APPLICATION OF ENTERPRISE AND PROCESS ARCHITECTURE PATTERNS IN HOSPITALS

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The Project

In a previous paper in BPTrends [7], of which this is a sequel, we presented our approach to enterprise and process architecture design. Such an approach is based on proposing a generic architecture and process patterns that can be reused in a given domain. In this Article we present the application of such an idea to the domain of hospital management.

This application is part of a large project we are developing 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.

Architecture and Process Design

Our approach starts with the development of a process architecture. To do this, we used the Shared Services Architecture Pattern of the previous paper [7], which applies fully in this case. Shared services are a part of hospital practices since the several value chains for different services to clients – emergency, ambulatory, and hospitalization – use many internally common services such as laboratory services, operating rooms for surgeries, food services, and cleaning services. So our architecture pattern applies in a straightforward manner to this domain. Applying our pattern specifically to hospitals results then in the architecture of Figure 1. Such architecture has been fully validated by the management of three representative public hospitals and also by the staff of one of the largest private hospitals in Chile. The complete architecture was detailed by deconstructing first level processes into two more levels of detail as we will present below.

From the architecture, we present in greater detail processes that have proved to have more potential to produce great improvements in service and optimization in the use of resources. They are Demand Analysis and Management and Operating Room (OR) Service, which are part of the diagrams in Figures 2 and 3.

In doing the decompositions shown in Figures 2 to 5, a general process pattern previously developed for Macro1 was used [1,2,3,4,5]. 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 general processes or subprocesses defined in Macro1; also, many of the flows in these decompositions are specializations of general flows defined in the pattern.

In Figure 2 the decomposition of Service Lines for Patients is shown. There are three service lines at Hospitals, which patients can access directly or by being referred from another line. The detail of these lines is shown in the following:

- Emergency Medical Service: Attends non-elective patients, e.g., that need urgent medical attention and, as a consequence, cannot be programmed beforehand. Each patient that arrives to this service line is categorized according to the severity of illness so that patients with more urgent needs receive attention first. Here, the patient may also be referred to any of the other service lines, in case he or she needs to be hospitalized or requires specialized medical attention.

- Ambulatory Elective Care Service: Attends elective patients, e.g., those where medical attention can be anticipated and programmed beforehand. 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 for or to recover from a surgery or procedure.

In addition to the service lines mentioned, other complementary services might be offered to single patients or groups; for example, health plans for specific profiles of patients or certain company employees. This takes place in the Other Services Offer line – services that 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 nature of a demand, and allows them to prepare their resources to attend such a demand. This process will be described in detail below.

In Figure 3, the decomposition of Internal Shared Services is shown. Those services are shared by the service lines mentioned above, and they are 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: consultations, exams, procedures, etc. The patient may request the appointment to the service directly or through the service lines.

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

- Operating Room Service: Receives and prioritizes the waiting list for surgery, schedules the Operating Rooms, and performs the programmed surgeries. This service will be explained in detail below.

- Other Internal Services: Contains other services shared for 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 patients procedures and treatments 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 for the service lines and internal shared services.

- Bed Service: Provides and manages the different bed types for the service lines and internal shared services. Its principal goal is to locate each patient in the right bed at the right time, according to the complexity of the patient’s pathology and the evolution of that pathology.

- State Status Service: Stores, updates, and provides the state of every process of the hospital; so, it is a shared information service.

Demand Analysis and Management is the process that should be able to forecast demand for hospital services and manage such demand and the hospital capacity to assure that an adequate balance is reached. The basic idea is to proactively insure that all relevant demand are processed with quality of service and that the current long patient waiting lists are eliminated. Our premise was that better use of resources, without additional investments in capacity, could reduce the number of unsatisfied customers, and that is starting to be proven true according to the results we will present in the last section. The details of this process are shown in Figure 4, and its subprocesses are the following:

- Demand Forecasting and Characterization: This process uses a forecast and characterization model that allows the hospital to anticipate demand through its periodic execution and the analysis of its results.

- Capacity Analysis: Evaluates if the capacity of the hospital will be enough to attend to the demand forecast in the previous process, depending on the resources required for each segment of patients. If it is concluded that there is a lack of or excess of capacity, then actions can be taken in order to decrease the expected demand or adjust capacity.

- 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 or characteristics that other health services can attend to their needs.

- 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 takes the demands for surgical interventions, prioritizes them, and schedules them in such a way that maximum waiting times, specified by doctors to perform an intervention due to medical reasons, are met, with optimum use of the resources associated with the facilities. The detail of this process is shown in Figure 5, and its subprocesses are the following:

- Demand Analysis: In this subprocess, medical orders for surgery are added to the waiting list and then prioritized according to medical criteria previously formalized as business logic. Afterwards, a waiting list analysis determines if the resources will be enough to process that demand on time, or if further efforts must be made in order to achieve it.
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- Operating Room Scheduling: Generates the OR schedule using the waiting list prioritized in the previous process. Though this scheduling is based on the maximization of the use of facilities, it also includes good medical practices to decide the order and time of surgical interventions.

- Surgery Resources Scheduling: Assign the resources that are necessary to perform the surgical interventions previously scheduled.

- Surgery Performing: Executes every surgery scheduled, including the preparation of the patient, the surgery itself, and the recovery. After surgery is performed, the patient 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 subprocesses of Figures 4 and 5. Such execution must show the sequence of activities involved, the logic of the flow, and the computer application support that each activity will have. So the modeling style changes from the activity flow diagrams of previous figures to full BPMN models that are formal, in order to make possible their simulation and, eventually, to execute them with, for example, a BPEL orchestration. To show how this is done, we selected two subprocesses from Figures 4 and 5, and present their diagrams in Figures 6 and 7.

Demand Forecasting and Characterization: In the first activities of this process, data to be used in forecasting is obtained, consolidated, and shown 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, which 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 such demand, depending on contingent events and experience. With this analysis the process ends.

Operating Room Scheduling: This process was conceived to be executed with a certain periodicity; the scheduler requests the software to schedule the operating rooms, which is done using a heuristic that includes best practices for OR scheduling, from the medical and efficient use of resources perspectives. For example, from the resources perspective, it is considered better to perform ambulatory surgical interventions first, in the morning, in such a way that the resource bed will be released for another patient in the afternoon. After the software suggests a proposal of scheduling, 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, according to experience. The final schedule is then saved and sent 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 discussed in a previous paper [6].

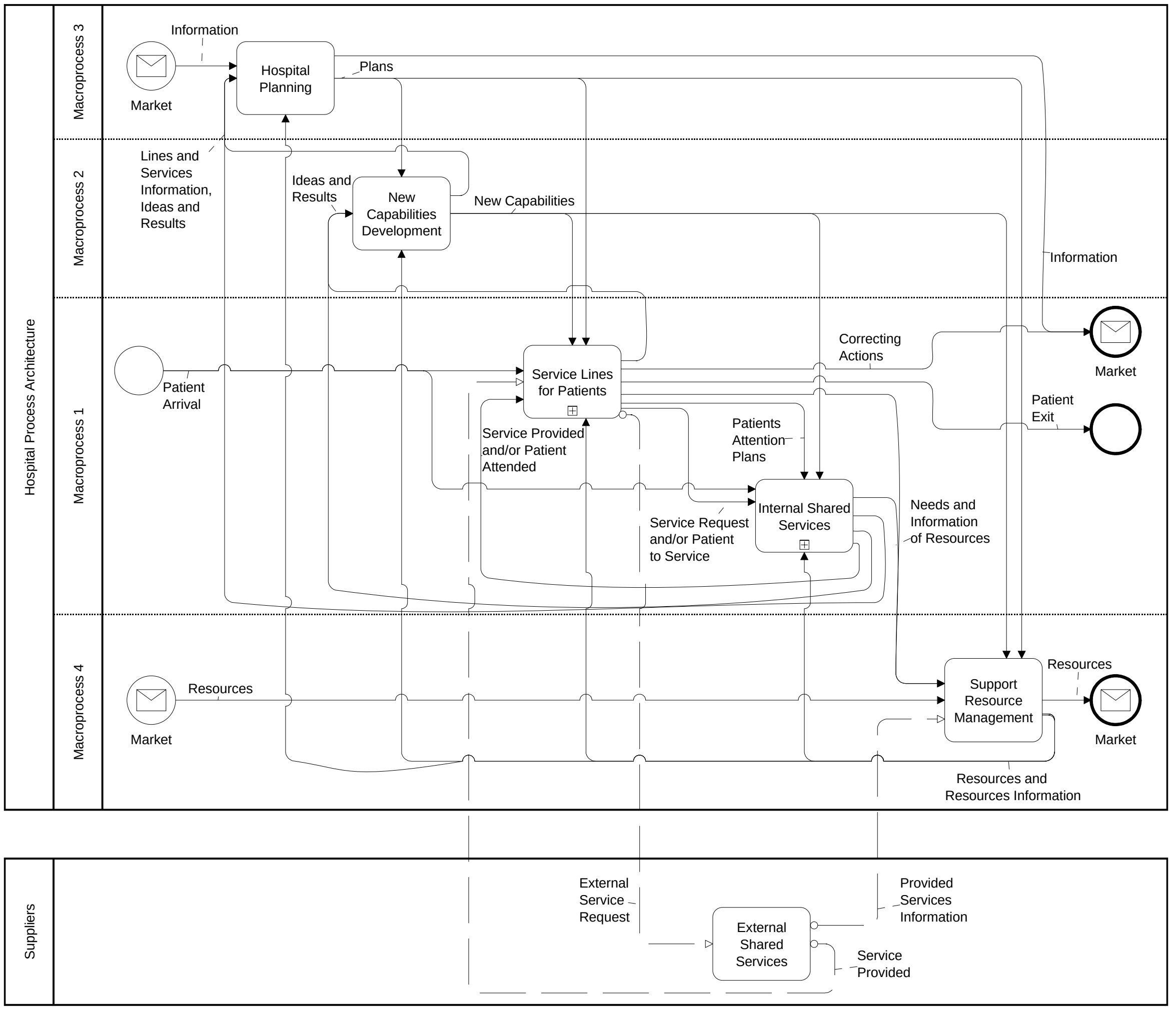

Figure 1. Process Architecture for Hospitals

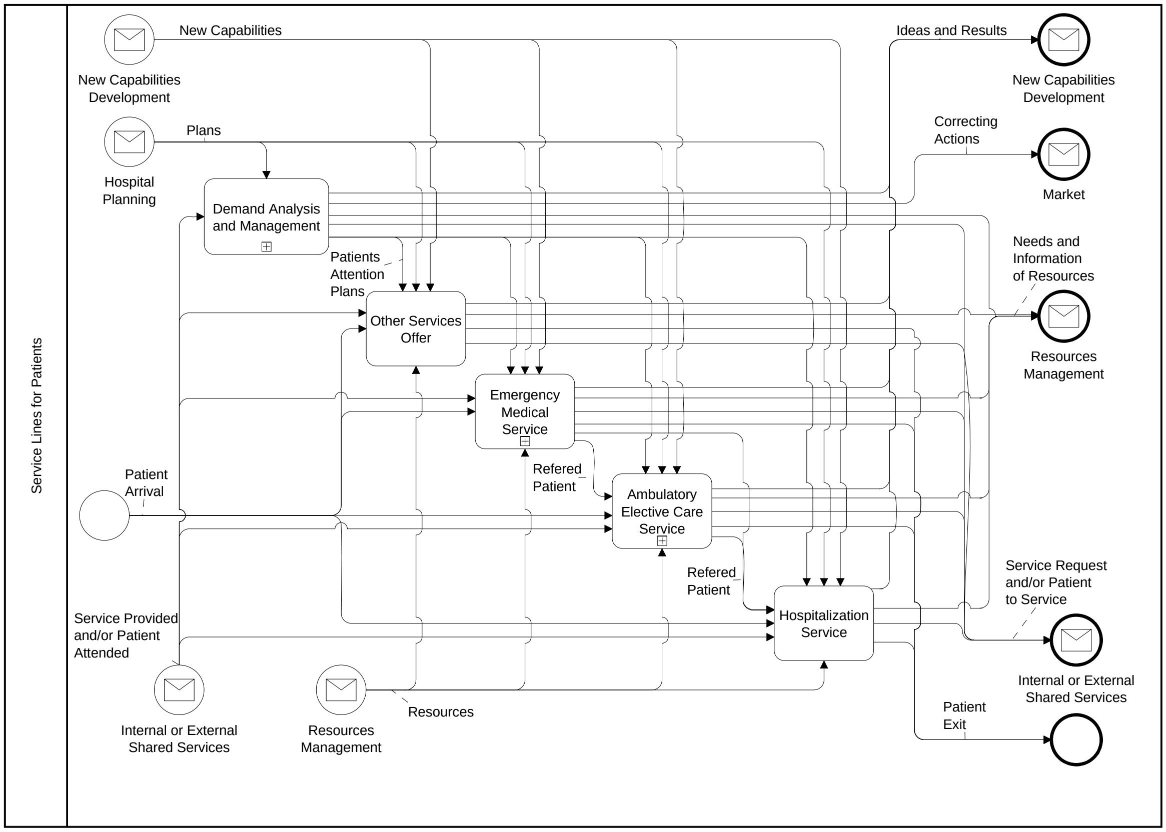

Figure 2. Detail of Services Lines for Patients

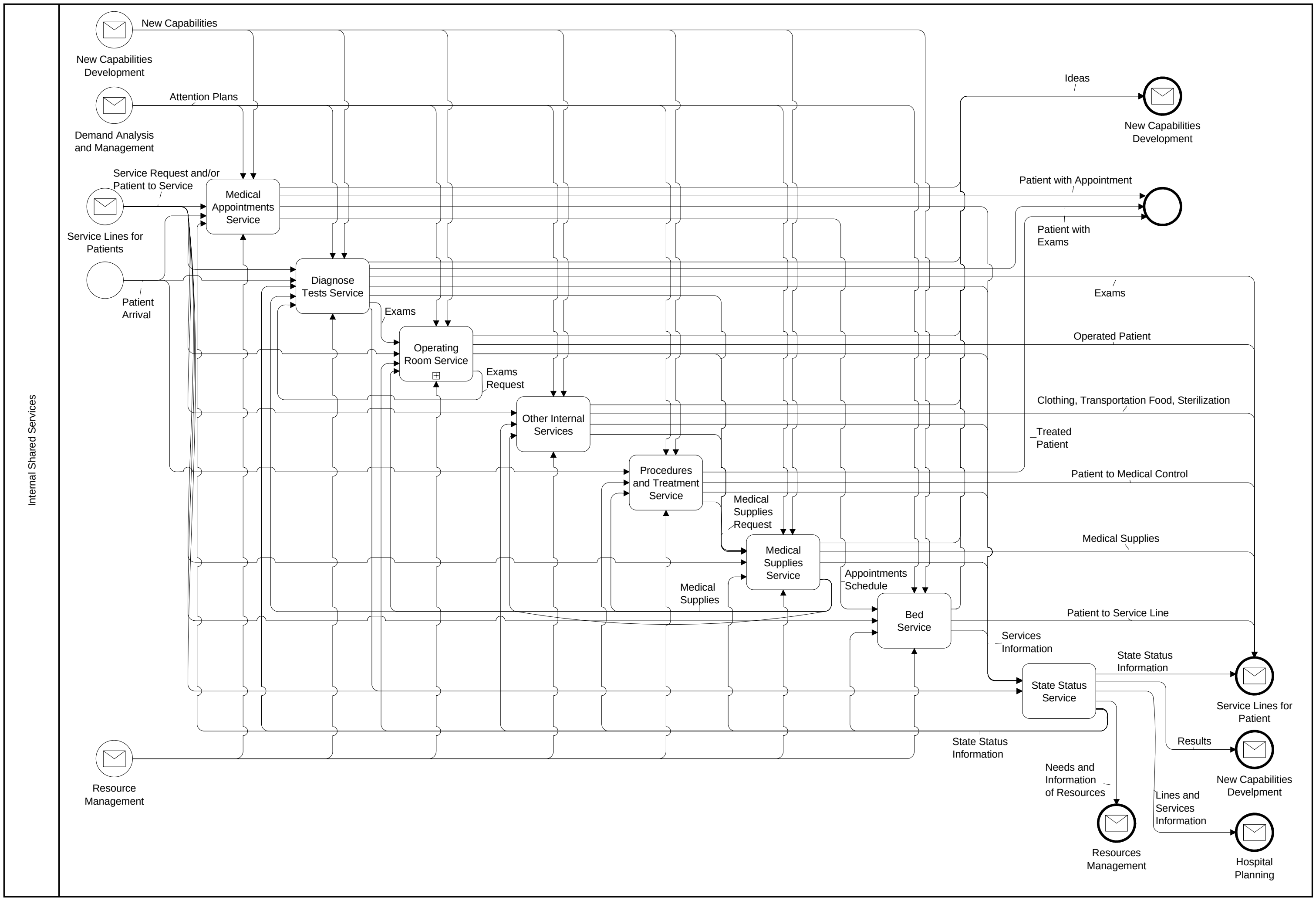

Figure 3. Detail of Internal Shared Services

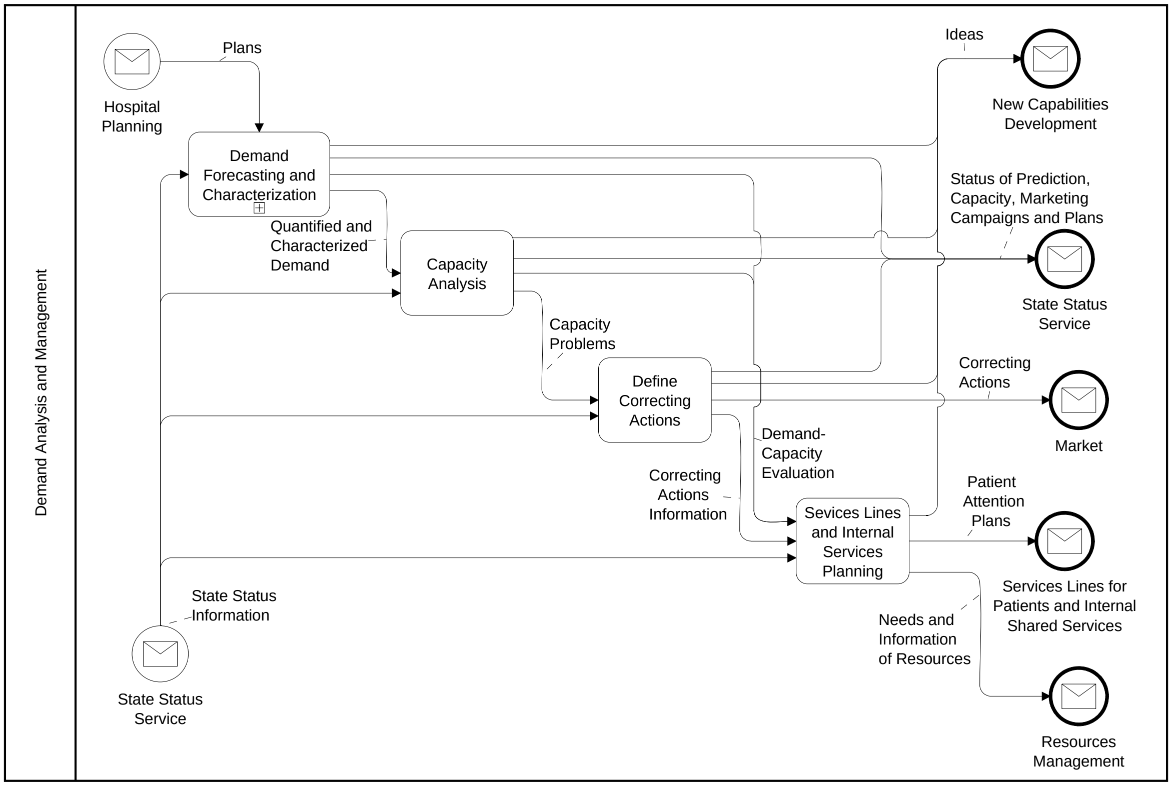

Figure 4. Detail of Demand Analysis and Management

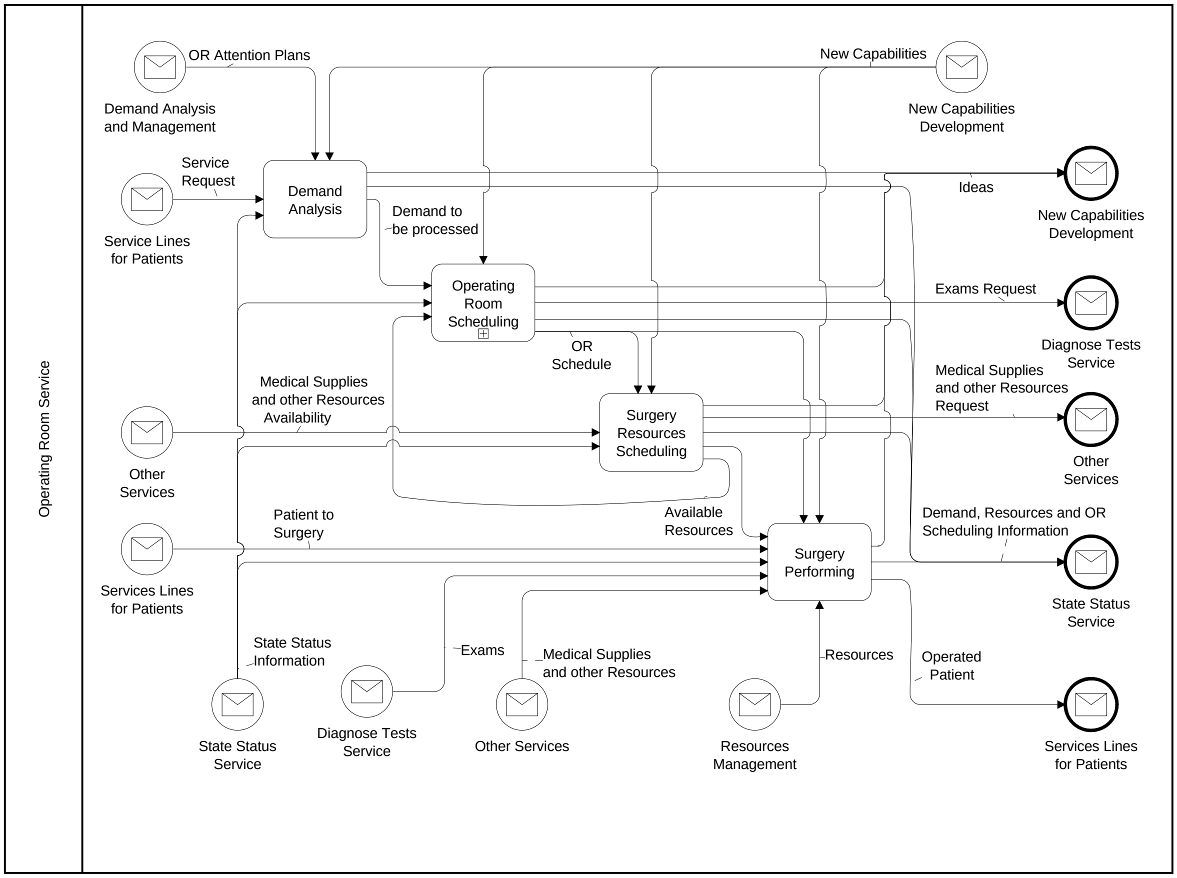

Figure 5. Detail of Operating Room Service

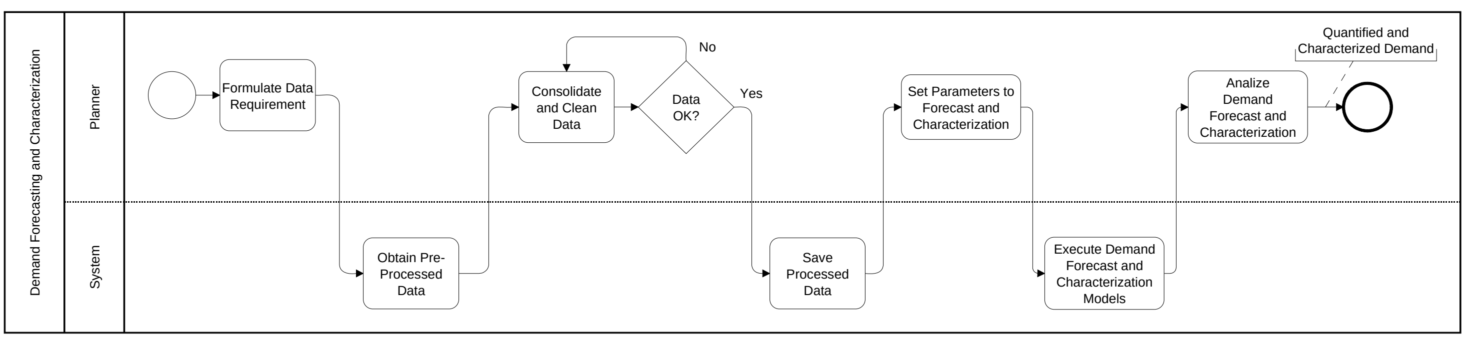

Figure 6. BPMN diagram for Demand Forecasting and Characterization

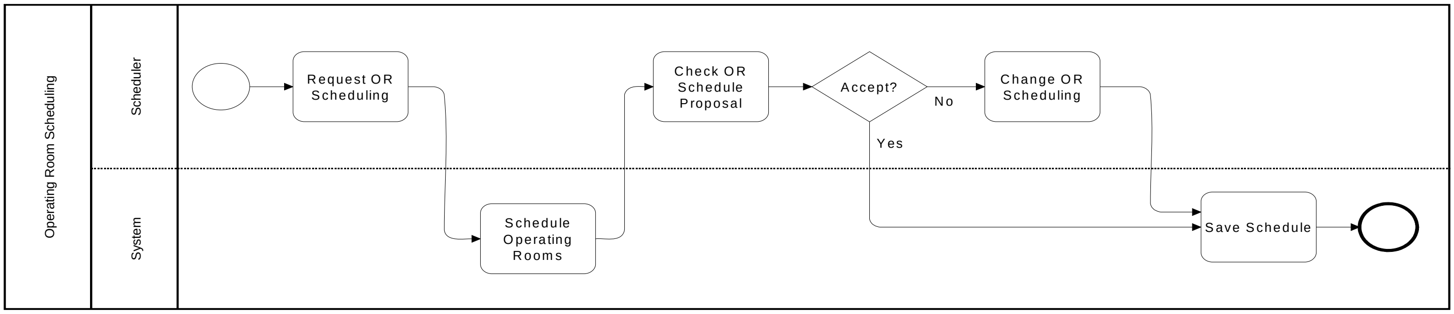

Figure 7. BPMN diagram for Operating Room Scheduling

We notice that the process design we have presented includes relationships to the other components of the Enterprise Architecture that were specified in the previous paper [7]. Thus, the relationship to the organizational structure is included in the process definitions, such as share 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 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 related to current systems architecture. The IT architecture is a consequence of new systems requirements since they may need its extension due to new technologies used by the design. For example, in the case of hospitals we used a 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.

Experience and Conclusions

The experience with the application of the Process Architecture 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 by using our process patterns.
- The designs were tested by executing the methods and logic proposed by them and determining results that can be obtained by implementing such designs. In particular, we processed the demand data, developed neural network models for forecasting, and showed that forecast has average errors of about 5%, which provides a very good basis for a capacity planning that it is not available today. Also, we tested the heuristics for operating room list prioritizing and scheduling, showing that service can be improved by doing a more careful selection of patients to go into surgery, and the rate of use of facilities can be improved from about 50% to more than 80%.
- Formal BPMN models for processes of the lowest level of detail allowed us to execute them by 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 need. This execution was 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.

All the experience above points to the conclusion that there are advantages, in terms of speed and quality of design, to having patterns of the type we have proposed to do architecture and process design. Furthermore, the combination with formal process modeling has also shown that process implementation with IT support can be accelerated with process execution with appropriate BPEL orchestration tools. This also has the advantage of providing flexibility for changes since editing process models can do this. Another interesting feature of our approach is the insertion of analytics within the process to make possible the optimal use of resources, such as hospital capacity and operating room facilities.

Author

Dr. Oscar Barros (Ph.D., U.Wisconsin) is the director of the Master in Business Engineering (MBE) at the University of Chile and is a businessman in the IT industry in Chile. He has written ten books with more than 100,000 copies sold. He has also published widely in international scientific and technical journals. Dr. Barros has also been active in consulting, having directed many large-scale projects on Operations Research Modeling, Information Systems Development, and Business Process Innovation. He is currently working on the development of business architecture and process patterns and supporting software; results of this work can be seen at www.obarros.cl and blog.obarros.cl.

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