Exploring The Relationship Between

Industrial And Enterprise Engineering

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Abstract

This paper proposes a referencing relationship between the Industrial and Enterprise Engineering disciplines and a logical linkage between their principles and practices. It is being proposed that the discipline of Enterprise Engineering uniquely builds upon reference disciplines in humanities, sciences, and engineering, specifically Industrial Engineering (IE).

Industrial Engineering has historically studied the interaction of humans and machines. Through this study, specific principles and practices have been established to address problems associated with improving human/machine interaction. Enterprise Engineering applies these principles and practices to the entire enterprise. Enterprise Engineering views the enterprise as a complex system of processes that can be engineered to accomplish specific organizational objectives [Liles et al, 1996]. Principles and practices of Industrial Engineering and other reference disciplines are adapted to engineer processes at a level of abstraction commonly considered *systems*.

This paper will explore the contributions of Industrial Engineering as a reference discipline to Enterprise Engineering including a logical progression of thought that traces the abstraction of principles and practices.

Keywords

Enterprise Engineering, Industrial Engineering

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Introduction

Enterprise Engineering is an emerging discipline defined as "that body of knowledge, principles, and practices having to do with the analysis, design, implementation, and operation of an enterprise" [SEE 1995]. As a discipline, it answers the fundamental question of "how to design and improve all elements associated with the total enterprise through the use of engineering and analysis methods and tools to more effectively achieve its goals and objectives" [SEE 1995]. Ontology, or worldview, is a characteristic of a discipline that determines that framework necessary to develop the discipline through practice and research [Doheny 1987]. The ontology should be complex and substantial enough to be divided into subdisciplines. To set the background for the Enterprise Engineering ontology, several assumptions must be made. First, the enterprise can be viewed as a complex system. This assumption accounts for the systems of organized complexity that compose an enterprise. Complexity in an enterprise is derived from the multiplicity and intricacy of man's interaction with other components of the system. Second, the enterprise can be viewed as a system of processes. These processes can be engineered holistically and individually. Third, engineering rigor can be used in the transformation process. Thus, the Enterprise Engineering ontology views the enterprise as a complex system of processes that can be engineered to accomplish specific organizational objectives [Liles 1995].

Enterprise Engineering: Reference Disciplines

A reference discipline is a body of knowledge used to help establish an emerging discipline [Keen, 1980]. To develop a recognized discipline, researchers must discover the contributions of supporting disciplines. History has shown that a discipline emerges from the need to solve new problems that are not presently addressed by existing disciplines. New disciplines build on the knowledge, subject matter, methods, tools, and theories of existing disciplines to solve these new problems. Assessing reference discipline implications on an emerging discipline assists researchers in understanding existing disciplines and help uncover how existing knowledge can be incorporated into new theories and concepts. Identifying and understanding the contributions of reference disciplines provide a foundation of support for a new discipline in the existing research community. Referencing reference disciplines formally recognizes the contributions of existing knowledge and provides a logical link to the new discipline. Researchers in the existing discipline communities can follow these links and develop a measure of acceptance and recognition for the new discipline. Without this linkage, existing disciplines may question the grounding theories of a new discipline and dismiss its importance.

It is being proposed that the discipline of Enterprise Engineering uniquely builds upon base disciplines in science, engineering, and humanities. These base disciplines need to be investigated to determine what contributions in terms of subject matter, theories, tools, and methodologies that can be applicable to Enterprise Engineering.

Enterprise Engineering: Principles And Practices

Principles and practices form the foundation of a discipline and promote further ordered study. Principles incorporate the world view and are the operating philosophy by which problems are approached. Practices are the methodologies, models, procedures, and theories used to apply the knowledge base of the discipline. In an engineering discipline, the body of abstract knowledge is developed by scientific research and logical analysis. Engineering principles and practices are embodied in systems of theory, abstraction, design, and implementation. What differentiates many engineering disciplines are the activities which occur in each of these processes.

It is important for principles and practices to be arranged logically to facilitate decision-making, critical thinking and problem solving. The following briefly describes the main elements of engineering practice:

- *Theory* - In developing a coherent theory four steps are necessary: 1) Characterize objects of study (definition), 2) Hypothesize possible relationships among them (theorem), 3) Determine whether the relationships are true (proof) and 4) Interpret the results. Theory is important because it contributes a foundation of sound principles from which to advance the discipline [Denning, 1989]. Theory sets the stage and gives focus to the development of principles and practices.
- *Abstraction* - Abstraction, also referred to as modeling, is rooted in experimental scientific method and consists of 4 stages to be followed during an investigation: 1) Form a hypothesis, 2) Construct a model and make a prediction, 3) Design an experiment and collect data, and 4) Analyze the results [Denning, 1989]. Abstraction provides a way for engineers to represent the focus of study in a way that can be tested.
- *Design* - The creative design process consists of four steps: 1) Preparation, 2) Incubation, 3) Illumination, and 4) Resolution [Kim, 1990]. Preparation is becoming oriented to the problem and defining the task. Incubation is the period of aridity or immersion in unrelated activities which occurs in the search for alternatives. The sudden spark of insight and recognition of a candidate solution is referred to as the illumination step. Finally, the resolution step assesses and implements the candidate solution. Creativity is an important element in the successful completion of the design process. Design is not merely selecting from alternatives, but is an iterative generation of alternatives that meet the identified needs.
- *Implementation* - Implementation is an integral part of the engineering process. It is the launching point for a design. Many good designs fail because of poor implementation. Once the design is implemented it can be further analyzed for improvements by both the designer and the user. This type of feedback is essential.

The principles and practices are the essence of a discipline. They incorporate the world view as well as the methodologies, models, and procedures necessary to advance the discipline.

Theory

Theory development in Enterprise Engineering at The University of Texas at Arlington (UTA) has occurred in the course of developing dissertations. These dissertations in Enterprise Engineering concern process complexity measures, process analysis, representation methods, and process enablers.

The objective of the complexity measures research is to develop and test a method to evaluate the complexity of a business process. The basic research assumption is that there is a relationship between process complexity and the performance of a designed process, and that more complex processes tend to perform poorly compared to less complex processes. Process measures have been a cornerstone of Industrial Engineering since its inception back in the days of Frederick Taylor who stressed the importance of scientific management. Measuring performance is common among Industrial Engineers. Measuring complexity is important to Enterprise Engineers who make decisions about processes at the enterprise level of abstraction. The process analysis work will develop a methodology to determine critical or core enterprise processes and to develop an agile process configuration method based upon a holistic evaluation model which considers both strategic and operational factors. Process analysis is another area considered fundamental to Industrial Engineering. Processes have been traditionally analyzed to compare standards to actual performance. Upon deviation, these processes were changed. This research will assist Enterprise Engineers to determine what processes should receive limited resources for the transition to agility. A representation method for Enterprise Engineering is also under development that uses an agent based approach to represent processes where the activity being modeled is encapsulated with the agent performing the activity. Industrial Engineering has long been associated with activity and process modeling with such methods as IDEF0 and IDEF3. Since Enterprise Engineers are modeling at a higher level of abstraction, a new ontology is needed. The process enablers research is assessing the impact of five key enablers of agility for manufacturers. Process enablers are important to the Industrial Engineer when considering process improvements. Agile process enablers are important to Enterprise Engineers since agility is usually associated with enterprise level processes.

Abstraction

Abstraction (or modeling) provides a way for engineers to represent the focus of study in a way that can be tested. Object oriented modeling, and the Industrial Engineering based IDEF modeling suite are different ways of representing the enterprise. In order to improve the enterprise it is necessary to be able to model it.

The representation of processes is being accomplished through the development of "business process templates". These templates, which will be useful for both conventional business process reengineering efforts as well as for the formation of virtual enterprises, provides a standard approach for defining and modeling a process. The prescriptive nature of the template is especially important for deployment purposes because companies can use them as an archetype from which to design their own processes.

Abstraction is fundamental to Industrial Engineering improvement efforts. The engineer must be able to abstract the problem to reduce complexity and increase understanding about its nature. Typical IE applications include process models in reengineering projects, simulations of current conditions and physical mock-ups of potential floor layouts. At UTA, Enterprise Engineering abstraction has taken the form of new modeling schemes.

Two modeling approaches are being explored at UTA for process modeling. The first, employs an object oriented scheme to model business processes [Jacobson, Ericsson, and Jacobson, 1994]. In this scheme, the enterprise is made up of processes and the information and tangible things (which are referred to as "products") interacting with the processes. All representations are in terms of objects as opposed to the very different entities used in traditional methods. From this, the user can extract the view or information of interest. This method also supports the specification and implementation of information systems for automating the modeled processes [Barnett, Hari, and Liles, 1995].

The second approach, described in more detail in Presley, 1996, uses IDEF5 (ontology capture method), IDEF0, and IDEF3 to develop an integrated multi-view model. IDEF5 is used to capture information about the enterprise and its environment. From this an IDEF0 activity model is extracted. A resource view is identified by assigning potential resources (partner companies in a virtual enterprise setting) to the activities of the IDEF0 model. This in effect defines the agents in the model and related activities. For each agent, we would then identify the organization view and business process views.

Design

Design is concerned with making things how they should to be, and is what distinguishes the professions from the sciences [Simon, 1981]. A result of an engineering effort is a design that satisfies a specified need within the identified constraints. When designing a system, an engineer is faced with many constraining factors. The system design must have the proper form, fit, and function within the constraints of cost, time, resources, and ethical and regulatory constraints. These designs may take the form of a device, structure, or process. It is recognized that engineers are expected to know how to both analyze and design systems. However, most are taught in the classroom how to analyze, but are never taught how to design. Good design skills are currently gained through experience.

A good design process should include considerations of implementation, operation, and final disposition of the system in relationship to the system environment. There are many design processes available in the engineering literature. Sometimes, the design process is broken down into phases, such as conceptual design, prototype design, detailed design, and limited production. Another way to look at the design process is in steps; such as identify the need, define the problem to be solved, search for alternatives, establish criteria and constraints, consider the alternatives, analyze alternatives, decide on design, produce a fully specified design, and communicate the design to others.

One major weakness in these processes is the consideration of alternatives. Designs may have feasible alternatives already existing. But design is not merely selecting from alternatives, but is more importantly, the generation of alternatives that meet the identified needs. Currently, the best advice contained in these design processes on ***how*** to generate alternatives is to look at existing designs to develop ideas. The importance of creativity in the design process is not well represented. It is a goal of Enterprise Engineering research to develop an enterprise design process which includes creativity to generate innovative solutions.

Enterprise Engineering may be viewed as the process of designing, analyzing, and implementing enterprise-wide change [Liles et al., 1996]. The design process must take into account the transition from the as-is to the to-be. Enterprise Engineers transform the enterprise in a structured, logical way that may require both radical and continuous change [Liles et al., 1996]. The enterprise change methodology developed by ARRI [Presley et al, 1993] is that cultural change, process improvement, and technology strategies are developed from a coherent enterprise vision. It is these strategies that act together as requirements for enterprise analysis and design. The objective of one ARRI research project is the development of an enterprise transformation methodology designed to guide the fundamental redesign of the manufacturing enterprise. This methodology will be based upon and extend the existing enterprise excellence methodology that ARRI has used with over 20 small manufacturing companies for five years [Underdown and Deese, 1996].

Design in Industrial Engineering has traditionally been concerned with operational efficiency and the man-machine interface and, usually in a segment of a company. Enterprise Engineering extends the design interest from process and technology to include the cultural and strategic aspects together in a more holistic manner. The enterprise is not restricted by company borders, but includes the suppliers and customers. Processes are designed from the point of entry into the enterprise to the point of exit. One example of where Enterprise Engineering design skills are in demand is the virtual enterprise. The virtual enterprise is a temporary relationship with two or more participants which is formed, operated, and dissolved to accomplish specific short term goals. It differs from existing inter-organizational models by the degree of shared accountability and responsibility of the participants and the structure by which companies contribute their competencies [Reid et al, 1996].

Implementation

Implementation issues such as dealing with the cultural changes, radical versus incremental change, and the number of iterations of improvements all need to be addressed. An agile enterprise is a "learning organization" and must accept that change and implementation of new ideas will be a common experience. At UTA, Enterprise Engineering uses several traditional Industrial Engineering tools in combination in order to create a successful implementation methodology. The following sections will describe three such methodologies.

Strategic Justification Methodology

The Automation & Robotics Research Institute in conjunction with the National Center for Manufacturing Sciences (NCMS) has developed a pervasive activity based business case tool (NCMS, 1994). This methodology considers both traditional financial and strategic benefits of the technology under consideration. Many Industrial Engineering concepts are pervasive throughout this model such as engineering economics, utility theory, and IDEF0. Furthermore, the impact of systems transition or implementation path is specifically addressed. The methodology is organized into five phases shown in Figure 1: *Identify System Impact, Identify Transition Impact, Estimate Costs and Benefits, Perform Decision Analysis,* and *Audit Decision*. The analysis in this methodology is accomplished through a series of documents and matrices in which the pervasive impact of the technology on the enterprise is determined.

In the *Identify System Impact* phase, the technology is linked to the enterprise. This linkage uses an activity based approach to estimate financial costs and benefits. The impacts of the new technology to the strategies of the enterprise are also identified. In much the same way, the *Identify Transition Impact* activity identifies the impacts of the process by which the new technology is implemented. The *Estimate Costs and Benefits* activity estimates the actual magnitude of the strategic and financial impacts. In the *Perform Decision Analysis* activity, the analyst(s) performing the justification arrives at a decision recommendation. The *Audit Decision* phase allows for an evaluation of the justification process so that improvements can be made to the methodology itself [Meade, Johnson, Sarkis, and Liles, 1995].

Advanced Industrial Engineering techniques such as the Analytic Hierarchy Process (AHP) and Fuzzy Set Theory are being researched as possible additions to the SJET to add increased mathematical validity to the analysis. New and novel applications of the SJET are also being developed, for example, in such diverse areas as environmentally conscious manufacturing and business process reengineering.

Business Process Configuration Methodology

Two tools based on Industrial Engineering principles, IDEF and the Analytical Network Process (ANP) are used together to create a methodology for configuring business processes. This methodology takes a systems view of an enterprise in which an enterprise is seen as a system which takes in inputs and produces outputs under some set of environmental constraints [Schoderbek, Schoderbek, and Kefalas, 1990]. The (ANP) model is utilized to aid the decision maker in considering all the multiple criteria involved in transforming a business process into an agile business process. Madu and Kuei [1995] introduced using a traditional Industrial Engineering tool, Statistical Process Control (SPC) with the Analytical Hierarchy Process (AHP) to aid the stability and reliability of the group decision making process.

It is proposed that business processes naturally fall into three categories: (1) those processes which transform external constraints into internal constraints, (2) those processes which acquire and prepare resources, and (3) those processes which use resources to produce enterprise results [ARRI, 1990 and Presley, Huff, and Liles, 1993]. Each one of these categories as well as subsets of business processes in these categories will be developed. A separate ANP model is created for each category of business processes.

Conclusion

This brief discussion of the ties between Industrial and Enterprise Engineering illustrates the functional similarities and the hierarchical differences. The disciplines are similar in their fundamental methods. Both disciplines use similar principles and practices of theory, abstraction, design and implementation. Hierarchical differences are prevalent in the levels of abstraction considered by each discipline. Industrial Engineering has traditionally been concerned with operational activities and processes within a given facility. Enterprise Engineering is concerned with the entire enterprise and the linkages between enterprises. This higher abstractional perspective provides an opportunity to apply Industrial Engineering principles and practices to the enterprise as a whole.

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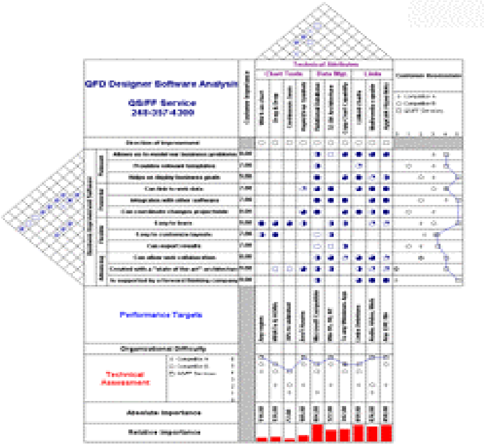
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