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Exploring the Representation of Complex Processes in Information Intensive Services

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Abstract

It is well known that information-intensive services (IIS), such as financial services, information technology services, health care, telecommunications and broadcasting, and education, have shown some of the highest growth rates in the service sector of the U.S. economy. In such services, the business processes are often complex, involving a number of different parties. For example, multiple people from both the service supplier and the customer participate to co-produce a desired service outcome. Through a few case studies, we observe a set of common characteristics of such complex services processes. To obtain a systematic understanding of such processes, we explore the possibility of using existing modeling or representation frameworks and evaluate them based on the how well they address the characteristics of complex processes in IIS as well as other analysis requirements.

Keywords: service modeling, business process modeling, modeling framework

1. Introduction

The service sector represents the largest and the fastest-growing segment of the economies of the U.S. and other developed countries. For example, in the U.S., services accounted for roughly 80% of employment in the year 2004 (Apte et al., 2011). In the past few decades, information has also come to play an important role in almost every aspect of life. Apte and Nath (2007) estimate that the share of the US information economy in total GNP grew from about 46 percent in 1967 to about 63 percent in 1997. They conclude that in comparison with the total economy, the information economy has been growing at a faster rate, and within the information economy, information-intensive services (IIS), such as financial, business services, professional services, health care, telecommunications and broadcasting, web-based consumer services, publishing and media, and education, are growing at even faster rates.

The paucity of research in operational aspects of services in general, and information-intensive services (IIS) in particular, has been well documented (Roth and Menor 2003, Chase and Apte 2007). A group of companies and professional industry associations has recently formed the Service Research and Innovation Initiative (2011) to address this dearth of research in service. Similarly, in contrast to traditional manufacturing processes, the qualitatively different nature of IIS is also well documented (Karmarkar and Apte 2007). For example, IIS are characterized by the sheer volume of data they use and generate, and the complexity of the data and communication networks.

To better understand the characteristics of such services, we refer to the classification proposed by Apte & Mason (1995) whereby the service activities in a process are divided in four categories:

(1) Physical actions that involve manipulation of physical objects

(2) Informational actions that involve collection, processing and dissemination of symbols—data, information and decisions

(3) Interpersonal actions that involve working with customers and others

(4) Other Indirect actions that do not belong to any of the above categories.

Clearly, the above action types are not mutually exclusive. In a given activity, one may be collecting information (category 2) while also interacting with a customer (category 3). Apte & Mason (1995) propose that the relative amount of time spent in the above activities can be used to characterize a service process. For example, the information intensity of a process can be defined as the ratio of time spent in dealing with information in a process to the total time spent in that process. The other terms characterizing a process, such as customer contact intensity (Chase 1983), can be defined in an analogous manner.

The inherent intangibility of information makes IIS intangible, which leads to a fundamental difficulty in measurement and quantification of their inputs and outputs (Karmarkar and Apte 2007). Information Intensive Services are frequently produced and consumed simultaneously as exemplified by education, consulting and financial planning. Co-production is an important characteristic of IIS (Fuchs 1968, Fitzsimmons and Fitzsimmons 2007). Co-production implies that both the service provider and the customer participate in producing service outputs. Thus, the production of IIS depends on the interaction of the processes of the service provider and the customer. This collaboration contributes to the potential for a high degree of variability in the service creation process and also leads to processes which are controlled by multiple actors.

As alluded to earlier, measurement and quantification are two fundamental challenges associated with IIS. For example, consider the field of education which, at the most root level, results from the co-productive efforts between teachers and students to transfer knowledge and problem-solving skills. Although teaching assessments given by students of the teachers and course grades given by the teachers for the students are typical measures of achievement, they may not capture the actual value of the output from the educational co-production. The measurement of quantity and quality of output is extremely difficult. Some obvious measures such as time may be misleading; for example, a lecture lasting three hours is not necessarily three times better than a lecture lasting one hour. At a more basic level, it is difficult to clearly describe and define the knowledge transfer and absorption process as it transpires in a classroom. Traditional tools and concepts such as productivity, quality, and cost depend crucially on the ability to measure and quantify inputs and outputs of an operational process. Since this ability is elusive for IIS, it becomes hard to rely on traditional tools of operations management and industrial engineering in analyzing and improving IIS (Karmarkar and Apte 2007).

In this research we focus on business related internal or inter-organizational (business-to-business (B2B)) information intensive service processes that would impact sectors such as manufacturing, service, or government. For example information intensive internal processes in the manufacturing sector include product development, financial management, sales, and after-sales services. In the service sector, examples can be found in management consulting, accounting and auditing, financial management, insurance, healthcare, and management education. Within the government sector, many internal processes related to urban planning, service administration, legislation, or the judiciary are information intensive. We also note that interactions between two firms fall into this category, regardless of what sector the firms are in, such as those in collaborative planning and joint product or solution development. It is easy to see that this class of processes is commonly found across industries and sectors and is therefore important to the economy in general.

It is useful to understand the behavior of IIS processes at a fundamental level – how they evolve over time, behavior of the individual actors, and how they interact. With such an understanding, an enterprise can design business processes more effectively, with more productive use of resources. In this paper, we examine methods that have been used in manufacturing and services to better understand the behavior of information intensive service processes through modeling. Section 2 discusses the subject of interest, complex processes in IIS. We selected two case studies and describe them in some detail as representative examples of the type of processes in scope. Then we identify the salient characteristics of such processes in general. Section 3 briefly reviews literature that is relevant to our study but is not used in the following section. We discuss five potential modeling frameworks in Section 4, drawn from existing literature, and evaluate them subjectively in section 5 based on our experience in this area. Section 6 contains our conclusion.

2. Complex Processes in Information-Intensive Services

2.1. Case studies

To help set the context for the types of IIS processes that are of interest, in this section we describe two case studies – the insurance claims handling process and the response to strategic outsourcing RFP. The observations of these (and other) case studies serve to illustrate the common salient characteristics of the complex, collaborative processes in IIS.

2.1.1. Case 1: Insurance Claims Handling Operation

The insurance business requires an insurance company to pay the insured in the event of a loss in return for the insured's payment of the insurance premium to the company. In case of a loss, the insured files a claim with the insurance company, that performs the necessary investigation and evaluation of the claim before making the appropriate loss payment to the insured. The process of claims investigation, evaluation and payment is known as the claims handling process (CHP) and is one of the most essential and critical functions of an insurance company.

The claims handling process has a significant impact on the profitability of property and casualty (P&C) insurance companies which sell such insurance policies as automobile, homeowners, product liability and workers compensation. The claims handling process in P&C insurance companies begins with the *reporting* of a claim by a policyholder, claimant, or agent to the insurance company. Upon receiving the report, the insurance company establishes a claims file, and records some essential data pertaining to the loss event and the identities of the policyholder and claimant/s. The claim is then forwarded to a manager who judges its nature and complexity, and *assigns* it to a suitable claims representative. The claims representative begins his/her work by ascertaining that the loss is covered under the insurance policy and that the company is potentially liable to pay. An appropriate *reserve* for the estimated amount of loss is also established at this point. The time consuming process of claims *investigation*, which can last from a few days to several months, now begins. All the necessary information and documentation pertinent to a claim, including claimant and witness statements, police and medical reports, photographs, etc., are gathered as needed. All the case-specific and other factors are considered next in *evaluating* (i.e., estimating the size of a fair loss payment for) claims. The *negotiations* with the claimants or their representatives are then undertaken. When all the parties are in agreement, a claim is finally *settled* by the claim representative by authorizing a loss payment and closing the claim file.

While the steps, as described, above represent a typical flow of the claims handling process, a very large number of variations are experienced in practice. For example, if the claimant hires an attorney or files a law suit, the process can be become considerably longer and the process steps undertaken and their sequence can be significantly different. Nevertheless, the claims handling process offers an interesting example of a complex information intensive process involving multiple decision makers and collaborative production of outputs.

2.1.2. Case 2: Response to Strategic Outsourcing RFP

Strategic outsourcing of services is where one company performs essential business operations for another company. The economic premise of an outsourcing deal is that the Outsourcing Provider has greater experience and superior know-how in a particular business operation; and can therefore perform the business operation more efficiently and effectively than the Outsourcing Client. The Outsourcing Client tends to outsource services that are central to doing business (e.g., payroll or information technology) but are not central to its core business mission (e.g., banking, insurance, or manufacturing). Thus, the Outsourcing Provider delivers value to their Outsourcing Client primarily through reduced costs of running the outsourced services. Additionally, the Outsourcing Client may receive improved scalability, adaptability, availability, and service quality and industry competitiveness. It is worth noting that outsourcing is not synonymous with off-shoring, which is the practice of moving work to a country with lower labor cost and/or available skills.

In the case of information technology (IT) operation services, the business of IT outsourcing involves an IT provider (Outsourcing Provider) who assumes responsibility for managing and maintaining an agreed upon set of IT functions for their client (Outsourcing Client). The following summarizes a study that was performed to examine how work is enacted by a service provider in response to a request for proposal (RFP) from a potential client. Work performed to respond to an RFP is highly customized, knowledge intensive, and dependent upon the terms of the RFP itself. Even under these conditions, it is assumed that efficiencies in organization and individual's work practices can be gained through improved processes and technologies for quicker and more accurate response. This work was undertaken to gain a detailed understanding of the work and organizational practices in IT outsourcing to inform the development of organizational interventions (new technologies and processes) and to help anticipate their impact on the service system as a whole (Bailey et al. 2008; Kieliszewski et al. 2007; Kieliszewski, et al. 2010).

As a brief overview, IT outsourcing can be described in four phases:

- Phase 1: Pre-sales: identifying and qualifying potential clients.
- Phase 2: Engagement: the provider works with the client to develop a business and technical proposal to be embodied in a signed contract.
- Phase 3: Delivery (or Transition): transitioning the technical, business and human elements of the service from the client to the provider organization.
- Phase 4: Production (or Steady State): ongoing IT operation and management by the service provider.

This case focuses on Phase 2: Engagement of an IT outsourcing deal that was supported through technologies as a series of process steps (Figure 2.1). The important point to note here is the assumption and emphasis on serialization of the process, similar to a manufacturing fabrication process. While a document, embodied as a solution and contract, is being fabricated, the activities required to respond to an RFP are knowledge and information intensive.

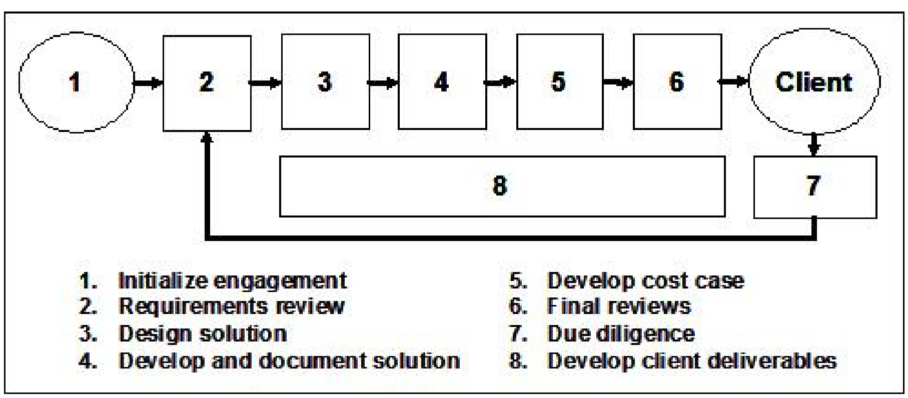

Figure 2.1. Engagement phase process diagram.

Findings from the study brought to light contradictions to commonly held views of how and when work was performed during the IT outsourcing engagement phase. That instead of work being aligned and conducted in a sequential process (Figure 2.1) it was composed of activities that were iterative, parallel and highly collaborative (Figures 2.2 and 2.3). These findings led to opportunities for improvements that impacted work activities in three major areas: collaborative disambiguation, tracking of dependencies, and tracking of assumptions.

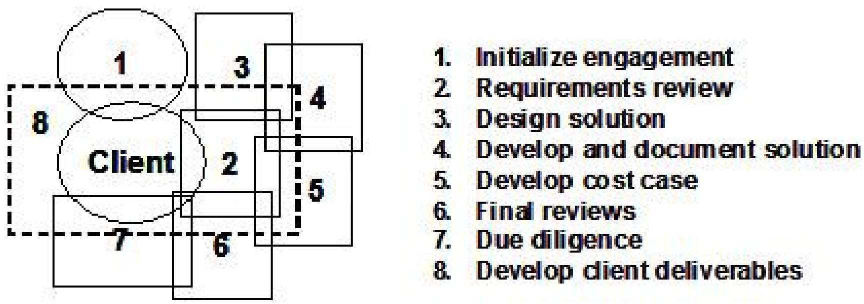

Figure 2.2. Engagement phase diagram showing parallel and interdependent relationship among activities.

Process View	Practice View
Serialized, Staged	Asynchronous, Iterative
Process stages are central to performing the work	Client deliverables are central to performing the work
Work and information is compartmentalized	Information flows back and forth freely, work is collaborative

Figure 2.3. Comparison of process and practice views of engagement phase work.

Collaborative Disambiguation. Each RFP that is received and pursued has to be disambiguated. This is in part due to the RFP being written from the client's perspective (e.g., what they have and their requirements for what they need and/or want) versus the provider's perspective (e.g., what to keep, what to transform, how to innovate for greater value). Disambiguation was done iteratively and often in parallel by practitioners reviewing the RFP documents independently or in small groups. The activity was conducted in this manner to discover specific statements that might be interpreted differently by people with diverse domain expertise or to identify statements that had unspecified implications across multiple domains. This slow and tedious work required the careful attention of experienced professionals to ensure that nothing was missed. Even the smallest of details were inspected. A majority of the important work of disambiguating the RFP happened outside of the standard tooling with ad hoc technologies to support the activity.

Tracking Dependencies. Business-to-business outsourcing proposals are often very complex documents to create. The proposals include multiple, interrelated tooled and non-tooled components with numerous dependencies amongst the components. There were tool systems in place that mimicked the Engagement Phase process (Figure 2.1) and they were not used in the intended manner. Hence, as a workaround, the activity of tracking dependencies and keeping related parts of the solution synchronized was done manually, usually by email or telephone. This was typically enacted with a project manager overseeing the timing and sequencing of the process and each person on the team responsible for identifying and tracking dependencies of consequence to their work. If someone failed to notify their counterparts of a change, or the recipient of a notification failed to react, then the components of the solution were temporarily out of alignment, potentially leading to costly redesign and time lost later in the process.

Tracking Assumptions. Another finding, related to both disambiguation and tracking dependencies, was the tracking of proposal assumptions. Assumptions were made frequently during iterations on the solution designs and proposal development to match expectations of the client with the capabilities of the provider. Once again, the common practice was for assumptions to be recorded manually and communicated during meetings and via emails. Missed, lost and conflicting assumptions were corrected regularly by a team of technical leads meeting to review and deliver a consolidated list to the team. The team would then need to check their designs to ensure the assumptions were accurately reflected in their piece of the solution design.

In summary, the work required to respond to a strategic outsourcing RFP is asynchronous, information intensive, and collaboration intensive. The timely delivery of an proposal (which includes a technical solution, business solution, and corresponding contracts) is dependent upon timely coordination of a distributed team of experts. This coordination is dependent upon the accurate and iterative exchange of information. While a process (and tooling to fit that process) was in place, it was generally avoided and instead everyone on the team used general purpose tools (e.g., word processing, spreadsheets, email, instant messaging, presentation tools, telephone), worked in an iterative and collaborative manner and then fit the outcomes to the process. This case illustrates how these collaborative activities occur and the opportunities for improvements in the process and technologies to support for improved work efficiency and quality of the outcome.

2.2. Process Characteristics

Process modeling and representation methods have been widely used for manufacturing processes and systems. Techniques including graphical modeling such as flowcharting or IDEF, algebraic modeling, queuing theory, Markov chains, Petri nets, and discrete-event simulation have been successfully applied. While certain types of information intensive services such as call centers (Whitt 2007) have used manufacturing-like models effectively, the nature of many of the more unstructured information intensive service processes is rather distinct. Some of these distinct characteristics are as follows.

1. *The influence of human behavior, perceptions and relationships*. In many information intensive service processes, human creativity and decisions play a critical role in determining how the process will evolve. This makes the structure of the process uncertain. Entire steps could be inserted or deleted based on the results of prior

operations. Each individual operation might be changed by the person performing the work, possibly impacting the future evolution of the process. For example, a person might trade quantity and quality and declare his/her work complete even though others might disagree, and return the task for rework. To reflect these characteristics, aspects of human behavior needs to be included in the process model. For example, utility functions from decision theory could be a useful tool to model individual objectives and choices. The process state may need to include the perceptions of key individuals and options available to individuals. In some cases the status of a relationship may have to be ascertained (an example is trust).

2. *Multiple "actors" and decision makers*. A key issue in the processes we study is the impact of multiple actors, any of whom might be able to affect the course of a process. Furthermore, the actors or players might have different roles and relationships (e.g., customer-provider, supervisor-subordinate), so that there may be varying degrees of cooperation and or competition between them leading to different dynamic behavior. Some of these relationships are explicitly set out, as in contracts or service agreements. Others might be implicit but well understood, as with roles in a process team. Sometimes the rules are not explicit, and not necessarily well understood.

3. *Joint or collaborative production of outputs*. Traditional business processes usually do not include joint production by different actors. However, this is quite common in IIS. An inherently joint production process is one where the outputs can be greater than what can be achieved by the individual resources. A simple example in a material-oriented industry is moving a heavy load that requires two people to lift it. In education, learning requires both teachers and students to work together. The same is true for many information intensive services such as consulting, IT service planning, and the creation and delivery of business services.

4. *Multiple concurrent processes or multi-threading with threads converging and diverging at different points*. While manufacturing processes also include some degree of parallelism such as that in product assembly, the extent is usually lower and usually well defined or structured. For example, we seldom see disassembly after assembly in manufacturing. In IIS, the processes can be partially hidden, and different threads may be controlled by different individuals. For this and other reasons, it has been observed that traditional flowcharting is inadequate to represent processes in IIS and alternative techniques have been proposed (Kieliszewski et al. 2007). This is discussed in more detail in Section 5.

5. *Simultaneous use of multiple resources*. Typical information intensive service processes involve different resources being used simultaneously or separately at different times. A typical trajectory of such a process might be a first operation involving all resources assigned to the process, then parallel threads start with each thread using a few resources simultaneously, then all resources come back together for an operation, then a different set of parallel threads occur, and so on. To complicate the situation further, the unavailability of a single resource that is required by an operation may not hinder its occurrence, but rather generate an additional operation for that missing resource to synchronize with the work already done without the resource. We note that even in very well defined manufacturing settings, simultaneous resource models are rare (e.g., Dobson and Karmarkar 1989) and remain an area for further research.

6. *Large variance in individual operations and across operations*. The intrinsic variance of, say, the completion time of a single operation is large since it is highly dependent on human input. Conscious decisions made by humans based on perception, utilities and the current environment contribute to the high variance as well. Because some operations may be automated by information technology while others are completely

manual or intellectual activities, the differences in variances and means between operations may be different by orders of magnitude. Traditional business process models do not handle such situations well. However, there are modeling tools from stochastic process methods (such as queuing theory or semi-Markov processes) which may apply.

In the present paper we focus on information intensive service processes with some or all of these characteristics. Our goal is to address the representation and analysis of these processes from both a theoretical and applied perspective. To this end, our starting point will be the detailed study of two or three real information intensive service processes. Critical features of these processes will then be abstracted to define the modeling requirements. We recognize that it will be very difficult to model a real service process in its full scope and detail, to include all the complications and difficulties that we have listed above. So we anticipate that our models will be simplified versions of our case examples. Nevertheless, we expect that we will be able to make significant contributions towards representation and conceptual modeling. We should be able to contribute to the topic of performance measurement methods that recognize many of the complexities of IIS. We also expect that we will be able to use techniques such as simulation that are closer to reality. The most difficult aspect will be the development of analytical tools. Here, in the least, we expect to develop stylized and simplified models that capture a few of the characteristics of the settings that we study.

3. Relevant Literature

Modeling methods and frameworks that influences the representation of complex processes includes research in areas such as workflow, queuing, and collaboration. This section presents a brief review of such influencing that is not included discussed in detail in the following sections, yet thought to be important.

A closely related area, catalyzed by the needs of developing information systems, is workflow modeling. Workflow modeling includes data flow, process flow, the task performing resources and their roles. These systems are typically analyzed by techniques such as Petri nets (see, e.g., van der Aalst and van Hee 2004). Properties such as reachability (to ensure that a desirable state can be reached from a selected state) and deadlocking (to ensure that the system will not enter into a deadlocked state from a selected state) can be derived from a Petri Net model. Because of their information system orientation, these models suit processes that are well defined or well structured, and have a clear control mechanism (e.g., transitions are controlled by well defined business rules).

Stochastic models and, in particular, queueing models have been used in manufacturing and service operations modeling for design and planning. This goes back at least 50 years when a systematic business process meant a physical production process. Buzacott (1967), for example, developed a Markov Chain model representative of serial production lines. This area blossomed into a major research area, resulting in probably thousands of papers and a number of text books (e.g., Buzacott and Shanthikumar 1993). In most of these models, we follow a product being manufactured (or a customer order being filled, or a customer request being handled) through a system of resources, and model this as a state-based stochastic process or map it to an appropriate queueing process. Other non-manufacturing applications include physical services, like transportation of people and goods, or, consumer services such as banking or retailing.

In information-intensive services, telephone call centers and healthcare facilities have received substantial attention. The former is especially a popular research topic in recent years (e.g., Duder and Rosenwein 2001, Harrison and Zeevi 2005, Whitt 2007). An extensive literature survey is contained in Gans et al. (2003). Healthcare facilities such as hospitals or outpatient clinics have also been modeled using queueing (e.g., Gorunescu et al. 2002, Khan and

Callahan 1993, Koizumi et al. 2005). Issues such as staffing, resource utilization, and customer satisfaction in terms of waiting times or sojourn times have been addressed. An extensive bibliography of applications of queueing in healthcare is contained in Preater (2001).

In the manufacturing or service industries, the primary focus of existing stochastic models is on the structured, well controlled aspects of these operations (e.g., steps needed to produce a product, patient flow between departments, or standard handling procedures for a call coming into a call center). By this we mean that each event occurrence in the system of interest can be modeled by a set of finite (and often relatively small number of) choices and associated, fixed probability distributions. In reality, some may argue that all events in these systems are deterministic. Some cases are obviously so, with a stochastic model being used to abstractly represent the outcome of a set of deterministic conditions, such as those specified in manufacturing process plans or business rules. In other cases, events, such as the breakage of a tool during a manufacturing operation, may appear to be stochastic only because we do not have adequate knowledge or data or computing power to properly characterize them. To our advantage, it has been found that the performance characteristics of these systems can be adequately characterized by probabilistic models which are abstractions of the actual deterministic behavior. On the other hand, workflow models are deterministic in nature, because their main purpose is to specify an information system that has to be executed to support a business process in reality, and clearly no business process will depend on the roll of a dice. For the same reason, workflow models have to capture the detailed conditions under which a next event will occur.

We note that stochastic models, to date, have been custom built for a particular process under study. Mathematical relationships between parameters of the process and the target outcome are manually developed, exploiting certain characteristics of the process, such as the flow dynamics. Appropriate mathematical techniques are then utilized to solve the obtained equations. For modeling business processes, the few applicable mathematical devices are typically queueing processes, Markov chains, or the more general semi-Markov processes. Once the business process is mapped to one of these standard processes, techniques developed for such standard processes can be used to solve the model.

Stochastic or workflow models for unstructured processes with the characteristics discussed in Section 1 are seldom seen. To pursuers of workflow, these processes may appear to have too vast a possibility of outcomes at each step, or that the set of possible outcomes is not well defined. To pursuers of stochastic models, the use of state dependent probability distributions (or other suitable mathematical constructs) is a possibility, but due to their complexity these models are not likely to yield elegant mathematical results. Although appearing to be unstructured, it is perhaps possible to abstract processes of an IIS into a well-defined, finite set of possibilities and then apply existing stochastic approaches. The abstraction procedure is non-trivial and can only be discovered with a highly detailed study of a real process in an IIS.

One stream of work on collaboration and collaborative processes is based on empirical and conceptual models, driven by information and knowledge work in organizations, including distributed virtual teams. This includes the papers by van de Ven et al. (1976), Kumar and van Dissel (1996), Jarvenpaa et al (1998), Cramton (2001), and Kogan and Muller (2006). In economics, the work of Marschak and Radner (1972) on the economic theory of teams was seminal and perhaps applicable to IIS process modeling.

The related issue of joint production, has received limited attention. It leads naturally to game theoretic settings. The topic was addressed at a conceptual level in the early work by Fuchs (1968). More recently Karmarkar and Pitbladdo (1995) present models of joint production in the specific context of services, and particularly information intensive services. This approach has been carried forward by Roels et al. (2010) using a game theoretic framework related to agency theory.

4. Process Representation Frameworks

In this section we discuss five existing representation frameworks that can be used for collaborative processes in IIS. These frameworks have been developed for purposes other than the subject of the present paper, but are deemed top candidates for the present purpose in our opinion. Later on we systematically match the capabilities of these frameworks with characteristics of collaborative processes in IIS, together with other modeling requirements.

4.1. Business Process Modeling

Modeling business processes is of course not new. It is a natural starting point of investigation for representing collaborative processes in IIS. For our purposes we find the evolutionary view presented by Kamath et al. (2003) useful – in the early days of enterprise process modeling (i.e., 1970-80) the emphasis was on data and later on (1990's and onwards) the emphasis shifted to process or control flow. A main reason is the desire to develop information systems to automate the business processes. Common techniques to model control flow include Event-driven Process Chain (EPC) and Dynamic Enterprise Modeling (DEM), which are the languages used by two of the most common commercial Enterprise Resource Planning (ERP) systems, and Unified Modeling Language (UML) Activity Diagrams that grew out of software development. The emphasis of these process modeling languages is on the representation of a process, rather than dynamical analysis. Kamath et al. (2003) gives an illustrative comparison by modeling the same business process using each of these techniques. Giaglis (2001) discusses business process modeling techniques at a more general level, noting flowcharting, Integration Definition (IDEF) techniques, Petri nets, simulation, knowledge-based techniques, and role-based diagramming as the major classes.

One of the most relevant simulation models for our purposes here is a discrete event simulation model developed (Jin and Levitt, 1996) to study the behavior of project teams, such as a team purposely formed for a significant construction project. Unlike a typical simulation model of production work, the model in Jin and Levitt is highly detailed so that both primary production work and non-production work (such as coordination activities and communication among workers which may not be directly related to the task at hand) are modeled. Each actor works on his own queue of work items and processes them based on the work requirement and his processing capability. The actors interact by exchanging work items and messages. Exceptions generated from the work items may appear, necessitating decision making by the actor or his line of management. Such a work environment is typical of IIS as well. After the initial work reported in Jin and Levitt,, other studies have appeared analyzing different issues related to project organizations (e.g., Nissen and Levitt 2002).

Lu and Sadiq (2007) classify process modeling approaches into graph-based and rule-based, and give a set of examples of each approach. These examples do not have much overlap with those discussed in Kamath et al. (2003), this is due to the workflow orientation of Lu and Sadiq and that workflow is grouped under a single class of techniques in Kamath et al. (2003). We therefore have a fairly broad view between the two complementary works. From the perspective of modeling control flow or process behavior, graph-based and rule-based systems are similar. Because of their artificial intelligence background, some rule-based approaches are able to handle process model changes at run time, which is an advantage for modeling human behavior.

Business Process Modeling Notation (BPMN) is a graph-based technique using Lu and Sadiq's taxonomy. It has been adopted by the Object Management Group (OMG) as the standard for specification of business processes. As a result, many software vendors support BPMN in their tools even though they may have their own modeling approach and notation. Business Process Modeling Notation is therefore quite indicative of the modeling capabilities of many process modeling representations. The general approach of BPMN is very similar to flow charts and hence rather intuitive to many people. For representing process behavior, there are several basic types of modeling constructs including activities, events, gateways, and connectors. These are used to build a logical flow of the business process. A key characteristic of BPMN, and all the techniques that are convertible to BPMN, is that they have a centralized world view – no matter how complex the process may be, a central entity (as represented by the very model) knows what to do next. The next step may involve rolling a dice (perhaps a virtual dice implemented in a computer), but all possible actions that depend on the result of the dice roll is unambiguously known by a single, central entity. A natural extension of this last property is that multiple entities of control may exist, creating a decentralized world view. This is indeed the premise of agent based modeling, discussed next.

4.2. Agent-Based Modeling

Agent-based models refer to computational models that study the system behavior of a collection of autonomous entities called agents. Each agent behaves according to their own decision making logic, typically representing that of an individual person or organization. The agents interact and each acts based on what it sees as the actions of other agents. Even though the behavior of an individual agent is known a priori, the resulting behavior of the entire system is hard to predict. To date, the only practical solution to a non-trivial agent-based model is simulation.

Agent-based models have been used in a number of different fields, such as economics, consumer behavior, and public health. These are natural application areas since they involve a large number of autonomous individuals. Many papers have been published; we merely point out a few as illustrations. In economics, agent-based models have been proposed to study economies that are not in steady state (Arthur 2005). In consumer behavior, Said et al. (2002) uses an agent-based model to study a population of consumers such as their reaction to marketing strategies. Straddling the areas of consumer behavior and economics, Kephart et al. (2000) utilizes an agent-based model to analyze a possible future scenario when both consumers and producers make use of software agents to buy and sell on behalf of their owners in order to maximize utility. In public health, Eubank at al. (2004) reports using an agent-based simulation model to study alternatives for controlling smallpox spread. With large-scale terrorist attacks a focus of attention in the last decade, some of these models have been designed to study disease spread caused by bioterrorist attacks, although they can also be used for natural disease propagation, e.g., Carley et al. (2006).

More relevant to the present paper are agent-based models proposed to study organizations (see, e.g., Carley 2002, Carley and Gasser 1999). Agents can be human or artificial such as an information system. Each agent has their own knowledge, skills, and capabilities. Agents interact and, in most models, cooperate to achieve a collective goal such as producing widgets. Organizational issues such as how do they learn and what kind of organizational structures will evolve, have been studied.

On the software tooling front, a number of agent-based modeling tools have been built and are available for general use. These range from high level programming platforms that include a programming language and a graphical user interface to the do-it-yourself frameworks and associated code libraries which can be included in the user's own code. Frameworks and libraries provide maximum flexibility at the cost of more effort to build a model. Two well-known examples are Multi-Agent Computing Environment (MACE; Gasser et al., 1987) and the Swarm Simulation System (Minar et al., 1996). In particular, Swarm has been developed into open source software with a significant community of users and volunteer developers. A specialized agent-based modeling framework (or meta-model) has also been proposed for modeling enterprises (Jureta and Faulkner 2005). A review of general agent-based modeling tools is in

Railsback et al. (2006), in which a given model was implemented in five selected tools for comparison.

4.3. Service Process Representation

To model information intensive services, one needs to know what actually happens in the doing of the service itself. A service that appears to be a relatively simple process, such as an individual purchasing a cup of coffee at their local coffee shop, may not be as unsophisticated and straightforward as one would imagine. Consider for a moment what needs to go into the delivery of that one cup of coffee – growing the coffee beans by a farmer; delivery of the raw beans from farmer to packager; roasting, packaging, and wholesale delivery to a vendor; vendor distribution to individual shops; hiring and training of employees; and treatment of the coffee for final delivery, one cup at a time, to the end consumer. Each of these steps could be considered a service unto themselves, with a complex set of interactions between people, technology, and processes. Imagine how the complexity of interactions grows as one step is included with the next and then replicated, for example, across geographical regions. Imagine now, the complexity of understanding and modeling the elements, relationships and interactions of one business running another businesses telecommunications, information technology, or business processes infrastructure.

As economic circumstances have shifted from an Industrial Age to the Information Age, people have for some time been investigating the organization and enactment of knowledge intensive work – evolving into information intensive services (e.g., Bryson et al. 2004; De Bandt & Dibiaggio 2002; Herzenberg et al. 1998). However, the empirical examination of services for the purpose of modeling them for increased efficiencies and/or improved customer service is a difficult problem and a relatively recent phenomenon. One of the reasons that modeling service processes is so complicated is that one service exists in two states: a stored or potential state, at the ready to be used or accessed; and a kinetic or actual state, the actual use or execution (Shostack, 1982). This two-state phenomenon lends itself to deviations in process, albeit within a set of tolerances. Understanding states and patterns of interaction is key to understanding what is of importance in a service system and how to model the process relationships and interactions.

Representation allows for evidence-driven examination and documentation of the different service process dimensions that need to be taken into account for further analytical or computational modeling. Service Blueprinting, introduced by Shostack (1982, 1984), is one of the earliest tools available in analysis and design that really attempts to address the two-state nature of services and multiplicity of dimensions. Even so, this method is in the same spirit as the traditional value chain diagramming approach. It is primarily designed for routine services where the work sequence is highly predictable with minimal variability. On the other hand, the co-production characteristic of IIS implies that both the service provider and the customer participate in producing IIS, contributing to the potential for a high degree of variability in the service creation and continuation process. Though an excellent tool, there has been need for more and better notation systems to capture the significant individual features of a service to facilitate the creation and implementation of sufficient process variables and variability.

Service Blueprinting is one example of service representation, another is Work Practice Designs (WPDs), which were influenced by Blueprinting, work performed by Wemmerlöv (1989) to create a framework of service production, and the work by Star and Griesemer (1989) to define boundary objects. Work Practice Diagrams were conceived to communicate the activities of people engaged in information intensive work – what they do, how they do it, what they use, what they produce, who they work with, how they are organized, how the work is organized (Bailey, Kieliszewski, and Blomberg, 2008; Kieliszewski, Bailey, Blomberg, 2007, 2010). The primary purpose of WPDs is to provide a set of artifacts that represent a wide range of information intensive work characteristics and aspects that convey the primary roles of the people performing work as dynamic and active forces in relation to each other and in relation to shared or individual tools, information, and processes. In this capacity, WPDs can be used early and ongoing in systems evaluation and design initiatives where the work that people do, as active processors of information, is an important component. The WPD representations are visual annotated maps and provide for drill-down, via successive layers of detail, on any given aspect or characteristic. The diagrams are useful for establishing common ground among the often disparate specialized participants in complex projects, serving as a conceptual bridge across differences in terminology and perspective to understand the impact of process and tooling on service activities.

Described above are two examples of service process examples and there are others to take into consideration for use depending on the objectives of the examination (e.g., Patrício, et al. 2011; Shaw and Cefkin 2010; Stucky et al. 2010). Service process representations are not generally categorized as analytical or computational models, however they serve as a method to render relationships and interactions between actors, objects, and events that allow for deeper examination of system components or the full system. This, in turn, can then be used for experimentation and/or computational modeling.

4.4. Empirical Framework for Service Performance

As illustrated by the claims handling operation described in Section 2.1.1, co-production is an important characteristic of IIS. Co-production implies that both the service provider and the customer participate in producing IIS. Thus, the production of IIS depends on the interaction of the processes of the service provider and the customer. This interaction contributes to the potential for a high degree of variability in the service creation process. It is evident that, depending upon the actions and information provided by the parties, the process could follow a large number of alternate paths.

Information plays at least three critical roles in IIS: as an input to the service creation process (e.g., a mortgage application), as an enabling factor in the service creation process (e.g., monitoring and control of information concerning the status of the process), and as an output of the service (e.g., a management consultant's report or a software program). It is within the service creation process that the impact of information intensity is most strongly felt. It is evident that consistently making correct decisions requires high-quality (i.e., relevant, accurate, timely, and credible) information. Hence, in taking actions required to create and deliver the service, the service provider should analyze the impact of those actions on the quality of information being received and ensure that suitable actions are taken so as to obtain the highest possible quality of information.

As Karmarkar and Apte (2007) suggest, a fundamental tenet of process management can help in this regard: if you manage the process correctly, the outcomes usually take care of themselves. Consequently, we adopt a process-centric viewpoint, and since the direct measurement of inputs and outputs is difficult in IIS, we rely upon managing the service creation process through indirect measures. Specifically, to manage the service creation process in IIS, we identify and measure suitable *process indicators* that can convey if the process is functioning satisfactorily. These process indicators can include inherent characteristics of the customers and the service providers, actions taken by the service provider or the customer as well as interim process outcomes, and operating/external conditions. It should be noted that, in general, only a small subset of the factors influencing service performance would account for a significant portion of the total impact on performance metrics. This critical subset constitutes the *Performance Drivers*.

Inherent characteristics are defined as those innate characteristics that the customers or the service provider are endowed with. Unfortunately, by their definition, the service provider does not have an opportunity to control the inherent characteristics of the customer and thereby favorably influence service outcomes. However, in some cases, there exist process indictors that can be influenced by the actions taken by the service provider. We term these as *adjustable* process indicators. These *adjustable* process indicators give the service provider a powerful mechanism with which to influence service outcomes.

In the insurance claims handling process studied (Apte et al. 2010), we note that attorney presence is an important *performance driver* since the presence of an attorney has a significant detrimental impact on all the performance metrics, such as cost, quality, customer satisfaction, and cycle time. Interestingly, attorney presence also happens to be an *adjustable process indicator* in that the service provider (i.e., the insurance company) can initiate preemptive actions to favorably influence this process indicator. Specifically, the case study of claims handling operations showed that by making an early contact with the claimant, the insurance company can establish trust with the claimant and thereby reduce the likelihood of attorney presence.

With the framework for the *analysis of service process performance* in place, we have available a structural roadmap to analyze the service creation and delivery process of an IIS and determine the performance drivers and adjustable process indicators for improving the operational performance of the service. As illustrated by the case of insurance claims handling process, the adjustable process indicators can give the service provider a powerful lever with which to influence service outcomes.

4.5. Game-Theoretic Models

The presence of multiple decision makers in service settings, suggests the relevance of game theoretic models for service process representation and analysis. The decision makers could have very different objectives, and the interactions between them can be cooperative and collaborative, or competitive and adversarial. Such models can also accommodate stochastic state transitions, joint production (collaboration), lack of observability of outcomes, contracting and reward structures, moral hazard issues, and the effect of the "rules of the game" or of organizational structure. In short, they have great promise in terms of richness of modeling and representation. However, the complexity inherent in these models means that it is not possible to analyze (mathematically) large scale settings. Simulation can be used, but the game theoretic approach in itself does not provide a standard means for simulation, and simulation may or may not work to solve games. But simulation has been used by some to look at repeated games with fixed decision policies (e.g. Axelrod, 1984). So the value of this approach may for now lie more in developing an understanding of complex service settings rather than in computing "answers" or specific solutions. To illustrate the basic idea, we present the following two-actor example.

Suppose that there are two actors A and B who are collaborating on a project (say a research proposal). Progress on the project is measurable in terms of an observable output measure, and the goal is to reach a target level of that measure. An example of the output measure might simply be total time spent (cumulative), perhaps weighted to reflect who is doing the work (e.g., more or less expertise). The measure cumulates based on the effort expended in each period. At that point, there is a fixed reward to be shared by the actors. The time horizon for the project is T discrete time periods.

In each period, the actors make decisions to either work alone, work together, or to do no work. The outputs per period when working alone (in terms of the measure) are x and y for A and B, respectively. If they work together the output is z. The costs of working alone are c_a and c_b, the costs to each for collaboration are k_a and k_b, all in terms of ($/time period). We may assume that the costs are discounted, so that they decline over time. By prior mutual agreement, if either actor chooses to initiate collaboration, the other must also participate or pay a substantial penalty (which effectively represents a constraint).

Effort and output are observable and known to both. Both actors are required to state a decision policy for each period t, which states what they will do in period t as a function of the state variable of accumulated output at time (t-1). We assume that the shares of the reward are predetermined, and that the reward is large enough to exceed any costs. So if necessary (e.g., if they had to do it all alone), both actors would be willing to work all periods alone to reach the target level and they would be able to complete the task.

As an illustration consider a one period problem, with starting state $S = 0$. Assume that $z \geq x,y$ and that $x = y$. The possible strategies for each actor are:

- do nothing
- work alone
- work collaboratively

If the target state is such that $S^* > z$, both actors do nothing (give up). If the target state is such that $x < S^* \leq z$, then both actors will choose to collaborate. Now suppose the target $S^* \leq x$ (or y), so that the task can be completed by either of the collaborators. Then the matrix of strategies and payoffs is in Table 4.1, where the rows and columns represent strategy choice for A and B, respectively, and the table entries represent the costs to A and B, respectively. Here M is the penalty for not collaborating when asked, R_1 is the reward when one actor completes the work and R_2 is the reward when two actors complete the work collaboratively, where $R_2 > R_1$.

<u>Table 4.1</u>: Strategies and Payoffs for a 2-actor Game

Strategies	0	y	Z
0	(0,0)	$(R_1 , R_1 - c_b)$	$(-M, R_1 - c_b)$
x	$(R_1 - c_a , R_1)$	$(R_1 - c_a , R_1 - c_b)$	$(R_1 - c_a - M, R_1 - c_b)$
z	$(R_1 - c_a , -M)$	$(R_1 - c_a , R_1 - c_b - M)$	$(R_2 - k_a , R_2 - k_b)$

Now if the costs of collaboration are less than the costs of working alone ($k < c$) then both actors will agree to collaborate. If $k < c$ for one of the actors, then that actor will initiate collaboration (and the other must accede so as not to pay a penalty of M). But if not, and $k > c$ for both and $(R_1 – c) > (R_2 – k)$, then there are two solutions (x, 0) and (0, y). But which of these will result is not determined.

This problem setting is a variation of the game of “chicken” in the game theory literature. The games of “hawk-dove” and “brinkmanship” are similar. The setting is also related to the concepts of “free riding” and “social loafing”.

We could continue the analysis for two periods only if the condition for collaboration holds. And a similar result will again appear though with more complexity depending on how much work remains to be done to meet the target. First, this example shows that under very simple circumstances, there may be no determinate solution to the problem. It is also clear that the setting can be improved by introducing different rules, for example, by introducing a payment for participation, or introducing rewards that are proportional to effort. There may also be natural circumstances which foster collaboration, which are not captured here. For example, the product of collaboration greatly exceeds individual outputs (as in some examples of education). Or there are multiple subtasks and each participant is an expert at one of them.

As yet, the study of services processes using game theory or competitive market models is scant. An early model of markets, prices and outputs with joint production between providers and buyers, is presented by Karmarkar and Pitbladdo (1995). This model does not get to the level of processes and service execution, but does consider the division of inputs across vendors and buyers. The paper also discusses the implications of joint production for service execution at a qualitative and conceptual level. Roels et al., (2010) examine contracting between vendor and buyer of B2B services, when the two parties both contribute jointly to service outputs, when outputs and efforts may not be observable. Again, they do not model service processes in depth, abstracting to a Cobb-Douglass type of model to capture joint production.

Rahmani et al., (2011a) consider a multi-period model much like the example above. They get around the indeterminacy issue by making the individual action cases identical, so that it does not matter which holds. Then they are able to solve the multi-period case to show that there are basically two patterns of collaboration that emerge. The question of contracting between parties is also addressed and shown that different contracts lead to substantially different collaboration behavior and service quality.

Game theoretic models of service processes remain the way to formally model multi-agent decision making in service processes. But the complexity of these models may mean limited application in large problems. An alternative approach that is better suited to large problem setting is multi-agent simulation (section 4.2 above). However, that in turn lacks the ability to rigorously establish general results.

5. Evaluation of Frameworks

After having provided a summary the five candidate service process frameworks, we go on to provide an evaluation of them using the following four categories of criteria. For each criterion we rate each candidate framework discussed in Section 4 from 1 to 3, with 1 denoting substantial support of the criterion by the framework, 2 being moderate support, and 3 being little or no support. The ratings are absolute (i.e., not relative to each framework, but their relative positions can hence be seen) and represent a subjective evaluation of the inherent capability of the framework by the authors based on our collective experience. It is important to note that the ratings are only based on the development to-date of these approaches. If certain breakthroughs appear in any of the approaches in the future, the ratings may well change significantly. We refrain from guessing whether any such event will happen.

1. How well does the framework address each of the characteristics of IIS described in Section 2? Table 5.1 contains the rating results for this category.
2. How well developed is the means of representation:
    a. Does the framework provide a visual representation of IIS, or an algebraic representation, or both?
    b. Does the framework utilize formal logic?
    c. Does the framework provide a means of computation of dynamic or other behavior of IIS – is it a native means or is it being mapped to another computational framework?
    d. Is the framework amenable to, or does it directly support computer simulation of an IIS?

    Table 5.2 contains the rating results for this category.
3. For a practitioner, how far along is the framework developed for practical use:
    a. What is the method's propensity to address realistic problems?
    b. How well does the framework support downstream implementation activities, such as an ability to generate code for work flow?
    c. Is the framework implemented in commercial or open-source software?

Table 5.3 contains the rating results for this category.

4. How easy is a model developed using the framework communicated to other people or systems:

    a. Does the framework support a machine readable format?

    b. Is the framework part of an industry standard?

Table 5.4 contains the rating results for this category.

In addition, Table 5.5 summarizes the rating results by listing the average ratings for each category of criteria in a single table. From this table, we see that there is no single framework that is the most desirable in all assessment categories. In representation of process characteristics, service process representation achieves the best average rating. This is not surprising, considering that it was purposely designed to model processes of our type. In representation means, agent-based modeling achieves the best rating. It is the most "computable" of the five frameworks. In practice considerations and information exchange with other systems, business process modeling achieves the best rating. This is also not surprising since it is commercially the most well developed approach to-date for modeling business processes in general.

From the ranking numbers in Table 5.5, it appears that agent-based modeling is the framework of choice out of the five candidates. Of the four categories of evaluation criteria, it ranks first in one and second in all others. No other framework is able to achieve such a well-rounded score. Business process modeling gets good points on practical issues but is the lowest ranked framework in terms of ability to represent characteristics of IIS processes. Service process representation does well in the latter, but is not designed for computation. Empirical service performance framework and game-theoretic modeling end up ranking about the same overall.

Intuitively, the former is not quite detailed enough for practice widely and the latter is too detailed analytically to be practically useful.

One way to examine the rating results is using Figures 5.1 and 5.2, where we classify the categories of representation of process characteristics and representation means under analytical capability, the categories of practice considerations and information exchange with other systems under practicality, and plot the five frameworks in their performance in analytical capability and practicality. In analytical capability, if we put equal weights of the two dimensions, agent-based modeling is shown to be the dominant framework. (In fact, this is true over a wide range of weights, assuming that we use a weighted Euclidean distance from the origin as the final measure.) In practicality, it is business process modeling which is dominant, but followed by agent-based modeling.

Table 5.1: Assessment of frameworks on representation of IIS characteristics

Criterion		Business process modeling	Agent-based modeling	Service Process Repre-sentation	Empirical Service Perform-ance Frame-work	Game Theoretic Modeling
Representation of process characteristics	Human behavior & relationships	3	1	1	1	1
	Multiple actors & decision makers	2	1	1	1	1
	Joint, collaborative production	2	2	1	2	1
	Multi-threading of processes	1	1	1	2	2
	Simultaneous use of multiple resources	1	2	1	2	2
	Large variance in operations	2	2	2	2	2
	Average rating	*1.83*	*1.33*	*1.17*	*1.67*	*1.50*

Key:

1 = Substantial support
2 = Moderate support
3 = Little to no support

Table 5.2: Assessment of frameworks on representation means

Criterion		Business process modeling	Agent-based modeling	Service Process Repre-sentation	Empirical Service Perform-ance Frame-work	Game Theoretic Modeling
Representation Means	Visual or algebraic representation	V+A	A	V	V+A	A
	Use of formal logic	1	1	2	3	1
	Means of computation	2	1	3	2	2
	Support of simulation	1	1	3	3	3
	Average rating (except visual or algebraic representation)	*1.33*	*1.00*	*2.67*	*2.67*	*2.00*

Key:

1 = Substantial support
2 = Moderate support
3 = Little to no support

Table 5.3: Assessment of frameworks on practice considerations

Criterion		Business process modeling	Agent-based modeling	Service Process Repre-sentation	Empirical Service Perform-ance Frame-work	Game Theoretic Modeling
Practice Considerations	Propensity to address realistic problems	1	1	1	1	3
	Support for downstream process implementation	1	3	3	3	3
	Available in the form of software	1	1	3	3	3
	Average rating	*1.00*	*1.67*	*2.33*	*2.33*	*3.00*

Key:

1 = Substantial support
2 = Moderate support
3 = Little to no support

Table 5.4: Assessment of frameworks on information exchange with other systems

Criterion		Business process modeling	Agent-based modeling	Service Process Repre-sentation	Empirical Service Perform-ance Frame-work	Game Theoretic Modeling
Information exchange with other systems	Support for a machine readable form	1	1	3	3	3
	Part of industry standard	1	3	3	3	3
	Average rating	*1.00*	*2.00*	*3.00*	*3.00*	*3.00*

Key:

1 = Substantial support
2 = Moderate support
3 = Little to no support

Table 5.5: Overall assessment of frameworks – Summary of average ratings

Category	Business process modeling	Agent-based modeling	Service Process Repre-sentation	Empirical Service Perform-ance Frame-work	Game Theoretic Modeling
Representation of process characteristics	1.83 (5)	1.33 (2)	1.17 (1)	1.67 (4)	1.50 (3)
Representation Means	1.33 (2)	1.00 (1)	2.67 (4)	2.67 (4)	2.00 (3)
Practice Considerations	1.00 (1)	1.67 (2)	2.33 (3)	2.33 (3)	3.00 (4)
Information exchange with other systems	1.00 (1)	2.00 (2)	3.00 (3)	3.00 (3)	3.00 (3)

Key:

1 = Substantial support
2 = Moderate support
3 = Little to no support
(n) = Number in parenthesis indicates the ranking of the framework in the assessment category

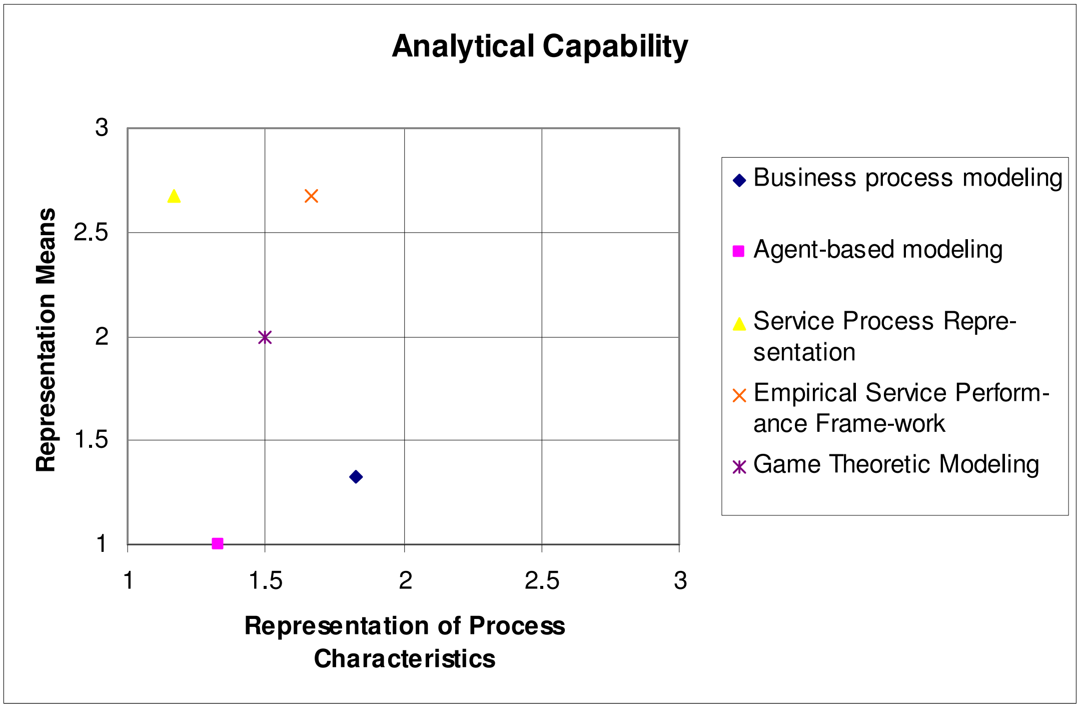

Figure 5.1. Analytical capability assessment of the five frameworks

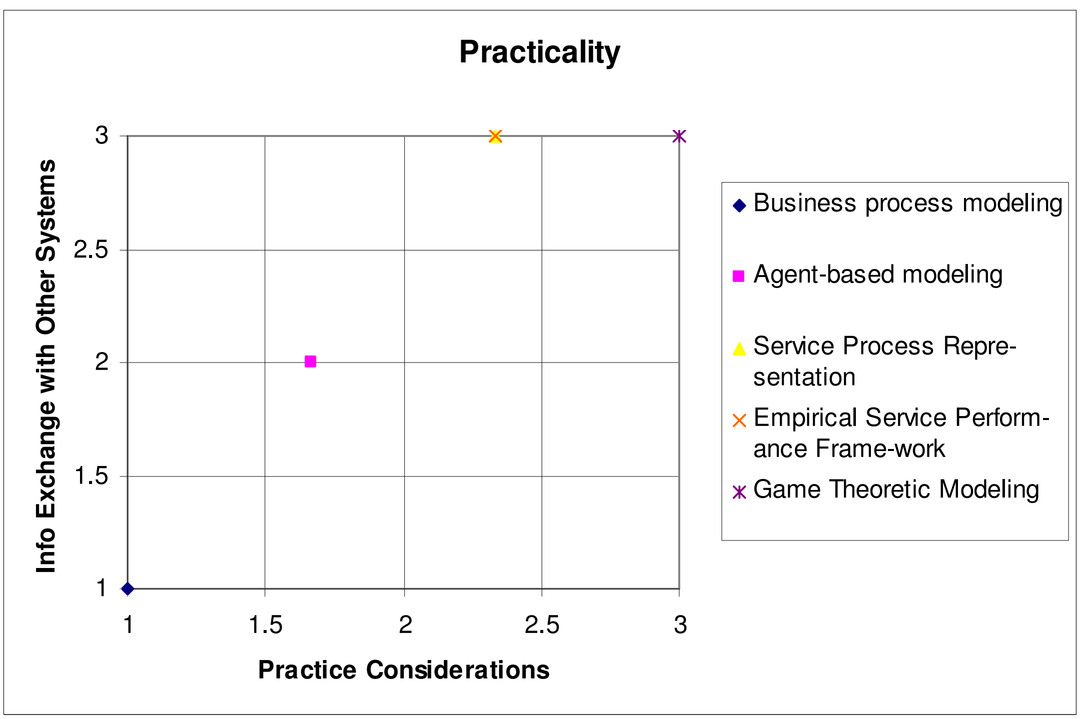

Figure 5.2. Practicality assessment of the five frameworks

6. Conclusion

Services have long been pointed to as suffering from low productivity relative to manufacturing (e.g. Baumol, 1967). More recently, there has been some evidence for increasing productivity, thus decreasing delivery costs, in services (Jorgenson, 2001, Jorgenson et al., 2002). Much of this evidence appears in information intensive services (Apte and Mason, 1995) where information and communication technologies have provided the means for productivity improvements. Casual observation suggests that productivity improvements are less visible in environments with high levels of collaboration and human interpretation of information content, such as professional services (like management consulting, finance, and health care). In these kinds of businesses, information-intensive collaborative processes represent a major portion of their daily operation and are therefore major contributors to the overall performance, including productivity, of the business. It is therefore important to understand the dynamics of such processes and hence strategies for improving their performance and productivity. A suitable representation framework is a basic step in this direction.

In this paper, we selected five existing approaches as top candidates for a sound representation of IIS. Using a set of requirements derived from characteristics of IIS and analysis needs, we explore the applicability of these candidates, based on what we know about them today. While there does not seem to be a single approach that is the most desirable in all assessment categories, agent-based modeling stand out as the candidate of choice. It is rather capable in representing IIS characteristics (among the existing candidates) and yet quite practical. As the cost of computing continues to decrease (e.g., with the recent introduction of cloud computing which can support parallel simulations), agent-based modeling seems increasingly more attractive. At present, commercial tooling and peripheral capabilities lag behind business process modeling; but with wider use it is likely that they will catch up.

It is evident that we can do better by combining the salient features of some of the candidate approaches. Fortunately, some of these approaches (e.g., agent-based modeling and business process modeling) are fairly compatible in nature. In fact, we can potentially design new features within say the agent-based modeling framework that possess capabilities similar to the desirable features from all five potential approaches. This subject should make a good candidate for future research by the service research community.

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