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ENTERPRISE AND PROCESS ARCHITECTURE PATTERNS

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ENTERPRISE AND PROCESS ARCHITECTURE PATTERNS

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Abstract

In this paper we propose a method to support business process architecture and business process design, and present an application to the domain of public hospitals in Chile. This method is based on the formalization of generic architectures and their internal process structure, proposed in this work as architecture and process patterns, which have been developed in the MBE at the University of Chile and validated empirically in hundreds of Chilean firms from different industries. We have found that the use of architecture and process patterns accelerates the design of such structures until the last level of detail, providing a good basis for IS design. In particular, we were able to develop a comprehensive generic process architecture for public hospitals in two months. Our approach considers explicitly the relationships among the architecture and process components, providing a systemic view of the business structure and ensuring the alignment between its elements.

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Keywords: Enterprise Architecture, Business Process Design, Process IT support, Information Systems Requirements

ENTERPRISE AND PROCESS ARCHITECTURE PATTERNS

1. Introduction

For more than 30 years many authors have attempted to synthesize the knowledge about how an enterprise should structure its business processes, the people that execute them, the Information Systems that support both of these and the IT layer on which such systems operate, in such a way that they are aligned with the business strategy. This is the challenge of Enterprise Architecture design, which is the theme of this paper. We will provide a brief review of the literature on this subject with an emphasis on more recent proposals and methods that have been applied in practice. We also select approaches that propose some sort of framework, which provides a general Enterprise Architecture in a given domain that can be reused as a basis for specific designs in such domain. Then we present our proposal for Enterprise Architecture design, which is based on general domain models that we call Enterprise Architecture Patterns.

The literature on Enterprise Architecture can be classified into professional, produced by people for direct practical use in businesses, and academic, developed by people in universities and other organizations without concern for immediate application.

In the professional literature we have selected the following works:

- SCOR, which was originally centered on the supply chain and subsequently generalized to the whole enterprise [13]. This method has been developed by an association of companies and basically provides a structured classification or general architecture of all the processes an enterprise of the type in the SCOR domain (enterprises with supply chain) should have. The method also provides, at the lowest level of processes definition, metrics to measure performance and some information about links that connect processes.

- APQC [1], which is also a consortium of companies, including IBM, involved in the development of generic process architectures for companies of different domains, such as telecommunications, banks, automotive and electric utilities. Using benchmarking these firms created the APQC process classification framework (PCF), which is constantly updated as new companies join the group.

- FEA [16], which is an initiative of the government of the USA for the development of an Enterprise Architecture for the whole of the public sector.

- CBM of IBM [11], which is not labeled as an Enterprise Architecture but as the structure of business components an enterprise should contain. They have a general version and different versions for several industries. These business components can be assimilated to a process structure.

- TOGAF, which is a framework for the development of an Enterprise Architecture, proposed by The Open Group and based on an initiative of the US DoD [14]. From this perspective, TOGAF is more a methodology than a general enterprise architecture proposal. The Enterprise Architecture is composed of four different architectures: Business, Applications, Data and Technical, for which an Architecture Development Method (ADM) is proposed.

We subsequently review a few academic approaches:

- MIT´s methodology, which links Enterprise Architecture with strategy, provides a conceptualization of different operating models that determine the architecture of the enterprise [12]. Four types of enterprise structures are proposed based on the degree of business process integration and business process standardization: Diversification, Unification, Coordination and Replication. Diversification focuses on decentralized organizational design with high local autonomy, as opposed to the Unification model, which pursues low costs and standardization of business processes through centralization. The Coordination model focuses highly on integration without forcing specific process standards, whereas the Replication model pursues standardization with low integration among the different units.
  Then, depending on the operating model one chooses, a corresponding architecture is selected.

- ANSI/IEEE 1471-2000, which is a standard to describe the architecture of software intensive systems, developed by the IEEE Computer Society [10]. It establishes a conceptual framework to discuss about architectural issues of systems, such as the structure of its components, their relationship to each other and to the environment, and the principles guiding its design or evolution.

All of the approaches above attempt to describe an enterprise in terms of the structure of the process components needed to run a business. Most of them emphasize components classifications and do not explicitly consider relationships among them. Our experience in Enterprise Architecture and process design is that the most important factor is the design of the relationships that coordinate all the components of an architecture and make them perform as a system. For such design it is very useful to have a general architecture model that explicitly provides the relationships processes and other elements should have. The approach we will describe below provides such a model of Enterprise Architecture with relationships, which we call an Enterprise Architecture Pattern. These patterns have been under development since 1995, independently of all the methods reviewed above, and several publications in Spanish, starting in 1998, have circulated in Latin America [2,3,4]. Publications in English started in 2004 [5,6,7,8,9]. Our approach is a mixture of the professional and academic versions, since although it has been developed at a university, it has been applied to hundreds of real life projects. This has allowed us to test the proposed methodology and its continuous improvement, based on the generated experience.

2. Basis of our proposal

Our proposal is based on the formalization of knowledge derived from many practical projects of business design, performed by graduate students of the Master in Business Engineering (MBE) at the University of Chile in collaboration with the most important Chilean firms. By 1998 we had posited that all processed performed in an organization are part of one of the following types [2]:

* Macroprocess 1 (Macro1): Collection of processes for the production of the goods and services the firm offers to its customers, which starts with their requirements formulation and finishes with the satisfaction of the requests. We call this macroprocess Value Chain, adopting a definition slightly different than Porter´s, which includes other processes inside it, such as the development of new products that we include as part of another macroprocess.

* Macroprocess 2 (Macro2): Collection of processes for the development of new capabilities that the firm requires to be competitive, such as new products and services, including business models; necessary infrastructure to produce and operate those products, including IT infrastructure; and new business processes to assure operational effectiveness and value creation for customers, establishing, as consequence, systems based on proper IT.

* Macroprocess 3 (Macro3): Business planning, which contains the collection of processes that are necessary to define the direction of the organization, in the form of strategies, materialized in plans and programs.

* Macroprocess 4 (Macro4): Collection of support processes that manage the resources necessary for the proper operation of the other macroprocesses. Four versions of these processes can be defined a priori: financial resources, human resources, infrastructure and materials.

We call these process types macroprocesses because they contain many processes, sub processes and activities that are necessary to produce key products, such as the ones offered to clients, strategic plans, new facilities and so on.

Recently and independently, several proposals of what we call macroprocesses have been made, almost identical to ours. For example, a process structure proposed by HP based on SCOR [13], has the following macroprocesses: Design Chain, similar to Macro2; Business Development, to Macro3; Enabling Processes, to Macro4; and Supply Chain and Customer Chain that together form Macro1.

Also, the classification proposed by APQC can be assimilated to our macros in the following way: Develop Vision and Strategy is similar to Macro3; Design and Develop Products and Services is part of Macro2; Market and Sell Products and Services, Deliver Products and Services and Manage Customer Service conform Macro1; and Management and Support Services is similar to Macro4.

Our approach and proposals such as SCOR, APQC and eTOM [15] have in common that they provide reference models and general process structures, in given domains, as a starting point to design the processes of a particular case. However, and as it was mentioned before, the main difference between our proposal and other approaches lies in the explicit specification of all the relationships among the processes, at different levels of detail, that allows to show with more realism and precision how the process model is expected to work in practice.

For each of the macroprocesses defined above we have developed detailed process patterns, which give, in several levels of detail, the processes, sub processes and activities they should execute in order to produce the required product. Patterns are normative in that they include what it is recommended as best practices and what we have found that works in reality. They also include the relationships that should exist among processes, sub processes and activities. These patterns have been documented in several books (in Spanish) [3,4] and papers (in English) [5,6,7,8,9]. They have been validated in hundreds of practical projects, where they have been used as a starting point for business process redesign. This has allowed to gradually improve these patterns with the experience of more than ten years of projects. Examples of such patterns will be presented below.

The four macroprocess patterns can be combined into different structures depending of the business type. We call these structures Enterprise Process Patterns and we will detail them below.

Now an Enterprise Process Pattern is part of an Enterprise Architecture Pattern that can be modeled in the style of ANSI/IEEE 1471-2000, as it is shown in Figure 1. In some of the processes designs inside the enterprise architecture, the relationships of such model are made explicit, which we will illustrate when we explain different Enterprise Process Patterns types and apply them to design a specific case.

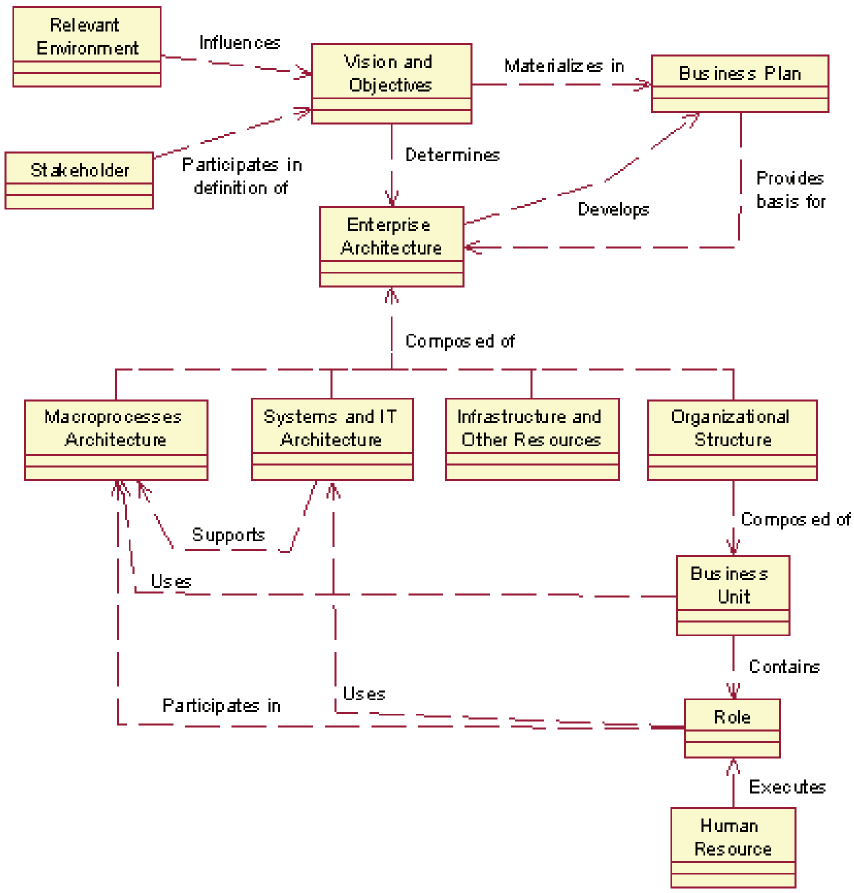

Figure 1. Class model for Enterprise Architecture

3. Process Architecture Patterns

The basis for any architecture pattern should consider the relationships among the macroprocesses defined in Section 2, since any process structure, according to our premise, is a combination of such macros. At the most basic level the general structure of relationships among these processes, which we proposed in 1998 [2], is the one shown in Figure 2. All the architecture patterns we present below are based on this general structure, which shows the interaction of the different macroprocesses with markets, customers and suppliers by means of information flows and internal flows, such as Plans coming from Macro3 that direct the behavior of the other macroprocesses; Needs that request Resources to Macro4; flow of Resources and feedback flows of Ideas and Results to monitor processes and initiate new plans in Macro3 and change in capabilities in Macro2.

Since our patterns model business practices, they must represent different business structures. For this we define structure types as follows:

- Businesses with just one value chain of the Macro1 type.

- Businesses with several value chains each of which operates independently (Diversification from the MIT Operating Model).

- Businesses that have several value chains, each of which operates independently but may share some supporting central services, such as business planning (Macro3), product design (Macro2) and financial, IT and human resources services (Macro4); they may also use instances of centrally defined processes in their operations (Coordination and Replication from the MIT Operating Model).

- Businesses that have several value chains, which share several of their internal processes and that also share supporting central services (Unification from the MIT Operating Model).

These Process Architecture Patterns types are shown graphically in Figure 3, where we represent, in a simplified way, the structure of the basic pattern of Figure 2, which is integrated in such architecture patterns. These types can be mixed to form many other structures; for example, an architecture that is partially of the Diversification type but has some business that follow the Unification type.

Each of these structures will have different architecture patterns, some of which we will detail below. But the interesting thing is that they all can be derived from the basic structure presented in Figure2.

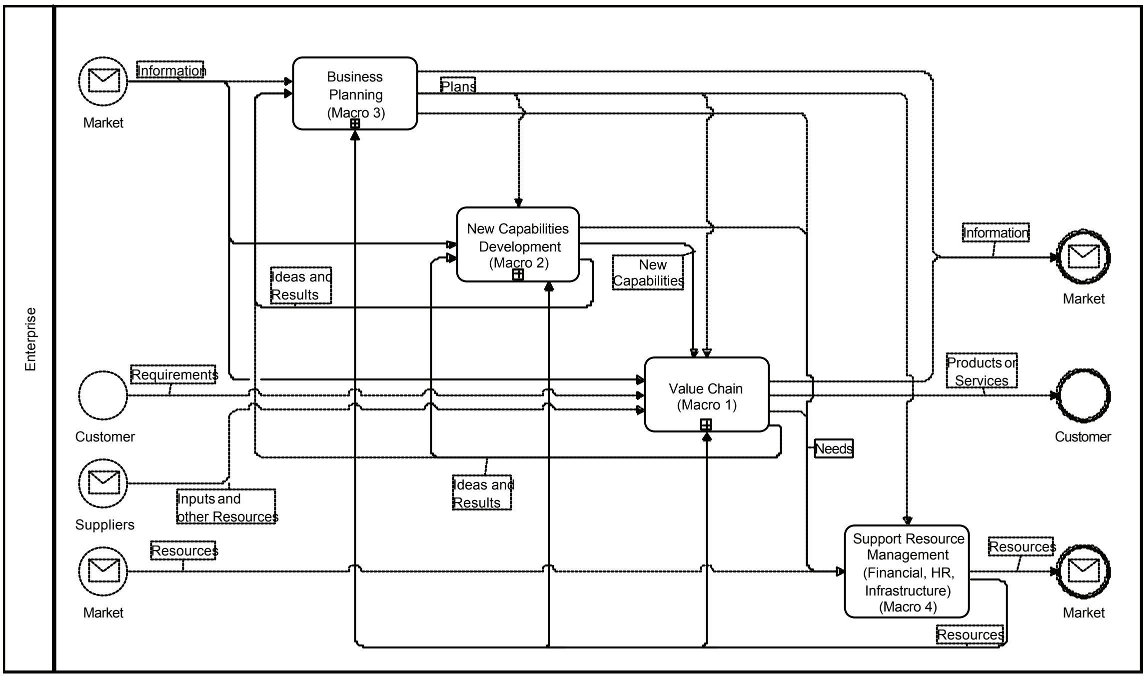

Figure 2. Basic Process Arc hitecture Pattern

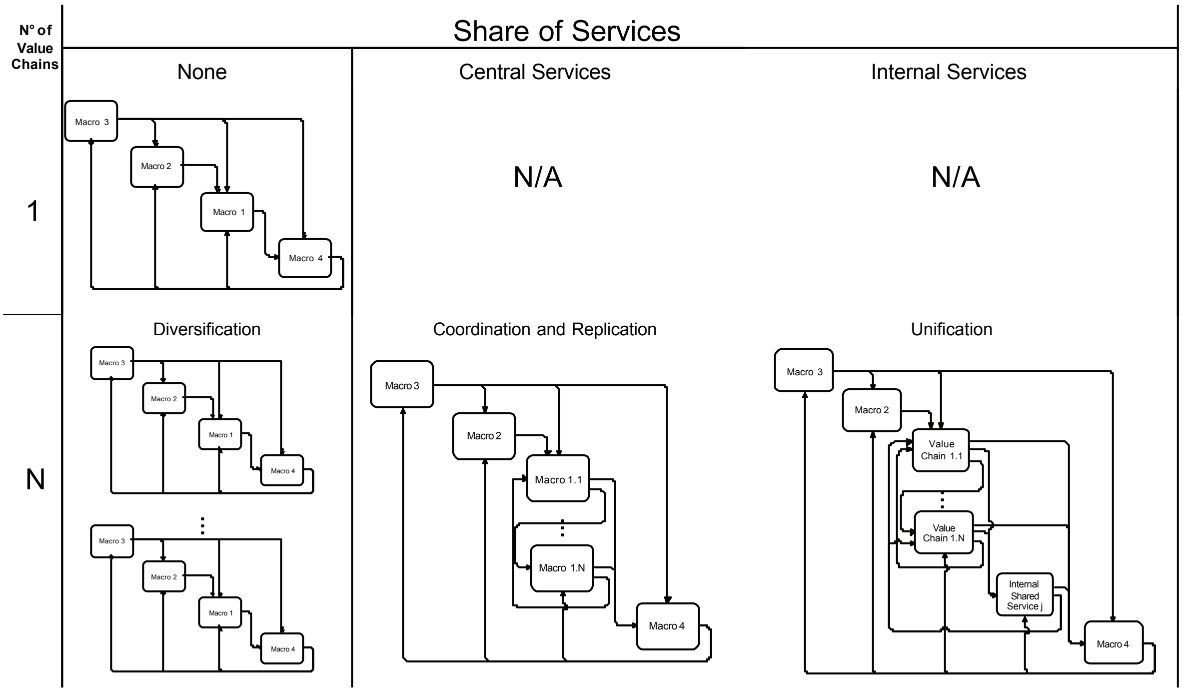

Figure 3. Process Architecture Patterns Types

The case we have developed in more detail so far, because of its relevance in the projects we have worked on, is the Unification one. For this case we propose the pattern of Figure 4, which we call Shared Services Architecture Pattern. The basic idea of this pattern is to factor out of the different value chains [i] several services [j] that can be centralized because of economies of scale or scope, transaction costs, agency advantages and other economic reasons [2,3,4]. For example, credit authorization for several banking business lines, supply management for several productive businesses and IT support in any business with several product lines. We will show an application of this architecture to a real case on the next section. We notice that some of the shared services can be externalized to suppliers.

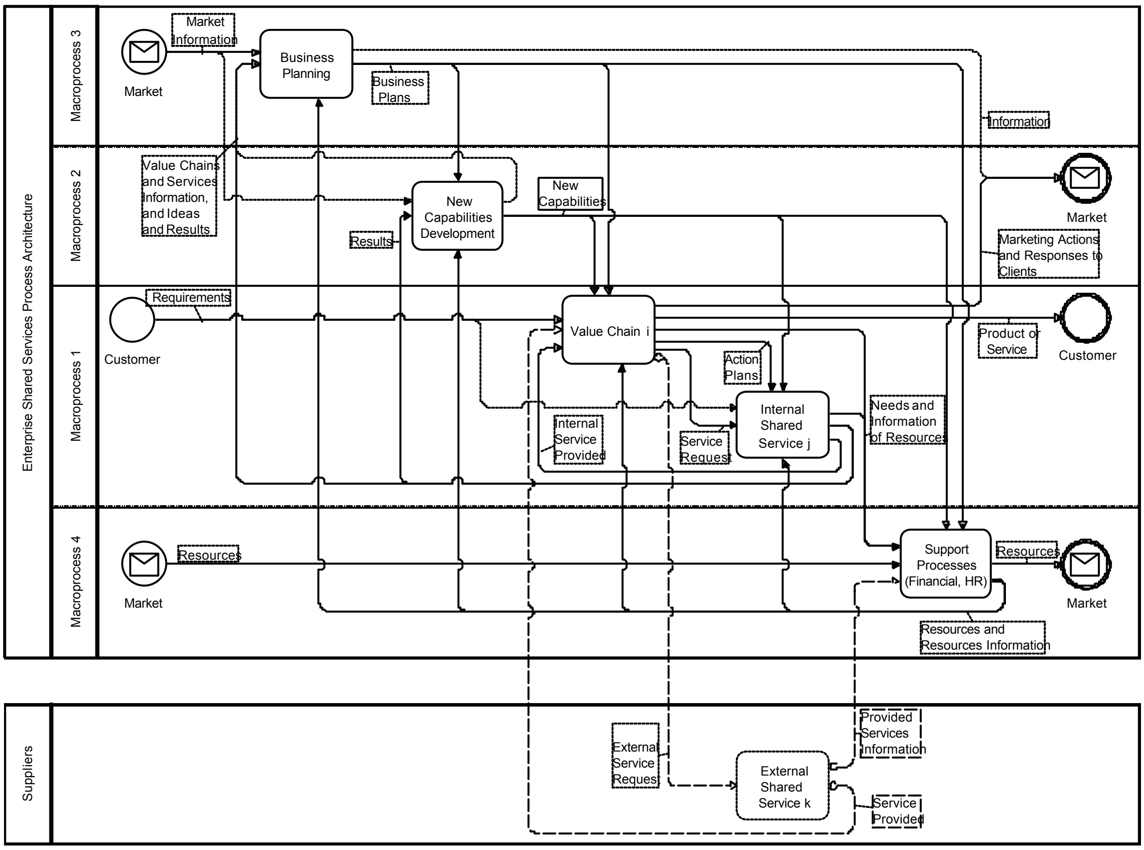

Figure 4. Shared Services Process Architecture Pattern

4. Application of Architecture Patterns in hospitals

We are developing a large project for public hospitals in Chile, which is supported by the Health Minister. The objective is to introduce innovative businesses practices and state of the art IT to improve service for patients and generate large increments in productivity in the use of hospital resources. This will result in new processes and IT applications to support them that will be eventually be implemented in all the public hospitals of the country.

Our approach starts with the development of a process architecture. To perform the design of the architecture we use as a starting point the Shared Services Architecture Pattern of the previous section. Shared services are a part of hospital practices, since all the existing value chains that provide different services for patients –emergency, ambulatory services and hospitalization- use several internal common services, such as laboratory services, operating rooms for surgeries, food services and cleaning services. Therefore, our architecture pattern applies straightforwardly to this domain. The specialization of our pattern to hospitals then results in the architecture of Figure 5. Such architecture has been fully validated by the managers of three representative public hospitals and also by the staff of one of the largest private hospitals in Chile. The complete architecture was detailed decomposing first level processes into two more levels of detail.

To present further details of the architecture, we selected processes that have proved to have more potential to produce great improvements in service and optimization in the use of resources. These processes are Demand Analysis and Management and Operating Room (OR) Service, which are part of the diagrams in Figures 6 and 7.

When performing the decompositions shown in Figures 6 to 9, a general process pattern previously developed for Macro1 was used [3,4,5,6,7]. For example, processes such as Demand Analysis and Management, State Status Service, Demand Forecasting and Characterization, Define Correcting Actions, Demand Analysis and Operating Room Scheduling are instances or specializations, in our terminology, of generic processes or sub processes defined in Macro1; also many of the flows in these decompositions are specializations of general flows defined in the pattern.

In Figure 6 the decomposition of Service Lines for Patients is shown. There are three main service lines at Hospitals, to which patients may access directly or by being referred from another service line. The description of these lines is presented in the following:

- Emergency Medical Service: Attends non-elective patients, e.g., those that require urgent medical attention and, as consequence, cannot be programmed with anticipation. Each patient that arrives to this service line is categorized according to the severity of its illness, in such a way that more urgent patients are attended with priority. Here, the patient may also be referred to any of the other service lines, in case it needs to be hospitalized or requires specialized medical attention.

- Ambulatory Elective Care Service: Attends elective patients, e.g., those patients which medical attentions can be programmed with anticipation. In this line, medical consultation takes place and some procedures are performed.

- Hospitalization Service: Attends elective and non elective patients that must be hospitalized, either to prepare to or recover from a surgery or procedure.

In addition to the aforementioned service lines, other complementary services might be offered to single patients or groups; for example, health insurance plans for specific patients classes or certain company employees. This process takes place in the Other Services Offer line, which services are typically found in the private health system.

The process Demand Analysis and Management is defined as a shared process for all service lines, in such a way that it captures the behavior of their demand and allows them to plan their resources to attend such demand.

In Figure 7 the decomposition of Internal Shared Services is shown. Those services are shared by all the service lines mentioned above and constitute a fundamental part of the service provided in them. These services are the following:

- Medical Appointments Service: Assigns to patients a medical appointment for any kind of elective medical attention: diagnosis, exams, procedures, etc. The patient may request the appointment directly to the service or through the service lines.

- Diagnose Tests Service: Performs all necessary tests to diagnose the patient. For example, blood tests, x-rays, lab analysis, among others.

- Operating Room Service: Receives and prioritizes the waiting list for surgery, schedules the Operating Rooms and performs the programmed surgeries.

- Other Internal Services: Contains other services shared by the service lines for patients, such as blood bank, internal and external transportation of patients, food and cleaning service, sterilization, etc.

- Procedures and Treatments Service: Provides procedures and treatments to the patients that do not require a doctor to be performed. For example, wound healing treatment, physical therapy and vaccination.

- Medical Supplies Service: Provides the medical supplies requested from the service lines and internal shared services.

- Bed Management Service: Provides and manages the different bed types for the service lines and internal shared services. Its principal goal is to locate each patient on the right bed at the right time, according to the complexity of the patients pathology and its expected evolution.

- State Status Service: Registers, updates and provides the state of every process of the hospital, which makes it a shared information service.

Demand Analysis and Management is the process defined to forecast the demand for hospital services and manage such demand and the hospital capacity to ensure that an adequate balance is reached. The basic idea is to proactively ensure that all the relevant demand will be processed with a required quality of service and that large current lists of patients waiting for services are eliminated. Our premise was that a better distribution of the existing resources should increase customers' satisfaction, without additional investments in capacity, which is starting to be proved true according to the results that will be presented in Section 5. The detail of this process is shown in Figure 8 and its sub processes are the following:

- Demand Forecast and Analysis: This process uses a forecast and characterization model that allows the hospital to anticipate the behavior of the demand through its periodical execution and the analysis of its results.

- Capacity Analysis: Evaluates if the capacity of the hospital will suffice to attend the demand forecasted in the previous process, depending on the resources required for each category of patients. If lack or excess of capacity is concluded, then actions can be taken in order to increase capacity or decrease the expected demand.

- Define Correcting Actions: Defines the correcting actions to decrease the demand for services or adjust capacity. For example, to inform non-elective patients with certain pathologies that they can be attended in other health services.

- Services Lines and Internal Services Planning: Analyzes the impact that previous correcting actions will have on the forecasted demand, in order to design plans that improve the quality of service for the new demand expected.

Operating Room Service is the process that prioritizes and schedules the incoming demand for surgical interventions in such a way that maximum waiting times, defined by medical experts, are met and the use of resources associated to the facilities is optimized. The detail of this process is shown in Figure 9 and its sub processes are the following:

- Demand Analysis: In this process, medical orders for surgery are added to the waiting list and then prioritized, according to the medical criteria previously formalized as business logic. Subsequently, a waiting list analysis determines if the resources will suffice to attend such demand on time or if additional resources are required to achieve this objective.

- Operating Room Scheduling: Generates the OR schedule using the waiting list prioritized in the previous process. Even though the scheduling maximizes of the use of facilities, it also includes good medical practices to decide the order and time of surgical interventions.

- Resources Scheduling: Schedules the resources that are necessary to perform the surgical interventions schedule.

- Surgery Performing: Executes every surgery scheduled, which includes the preparation of the patient, the surgical procedure and recovery. After surgery is performed, the procedure protocol information is registered and the patient is removed from the waiting list.

The last level of detail of the Hospital Architecture concerns the procedural execution of each of the processes presented in Figures 8 and 9. Such execution must show the sequence of the activities involved, the logic of the flow and the computer application supporting each activity. At this level, the modeling style changes from the activity flow diagrams presented in previous figures to full formal BPMN models, in order to make possible their simulation and eventually execute them with, for example, a BPEL orchestration. To illustrate how this is done, we selected two processes from Figures 8 and 9, and present their diagrams in Figures 10 and 11.

Demand Forecasting and Characterization: In the first activities of this process, the data to be used in forecasting is obtained, consolidated and showed to the analyst for its cleaning and preparation to enter the model. This allows the analyst not only to check the quality of such data, but also to incorporate qualitative criteria about the behavior of the demand. For example, an outlier could be replaced by an appropriate average. Once everything is set to run the model, the analyst requests the system to forecast the demand. The forecasting model, that was built using neural networks, receives the previous data and estimates the aggregated demand expected for the next 12 months, within a probabilistic range of error. Afterwards, this demand is segmented and characterized based on its historical behavior. Then the analyst decides which point of the forecasted demand range, formed with the mentioned error, will be used to manage its resources in order to attend it, depending on contingent events and its experience. With this analysis the process ends.

Operating Room Scheduling: This process was designed to be executed with a certain periodicity; the scheduler requests the software to schedule the operating rooms, which is done using a optimization model that incorporates medical best practices and resource constraints for OR scheduling. For example, from the resources perspective, it is considered better to perform ambulatory surgical interventions first in the morning because it allows to release the bed resource in the afternoon to be used by another patient. After the software proposes a schedule, the scheduler has the possibility to change the order in which surgeries will be performed, postpone patients and/or include non scheduled patients from the waiting list, based on medical criteria. The final schedule is then saved and submitted for patients confirmation and resources scheduling.

Although we have used two modeling styles in the design of the processes above -process flow diagrams and full BPMN diagrams-, they are fully compatible and can be implemented with the same BPMN modeling tool, as it was discussed in a previous paper [8].

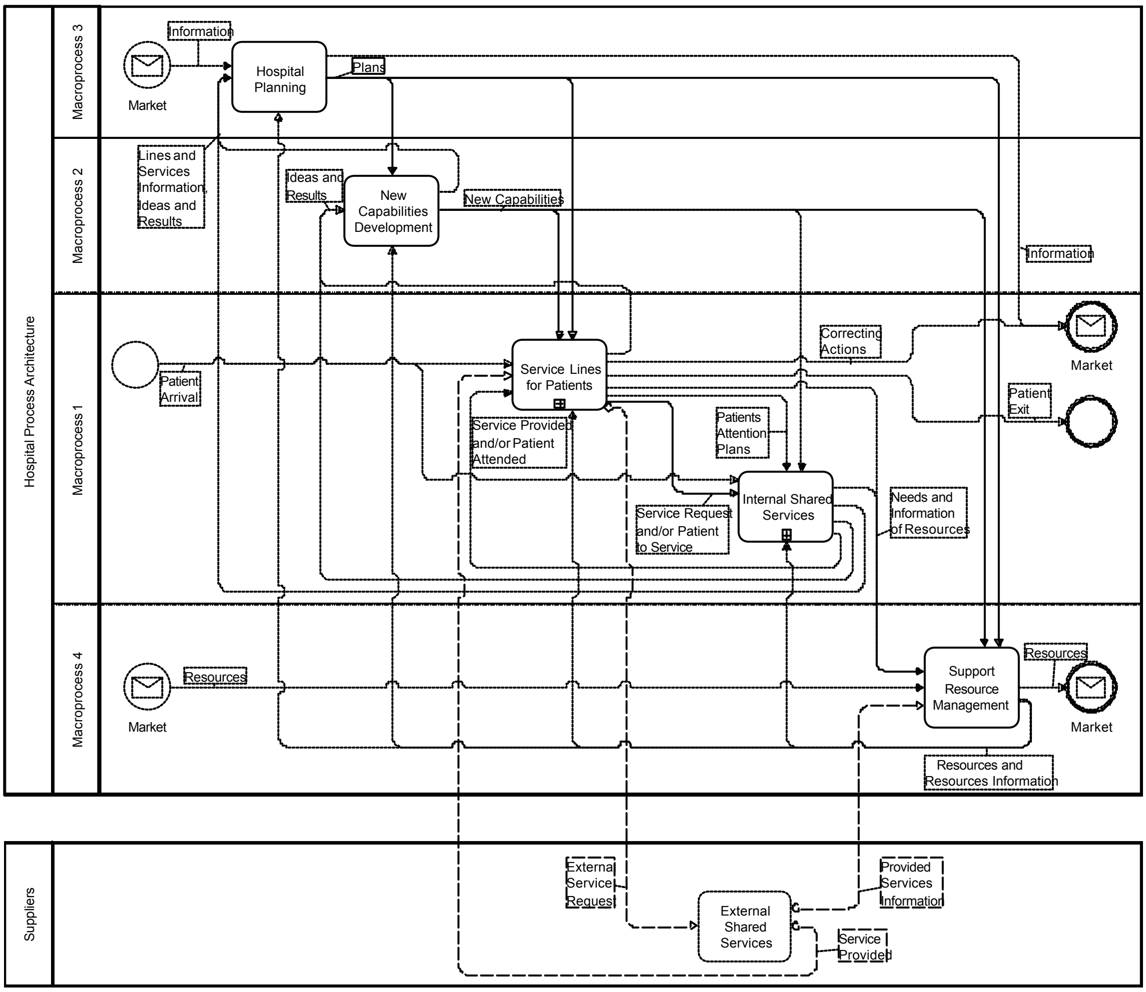

Figure 5: Process Architecture for Hospitals

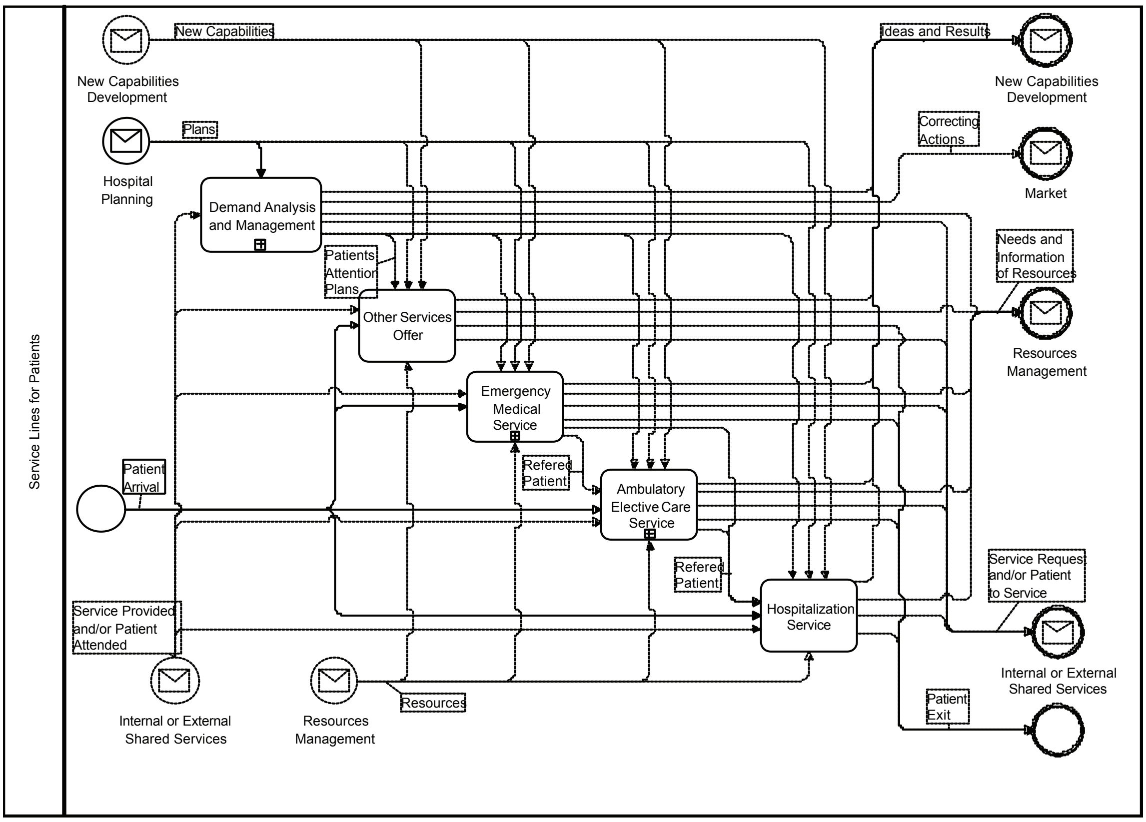

Figure 6: Detail of Services Lines for Patients

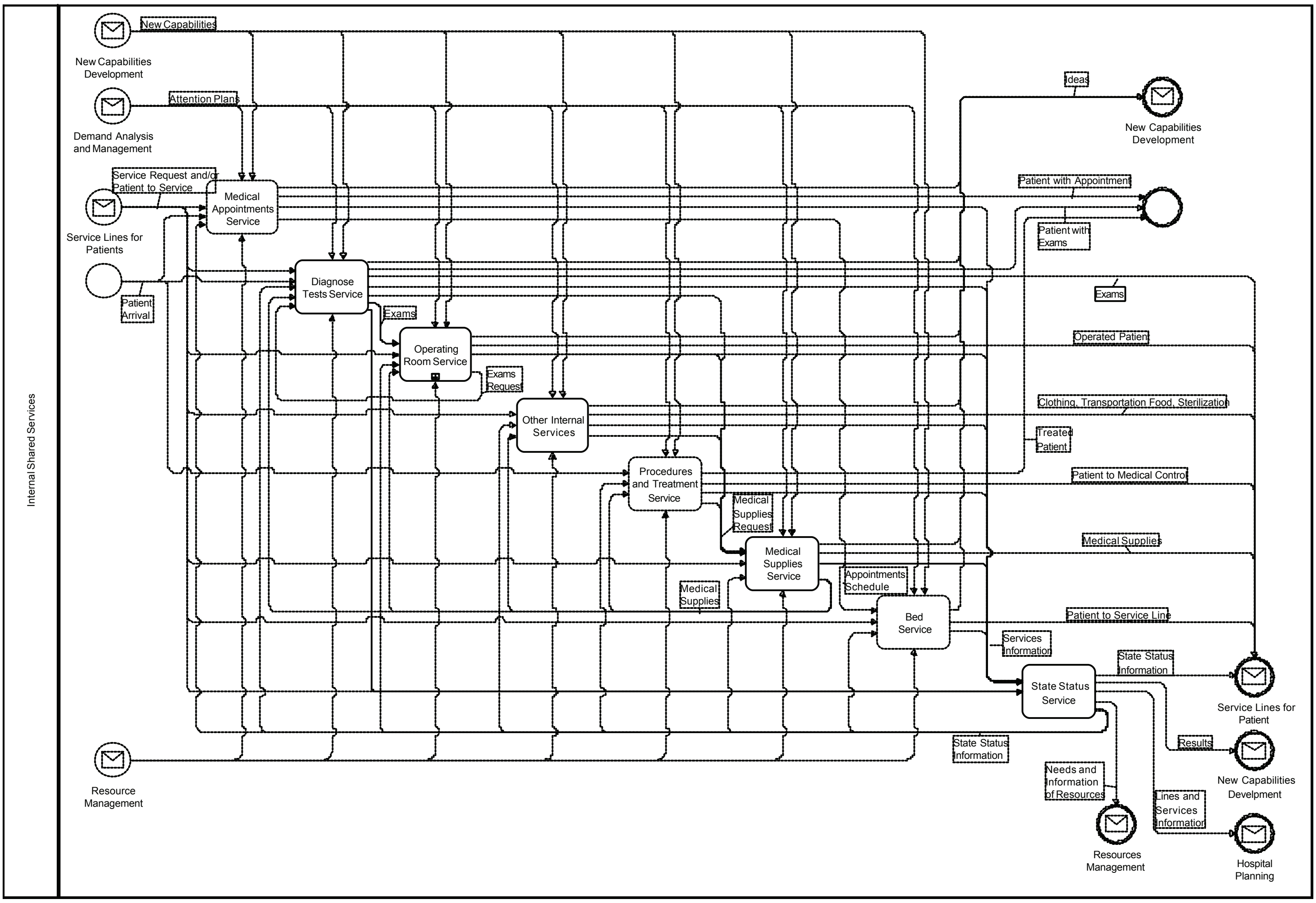

Figure 7: Detail of Internal Shared Services

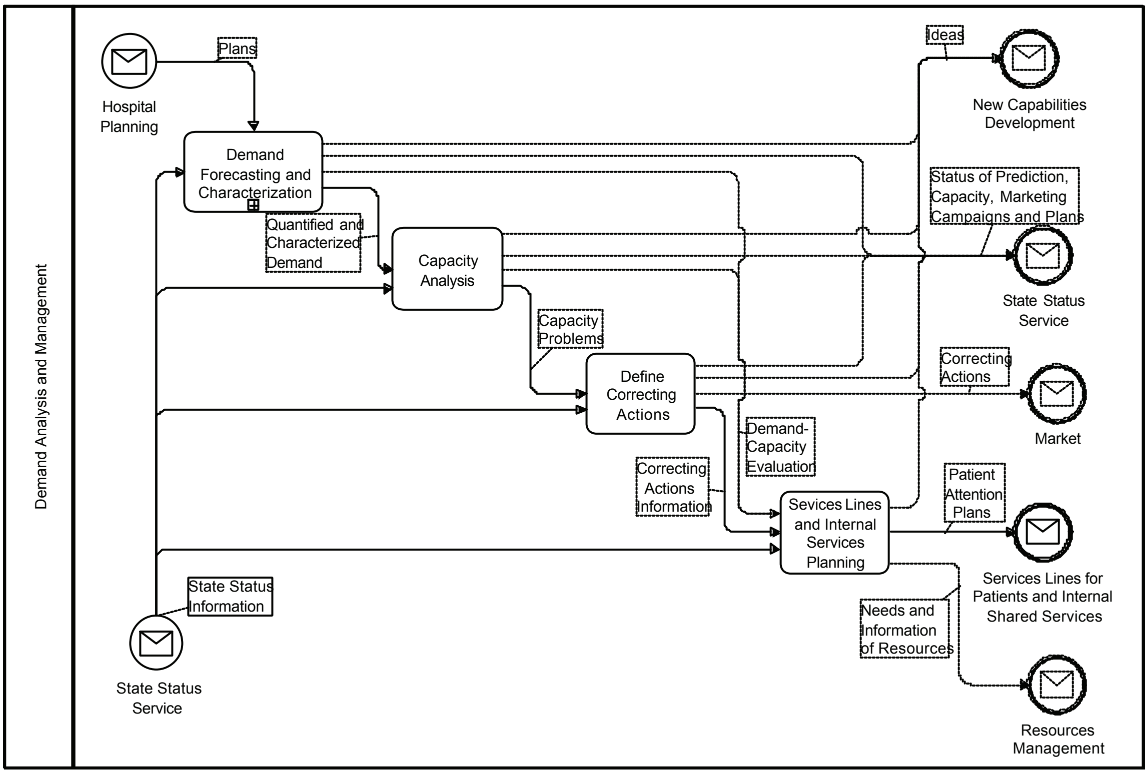

Figure 8: Detail of Demand Analysis and Management

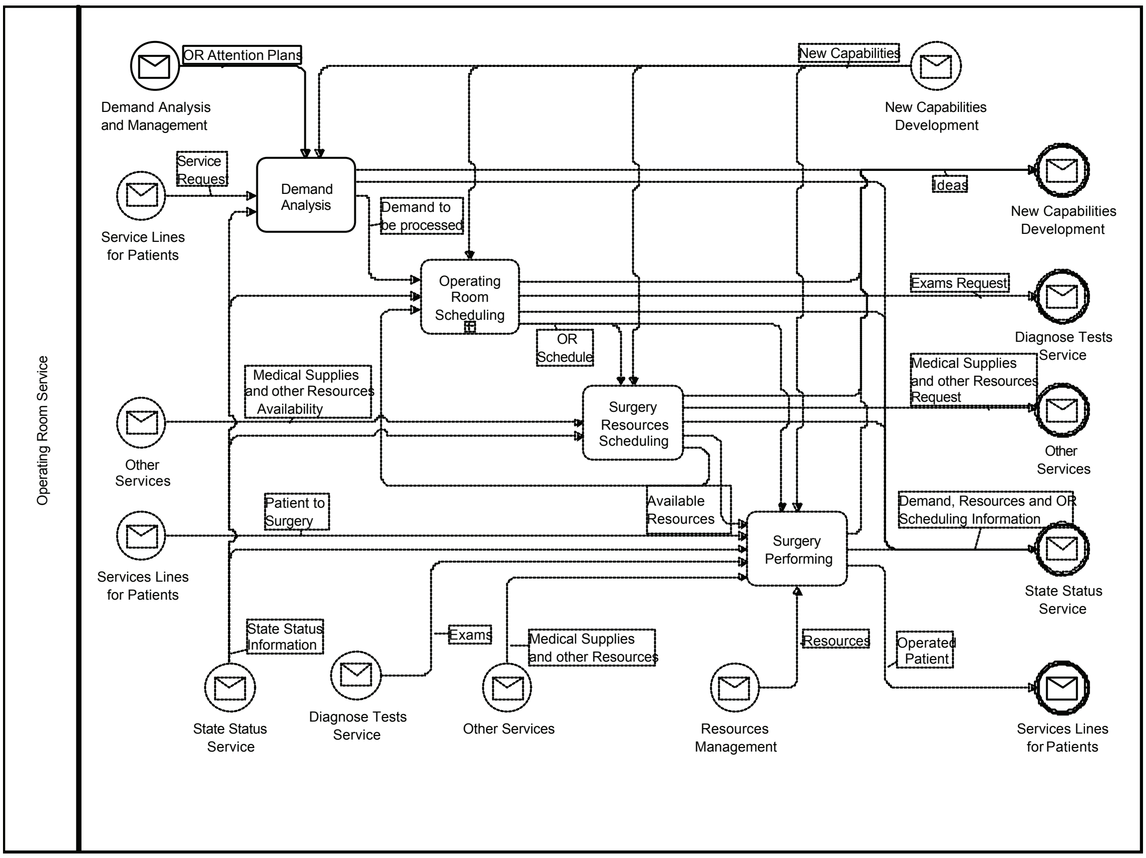

Figure 9. Detail of Operating Room Service

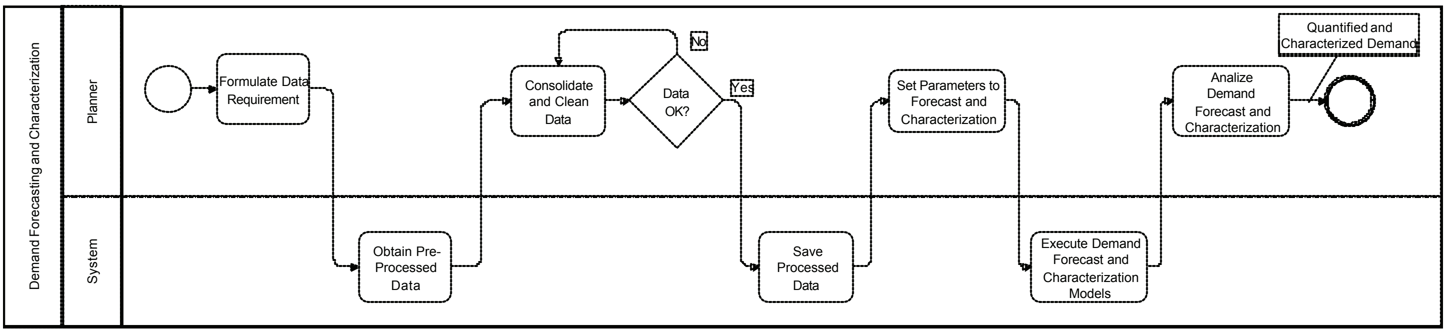

Figure 10: BPMN diagram for Demand Forecasting and Characterization

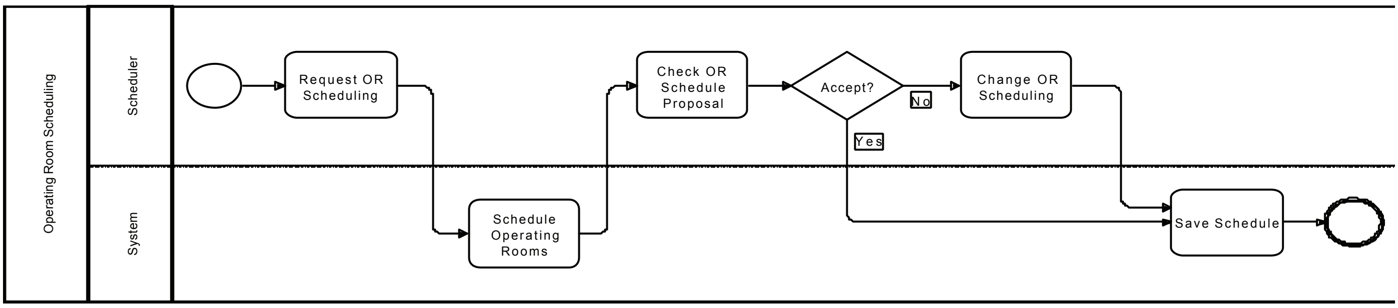

Figure 11: BPMN diagram for Operating Room Scheduling

We notice that the process design we have presented includes the relationships to the other components of the Enterprise Architecture, which were specified in Figure 1. Thus, the relationship to the organizational structure is included in the process definitions, such as shared services, and in the roles we define in the BPMN diagrams and the tasks that are assigned to each role, which can be new roles with new practices. In fact, this means that we are redesigning the organization at the same time we design the processes. Also, the relationships to the systems architecture and IT infrastructure are included in the diagrams. Hence, system support is shown explicitly in the diagrams, which requires that new systems should be designed and integrated to current systems architecture. The IT architecture is a consequence of new systems requirements, since they may need to be extended due to new technologies used by the design. For example, in the case of hospitals, we used BPEL orchestration technology for the execution of the BPMN models, which implies a change in the IT architecture of hospitals in order to integrate this technology with current hardware and software.

5. Experience

The experience with the application of the architecture and process patterns has been successful in that:

- It was possible to develop a process architecture for hospitals in a very short time (two months), starting with the Shared Services Pattern. The resulting architecture was fully validated by hospital management and allowed us to select some of the key processes to design them in detail using our process patterns.
- The designs were tested through the execution of the methods and logic embedded in the processes, which provided the results that can be obtained by implementing such designs. In particular, we developed neural network models for forecasting using the demand behavior and characterization data, and showed that demand can be forecasted with an average error of about 5%. Such forecast provides a very good basis for capacity planning that is not available today. We also tested the heuristics and optimization models to prioritize and schedule the waiting list for the operating room, and found that this service can be improved from about 50% to more than 80% use rate. Priority for the selection of patients was determined based on medical criteria, where the illness severity and several aggravating factors, such as patients age, define, by means of formal rules, the maximum time he/she can wait before surgery.
- Formal BPMN models for processes of the lowest level of detail allowed us to execute them using a BPEL orchestration tool on a BPEL engine and web services connection to implement complex logic and connect to data bases that contain the data processes require. This execution was performed in a pilot way, but with full user participation, before going into the full implementation of the new processes.

This experience, which was accomplished in little more than six months, has been confirmed by other cases we have developed for other organizations, where it has also been possible to generate architectures in very short times, starting with the patterns. In particular, among others, architectures have been designed for a large mining company, one of the leading telecoms in Chile and an international airline.

6. Conclusions

In this paper we have presented an approach for the solution of the problem of business architecture and process design. Such solution is based on the thesis that the architecture of any enterprise can be modeled by means of four general Business Process Patterns, which we call macroprocesses. Different structures built with these macroprocesses provide several typical architecture patterns that can be used to perform architectural design in particular cases. Each of these macroprocesses is, in itself, a layered normative structure of processes – which specifies the processes, sub processes and activities that should be executed to produce a desired result- that also provides a solution for the design of the processes within a selected architecture. Both architecture and macroprocesses patterns are modeled with BPMN constructs, in a consistent and integrated way, which, besides giving the components of the patterns, specify the relationships among them by means of flow specifications. This is an innovation with respect to other approaches to architecture and process design based on reference models and frameworks that only provide hierarchies of components. An important conclusion of our approach and experience is that the most important factor in the design of an architecture is the design of the relationships that coordinate all its components and make the whole perform as a system.

The patterns we propose have been validated in hundreds of practical projects in several domains, where they have been specialized and used as a starting point to perform architecture and process redesign. In particular we have been able to generate, starting with the general patterns, architecture and process solutions for hospitals, in a very fast and efficient manner, that have been implemented in practice. The experience generated with these projects supports the conclusion that it has advantages, in terms of speed and quality of design, to have patterns of the type we have proposed to perform architecture and process design. Furthermore, the combination with formal process modeling has also shown that process implementation with IT support can also be accelerated with process execution using appropriate BPMN-BPEL orchestration tools. This also has the advantage of providing flexibility for changes, since this can be done by editing process models. Another interesting conclusion of our ideas is that the insertion of analytics within the process design makes possible the optimal use of resources, such as hospital capacity and operating room facilities, which is an innovation with respect to current process design methodologies.

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