Mass-Customize Service Agreements for Heavy Industrial Equipment*

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Abstract – *This research investigates the requirements for proactive service delivery for heavy industrial equipment and generalizes the results into a reference model for the development of service agreements in the field. The observer-participant method was used to develop and test the model with manufacturers of gas turbines, jet engines, and locomotives. The reference model organizes the requirements for information, processes, and service offerings and provides multiple views for different types of users. The reference model can also prescribe the contents of the service agreement based on goals dictated by the service provider and the customer; thus providing for mass-customization of the service agreement.*

Keywords: Service contract, heavy industrial equipment, proactive service delivery, reference model.

1   Introduction

Manufacturers of heavy industry are increasingly expanding into the service sector, not just offering financial services to customers but also becoming service providers to industrial equipment and machinery. These new service products, in the form of service agreements, are strategically important to them for reasons more than one. To begin with, heavy equipment service has increasingly become a proactive, complex, and perpetuating process that generates much more revenues than the sale of the products themselves. For example, an aircraft engine or a power generator could last for decades, and hence their service tends to be a dominating cost item on the customers' long-term budget. This trend, as evidenced in General Electric (GE), General Motors, Otis Elevators and similar companies, is part of a general pattern in the heavy industry sector; and the pattern is even more pronounced in the Information Technology (IT) industry and the IT-based non-manufacturing service sector. The recent redefinition of IBM as a solution provider is a visible example, adding to the continued movement of banks and other service businesses towards outsourcing their IT. The application service providers of e-business have also broadened the practice of business processes outsourcing. Service agreements are at the center of all these new products of service.

Unlike selling physical products, service agreements are not one-time transactions. A complex service agreement in the above domains exposes the customer to long-term quality, reliability, and risk ramifications, and commits the provider's processes and resources over a long time. The customer must be able to analyze sufficiently the service agreement they accept; while the provider must be able to plan, design, and commit its enterprise assets to deliver the service they promise. Neither is easy and both are important, since the customer bets its business on the service agreements and the provider its profitability. However, the field does not offer much of a scientific basis for either side to assess and engineer their service agreements, and both sides continue to rely on ad hoc efforts to develop the one-of-a-kind service agreements. This problem clearly adds to the low productivity in the service sector.

We submit, however, that the new breed of service agreements is amenable to the same level of performance of mass customization of manufactured products. While IT is transforming the traditional manufacturing paradigm into one of striving towards customization, traditional service products are also seeking a transformation into relying on re-usable processes and resources, as evidenced in e-business practices. Therefore, we develop a new, *reference-model-based approach* to help mass-customize service products using proven IT methods, and achieve a level of performance comparable to that of products engineering in manufacturing. Although this approach has promises for service agreements in many domains, we stress *heavy equipment, IT outsourcing,* and the *application service provider (ASP)* model of service in this research. These practices feature real-time online processes across the clientele and the host enterprise, and can all benefit from mass-customization to configure and re-use the enterprises processes and information resources. Among them, however, service agreements for heavy equipment pose arguably the highest complexity on the execution processes of the service providers, and hence represent the largest challenge to the research on a reference model. Results for this problem will be poised for generalization into domains of lesser complexity.

The challenge of servicing heavy equipment stems from the complexity of delivering service in the new *proactive* manner. The scope of the proactive service processes and systems extends much beyond the servicing of the equipment per se. Some of these enabling processes or systems would have to inter-operate between the manufacturers and the buyers of the equipment in an extended enterprise manner. They include, for example, the continual monitoring of performance with operational data, identification of anomalies from the data to diagnose the root cause of problems, and prognosis to estimate the life of the equipment. They also lead to pooling of the information drives, the forecasting and control of the inventory, as well as managing fleets of equipment. These processes and systems also feed directly into fleet analyses for the contracted equipment and risk assessment and management for a portfolio to which it belongs. The aggregation of data, knowledge and decision logic gives rise to the costing and pricing of the (long-term) service agreements. This proactive service delivery dictates additional integration of information and the flow of data and knowledge among the service provider, the customers, the suppliers, and the divisions within the enterprise. Thus, engineering service agreements means the planning and designing of the service delivery platform as much as the planning and designing of the service agreement contents. To define the requirements for service agreements and their platform on a case-by-case basis is a daunting task with numerous obstacles and challenges. Since no two service agreements are identical, the individual designs could all be different in their execution details. Thus, engineering service agreements on an ad hoc basis is not a preferred solution. We also recognize that a service agreement need to encompass multiple viewpoints and has value for top-level managers as well as for operational managers, system developers, customers, supplies and other stakeholders. Thus, we need a reference model abstracting the fundamental requirements into generic processes and resources to guide the engineering while achieving customization. The reference model should serve as a starting point for a corporate to plan and design the overall service platform, as well as serving as a blueprint to steer the development of individual service agreements.

The general literature of service does not provide many results in the way of reference models or mass customization [1]. This work contributes an analysis of such requirements, a new reference model based on the analysis, and a new method of mass-customization using a reference model to optimize the development of service agreements for heavy equipment industry; all of which are empirically established. We discuss the research approach in the next section, Section 2, and present the reference model in Section 3. Testing results at GE, along with illustrating cases, are analyzed in Section 4 to substantiate the claims of the work. The last section, Section 5, concludes the paper with a summary of the contributions and future work of the research presented.

2 Research Approach

The proposed reference model is based on a study conducted at GE over the past several years [1]. We used primarily the *observer-participant* research method [7], supplemented with studying results from the literature, to investigate significant and representative industrial practices and thereby abstract the common elements into a reference model. In particular, we studied in depth the case of GE as a service provider for heavy equipment, including the scope of typical GE service agreements, the processes and resources required of their (proactive) delivery, and the implied enterprise systems at GE Power Systems, Transportation, and Aircraft Engines. The results give rise to a reference model for heavy equipment.

3 Reference Model

3.1 An Overview of the Model

The general practice of service agreements involves several different classes of users (e.g., customers, engineers and managers), uses, and perspectives [1]. The model starts with the basic goals and objectives of the provider and the customer, and then builds bi-directional linkages or associations between the goals (strategic perspective) and the basic information, processes, and offerings of service delivery (tactical perspective), in an ontological manner [3]. By applying these multiple views, the reference model provides a starting point and an anchor point for executives, senior level management, business planners, system designers, users and others, involved in the development and execution of the service agreement, as shown in Figure 1 below.

Figure 1. Overview of the Reference Model

The model has two tiers. The top tier, Strategic, contains goals and goal hierarchies. The bottom tier,

Organizational and Operational, contains views of business entities and processes.

The model provides for multiple entry points depending on the user's area of interest or focus. Top-level managers and strategic planners may begin with a particular goal in mind so would enter the model from the top tier. A customer or a sales person may also begin with a goal or may start with the service agreement. Operational managers and systems designers typically would focus on some particular aspect of the business such as a process or organizational need, so they would begin with an entity or process from the bottom tier. Next we discuss each tier in more detail beginning with the strategic views.

3.2   The Strategic Tier: Service Agreement Planning

The strategic views include the customer goals, the service provider goals, the goal hierarchies, and the associations between the goals and the elements of a service agreement in the bottom tier (as a business entity). The customer goal hierarchy identifies the goals and the associated sub-goals that are important to the customer and may be influenced or contributed by the service provider. These goals represent the subset of the customer's business goals that are incumbent on the complex equipment they own. These goals are included in the model for the following reasons: to align the business' goals with the customer's goals through associations and to identify the information, processes, and offerings associated with achieving or supporting the customer's goals. The customer goal hierarchy uses the goal decomposition pattern [2] to identify and associate the goals and the sub-goals. The break down of higher-level goals into lower-level goals makes the goals more concrete and better addresses how the higher-level goals will be achieved by providing more specific lower-level goals. The customer goal hierarchy consists of the following goals: satisfied customer, increase profitability, increase market share, reduce loss opportunity, increase market differentiation, increase reliability, guarantee availability, increase availability, guarantee reliability, comply with regulatory agency, comply with insurer, guarantee by-product, guarantee efficiency, reduce operating cost, and reduce maintenance cost. For brevity, we depict the five sub-goals that contribute to achieving the satisfied customer goal in Figure 2, and the satisfied shareowner goal in Figure 3.

The service business goal hierarchy identifies the goals and their sub-goals that are important to the service provider and to the manufacturer. This portion of the model most likely needs to be customized for individual companies. The hierarchy consists of the following goals: satisfied share owner, increase profitability, service leader, positive public perception, satisfied customer, reduce service cost, increase revenue, improve service quality, increase market share, increase service density, growth through acquisition, increase market differentiation, expand

to 3rd party equipment, increase service depth, increase service level guarantee reliability, guarantee availability, guarantee performance, optimize operation, and develop proprietary technology.
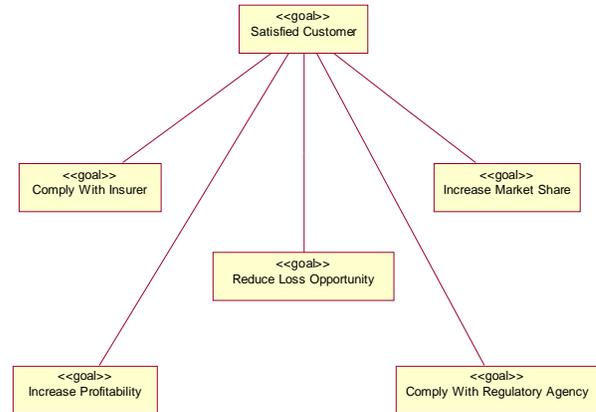

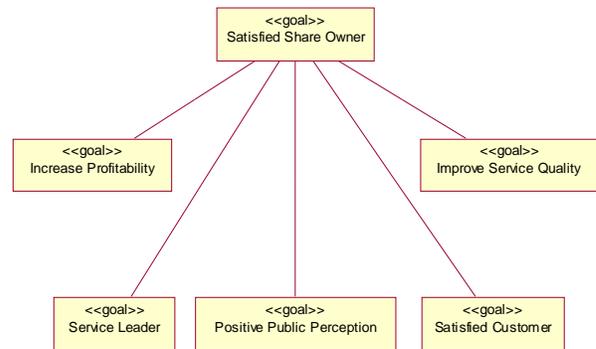Figure 2. A Subset of Service Business Goal Hierarchy

Figure 3. A Subset of Service Business Goal Hierarchy

The third set of views associates certain service provider goals and customer goals with the appropriate subset of service standards. The intent is to define the service standards elements that are to be included in a particular service agreement to address the goals as deemed important or necessary by the service provider and/or customer. The service standards dictate how the services are to be performed. For example, to achieve the "comply with insurer" goal, the service agreement may have the following service standards: availability of equipment, equipment performance, equipment reliability, response time, problem resolution time, availability of service personnel, and availability of equipment for servicing. The specific set of standard elements depends on many factors including the types of risks covered by the insurance policy and requirements by the insurer for operating and maintaining the equipment.

3.3 The Organizational Section: Service Agreement Design

In the lower tier on the organizational section of the model, the model provides entity views describing important concepts of the service delivery business as high-level abstractions of key entities and the relationships between the entities. These views also establish a common vocabulary that is essential for the understanding of the service paradigm and for the development of other views and sections of the model. Some of the entities include service center, customer, service provider, portfolio manager, operator, equipment, service agreement, portfolio, service engineer, service manager, service agreement details, and service event. Using standard UML (Unified Modeling Language) notation, the entities are modeled as classes and relationships as associations, aggregations, and generalizations. The model provides entity views that center around a specific entity, which we define as the focus of the view. Within this section of the model, there are four such foci: the service agreement, the equipment, the service center, and the portfolio. Figure 4 illustrates the service agreement as an example, in UML.
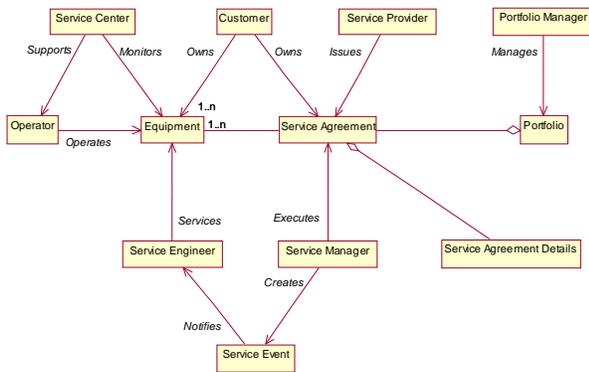

Figure 4. An Entity View: the Service Agreement.

As shown in the diagram, a service center of a provider supports the operator of the equipment, monitors the equipment on site, and issues the service agreement to the customer. A portfolio represents a collection of service agreements managed collectively by the portfolio manager. Typically, the service agreements belonging to a portfolio are either for a particular customer or for specific models of equipment. The service engineer services the equipment and is notified by the service manager of a service event. Views like this one provides guidelines to management on how to organize the service organization and what roles and behaviors are needed by the various entities.

From the modeling perspective, the service agreement is the anchor point because the other model elements are either directly or indirectly related to the service agreement entity or some element that is part of the service agreement. We discuss the fundamental elements

here. The service agreement should help manage expectations, clarify responsibilities and facilitate communication between the service provider and its customers, as well as assess risks and costs. For heavy equipment industry, an agreement can be very complex with numerous terms and conditions for performance, availability, and reliability; as well as provisions and penalties for when the equipment does not perform accordingly. The parties to an agreement refer to the service provider and the customer. The service provider can be a service division within the manufacturers or an independent third party that services equipment manufactured by another company. In the second case, the third party service provider may be contracted by the original equipment manufacturer (OEM) to provide service on their equipment. The next component of the service agreement is the contents of the agreement. Since the contents of an agreement varies widely across different industries and sometimes even within an industry, we need to identify and describe the different pieces that make up a service agreement in a more structured approach. We leverage the work of Karten [4] and begin describing an agreement in terms of its key elements: context-setting information, description of services, service standards, service tracking and reporting, periodic review, and change process. Karten organizes the key elements into two categories with the first three elements belonging to the service element category and the last three the managerial element category. We extended this work by adding terms of delivery and termination to the service element category, creating an additional category for financial elements including pricing, pricing schedule, deductible, incremental costs, and incentives, bonus and rebate and creating an administrative element category. These extensions are especially important for the more complicated service agreements. The reference model depicts the service agreement class as an aggregation of service elements, managerial element, financial element, and administrative element classes. The model provides a number of detailed diagrams for the service agreement entity, which further decomposes the element classes. As an example of such diagrams, Figure 5 shows the classes that provide additional specificity to the more general service element class.
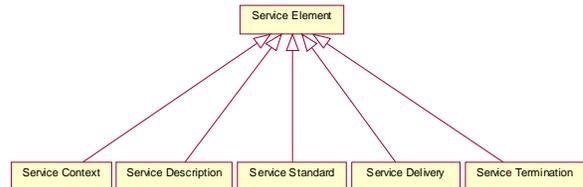

Figure 5. Partial Classes in Service Agreement

3.4 The Operational Section: Service Agreement Engineering

In the lower tier on the operational section of the model, the model provides process views, which describe the core processes of the service delivery business. The model consists of *processes, tasks, inputs, outputs, mechanisms, constraints*, and associated *goals* to substantiate the *service engineering* required. The processes and tasks define the business processes and the decomposition of the processes into tasks. The tasks represent the business processes decomposed into varying levels of granularity and detail. They are organized in a hierarchical structure to depict the relationships between processes and tasks. The model represents these processes and tasks as *objects* or *entities*. In addition, the inputs of business processes are defined as those *data classes* that are transformed by the processes into outputs. The model also represents the data classes as objects or entities. The outputs are also defined as data classes and represented as objects or entities. The process consumes input objects from one or more input data classes. The process produces objects from one or more output data classes. Since the objects from data classes are either consumed or produced by the business process, the model provides for the *association* of the data objects to the process at the task level. The mechanisms define the resources or agents required to carryout the process of transforming appropriate inputs into outputs. A process may be constrained by rules, regulations, finances, and such. Both the mechanisms and constraints are represented by classes in the model.

The model provides process views for the following six core processes: monitoring, health assessment, prognosis, service decision, service agreement creation and service agreement management. Each view defines the associations to the inputs, outputs, mechanisms, conditions and goals; and identifies each associated entity and the decomposition of the process into tasks, including the inputs, outputs, mechanisms and conditions for each task.

The monitoring process analyzes operational data collected for the equipment to detect trends, patterns, or anomalies in such conditions that may indicate a maintenance action, degradation in some part of the equipment or an incipient failure in a part or subsystem. The operational data comes from a number of digitized sources including sensors, the equipment controller, instrument systems, laboratory equipment, and manual inputs. The system defines a point for each external input to be tracked by the monitoring process. Ideally, the monitoring process should identify all anomalies before a failure occurs; but in practice this does not happen. The development of better algorithms and techniques is an on-going research area.

The health assessment process is responsible for determining the health of the equipment and to identify certain conditions in the equipment that may warrant some service action. The health of the equipment is assessed by comparing the current operational state of the equipment with predicted values or knowledge about how the equipment should be performing. The health assessment process measures and analyzes the state of the equipment to identify faulty conditions that may indicate an early warning of some failure. This type of fault is classified as an incipient fault. This capability is a key to proactive service delivery in which the service provider anticipates problems and takes action before the occurrence of some unplanned outage event due to a failed system, subsystem, or component.

The prognosis process is primarily responsible for making projections on the future health state of the equipment and the remaining useful life of the equipment given its projected operational profile [6]. The condition of the equipment is based on the measurements collected by the monitoring process, on the features produced by the monitoring process and on any fault sets determined by the health assessment process. The prognosis process analyzes the condition of the equipment together with the knowledge about the equipment to estimate how much longer the equipment may be operated at specific operational level(s) [5].

The service decision process makes recommendations to the appropriate personnel for service actions based on data and information from various sources, including the monitoring process, health assessment process, prognosis process, service policies, maintenance manuals, service agreement terms and conditions and regulatory requirements.

The service agreement creation process produces and executes a service agreement. In a proactive service delivery business, this process is complex in terms of data and information consumed, mechanisms to carry out the tasks, and conditions that control the tasks. The complexity of the process depends primarily on the agreement itself. The model provides the requirements including information and the process for creating the service agreement typically found in the complex equipment businesses, and outlines the complexity of this process.

The service agreement management process is responsible for overseeing the service related activities from the perspectives of equipment operations and performance, service related costs and expenses, contract coverage and compliance, and reporting on such to the appropriate stakeholders.

4 Validation of the Reference Model

In validating the reference information model from a contents perspective, we applied the model to a test case for evaluating the correctness and completeness of the model. This test case involves a business closely related to the three businesses used in the empirical study. We selected GE Power Systems Generator business.

The design of the test case follows a two-phase approach. The purpose of the first phase is to inform the interviewee on the objectives of the interview session, the contents of the model, and the different usage patterns for the model. During this phase, the interviewee was provided with a set of diagrams organized by the two levels of the model including the service agreement, strategic views, entity views, and process views. Also another set of diagrams was provided that depicted the following usage patterns: goal driven, opportunity driven, and organizational usage.

The second phase involves the actual usage of the model. The interviewer assists the interviewee in selecting views, retrieving more detailed information, and traversing the model between levels and within levels by following associations. The intent is to determine the usefulness of the model, the completeness of the model, and the applicability of the model to the particular business selected for the test case. During the second phase of the test case, we asked the interviewee to access various views of the model and to provide feedback on the correctness, the completeness, and the applicability of the model to the service business in which the interviewee is employed.

5 Conclusion

We have studied the requirements of proactive delivery of service for heavy equipment through General Electric Corporation, and generalized the results into a reference model for the development of service agreements in the field. Current results support different perspectives of service agreement design, including for example corporate strategy, organization, processes, and behavior; and unite them toward the logical structuring of service delivery. The logical structure prescribes the information contents and the execution processes underlying the service, and the enterprise systems that develop and implement the service. The model has been tested satisfactorily with some GE users. These results are presented in the paper.

The complexity of heavy equipment service is among the top of all manufacturing product services; thus, the resultant reference model should have direct applicability to other equipment service agreements and contribute to this significant sector of economy. However, the potential contributions go beyond this domain. We expect that the continuing research will yield sufficient results for engineering service agreements for IT outsourcing and some ASP type of e-business in non-manufacturing domains. The technical characteristics of the service products studied here, such as the reliance and emphasis on browser-based computing, extended enterprises, and re-usable, re-configurable enterprise processes and information resources and systems, are rapidly permeating into a much larger portion of the economy. As the applicability of this approach expands, the opportunity for major productivity gains in service through mass customization becomes more realistic, too.

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