model is a major task for this research. Workflow management systems usually consist of a process model and some also include an organization model. Although research in process modeling has been relatively matured, organization models employed by most workflow management systems are mostly elementary. Also, these systems usually fail to provide a model to integrate non-human actors (ex. automated machines, computers …) into the system [24]. Our enterprise model should correctly represent task dependencies and relationships of human/machine actors to enterprise operations.

To effectively address the above questions, our goal of this research is to understand the nature of enterprise modeling and integration and develop a new approach to improve the effectiveness and reliability of enterprise models base on well accepted theories. The result of this research is to provide a solid framework to systematically support enterprise modeling and introduce essential steps towards building a computer and network based system framework for process execution and management.

In rest of this paper, we first provide a literature review of the extant work related to enterprise modeling and analysis in Section 2. After that, we introduce a novel model of enterprise operations and organizations in Section 3 and provide some implement details of PMT in Section 4. A PMT based case study is discussed in detail in Section 5 to demonstrate the effectiveness of our PMT modeling and simulation approach. We conclude our paper and point out future research activities in Section 6.

2 Related Work

Along with the proliferation of computer and Internet technologies, the research on enterprise modeling, analysis, and management has been advanced in both theoretical and technological fronts. New models of business, processes and organizations have been proposed, and new computer tools developed. Our approach attempts to integrate well established theories from different research areas. In the following, we briefly review the research in three relevant fields, namely, coordination research, organization modeling and business process reengineering.

Coordination research in general deals with how people work together. Social scientists focus on organizational behaviors and developed organization theories to explain these behaviors. Computer scientists attempt to facilitate humans working together by developing communication and planning support tools. In addition, they are also developing theories and technologies to allow multiple computer systems or agents to work together through "data sharing". The data sharing approach allows collaborators to share their work information. Workers can timely retrieve the results of other collaborators and pass his or her results to others through the shared work model [35]. Cutkosky et al [35] investigated data sharing and interoperability between different engineering subsystems and disciplines. The Palo Alto Collaborative Testbed (PACT) was developed as a concurrent engineering infrastructure that encompasses multiple sites, subsystems, and disciplines. TOVE (Toronto Virtual Enterprise) [36] project as a generic, reusable enterprise data model has been also developed by Fox and his colleagues [36]. This model provides a shared terminology for the enterprise to support humans in their common sense questions about enterprise.

A part of data sharing research also focuses on collaborative CAD design. Chen et al [25] proposed a co-assembly representation including Master Assembly Model (MAM) and Slave Assembly Model (SAM). Kim et al [26] introduced a design formalism to capture the non geometric perspective of designer's intention in a co-assembly design environment. Lu et al [27] proposed a frame work to capture and represent design modification in a collaborative assembly design environment and Bidarra et al [28] proposed a collaborative framework for integrated part and assembly modeling.

In this area of research distributed artificial intelligence (DAI) has been widely used. Multi agent system application is a very promising approach as a foundation for enterprises to build computer and network based system framework for processes execution and management on top of it. DAI systems use various protocols for communication of intelligent agents. The key to developing multi agent systems is to design collaboration mechanism among agents. There have been various mechanisms introduced as contract net [29], blackboard and message passing.

In organizational science, vast theories have been established. We have mainly inspired by the fundamental work of Simon [30][23] in his model of bounded rationality, Thompson [12] and Galbraith [2][10][11] in their definition of contingency theory. Simon has pioneered the research on bounded rationality and intellectual effects of his work made lots of contribution in understanding of humans about organization. His model aims to represent how limited rational humans make decisions and solve problems under different environments. He views human beings as bounded rational entities limited by computational and informational barriers. Simon describes human beings as "satisfying" rather than optimizing, meaning that in dealing with problems, they tend to satisfy their targets under given constraints according to their informational and reasoning capacities. Galbraith introduced his information processing view of organization [2] by modeling humans in organizations as information processors. This work is a foundation of many organizational models [5].

The main proposition of contingency theory is that there is no best way of organizing an organization. A successful organization design in one situation might not be successful in different situations. Therefore the design of the organization and its sub-systems should be performed according to the type of task environment. Galbraith's information processing view of organizations [10][11] and Thompson's detailed account of task dependencies [12] provided needed clarification about the relations between organizations and the their environment, characterized task environments, and identified the natural and rational response of organization to different task environments [10][11][12].

Beside the theoretical advances in organizational science community, computational organizational models have been developed [5][31][32][33][34]. Burton et al's U-form and M-form model of organization provides macro contingency view to organization [34], while Carley's [33] model of "organizational learning and turnover" and the virtual design team [5] developed at Stanford provide more micro level views of organizations. The two latter models are differentiated from each other because of the type of human actors they use. Human actors in Carley's [33] model have adaptive behavior while VDT models human with indirect behavior. The Virtual design team (VDT) models micro-level behavior of project team members in performing a project for a limited time in order to predict the team performance. This computational organization model targets project based organization whereas our PMT model targets service-based organizations or enterprises where there are continuous flows of requests from the market as well as perpetual enterprise operations in response to the requests.

The last area of related work, business process reengineering [3], particularly focuses on enterprises' processes for drastic improvement and attempts to generate potential benefits such as increasing productivity through reduced process time and cost, improved quality, and greater customer satisfaction [4]. Workflow management systems which are built to model and analyze business processes can be divided into activity based and communication based. In activity based workflow management systems, processes act as information containers and human actions are ignored. An extensive review of activity based process modeling methods can be found elsewhere [27]. To bring human action into the workflow, communication based workflow management systems such as action workflow [17] have been introduced. We will review this method in section 3 where we describe our client service model of enterprise.

3 PMT: A Model of Enterprise Operations and Organizations

It has been pointed out that enterprises benefit from enterprise models in three different categories namely *design*, *analysis* and *operation* [1]. An enterprise model should be capable of benefiting each of these categories. From a design perspective, an enterprise model should provide essential concepts to define the whole enterprise. Enterprise designer should be able to reason about different designs of the enterprise by exploring alternative models. From an analysis point of view, an enterprise model should provide the essential means for enterprise analyzers to predict the effect of particular changes on all parts of the enterprise. Finally from an operation perspective, the enterprise model must be able to represent what is planned, what might happen, and what has happened [1]. It must provide the information and knowledge necessary to support the operations of an enterprise. Our goal of enterprise modeling in this research is to develop a computer simulation system that allows enterprise managers or designers to perform various "what-if" simulation studies in order to identify managerial risks in the current enterprise settings and evaluate or predict performances of new enterprise designs. To achieve this goal, our enterprise model must be useful—i.e., covering sufficient level of enterprise operation details—and truthful—i.e., providing real-world or close-to real world simulation results. To satisfy these requirements, we restrict our scope of object enterprises by introducing following assumptions.

3.1 Modeling Assumptions

Enterprise organization is a "boundedly rational system": A boundedly rational system is a system that strives to make rational decisions but is limited due to the finite information resources available for making them [30]. We view an enterprise organization as a "boundedly rational system". Organizational actors have clearly defined goals and consensus on the "the most efficient means to achieve these goals" [10]. Therefore the appropriate description of organizational action will be one of the purposeful and goal-oriented searches for solutions trying to "satisfy" rather than "maximize" [23].

Most of the tasks in an enterprise organization are routine and repeated: Enterprise operations are dominated by conservatism and incremental improvement. Therefore, the nature of tasks in enterprises does not involve intrinsic innovation and creativity, but rather consist of routinized and repeated daily problem solving. This means that the enterprise organizations, operations, and business and technological environments are all known and relatively stable during the period of concern.

Enterprise organization adapts and responds to external environment as an open system: We view organizations as open systems [37] whose performance is highly dependent of external forces in the environment. More specifically, we attempt to directly model business environment for enterprises and capture political and economical environment factors indirectly through the business environment.

3.2 A Client-Service Model of Enterprises

Traditionally, researchers look at enterprise's processes as an "information factory" [17] with a focus on flow of information content. Workflow management systems using this approach are referred to as activity based. They tend to neglect human actors and their action and co-action within organizations [17]. Theories of speech acts and communicative action [20][21] inspired researchers toward a method with a focus on human actors. The fundamental idea of speech act theory is that a statement consists of both a "propositional content" (describing the world) and an "illocutionary force" (action mode). The illocution used expresses the action performed through speech and thus the type of relationship established between speaker and listener [17].

One of the most well recognized communication-based workflow methods is "action workflow" by Winograd et al 1992 [6]. Action workflow was first introduced to address information systems, but the idea also breaks through the area of Business Process Reengineering. BPR software tools such as "action technologies" have been developed based on the idea of action workflow. This framework describes the interaction of two individuals as customer and performer which construct the flow of work in organizations. Action workflow claims that any workflow consists of two actors and four phases. Two actors are "Customer" and "Performer" and four phases are: *Proposal*, *Agreement*, *Performance*, and *Satisfaction*, as shown in Figure 1.

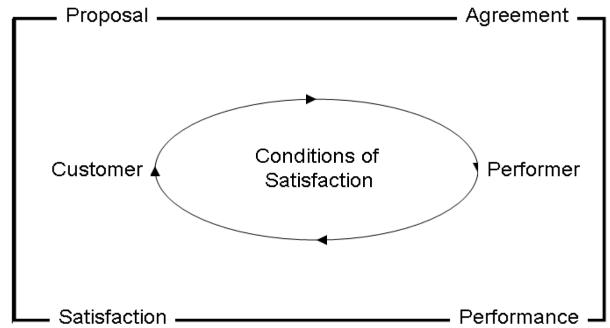

Figure 1: Action Workflow Model [6]

The main idea of this framework is that upon customer's request, performer makes a commitment to perform the work. The first phase of the cycle starts when customer requests a work from performer. It can be in opposite direction meaning that performer offer a work to the customer. In the second phase performer agrees to perform the job. In this phase customer and performer may go into a negotiation process. In the third phase which is the main phase of the cycle, performer performs the actual job. Finally in the last phase, performer delivers the result of the job to customer for evaluation.

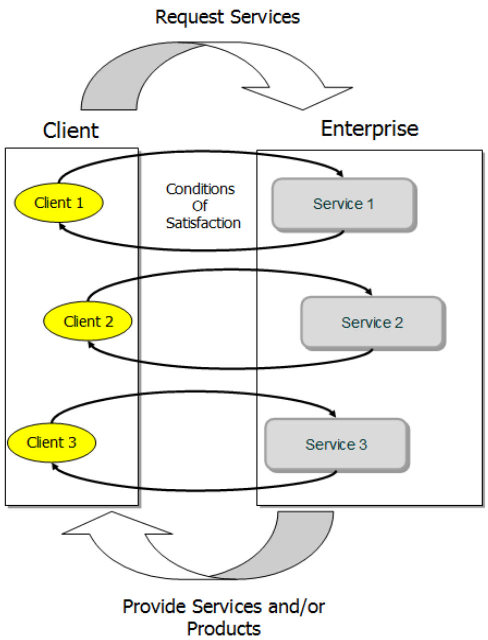

Figure 2: A Client-Service Model of Enterprises

In our PMT model of enterprise, we have extended the idea of action workflow by enlarging the interactions between two individuals to those between two companies; one is *clients* and the other *enterprise*. Furthermore, we view *client* and *service* provided by enterprise as *customer* and *performer* of an enterprise "business system", as shown in Figure 2. A "Business System" describes enterprise business processes and client-service interactions which lead to the delivery of product or service to from the enterprise to their client. In modern enterprises, clients and enterprises are involved in everyday's "business transaction". We call an activity *business transaction* if it generates revenue for enterprise. Following action workflow, four phases has been introduced in our framework for modeling enterprise "business transactions". A business transaction starts with a client sending a *request* to a service. In this phase, the client is engaging in a number of Client Operations (COP). During such COPs, the client sends its Service Request Items (SRI) to corresponding services of an enterprise when needed (modeled as probabilistic functions). In the second phase, within the requests are generated and being sent to corresponding services of enterprise. Service fulfills the requests according to its capacity and provides a report for the client in the third phase. Finally in the last phase, the enterprise performance is evaluated and if not satisfactory, client may resent its request to their service providers.

In this framework, we aim to analyze the response of enterprises in terms of their capacity in meeting market demands. Market demand is modeled by defining clients and their patterns of request generations. Enterprise capacity is constructed by organization, processes and resources and these elements have been separately modeled and their relations have been defined.

3.3 The PMT Structure

We view enterprise as an "operating system" where there are some applications running to serve user requests and these applications use available resources. This view gives a suitable structure for our computational enterprise model. According to this view, we have divided enterprise into 4 main components, namely, Client, Process, Organization, Resources, as shown in Figure 3. Each component is isolated and has its own boundary, but has multiple interdependencies with other components within the enterprise. Clients work by sending requests to enterprise and occupying enterprise human or non human resources. On the other hand, enterprises need to efficiently use their capacity in terms of their organization (i.e., human resources), processes and resources to fulfill clients' requests. In the following subsections, we describe some details of the models of the 4 components, i.e., organization model, process model, resource model and client model.

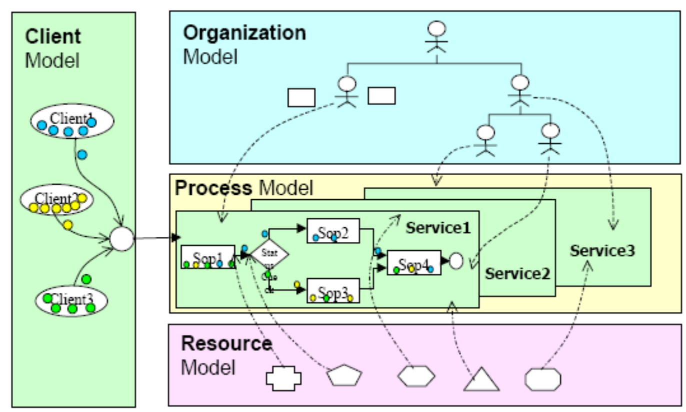

Figure 3: The PMT Client, Process, Organization, Resources

3.4 Organization Model

Our view of enterprise organization originated from Galbraith's information processing view of organizations [2], but we further extended this model to make it suitable for our computational enterprise model. Galbraith views organization as a network of human actors capable of information processing with limited capacity. In his model each task is associated with an amount of uncertainty which is defined as the difference between the amount of information required to perform the task and the amount of information already possessed by the organization [10]. While uncertainty as a general term in Galbraith' model defines the amount of information needed for processing the task, structure, skill and behavior of organizational actors define the capacity of organization in processing different tasks. If an actor does not possess the required information needed for a certain task, an "exception" is generated and he or she uses organizational communication and control system to obtain the required information. In response to exceptions, coordination work is generated and flows through the organization network. This coordination work is also associated with an information content which needs to be processed by organizational actors. Exception generation relieves the actor from exploring the required information and puts information processing load on others who should provide the information. It also leads to congestion of communication channels of organization. In organization, usually exception handling is the responsibility of managers and therefore more exceptions lead to more information processing for managers. Exception generation is necessary for organization to maintain the performance, but on the other hand, overwhelming the actors with exception handling and clogging of communication channels makes an organization inefficient and unproductive.

Inspired by Galbraith's view we have modeled enterprise organization as an information processing network consisting of "nodes" (human actors) and "links" (communication and control channels). Organization design problem for an enterprise then becomes the design of such a network for fluent processing of incoming requests. The work load of this network originates from clients' requests. Organizational network then is further expanded to receive work items from processes which themselves are connected to non-human resources, as shown in Figure 4.

According to contingency theory [12], each organization has its own characteristics and one-size-fits-all ways of organizing are not effective for any organization. Researchers in organizational science started characterizing task environment and organization and their interrelationships [11][12][22]. Following the previous work [12], we characterize the task environment and organization and strive to computationally analyze the adaptation of organization in different situations. Therefore each task as the primary work is associated with complexity, uncertainty, interdependence [12], and volume. On the other hand, organization is characterized by differentiation, formalization, centralization and organization matrix strength [13][14]. Rate of information processing and exception generation are the two important factors in actors' behavior. These two factors determine the "quality" of an actor. An actor

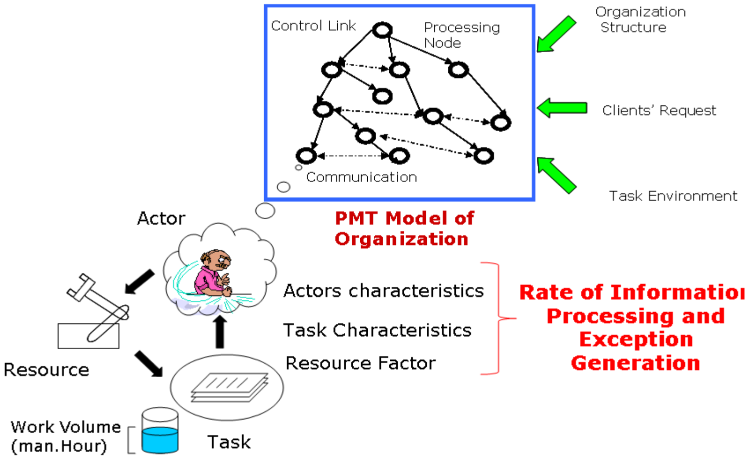

Figure 4: PMT Model of Information Processing

who is very slow in processing tasks (information), and generates lots of exception for other actors degrades the organization performance. But these two factors are not solely dependent of actor's skill. Although an actor's individual skill plays an important role, other factors such as task characteristics, organization characteristics and resource usage also affect the rate of information processing and exception generation. Therefore a good match of task characteristics, organization characteristics and resources leads to a better performance and efficiency for an enterprise.

In addition to processing tasks (service work), actors are involved in communication activities. Either in meetings or in face-to-face interactions, actors spend time to process communication items which indirectly improve the quality of service provided by enterprise. This improvement is achieved by the information that is exchanged between the actors. The information exchange provides information capacity for actors to fulfill requests more efficiently and effectively. Actors are also involved in non-value added activities. Actors may be idle for some period or process random noises generated from outside of organization, as shown in Figure 5.

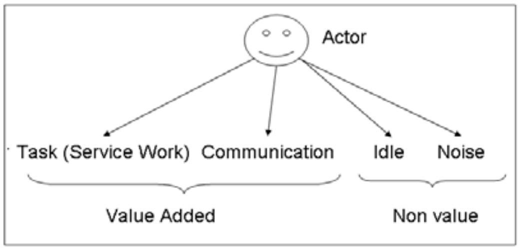

Figure 5: Actors' Activities

3.5 Process Model

Process model represents the task environment as mentioned in the contingency theory [12]. We have divided the processes into services that an enterprise provides to customers. For example a shipping company may provide navigation, loading and unloading services to its clients. Within each service many operations called *service operations* (SOPs) are performed by human actors to fulfill client's requests. The information processing framework of our organization model makes activity-based techniques more suitable for process modeling. There have been many techniques such as IDEF3, Pert/CPM and Petri-net that in addition to process modeling are useful for process monitoring and execution. We have adapted Digraph to represent enterprise process model due to its uniform process representation. This method is particularly compatible with our information processing view, where we can represent an activity as an information generator that creates information to be processed by human actors. The activities are connected to each other with directional or bidirectional arcs. According to Thompson's work [12], task environment can be characterized by interdependence, complexity and uncertainty. Figure 6 shows a sample process model.

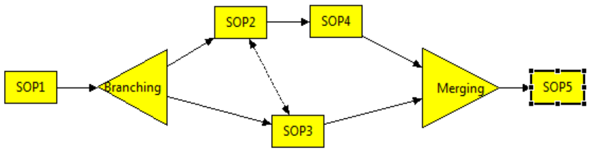

Figure 6: PMT Sample of Process model

3.5.1 Interdependence

The relation between activities represents *interdependence of activities* and can be categorized as *pooled*, *sequential* and *reciprocal* interdependence [12]. In the order introduced, the level of coordination required among humans to deal with these interdependences increases. In the *pooled* interdependence, each activity makes a "discrete" contribution to a pool of activities and each is supported by this pool. The progress of one activity does not depend on the progress of other activities and therefore the amount of coordination is minimal. In our model, since all service operations or activities are contributing to the *service-level* and *enterprise-level goals*, they are all share pooled interdependencies. Figure 7 illustrates pooled dependency.

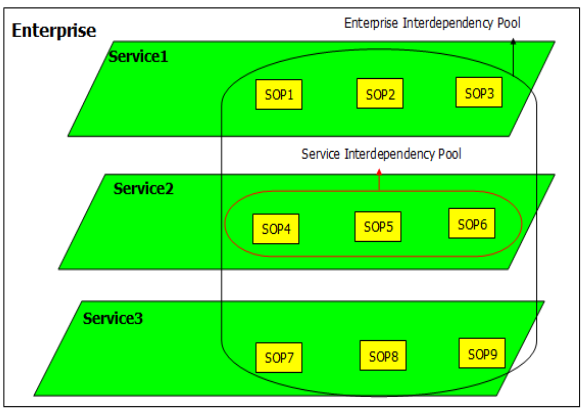

Figure 7: Pooled Interdependence in PMT Model

Enterprises with only pooled interdependent activities rarely exist in real world [12], and there are always activities that are directly dependent of each other. If activity-A should start only after completion of activity-B, then they have *sequential* interdependency. We model this interdependence in Digraph by representing two activities linked with a *directed* arc. The amount of coordination for this type of interdependence is relatively low. The third type of interdependence, *Reciprocal* Interdependence, is referred to the situation where the outputs of each activity become inputs for the others mutually [12]. This type of interdependence is coordinated by "mutual adjustments" and involves the transmission of new information during the process of activity [12]. This means that coordination load can be very high and as a result requires intense communication. We have modeled this type of dependency in digraph by bi-directional arc namely called *communication link*, as indicated in Figure 8.

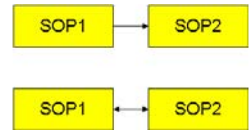

Figure 8: Sequential and Reciprocal Interdependence

3.5.2 Complexity

Thompson [12] describes complexity as the number of constraints on the actions of human actors within an organization. As the number of constraints increases, actors should act more rational, hence Fox [22] defines complexity as excessive demands on rationality [22] and distinguish between complexity of information (i.e., the difference between the knowledge of actors and the knowledge required to perform the task), complexity of task (i.e., the number of actions exceeds actors' available time) and complexity of coordination (i.e., the required communication exceeds the available communication capacity). Our extended information processing view gives us the ability to represent the above complexities in a uniform way of information processing. We associate each activity with a type of work (e.g., mechanical, electrical), a work volume and a level of complexity which represents the number of actions in terms of amount of work. In addition, actors are associated with a set of skills (e.g., mechanical, electrical) and skill level (e.g., high, medium, low). A good match of actors to activities can decrease information complexity. Also complexity of coordination is addressed by communication channels and information exchange activities. The effect of complexity in our computational model is modeled through delaying the information processing and generating exceptions and communication items. As the complexity increases, actors need to spend more time for information processing and the probability of exception and communication increases.

3.5.3 Uncertainty

Thompson defines uncertainty as the number of contingencies facing the organization [12]. Galbraith in a similar way defines uncertainty as the difference between information available and the information required to make the best decision [10]. Our view of uncertainty in PMT says: As the level of contingency increases actors are more uncertain about what to do next, therefore they cannot allocate their time efficiently.

In order to represent this inefficiency arising from uncertainty, we have defined *noise items* to be processed in actors' information processing cycles. According to the model of bounded rationality [23], we have implicitly modeled uncertainty of environment through its affect on actor's attention cycle. Another effect of uncertainty is its effect on the frequency with which human actors need to communicate. As the level of uncertainty goes up, actors generate more communication items. Hence actors need to allocate more time to attend the generated communication items.

3.6 Resource Model

Workflow management systems usually consist of a process model and an organizational model. These systems usually fail to provide a model to integrate non-human actors (e.g., automated machines, and computers) into the system [24]. While many systems may include enterprise resources as a part of their process model, we draw a line between them. There are three main reasons for separating between resource model and process model [24]. Firstly, the life cycle of enterprise processes is different from the life cycle of technical resources. Secondly, the isolation of each model leads to evolution of each model independent of the other adding to their robustness. Thirdly, isolated resource model can be shared by several enterprise services which reduce redundancies and increases the quality of the data maintained.

From our extended information processing view, we define *resource* as an entity that is assigned to an activity and is consumed to facilitate the information processing for the assigned activity. Note that in PMT, we have a clear distinction between human actor and non-human actors. We have represented human actors comprehensively through our extended information processing view of organization and we treat non-human actors as resources of an enterprise and capture them in the resource model. In our computational model this means that a resource affects the speed of actors in processing a task. The *resource model* then is defined as the description of resource arrangement and their assignment to the process model. We define four attributes for a resource:

- **Type:** A resource may be software, hardware, or a supplier. Depends on the type of service operation (SOP), different types of resource is required.
- **Availability:** During the 24 hours daily cycle of enterprise, a resource may or may not be available. Therefore a good match of resource availability and service operation execution results in a better performance and efficiency for the enterprise.
- **Consumability:** A resource can be consumable and diminishing over time, or non-consumable. Consumable resources need to be supplied as time passes.
- **Maintenance:** Different resources may require maintenance with different frequencies.

Resource allocation is a very important issue for enterprises. A good resource allocation in PMT model results in lower cost, better performance and efficiency.

3.7 Client Model

The driving force for any enterprise is the market. There are several reasons for explicitly modeling the market demand in PMT. The way market demand is modeled depends on the purpose of the modeling. We categorize demand modeling into two main perspectives namely *client point of view* and *enterprise point of view*. From a client's point of view, the main purpose is to study client's need and behavior (client analysis) in order to customize enterprise's services or products. The main question here is how to change the service or product to attract more customers and increase the profit. In this case, the main focus is client analysis. On the other hand, from an enterprise point of view, the main purpose is to adjust enterprise capacity (enterprise analysis) to meet market demands. Therefore, from this point of view the size of the market and the pattern of requests from the clients as the independent variable play a significant role.

Similar view from Keys [15] categorized market demand models for enterprise business simulations into two types namely *demand dependent across firms* and *demand independent across firms*. In the models that are demand dependent across the firms, the competition among the enterprises in the same business plays an important role and is modeled. Essentially in these models the focus is on client's analysis in order to obtain a greater share of the market. On the other hand, in demand independent modeling, competing firms' business does not affect the model. In this type of enterprises, the quantities demanded from the market depend only on the decisions being made within the boundary of the enterprise. Chiesl [16] stated that these types of modeling have several advantages. He pointed out that they reduce time delays, eliminate system hardware problems and improve the authenticity of the simulation. These types of simulations are also particularly powerful because, they tend to isolate the problem and therefore the results of enterprise's decisions can be calculated with less ambiguity.

Our computational model of market demand falls into the second type of the above discussed models. According to our extended information processing view, we focus particularly on the relation between the market demand and the enterprise capacity. The question that is quantitatively being answered by our computational model is how enterprise should adjust its business system (i.e., the enterprise capacity) in order to meet the market demand. In other words, if there is a jump in market demand how an enterprise should respond, e.g., hiring more people, reengineering business processes, or buying more resources? And if the market demand drops, what enterprise should do to maintain its profit?

A client represents an outside entity such as people, government or other companies. We define a *demand function* for each client that request services from the enterprise. In a demand function, x-axis represents time and y-axis represents quantity of demand or the amount of the *service request items (SRIs)*. A SRI in our computational enterprise model represents an event that is generated from clients and is being sent to an enterprise's service to be processed. Because usually enterprise has many clients, therefore many demand functions need to be defined to accurately represent clients' demand. On the other hand many services may be offered by an enterprise and there is a many-to-many relation between the clients in the market and the services of an enterprise. The demand function of each client for each of the requested service has its own characteristics. Therefore for each client a set of client operations is defined. Each client operation is associated with a demand function that represents the pattern of service requests.

A *simple client* consists of set of *disconnected client operations* (Figure 9) and is associated with one or more demand functions and can generate one or more types of service requests.

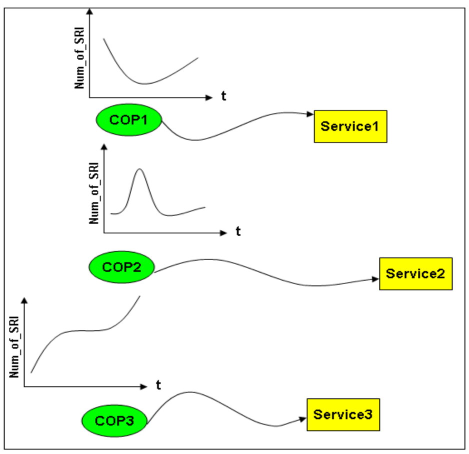

Figure 9: A Simple Client with Three Client Operations

An *operational client* is a kind of client in which client's demand function changes over the time. These types of clients are composed of a sequence of client operations (COPs). According to the arrangement of COPs, we categorize operational clients into following types:

Sequential: Client operations are sequentially dependent (Figure 10) on each other and they may request different services within the enterprise. The end of one client operation is the start for the dependent client operations.

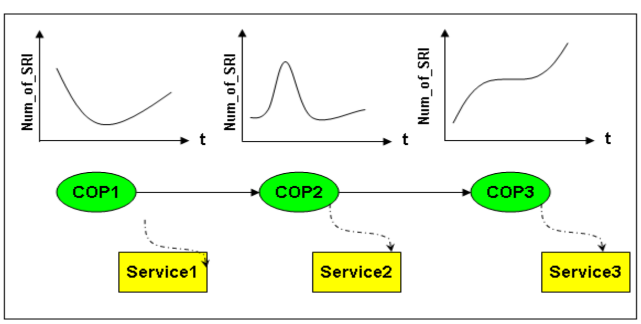

Figure 10: Operational Client with Sequential Client Operations

Parallel: Client operations can be arranged in parallel (Figure 11). In this case two or more client operations send service request items into services at the same time.

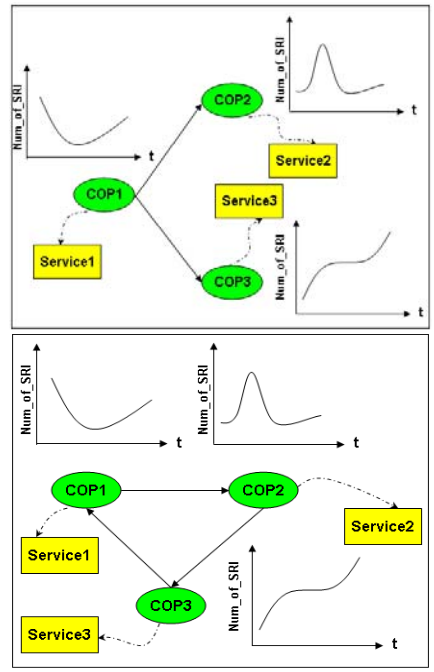

Figure 11: Operational Client with Parallel & Cyclic Client Operations

Cyclic: Client operations can be arranged in a cyclic way (Figure 11). The end of last client operation is the start of the first client operation.

4 PMT Simulation System

Our PMT model of enterprises has been implemented based on JAVA. Figure 12 shows the input and output of typical PMT simulations.

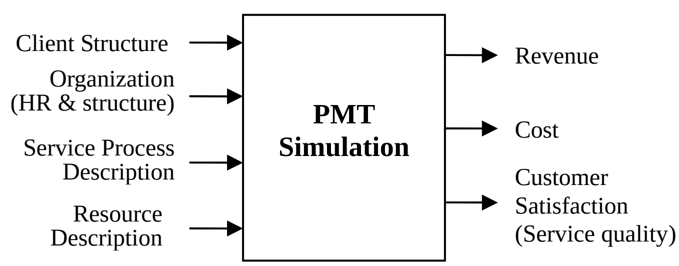

Figure 12: PMT Simulation Model

There are four major inputs to our PMT enterprise model:

- **Organization**: Human resources including managers, staff leaders and staff members; organization structure (e.g., hierarchies), communication channels (information exchange paths, flow of exceptions), behavioral descriptions including work processing behaviors, exception handling behaviors, communication processing behaviors, and decision making behaviors.

- **Clients (Description of client requests):** Who are the clients and what is the pattern of request generation?
- **Processes (Description of service operations and dependencies among them):** How the service operations are arranged within a service unit? What kinds of dependencies exist among service operations?
- **Resource (Description of resources within the enterprise):** What kind of resources is available within the enterprise? How they affect the speed of service operations?

The output of PMT simulation is quantitative measurements of enterprise performance. Enterprises are always seeking for increasing their profit by increasing their sales or decreasing their costs. As enterprises attract more clients, they have to increase their capacity; otherwise the quality of their service will drop. This is particularly true for the management companies where there are many human based activities. A careless increasing of clients may result in severe customer dissatisfaction and damage of enterprise reputation. Dealing with this trade-off to maximize enterprise profit is a big challenge for today's enterprises and usually managers are left with only their experience. PMT computational model supports managers in their high level decision making with regard to different aspects of their enterprises including clients, organization, processes, and resources.

Validation is a crucial step in developing computational organization models. Validity for a computational organization model is a relative term with a degree of confidence to the results coming from simulation [17]. The question here is not whether a model is valid or invalid but rather is how reliable are the results. Levitt et al [17] provides a trajectory for validating computational organization models, building serious of scenarios for step by step validation. They identified three levels of validity for computational organization models, i.e., reasoning, representation and usefulness. They also suggested different type of experiments for step by step improving the levels of validity. These experiments include toy problems, intellective, authenticity, generalizability, reproducibility, retrospective, natural, and prospective with intervention experiments. Success in each of these experiments builds more level of confidence in using the model's results.

In the last 3 years, serious of testing have been done for internal validation of PMT model to make sure the system is functioning as designed. We are currently in the process of external validation. As suggested by literature [17][18], case studies are performed by people from industry with no clue of system development, in collaboration with modelers. Series of interviews are currently being carried out with industry companies to gather necessary input data for modeling. The output results from PMT simulation are being compared with the real world data to continuously validate the model.

5 A Case Study

As a part of validation, we have conducted numerous case studies. The cases were taken from actual business processes of existing enterprises. In this paper, we describe a case study of a consulting enterprise, J Co. The procedure taken for this case study can be described as follows.

- Through interviews, the target business process, modeling scope, and focuses of case study are identified.
- The information regarding the target business process is collected according to the modeling scope and focuses.
- The information is summarized as a case scenario including a brief business process description and focuses
- The enterprise business process model is developed based on the case scenario.
- The model is verified by the simulation with and without considering generation of exceptions.
- The results are analyzed and examined, and the feedback from the target company is sought.

5.1 Case Scenario (J Co.)

A *case scenario* is a summary of the target business process and a brief description of the modeling scope and focuses.

Scenario and scope:

- J Co's business is consulting; The Company's clients are the projects being carried out for its customers.
- J Co categorizes its clients into 9 types of projects with each type requiring different tasks.
- 7 types of project tasks were found to be identical for all project types.
- 10 people are assigned to 40 projects annually. A person is usually assigned to multiple projects simultaneously.
- Recently, the labor cost is dramatically increasing due to staff members working over time.
- In J Co., managers suspect that the bad communication is the cause of poor process performance. Particularly, General Manager was suspected as a cause of the problem.

Focuses:

- Examining the communication performance of the company in carrying out its business processes.
- Identifying the communication bottlenecks.

5.2 Case Modeling

Based on the case scenario and modeling focuses, a model of J Co's business process is developed. The modeling procedure follows:

1. Model Client and Services Relations
   a. Define Clients
   b. Define corresponding Services
2. Model details of Clients
   a. Define COPs (Client Operations)
   b. Define COP-and-Service relations
3. Model details of Service

a. Model Organization by defining Positions and their supervising/report-to relations.
b. Model Processes by defining SOPs (Service Operations), and precedence/sequential and communication/reciprocal relations among them.
c. Assign Positions to corresponding SOPs.

5.2.1 Modeling Clients and Services Relations

According to the case scenario, all projects processed by J Co. are categorized into 9 types of projects. Depending on the type of the project, its required tasks differ, as shown in Table 1. For example, Project 1 is composed of "Inquiring" and "Document Study" tasks. Each type of the projects was modeled as a Client, and the tasks listed in Table 1 were modeled as a set of Service. Figure 13 shows the Clients and Services relations based on Table 1. In the figure, the sky blue bubbles are Clients and orange rectangles Services.

In this case study, we performed simulations only for the market environment captured by Table 1 and Figure 13 for as-is analysis. Various to-be analyses can be performed by designing possible to-be market situations, such as changing number or the types of annual projects and varying available HRs.

Table 1: The project types and required project tasks

		Required Project Tasks as Services						
		Inquiring	Document Study 1	Document Study 2	Field Survey	Traffic Simulation	Maneuvering Simulation	Anchoring Simulation
Project Types as Client	Project 1	X	X					
	Project 2	X		X	X	X		
	Project 3	X		X	X	X	X	
	Project 4	X		X	X	X	X	X
	Project 5	X		X		X	X	
	Project 6	X		X				X
	Project 7	X		X		X		
	Project 8	X		X			X	
	Project 9	X		X			X	X

5.2.1 Modeling Clients

Each project modeled as a Client has a set of required project tasks. Each project task requires its corresponding services from the J Co. The project tasks, therefore, can be defined as COPs (Client Operation), which are the generators of SRIs (service request items). Figure 14 shows the client description for Project 4. The green and blue colored rectangles are the project tasks or COPs. They are defined by execution duration, frequency of request generation, and its variance. Each task is linked to its corresponding service shown as orange rectangles. After a task is completed during the defined execution duration, its successor task is initiated.

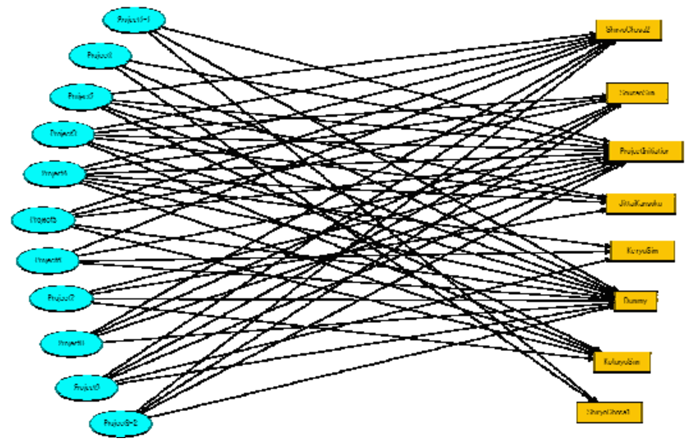

Figure 13: Client and required Service

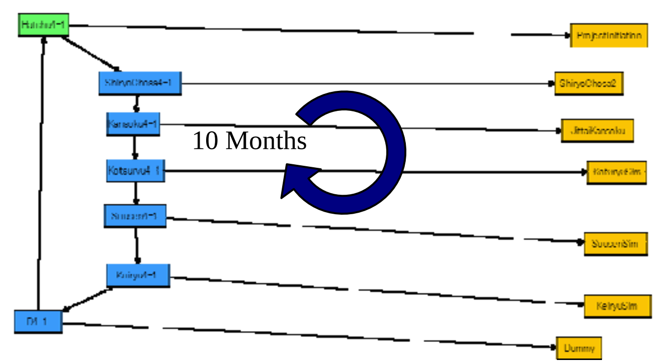

Figure 14: Project tasks as Client Operations

5.2.2 Modeling Services

Figure 15 is a model of a service provided by J Co. The green objects are the Positions of the service organization, which are Program Manager, Project Manager, and Project Staff. The yellow rectangles are the SOPs (service operations) for the service. In this case, three types of SOPs were modeled, which are Practical Operation, Customer Coordination, and Program Management. Practical Operation directly contributes to completing the client's requests. Customer Coordination is the coordination with the customer regarding the project. Program Management is the control and governance operation to align all projects and enterprise policies. Practical Operation and Customer Coordination, and Customer Coordination and Program Management are linked by Communication links, which indicate the communication dependency. In this case, communication is the most crucial focus. By defining the management operations for Project Manager and Program Manager with their communication dependencies, the focus was appropriately modeled.

5.3 Simulation Results & Discussion

In this case study, the simulation was performed for one year. In our system, efficiency, cost/profit, work breakdown, Number of work items in process, and processing time are measured.

As an example, Figure 16 shows the Work Breakdown Chart of an entire service, which reveals how much human resource is spent for the works, such as *direct work*, *rework*, *communication*, *decision-making*, and *idle*, respectively.

In the case scenario, the communication issue is considered as the most crucial focus. The communication quality of each position, therefore, was measured and examined. Figure 17 shows a set of simulation results. The communication quality plotted with respect to the number of annual projects. The communication quality is defined as follows.

CommunicationQuality = NumberOfProcessedCommunications / NumberOfGeneratedCommunications

According to the definition above, if a position cannot process the communication within the appropriate time, the communication quality will be decreased.

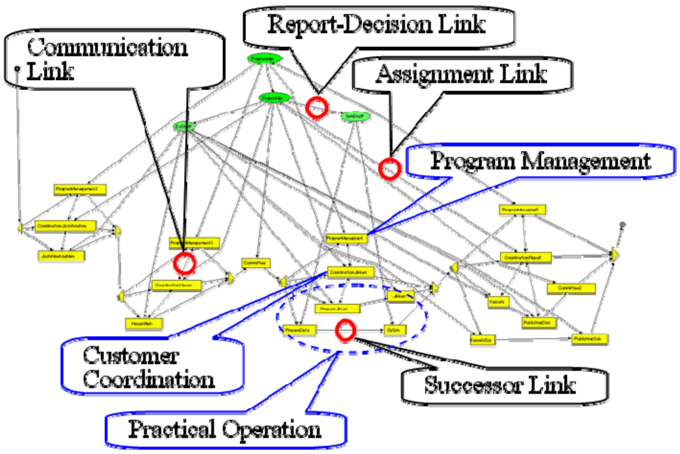

Figure 15: Service Operations and Organization

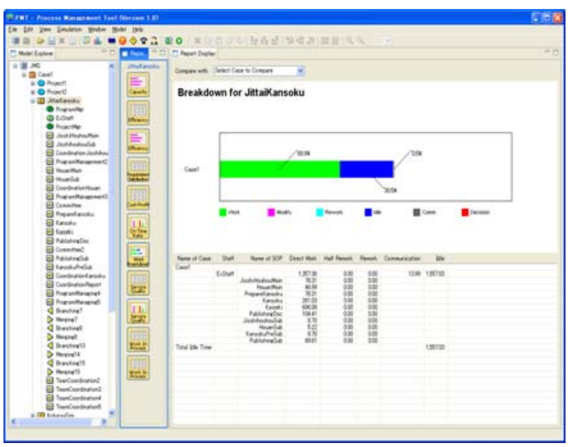

Figure 16: Work Breakdown Chart of PMT

From Figure 17, the following conclusions can be obtained.

- J Co initially considered the Program Manager to be the cause of communication problems. The simulation, however, indicated that the Program Manager was not the bottleneck but the Project Manager was.
- The insufficient communication from the Project Manager may have been the cause for the poor decisions of the Program Manager.
- Insufficient communication from the Project Manager might have also negatively influenced the Project Staff's operation quality, which depends on the Project Manager's timely responses.

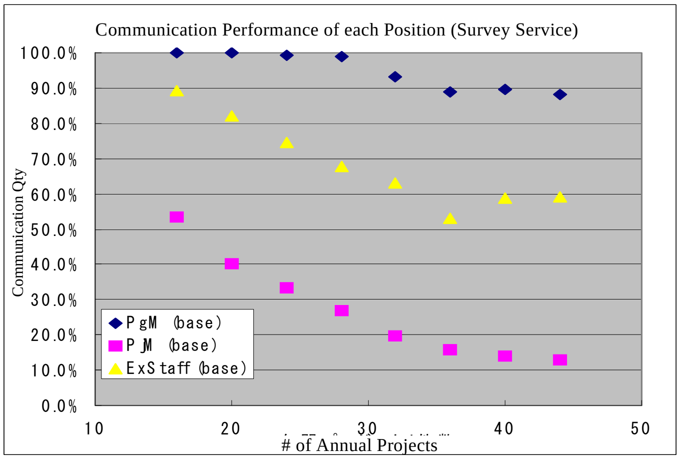

Figure 17: Communication Quality for Different Positions for Increasing Number of Projects/Year

We discussed these findings with the managers of J Co. Most of them shared these views. After reviewing the simulation results, they recognized that the problem was with the Project Manager who had been extremely busy with real consulting and customer relation work, leaving too little time for his managerial duties.

6 Concluding Remarks

Increasing competition in the market place and dynamic changes of the market demand in quantity, quality and variety have made it extremely challenging for enterprise executives and managers to keep their operations efficient and organizations effective. In our research, we attempt to develop a conceptual model and a computational technology to support enterprise management by allowing the executives and managers test-fly their enterprises through various possible "what-if" scenarios so that they can identify their market niches, configure most efficient operations, and construct most effective organizations. Although computer simulation technologies and management tools have been advanced recently, developing such an enterprise model and simulation system is still a challenge. Little research has been reported that explicitly captures all business, operations, organization, and technology aspects of enterprises in a coherent model or system. The challenge lies in identifying a right balance between the level of details of the enterprise that should be captured and the logic of enterprise operations that can be well understood and modeled. In our research, we view enterprises as performers that provide services to the market's clients.

Furthermore, the enterprises (i.e., the performers) perform their services through dynamic interactions among organizational people, service operations, and technological resources. Based on PMT model, given a specific situation of the market's clients, an enterprise manager can arrange their organizations, services, and resources for the best performance. On the other hand, given an organization, services processes, and resources, an enterprise can look for best market or client situations for the best performance as well. The PMT case studies conducted thus far including the one reported in this paper have demonstrated the effectiveness of our proposed approach.

The current PMT model has not yet included an explicit resource model. Furthermore, a large number of simulation parameters included in so called "behavior matrix" still need to be calibrated to match specific industrial domains. Our ongoing work is focused on developing a complete resource model, expanding the case studies in different industrial domains, and accumulating process models and behavior parameters for different domains.

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