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Business Engineering and the Design of Services: Application to Hospitals

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Business Engineering and the Design of Services: Application to Hospitals[1]

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Prolog

For more than fifteen years we have working on the development of the foundations of what I call Business Engineering, with the aim of providing tools, as other engineering disciplines have, for the design of businesses. This implies that enterprises should be formally designed and that their architectures, including processes, people organization, information systems, IT infrastructure and interactions with customers and suppliers should be considered in a systemic way in such design. This Enterprise design is not a onetime effort, but, in the dynamic environment we face, organizations have to have the capability to continuously evaluate opportunities to improve their designs. Others have recognized this need, as the ones who have worked under the idea of Enterprise Architecture (EA), but they have mostly concentrated on the technological architecture and just touched on the business design issues.

Our work resulted, almost ten years ago, in a graduate program of study, the Master in Business Engineering at the University of Chile, which has been taken by several hundreds of professionals. Such Master has been the laboratory where many of the ideas we propose have been tested and many new ones generated as generalization of the knowledge and experience generated by the theses.

I have published books (in Spanish) and papers (in English), all detailed in the references, that touch on different topics of my proposal. In this work we give a compact summary of it with two new additions: the adaptation of our ideas to services, based on work we have been doing in this domain for at least five years, and an application to hospital services design, where we have performed research and development work by adapting our approach to provide working solutions for a large number of Chilean hospitals. These solutions are already working and showing that large increases in quality of service and efficiency in the use of resources can be attained.

Our approach includes the integrated design of a business, its service configuration (architectures) and capacity planning, the resource management processes and the operating processes. Such approach is based on general patterns that define service design options and analytical methods that make possible resource optimization to meet demand. This is complemented with technology that allows process execution with BPMN tools and web services over SOA. In summary we integrate a business design with analytics and supporting IT tools in giving a sound basis for service design.

Business Engineering and the Design of Services: Application to Hospitals

1. Introduction

Since the idea of Service Science was proponed (IBM Research, 2004), several lines of work in what is now called Service Science, Management and Engineering (SSME) have been proposed (Chesbrough and Spohrer, 2006; Spohrer et al, 2007, Spohrer and Maglio,2008; Maglio, et al, 2010). The work reported here has to do with research in the engineering part of this discipline and, in particular, with the design of the components of service systems. As stated in the Prolog, the discipline behind our proposal is Business Engineering, which shares the ideas and principles of SSME, but tries to cover a larger domain including any type of business; it emphasis is on how to design any business relating strategy, business model, capabilities involved, processes and IT support (Barros, 2012a), in a way that it is outlined in Figure 1.

Our experience with the design of many different businesses, such as manufacturing, distribution, bank services and hospitals (Barros, 2012a,2012b), has made possible to propose the conceptual model (Ontology) in Figure 1. According to such model, designs are based on the strategy and the business model that an organization wants to put into practice. We have found that Porter´s (1996) ideas of strategic positioning, complemented with the options the Delta model (Hax and Wilde,2001; Hax, 2010), offers for such positioning -from "best product" to "integral service to clients", to "systemic lock in"-, are particularly useful in providing alternatives for business innovation. Also the ideas of (Johnson et al, 2008) and the Business Model Canvas (Osterwalder and

Pigneur, 2009) are adequate to define in a precise way the value innovations would provide to clients. Other ideas such as the innovation portfolio (Nagji and Tuf, 2012) can be useful in complementing value creation definition. But no strategy or business model specifies **how** the positioning and the value will be actually delivered in operational terms. This is what the business design will detail, starting with capabilities necessary according to strategy and business model; this has to be complemented with processes, systems, organizational and IT support designs that make it fully operational.

These general ideas of Business Engineering are applicable to services design and in particular to hospitals, which is what we develop in what follows.

This work poses and intends to prove that, in performing designs outlined above, patterns can facilitate the task. First business patterns are proposed that are derived or abstracted from massive experience and knowledge generated in service design, including our own and the one publicly known through the literature; they emphasize different structures –components and relationships- a business may adopt in providing services to their clients.

Then it will be shown that service designs can be made operational by business processes that detail how such designs can be implemented, also using patterns, including the technology support needed in their execution; these process patterns are documented in other publications (Barros, 1998, 2000, 2004, 2005, 2007, 2012a; Barros and Julio, 2011) and have been widely used in real projects (Barros, 2012b).

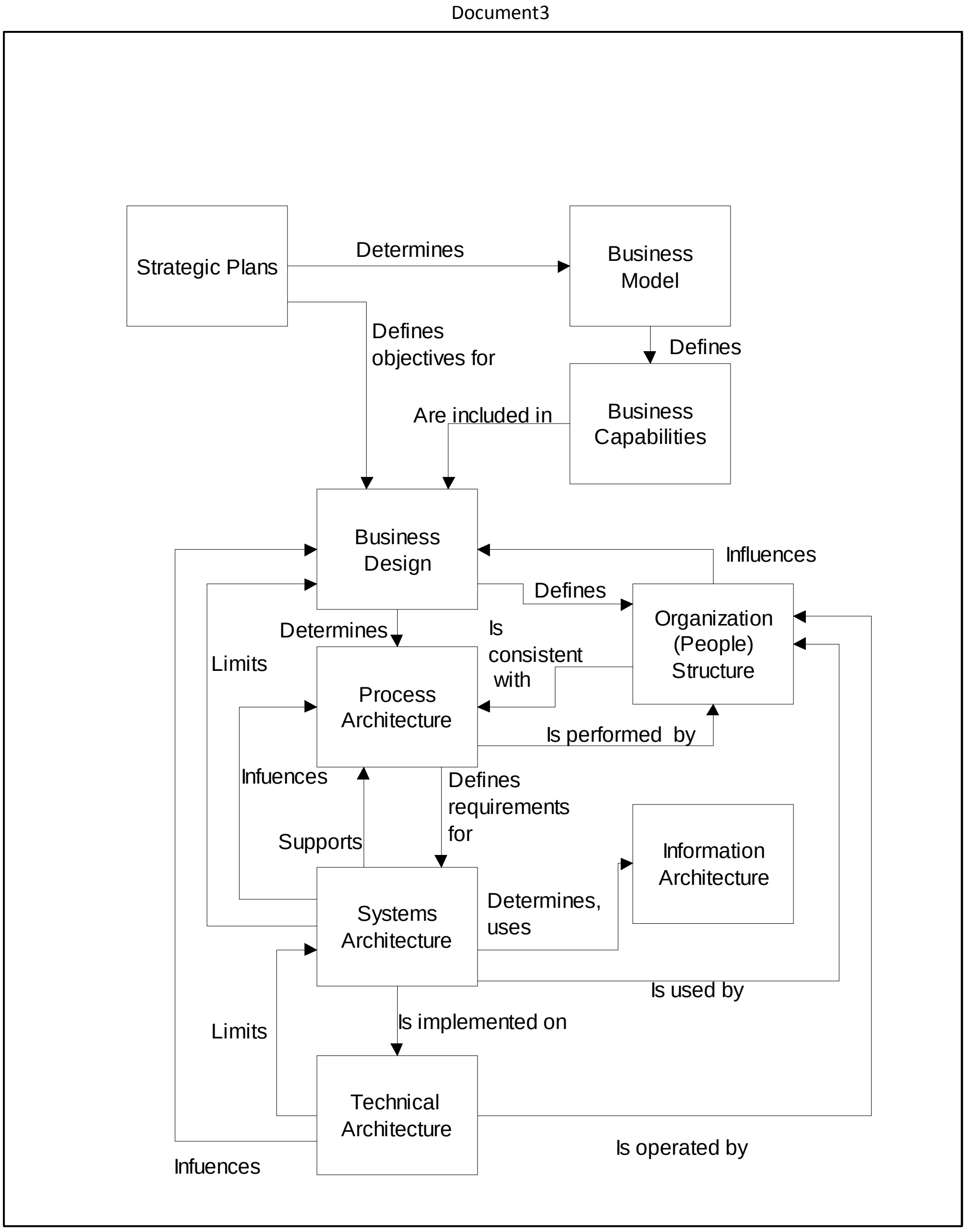


Figure 1. Ontology for Business Design

The main application domain has been hospital services, where research and development projects have been performed in five public hospitals that will originate general solutions, which will eventually be implemented in over a hundred facilities.

From the experience on service design, with an emphasis on business and process design, and taking into account the model defined in Figure 1, the following types of design problems can be abstracted:

i. **Business service design** that delivers the structure of components –production, management, supporting and others- and their relationships, together with the interaction with the environment that generates a business capability, which provides value to customers according to strategy and business model. It represents **what the business does** and does not map to organizational units, area or product.

ii. **Service configuration and capacity design**, which includes the determination of the processes that should be present to assure that the service defined in (i) is provided in an effective and efficient way. Also what capacity each process should provide in order to be able to attend the demand according to desired SLAs. For example, hospitals urgency services may have different configurations in terms of its processes : among others use of a Triage (patient routing), a fast track line and several different lines of service; once components are determined, capacity has to be determined in order to have a desired patient average waiting time. This problem is relevant only when demand behavior changes or there are possible innovations in service technology and it is usually related to strategic investment issues.

iii. **Managing of the resources** -people, equipments and supplies- that are necessary to provide the capacity established in (ii). For example, in hospitals, number of doctors of different specialties that will work in each shift. This requires a well designed process that, based on forecasted demand, plans and assigns resources in such a way that capacity is provided at the minimum cost. This process is executed regularly with a frequency that depends on the dynamics of the demand.

iv. **Design of the management processes** necessary for the day to day scheduling of the demand over the resources in order to provide the required level of service and optimize their use. For example, in public hospitals there are usually waiting lists of surgery patients that should be scheduled in operation rooms in such a way that priorities associated to the severity of patients´ illnesses is met and use of facilities is maximized.

We have developed an innovative approach to solve problems above in an integrated way. Such approach is based on explicit and formal general business and process models, which we call Business Patterns (BP) and Business Process Patterns (BPP), that allow to define service design options, and analytical methods that make possible customer characterization and resource optimization in designing the service. This is complemented with the modeling of the processes with the Business Process Management Notation (BPMN; White and Miers, 2009) and with technology that makes possible process execution with Business Management Process Suits (BPMS) tools and web services over SOA (Pant and Juric, 2008; Barros et al, 2011). In summary we integrate a business and process design approach with analytics and supporting IT tools in the way we present below.

We have applied the approach above to many types of services, but in this paper we will give details of its application to hospital services, based on the results of a large scale project we are developing for the health system in Chile.

In the next section a review of the relevant literature is reported. Then we will present the patterns that support design. Next the approach proposed and the role of analytics in the context of designs is explained. Finally, the application of our approach to hospitals is presented and some results provided; also ideas for future work are outlined.

2. Related Work

A proposal in the spirit of this work is the one by Tien and Berg (2003) on service engineering. They propose a systems approach and show how different disciplines can contribute to such an approach. They mention, among others, design and analytics (Operations Research and Management Sciences), which are the ones relevant to us, but they do not give methodological details on how to proceed; the focus of this paper is to provide such details based on process design ideas. Other papers which go further into service design is one by Bullinger et al. (2003) that concentrates on product design and the one by Johansson and Olhager (2004) that proposes service profiling, but neither consider processes. As to publications that explicitly consider services and processes we have the one by

Reijers (2002), which concentrates on the technical details of service workflow but it does not offer any service design methodology, and a paper by Hill et al. (2002) that only identifies research opportunities in service process design. A more recent proposal for design of service oriented systems, in the idea of SOA, based on business process modeling in the one by Gasevic et al (2010), but it does not enter real business design issues but technical ones related to systems design.

There are several proposals in the literature for general process models similar to what we call BPP; for example there is the Supply-Chain Operations Reference Model (SCOR; Suply Chain Council, 2007), the Telemanagement Forum Enhanced Telecommunication Map (eTOM; TM Forum, 2009), frameworks for processes of several industries (APQC,2006) and the Federal Enterprise Architecture (FEA; White House,2012). These proposals are basically hierarchies of processes that should be present in the domain to which they apply. Our BPP, which were proposed before these reference models or frameworks, besides process hierarchies explicitly consider the relationships among processes at any hierarchical level (Barros, 1998, 2000), which provides a better representation of the service design problem, where relationships are a key issue. Also there are IBM e-business patterns (Adams, 2001; IBM, 2010) and Fowler patterns (2011) that are mostly technological.

Although there are general papers on the potential of integrating processes and analytics (Davenport, 2006, 2007), the literature is lacking on a methodology and techniques to implement such an idea. Other papers considers the idea desirable (IBM, 2004) but they do not establish how to put it into practice. In this paper we show how to integrate analytics into service process design, including the methods coming from optimization and Data, Web and Process Mining (Witten, 2011; Liu, 2007; Van der Aalst, 2011).

In hospitals there has been proposals to use the process approach (Jansen-Vullers and Reijers, 2005), but there are not success stories reported in the literature. On the use of analytics in hospitals there is more work such as the one by Marmor et al. (2009), where a simulation approach is used to design an emergency service, but without introducing a process view. Other works using a simulation approach to capacity planning in hospitals are by Garcia et al. (1995), Samaha et al. (2003), Rojas and Garabito (2008), and Khurma and Bacioiu (2008).

There is a line of demand forecasts focused on services. In it the variable to predict is the number of clients who will demand the service, in order to manage capacity needed to provide a given level of service. In a recent work, joint demand and capacity management have been proposed for services in a restaurant (Hwang *et al*, 2010) where the main focus lies on optimizing revenue for a given dynamic demand without considering, however, demand forecasting explicitly. A similar study has been proposed for scheduling elective surgery under uncertainty (Min and Yih, 2010) but again without considering uncertain demand.

Many different methods have been proposed for forecasting (Armstrong, 2001; Box *et al*, 1994), and several studies compare such methods in terms of accuracy of results. One of these studies that is relevant to this work compares Neural Networks with other econometric methods and concludes that the former give, in general, better results (Adya and Collopy, 1998). As it will be shown below, in our experiments the technique of Support Vector Regression outperformed Neural Networks.

Few studies of formal demand forecast in the health area have been published. Some of these have focused mostly on predicting the number of beds required to meet emergency demand (Farmer and Emani, 1990; Jones and Pearson, 2002; Litvak et al, 2008; Jones *et al*, 2009; Schweigler *et a*l, 2009). These studies have focused on forecasting demand in the emergency room where all patients must be attended to, even with a considerable delay. This is important because there is no possibility of changing the appointment to another date, or of having patients leave without attention, which is relevant to the input data, because historical demand is equal to the number of patients attended. Several studies have shown, however, that in practice a small difference between patient arrival and care service could exist (Kennedy *et al*, 2008), a fact that has been taken care of in the application to hospitals. Another work that uses an approach similar to ours is reported in Shirxia *et al*, (2009) but we will show that our approach provides superior results.

For capacity management in hospitals the usual procedure has been to simulate the flow of patients through emergency facilities. None of the papers we have reviewed considers an explicit state of the art demand forecasting technique, except the one by Marmor *et al*, (2009) that estimates demand based on a long term moving average over the demand. Other papers that use the common approach of static arrival distribution are the following: Garcia *et al*, (1995); Samaha *et al*, (2003); Rojas and Garavito, (2008); and Khurma and Bacioiu, (2008); Mandelbaum (2009).

Recently, Maggio et al (2010) have proposed an approach for high level, systemic health system modeling and simulation for policy decision making. Complementary to such idea, our proposal is oriented towards the design of the components of the health system that are needed to implement given policies.

3. Patterns for design

As stated before, our approach relies on patterns that serve as reference models for generating design proposals. There are two types of patterns that we explain below.

3.1. Business Patterns

For organizations that provide the business services we intent to design we propose a conceptual model that shows an aggregated view of components and relationships involved in a business design, which is shown in Figure 2 and described bellow.

In Figure 2, a **Value stream** is a set of interrelated activities that go from generating orders for a client to successfully delivering the product/service. It has a more restricted scope than the typical Value chain defined by Porter and others and the one we will define in Section 3.2. The **Management system** is a set of interrelated activities that takes decisions about actions necessary to direct the Value stream to fulfill clients´ requirements. The rest of the components and relationships of Figure 2 are self explanatory.

Furthermore the domain of organizations for which these patterns apply has the following characteristics:

- They offer products and/or services which can be standard or customized for a client, but there is just one line of business, so we exclude holdings or other organizations with several business lines; examples of the first type are retail banks, distribution of office products, distribution of heavy machinery for mining, software distribution, software development and examples of the second type are government as provider of multiple services and a holding such as IBM that sells from computers to consulting services.
- There may be several separate product/service value streams but they share a common executive management.
- Even if the main line of business is product oriented, there is the possibility and interest in developing complementary Value streams to provide services associated to the products.
- Emphasis on the Value stream is in service definition, sales, production and delivery
- Other resources, such as human and financial, are not explicitly considered.

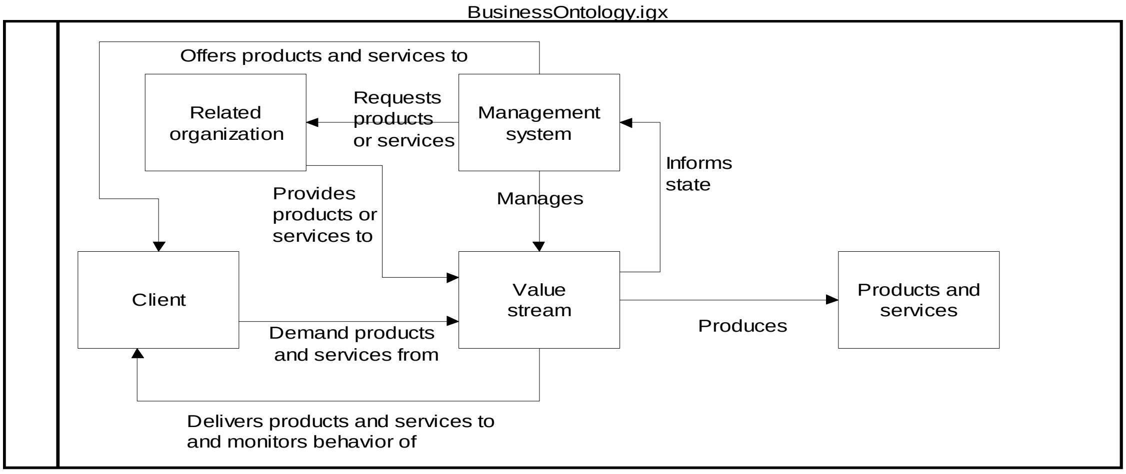


Figure 2. Entities and relationships in a business

For services organizations of the type described by the model in Figure 2 several **Business Patterns** (BP) can be abstracted from experience. They show how the elements in such figure can be structured in different configuration of components that generate a desired capability. Several of such patterns, which have been developed based on experience and knowledge generated by hundreds of projects, are presented bellow.

I. Business Pattern 1: Client knowledge based selling

As stated above, business design is oriented by strategy and business model. In summary, the common aim of the organizations that have motivated this pattern, which it is called Business Pattern 1 (BP1), is to advance to:

- Strategic positioning in the line of giving integral services to clients, as defined by Hax and Wilde(2001) and Hax (2010)
- Provide value to clients by personalized services

Real cases of use of these ideas are to perform active monitoring of customers to model behavior and customize offerings such as Amazon does constantly; a bank that proactively offers insurance to groups of clients that it has found are potential buyers of such products; and an IT consulting company that, through semantic modeling of the experience and knowledge generated with projects with clients, has been able to proactively generate ideas for new high value projects for them.

This implies, according to de ideas of Figure 1, to generate **capabilities** that allow to capture and organize customer data, to process that data with analytical machinery –Data and Web Mining, semantic analysis and the like- and to generate ideas, based on the analysis, for proactive offers to clients. A pattern, BP1, for this situation in shown in Figure 3, where the key idea is to complement typical components a service has with more advanced management elements that define what is required to generate the new capability. One of the typical components in Figure 3 is the Basic Management System, which includes the traditional practices of marketing and sales management, as supported by a standard CRM, plus the operations and logistic management necessary to generate the products or services requested by the customers.

A real case of use of this pattern is presented in the Section 4.

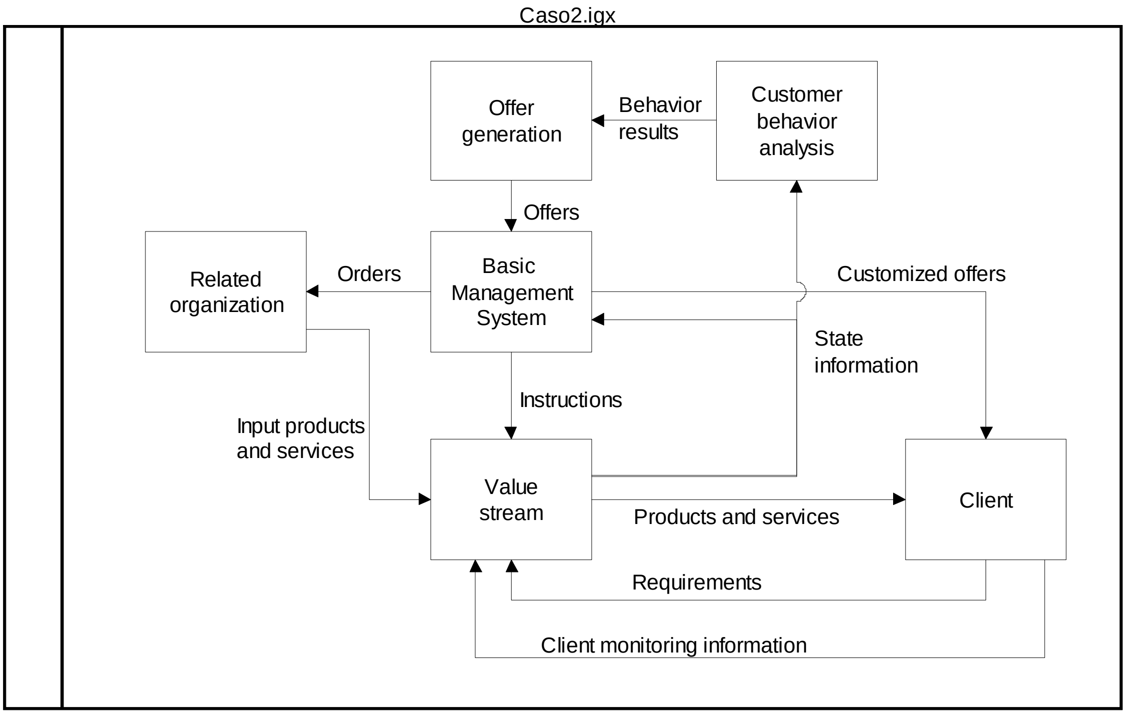


Figure 3. Business Pattern 1 (BP1)

II. Business Pattern 2: Creation of new streams of service

Again, from a strategic and business model point of view we aim to:

- Further integration with the client with new streams of business services that provide innovative added value services to them
- High value services, including the possibility that clients outsource us part of their business using the new Value streams

One of the cases that has motivated this pattern is one large bank that has a branch dedicated to small business that is constantly looking for new services for them; using an approach as the one we explain below they have been able to generate at least two new Value streams. In one of them the bank facilitates the transactions between distributors/manufacturers of food and domestic goods they sell to small groceries, by providing credit on line, when the goods are delivered, to these usually cash short business; they have been able to incorporate some of the largest distributors in the country, who cooperate by providing list of clients and acting as a channel to access banks systems to execute the credit, and tens of thousands of these small business. Another Value stream converts small hardware stores in sellers of credit for the bank when their customers want to buy expensive equipment and do not have the money to pay for them or other credit alternatives; the bank provides an on line system for sellers to access the bank, provide the necessary information and receive immediately an answer for the customer´s credit, for which a sophisticated mathematical risk evaluation model is used.

The capabilities that are needed in this case are, on top of the ones in BP1, to be able to process the customer analysis data to generate ideas for new services and economically and technically evaluate them, and then to design and implement the selected services as new Value streams, as shown in Figure 4. This requires a permanent, dynamic and innovative capability to visualize new business opportunities based on the analysis of customer data, which generates added value offers for clients and it is constantly generating and improving new Value streams to implement such offers. This pattern is called Business Pattern 2 (BP2).

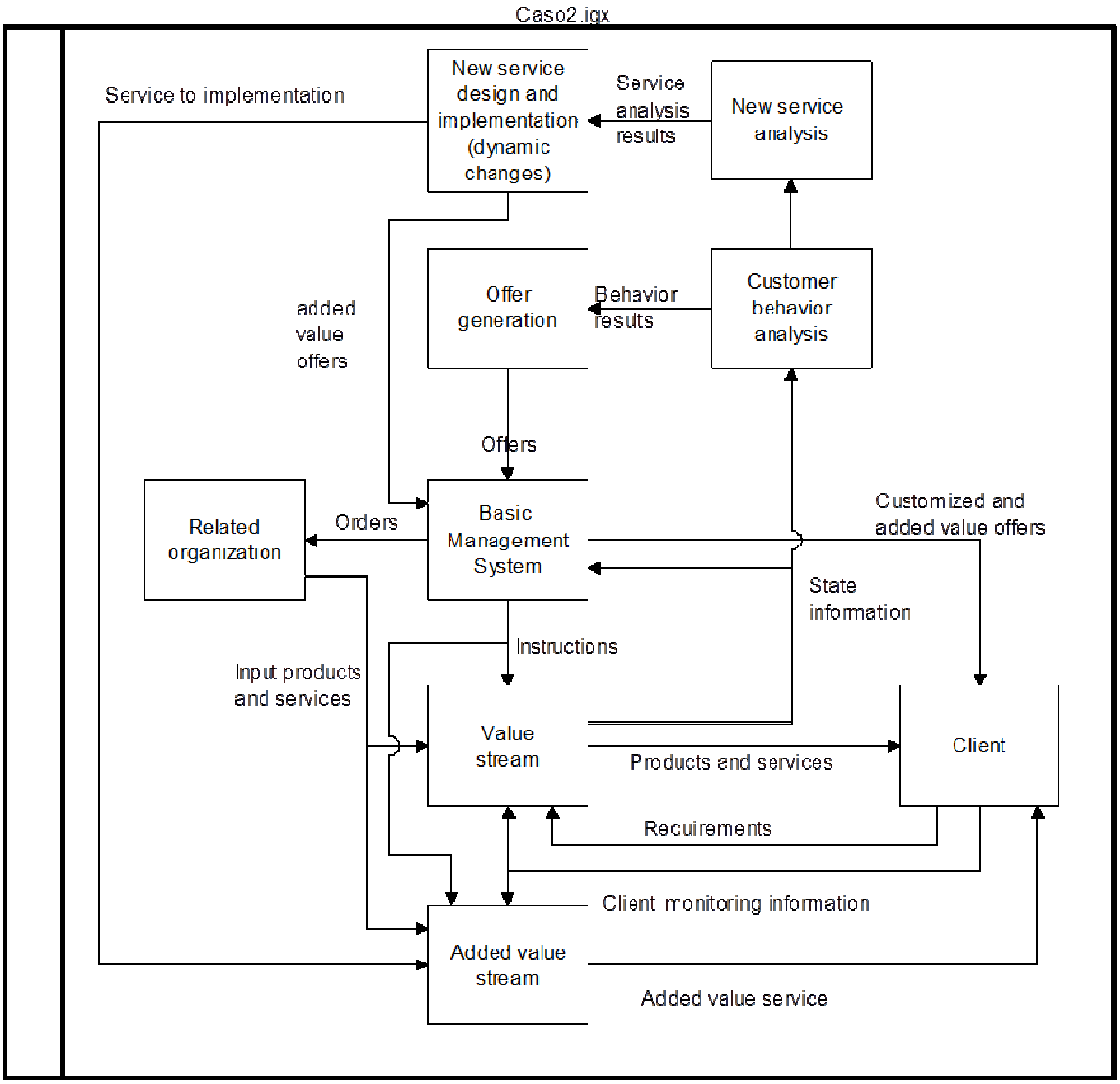


Figure 4. Business Pattern 2 (BP2)

Examples of the use of this pattern are a financial data processing organization that, based on analysis of credit card transactions they process for banks, is able to discover characteristic behaviors, for example of card use and card closing, which allows to dynamically define proactive campaigns to be executed through the "Added value stream" to offer deals to groups of card clients according to their behavior; and a distributor of heavy machinery to the mining industry that, besides the current business of just selling equipment, wants to be able to offer added value services for equipment maintenance. These new Value streams, when they execute externalized customers´ processes, produce a lock in effect that makes difficult for them to terminate the service.

The financial processing organization case will be further developed in the next sections.

III. Business Pattern 3: Internal learning for process improvement

This pattern is based on the following objectives coming from strategy and business model definition:

- The positioning that is selected is best product according to the definition of Hax and Wilde (2001) in the variant, also defined by Porter (1996), of operational effectiveness
- The value that is to be generated for clients is to provide attributes for the product that are appreciated by them such as low cost, due to better efficiency, quality, on time delivery and the like.

The capability we need for such strategy and value generation is to be able to systematically analyze the organization processes, in particular the Value streams, to detect opportunities for process improvement. This should lead to very efficient processes which are also convenient for the customer.

The Business Pattern 3 (BP3) in Figure 5 provides a way to implement such capability with an emphasis on the use of analytics to systematically analyze with hard data the origin and possible solutions for process problems. Real cases on which this pattern is based concern the processing of claims events, operational risk events and technological risk events (three different cases in various banks) to discover the most important factors behind the generation of such events and redesign the processes to eliminate their effects; also the analysis of events in the workflow of patients in ambulatory services and surgical operations in hospitals to discover events that delay or put into risk the treatment of patients to redesign the associated process to eliminate such events, and the monitoring of software development in an organization that gives services based on such software, in order to discover opportunities for producing software of better quality, on time and with better use of resources, in order to improve the service to clients. Also, recently, we have found that this pattern is fully applicable to public organizations. One is a public agency that assigns research and development funds to projects performed by universities and other research entities, which does not have the capability to monitor projects, evaluate their results, measure effectiveness of the research -hopefully, when possible, in economics terms- and, when results are not satisfactory, improve the design of the several Value streams they have; this means, for example, to be able to change criteria for project evaluation and fund assignment for any stream or redistribute funds among streams in order to increase the effectiveness of use of funds. Another public case concerns the inspection of labor practices businesses have, which is done by a Government Agency, in order to control that such businesses comply with labor laws; the application of the pattern generated a change in inspection practices from mostly a random approach to concentrate control on organizations that, through analytics, have been determined to have behaviors that imply probable violation of labor laws, notably increasing the effectiveness of the inspectors to correct situations that harm workers.

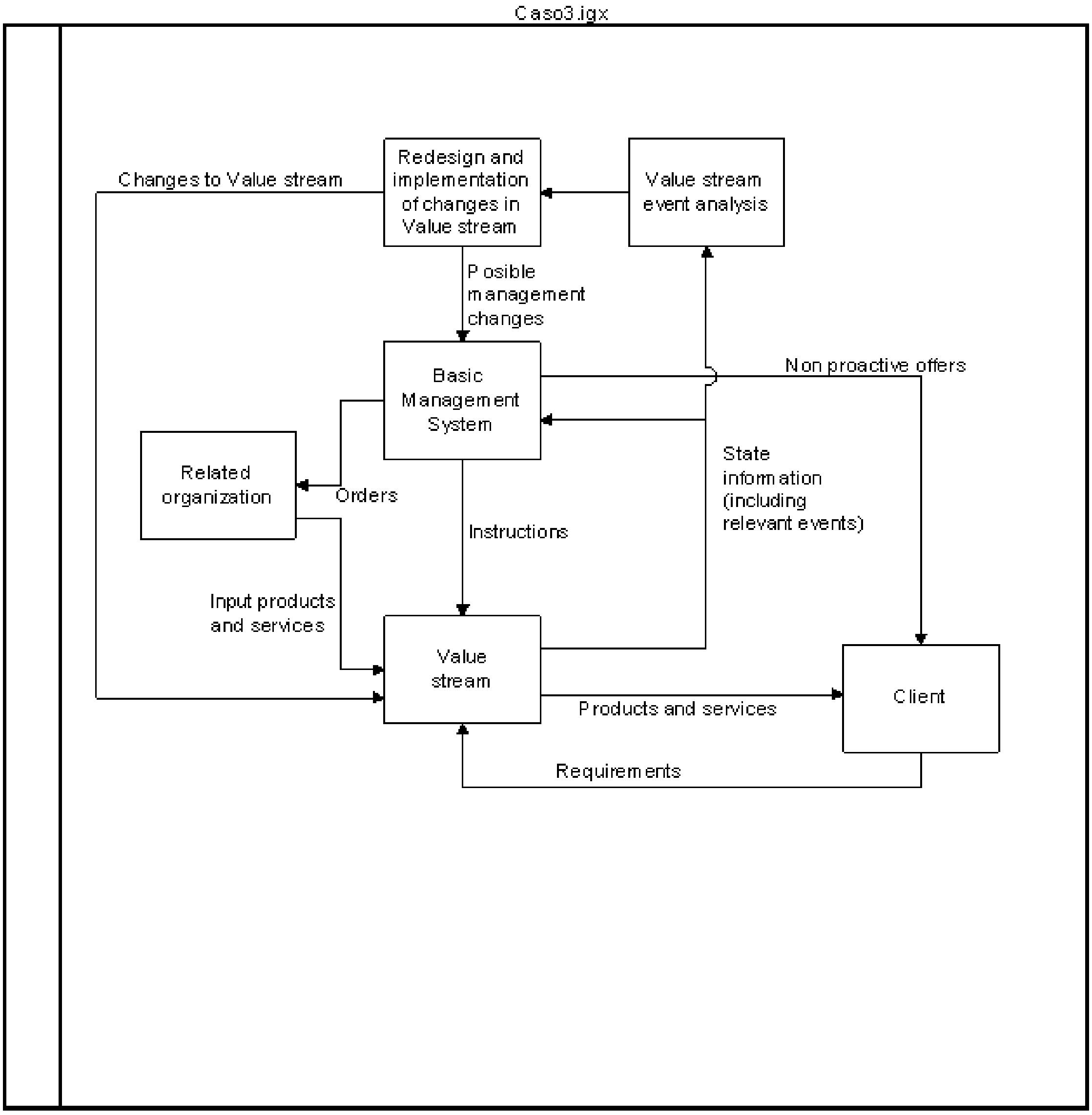


Figure 5. Business Pattern 3 (BP3)

IV. Business Pattern 4: Performance evaluation for re planning and process improvement

This pattern assumes:

- Strategy of operational effectiveness with well defined levels of performance (Key Process Indicators: KPI´s)
- Creation of value for clients because of assurance of well performing processes, according to strategic objectives (KPI´s)

The capability necessary in this case is to be able to generate formal strategic plans with a well defined methodology, such as Balanced Scorecard (Kaplan and Norton, 2001), which provides specific objectives for the operation of the business quantified in values for selected KPI´s. Also, another capability that is needed is to be able to measure actual performance, compare that with the desired KPI´s and then to take action to make changes in the Value streams to correct the situations that hinder the accomplishment of strategic objectives. The pattern that provides these capabilities is in Figure 6, which is called Business Process Pattern 4 (BP4).

Examples of cases in which this pattern is based are strategic planning and control for three technological services providers and strategic planning and control, including investment projects generation and management, for a large private medical clinic. Currently, it is being applied to strategic planning and control, including budget assignment, to the hospitals that form the health public system in Chile.

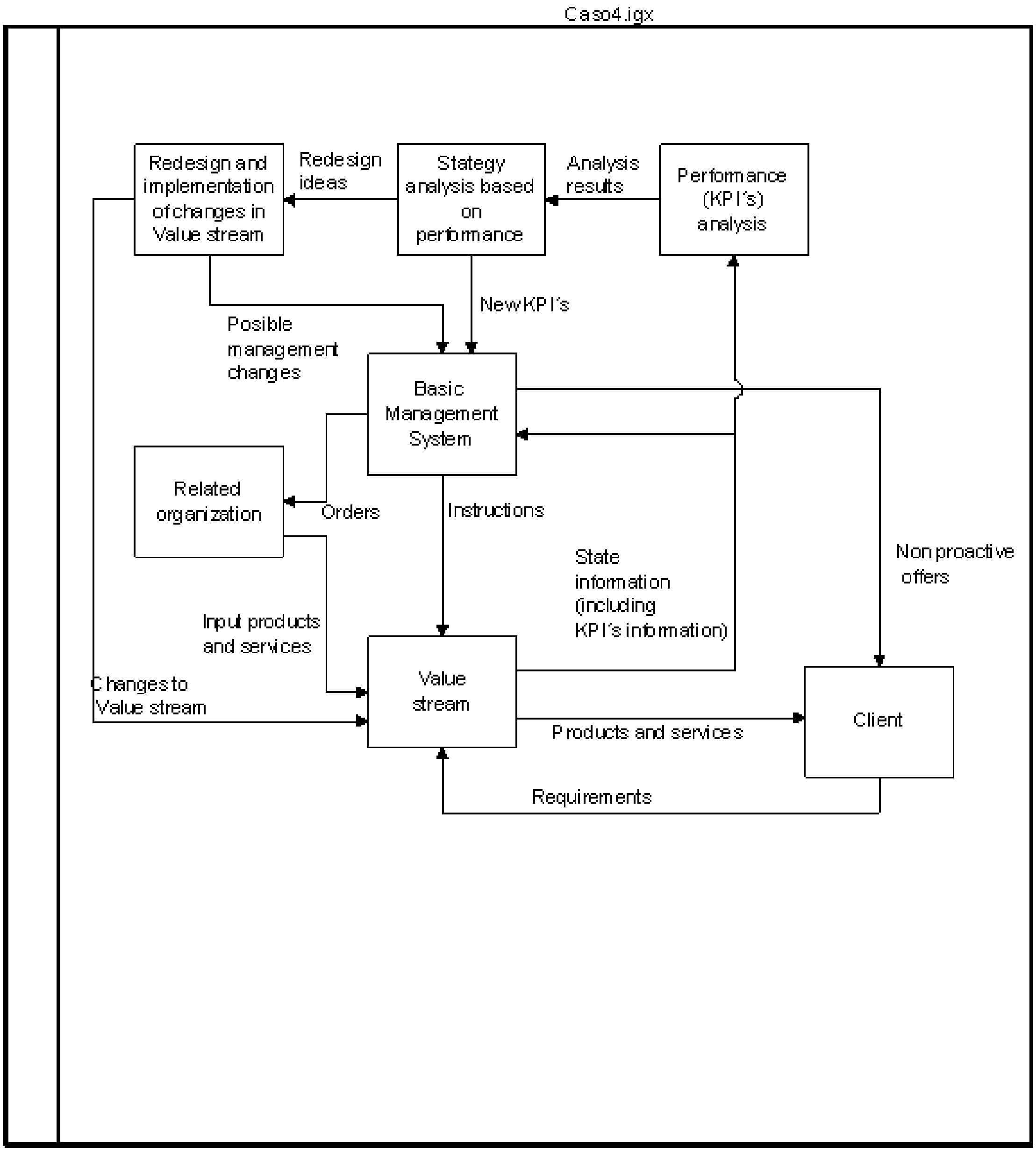


Figure 6. Business Pattern 4 (BP4)

There are several other patterns that cover other situations, such as integration with customers and suppliers, market oriented service innovation and innovations based on the social networks, which we will not present here.

3.2. Architecture and Business Process Patterns

Also Architecture and Business Process Patterns have been generated (Barros, 1998, 2000, 2004, 2005, 2007; Barros and Julio, 2010a, 2010b, 2011) that can be adapted to any domain in order to model service processes configuration options. All the patterns are based on extensive experience with process design in hundreds or real cases and share the idea that there are four aggregations of processes, called macroprocesses, which exist in any organization; they are:

- **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; it includes all the marketing, sales, supply, production/operation and logistics necessary to capture and generate the service. 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. Value streams are contained within Macro1
- **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 new 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 services, 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 (Supply Chain Council, 2007), 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. New versions of SCOR also include these new classes of processes (Supply Chain Council, 2007).

Also, the classification proposed by The Process Classification Framework (APQC, 2006) 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 (TM Forum,2009) have in common that they provide reference models and general process structures, in given domains, as a starting point to design the processes for a particular case. However 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 us to specify with more realism and precision how the process model is expected to work in practice.

The four macroprocess patterns can be combined into different structures depending of the business type. We call these structures **Process Architecture Patterns** and we will detail them below. The most basic is the one shown in Figure 7 where only one instance of each macroprocess is included and therefore there is only one Value Chain; also the relationships with clients, suppliers and other entities are not shown in detail. In real complex cases there can be several Value Chains, each of these containing several Value streams, integration of processes with clients, suppliers and business partners and other relationships.

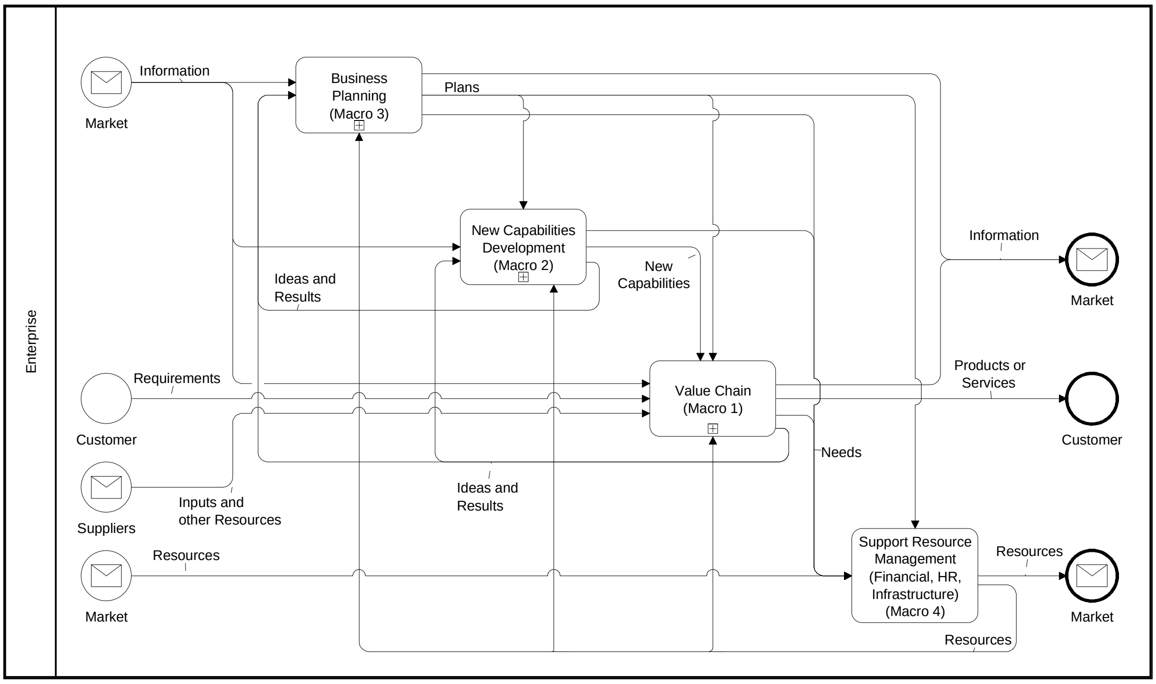


Figure 7. Macroprocesses´ Architecture Pattern

Another Process Architecture Pattern we have developed, taking as a basis the one in Figure 7, is the one of shared services, modeled with a BPMN tool using some of the constructs of this notation as explained in Barros and Julio (2009, 2010a, 2010b, 2011), which is shown in Figure 8. The basic idea of this pattern is to factor out of the different Value Chains(i), which generate the services an organization offers, several Internal Services(j) that may be centralized because of economies of scale or scope, transaction costs, agency advantages and other economic reasons (Barros, 2000). For example risk analysis for credit authorization for several banking business lines, supply management for several productive business lines and IT support in any business with several product lines. We notice that some of the shared services can be externalized to suppliers. We will later show the application of this architecture to the financial processing case and to hospitals.

For each of the macroprocesses defined above, detailed **Business Process Patterns** (BPP) have been developed that give, in several levels of detail, the processes, sub processes and activities they should execute in order to produce the required product or service. 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 (Barros, 2010, 2004 , 2012a), and papers, in English (Barros, 2005, 2007; Barros and Julio, 2009, 2010a, 2010b, 2011). 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.

One of the patterns is the one of Figure 9, also in BPMN, which is proposed to model any Value Chain (Macro1) of Figure 8.

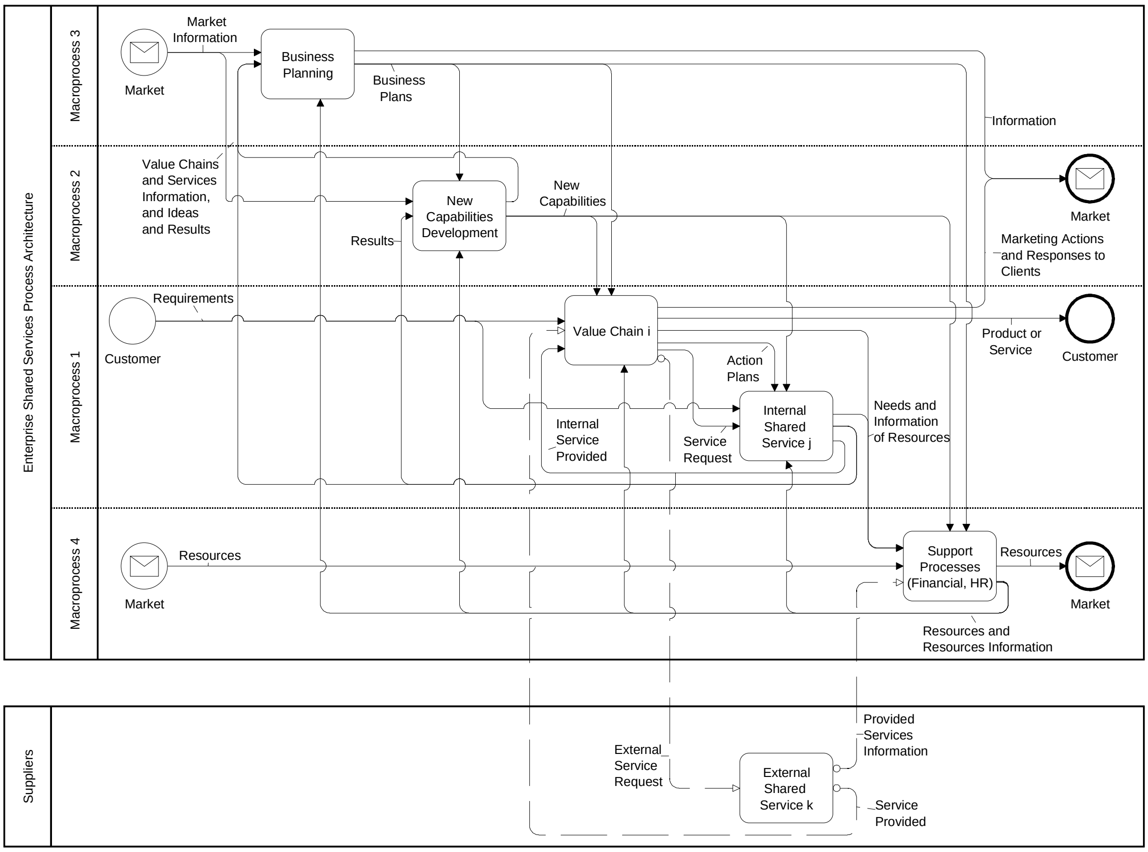


Figure 8. Shared Services Process Architecture Pattern

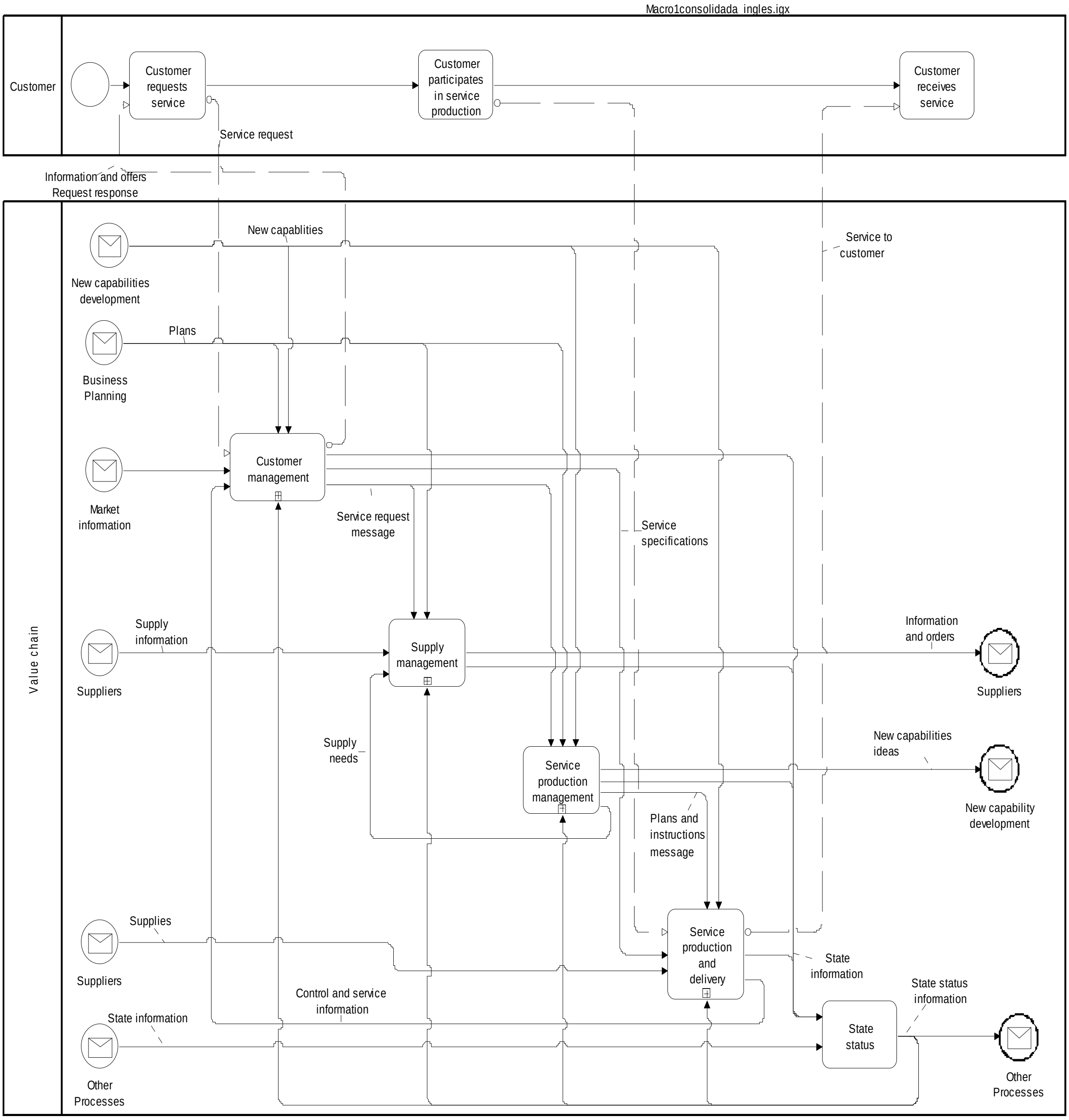
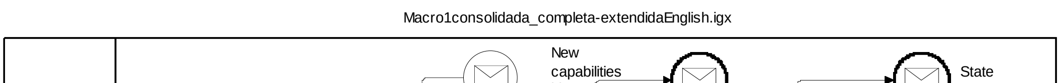


Figure 9. BPP for a Value Chain (Macro1)

Further details are given by decomposing processes of Figure 9. To exemplify this, “Service production management” is decomposed in Figure 10. The same can be done with sub processes of this figure; for example “Demand Analysis and Management” is decomposed in Figure 11. These



details are available for each of the macros, processes and sub processes (Barros, 2004, 2012a) and they can be used as reference models to design processes as we will exemplify with the hospital and other cases.

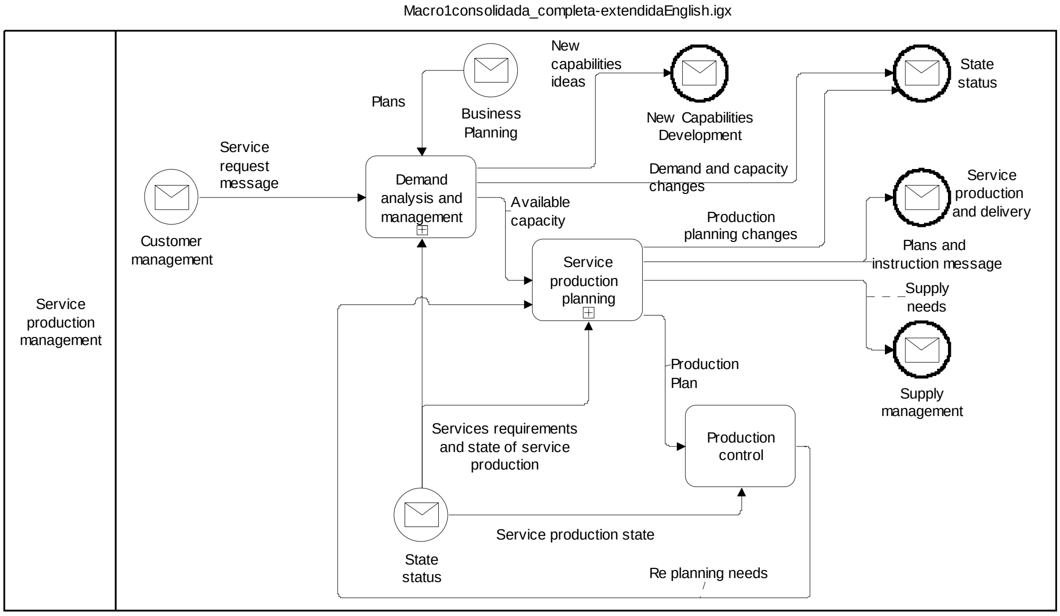


Figure 10. Decomposition of “Service production management”

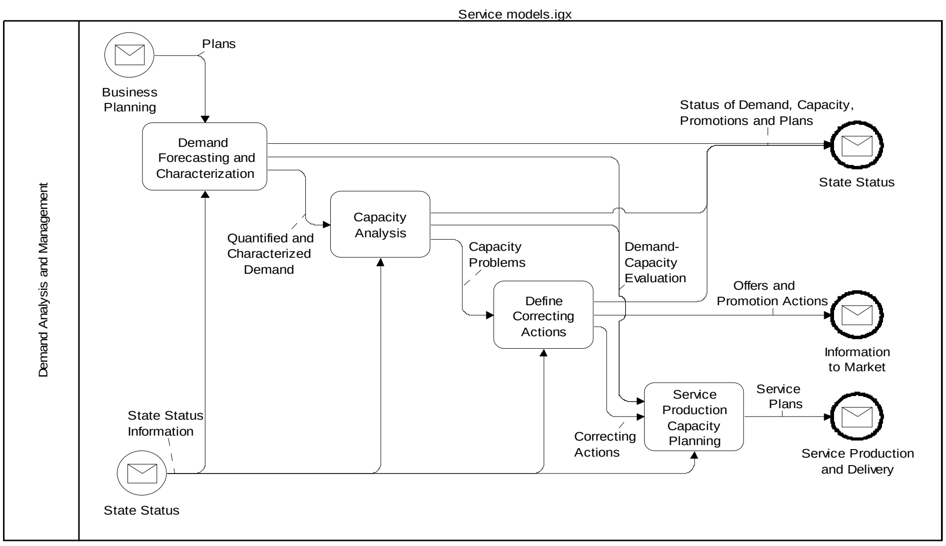


Figure 11. Decomposition of “Demand analysis and management”

4. The design of services

First we conceptualize the service design problem, using the classification given in the first section of this work; then we show how models and analytics support its solution.

4.1. Business service design

Business design consists of generating a set of components that provide a capability required by a strategy and a business model, as it has been explained above. So the approach to follow, based on the model in Figure 1, is:

- Start by defining strategy, for example based on Porter´ ideas (Porter, 1996) and the Delta Model (Hax and Wilde, 2001; Hax, 2010), and business model, for example based on Johnson et al (2008), or the Business Model Canvas (Osterwalder and Pigneur, 2008)
- Define the capabilities needed to put strategy and business model into practice
- Perform service design using Business Patterns, to implement capabilities

A real case of use of this approach is an international firm that sells office equipment, in which a design based on this approach has been implemented and is currently successfully operating. This organization has a strategy oriented to give integral services to clients and a business model based on the proactive selling of value added services. This is consistent with the objectives of BP1, so this pattern provides the necessary capabilities and applies in this case.

The application (specialization) of BP1 to this situation is shown in Figure 12, where we detail what is more relevant to this case. In particular, focus is concentrated on “Datamart creation and client clustering” where sales history is structured with appropiate technology and a Data Mining tool is applied to discover patterns through clustering and other analyses. Also "Clustering characterization and generation of sales campaigns" is important, since it is here where, based on the clusters, groups of clients with particular needs are discovered and specific customized offers are defined, which are implemented by means of campaings. The key idea behing this is to implement the capability that make posiible to go from passive selling of products to proactive selling of document solutions and, eventually, business solutions that provide high value for clients. Of course this has to be a permanent and constantly improving effort for which detailed processes have to be designed, using the ideas we will propose in the next section.

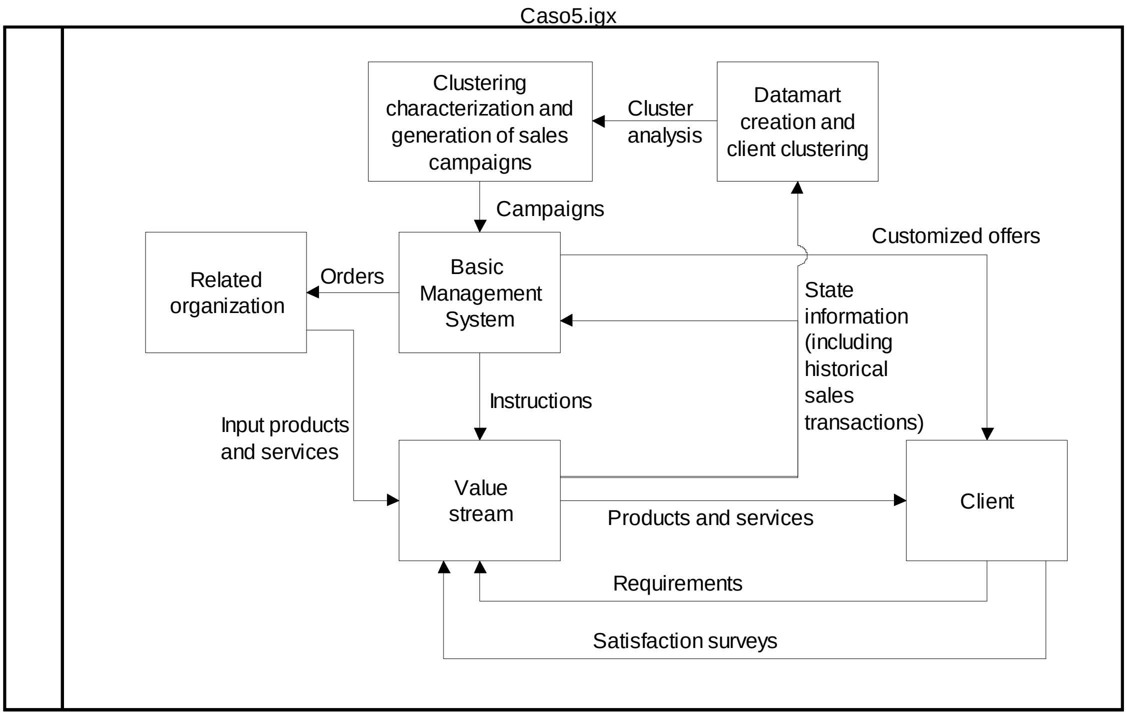


Figure 12. Business service design for office equipment distributor

This design has been implemented and is currently successfully operating; some of the results obtained are a 18% increase in business leads and a success rate of 42% for the proactive leads generated by the new capabilities.

Another case, which is based on BP2 and was introduced as an example for this pattern, is an organization that offers cards transaction services to banks and their clients. They provide several mechanisms and a network that allows clients to process transactions with credit card and other payment instruments, such as debit cards, giving the service they want –money withdrawal, buying goods and the like-, and to process the transactions to inform banks and clients of the financial results generated. This company wants to evolve to added valued services according to the following strategy and business model.

The strategy is to go into integral services to banks and their clients and a business model that provides value through new services that allow to proactively sell card products according to clients needs, which will be executed by the organization that process the transactions. The new value this organization provides for banks is to sell for them card products in a more focalized way that will increment transactions and their amount; and the value for their clients is to offer them services more adapted to their needs.

This means that the service organization has to generate the following capabilities:

- Be able to structure transaction data to discover, by means of business analytics, clients´ behavior patterns that present business opportunities, such as spending patterns for certain groups that suggest the selling of cards with certain characteristics, or behaviors that suggest card closing.
- From behavior results, to define sales campaigns to harvest opportunities.
- Create the Value streams necessary -including design and development of new sale processes, software support, human resources provision and other resources needed- to put into practice the campaigns, which today do not exist, and do this dynamically in time according to new opportunities that are discovered by business analytics and derived campaigns.

These capabilities are highly consistent with the ones behind BP2, so this pattern can be specialized to this case as shown in Figure 13. As the previous case, the capability of generating campaigns and adapting Value streams or designing new ones has to be dynamic and permanent in time.

Such types of design makes possible the use of analytical models to economically evaluate the results that can be obtained with its implementation; for example this was done in a case developed in a Ph.D. thesis of MIT for a two billion aerospace defense organization, with operating units in different segments. Collaboration problems existed among these units, so management decided an strategy of using budget allocation to induce integration. Then a business design similar to the ones we have presented was proposed for the development and sales of new products and services and the collaboration of the different units. Such design was evaluated with a set of models: Discrete Event Simulation Models for processes; Systems Dynamics for causal dependencies, temporal relationships and allocation of resources; and Agent-based modeling for simulation of micro behavior. These models were combined in a hybrid simulation model that allowed to perform an economic evaluation for variants of the business design (Glasner, 2009).

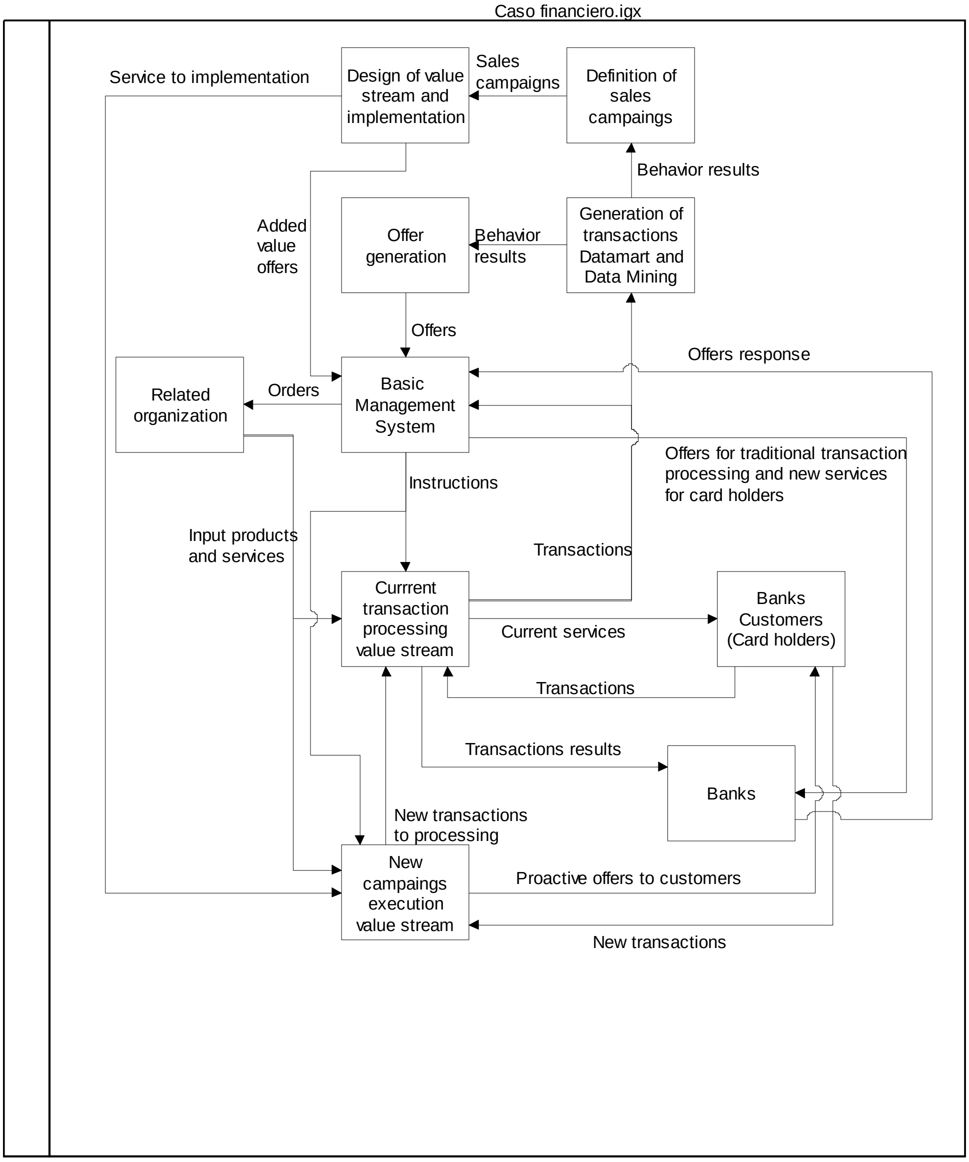


Figure 13. Business service design for the card transaction processing organization

4.2. Service configuration design

In order to put into practice the business design generated with the ideas of the previous section, the service configuration –components and relationships- and its capacity has to be designed. For this there are typically options as follows:

- Location of service units, which can be movable or distributed in space; this is relevant when demand is geographically distributed, as it is the case of public health services, where units of different type offer services of several complexity levels at locations that attend a given population, including possibility of transfers among them.
- Modular design, whereby the number of modules in operation defines the capacity in a dynamic way, as in the case of medical boxes that can be opened or closed according to demand.
- Standardizing service units and their practices; for example that each hospital of the same type in the public system has the same physical configuration and service processes.
- Flexibility of labor contracts and working hours to have more options in adapting capacity to demand, as it the case of hiring doctors part time and/or with flexible schedules.

These options can be modeled as business processes that can be configured dynamically. To support such configuration, we have proposed the Process Architecture Patterns, which were presented in Section 3, which can be specialized to any domain in order to model service configuration options. When specializing such patterns to a particular case, the different value chains and shared internal services are made explicit, generating a first level process model of the architecture of the overall service, which can be manipulated to explore different and explicit configuration options. Since such a model can be formally represented in a notation such as BPMN by any appropriate modeler at several levels of details (White and Miers, 2009), it can be simulated to generate performance metrics for any situation one have data to define. The general idea of this type of simulation is to be able to understand how a specific configuration handles the demand. In some cases, as the ones we will present for hospitals, there is the possibility to use optimization models to assign demand to given capacity in order to optimize some service metric, such as waiting time. This generates the need of a demand forecast, for which analytical models such as Neural Network and Support Vector Regression (Barros et al, 2010; Chen et al., 2005; Smola and Schölkopf, 2004; Zhang, 2007) can be used, as we will show when we present the hospital case. Other analytical methods may be needed to model how the demand is distributed among the elements of the architecture.

As a real example of use of this architecture, consider the case of the credit card transaction service, which business design is shown in Figure 13. The need is to map the components of such design into the processes of the architecture pattern of Figure 8, which is the one applicable to this case for reasons that will become clear soon. Such mapping is as follows:

- First, the quantity of Value chains has to be determined, which in this case is just one, since many of the processes of the current configuration will be used by the new Value stream in Figure 13; so it can be concluded that there is one Value chain with two Value streams: the current one that just process transactions and the new one that manages proactive offers.

- Next, the shared processes of the Value chain have to be determined, which, in this case, are the ones shared by the Value streams: “Sales management” which is determined to be common for both streams (design option based on economies of scale and scope) and “Information systems services” for the obvious reason that the streams share the same customer information. These components, with the required relationships, define the configuration of Macroprocess 1 or Value Chain in this case; which is shown as a lane in Figure 14.
- Then the mapping of the four top activities of Figure 13 has to be determined, which are oriented towards the generation of the new capabilities the business will have: generation of new offers to banks and new services to bank customers. This directly maps into the New Capabilities Development of Figure 8, which in this case take the name of “New offer, campaign and Value stream development” and it is shown in Figure 14 in the lane Macroprocess 2. Such macroprocess includes processes to perform the analytics, to generate campaigns based on them and to design and implement improved or new Value streams.
- Finally Business Planning is included in Figure 14, since it is clear that innovations generated in “New offer, campaign and Value stream development” should be aligned with the strategic planning of the organization and accepted by executives that perform such planning before implementation.

Several elements of the business design in Figure 13 and the architecture pattern in Figure 7 have not been considered to simplify the diagrams, such as supply elements and Support Resource Management. In some cases they may be relevant and should be included, as in a situation where external services are part of the production of the service and some resource, such as people, is key to providing it.

Design in Figure 14 is modeled with a BPMN tool and this makes it possible to perform simulations with it to evaluate the capacity of the different processes under a forecasted demand, as it will be exemplified in the hospital case.

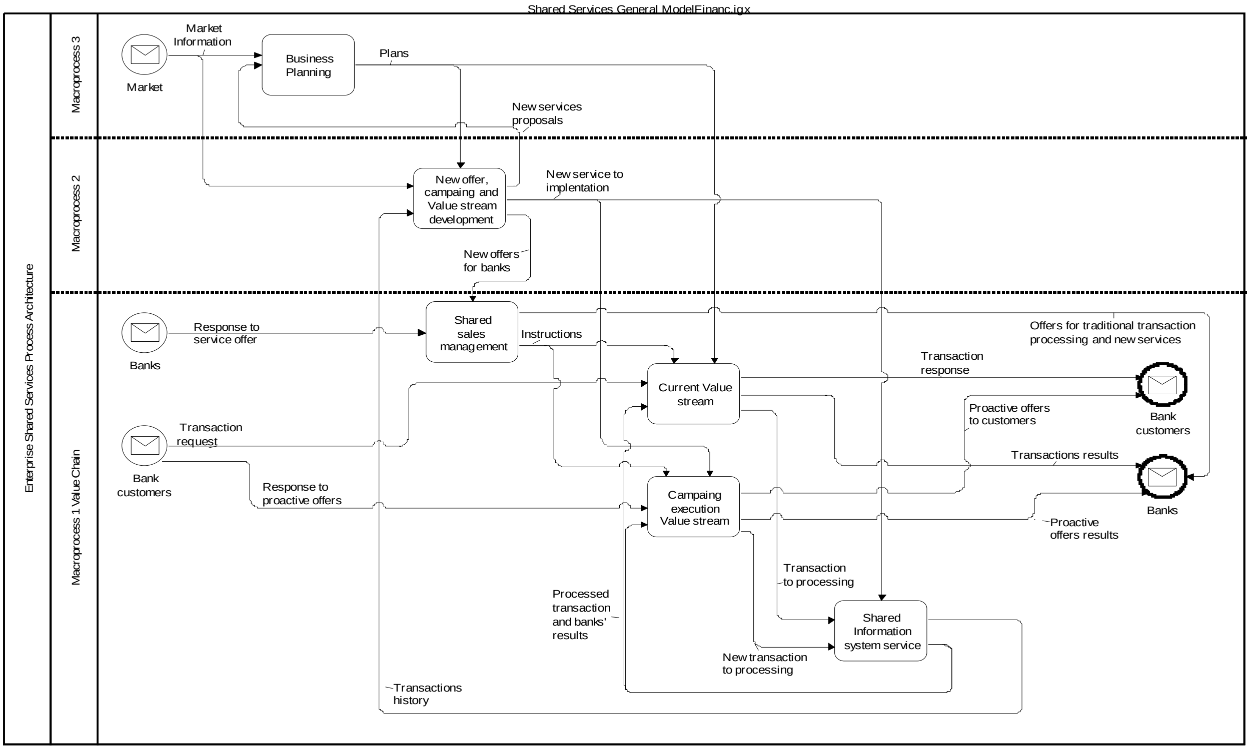


Figure 14. Process architecture for the card transaction business

4.3. Resource management process design

The third design level is for the resource management process and it starts with the architecture designed above; for each component of the architecture establishes the level of resources needed to process demand according to given SLAs. As opposed to the problem of architecture, which is resolved when the service is initiated and eventually when structural changes are needed, this resource management process is executed periodically to plan resources according to demand changes. To support this design problem, we also use patterns that allow to model the elements of the architecture with BPMN.

For example we proposed the BPP of Figure 9 to model any Value Chain of Figure 8. Such pattern can be specialized to a particular service problem and detailed by decomposition (Barros, 2005, 2007, 2012a). In such a decomposition, the problem of resource utilization appears; in particular the resources associated to the provision of the service are managed in the decomposition of “Service production management” of Figure 10. The decomposition of “Demand Analysis and Management”, part of Figure 10, is shown in Figure 11. This pattern models a process where first the demand has to be determined; then capacity to meet the demand has to be calculated and compared with current one, which determines correcting actions for excess or lack of capacity and corresponding plans to implement such actions. The same forecasting methods mentioned above are relevant to support demand determination in this case, but for more disaggregated demand data. The use of the forecasting models for “Capacity Analysis” in this process is further detailed in the design in Figure 15, which corresponds to the lowest level of decomposition and explicitly shows actors involved and computer system support, using BPMN constructs. Also simulation models can be used to evaluate different levels of resources to provide the right capacity and also it is possible to build discrete LP models to assign resources in an optimal way to meet demand in the “Propose resource assignment” activity of Figure 15. We will show the use of these types of models in a process designed to manage capacity in the hospital case.

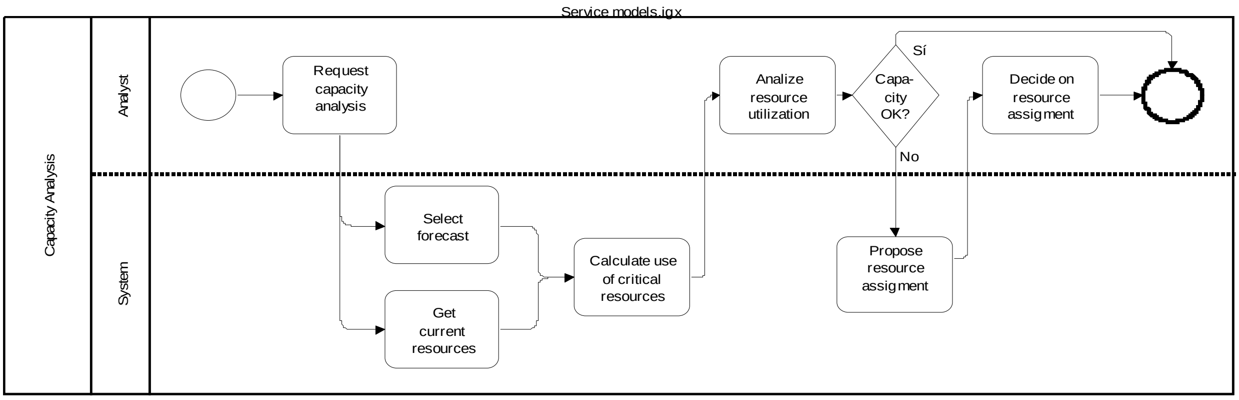


Figure 15. Capacity Analysis Business Process Pattern

4.4. Operating processes management design

The fourth design problem refers to the management processes necessary for the day to day scheduling of the demand over the resources in order to provide the required level of service and optimize their use. This problem is also included within the BPP in Figure 10, since in the decomposition of "Service production management" there appears the scheduling of resources for the execution of the service in processing a given demand in the activity ""Service production planning". One example of such situation is the pattern in Figure 16, where we present the typical sub processes that are needed to establish demand to be scheduled, do the scheduling of resources and determine the supplies necessary to implement the schedule. In the execution of such process, LP discrete models or heuristics run by a computer system are necessary, which we will exemplify in the hospital case with the scheduling of operating rooms.

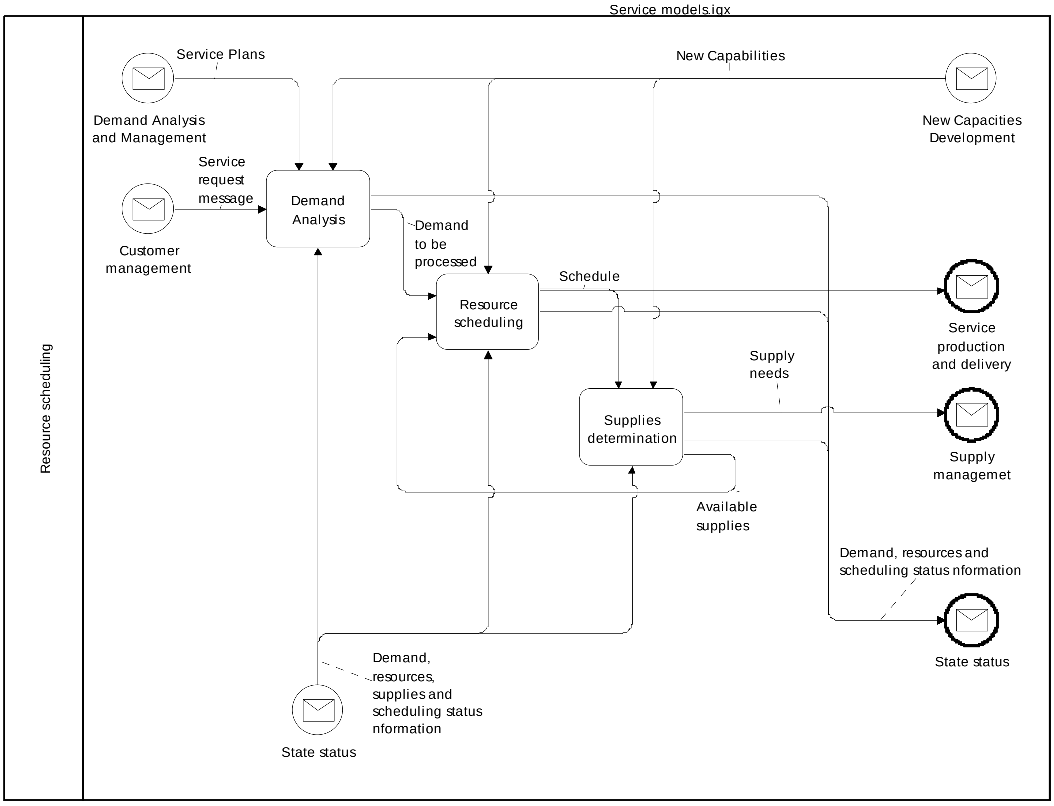


Figure 16. “Service production planning” process pattern

5. Service design in hospitals

5.1. Business design

Public hospitals have usually to cope with more demand than their capacity allows generating waiting lists of patients that cannot be attended immediately; hence they need to optimize the use of such capacity and have means to manage priorities in order to assure service to the patients that need it more urgently. Then from a strategic point of view they have to follow the positioning of best product and operational effectiveness, as defined by Porter (1996) and complemented by Hax and Wilde (2001). This strategy means to use the resources in the best possible way to provide quality services at the lowest possible cost. As to business model they provide value to patients (customers) by executing medical services and management processes in such way as to guaranty the treatments that patients need with the required quality and at the right time.

So the capabilities hospitals need according to strategy and business model are aligned with the ones provided by the business patterns BP3 and BP4. The common capability of these patterns is to be able to monitor, evaluate and change processes in order to implement strategy and business model above.

There are two ways to generate the capabilities stated above:

- The first is direct application of the BP2 and BP3 patterns, which has been done in the project we are reporting, is based on analysis of monitoring data to design and implement process changes in, among many others, urgency, ambulatory and operating room services, and also overall hospital performance data analysis to compare productivities for all the hospitals by means of efficiency frontier calculations to determine the factors that explain differences in productivity; these analyses allow to design new processes that push less efficient hospitals towards the efficiency frontier. All these applications share the idea, as it is detailed in the patterns, that there must be a continuous and dynamic effort to innovate and improve the processes. These applications will be not detailed in this work.

- An analysis of the state of the hospital capabilities in connection with above strategy and business model, and a one time redesign of architecture and processes that generate a best product and operational effectiveness to provide the best possible value to patients. We did this analysis and concluded that the architecture and processes that follow produce the expected results, which have been proved true according to figures we will report for each case we will present.

5.2. Hospital configuration design

Based on Business Design analysis above, the hospital project followed with configuration and capacity design. Such design is based on representing the design problem as a process architecture. To do this the Shared Services Architecture Pattern of Figure 8 was used, 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 services and hospitalization- use many internal common services such as laboratory services, operating rooms for surgeries, food services and cleaning services. So our architecture pattern applies straightforwardly to this domain. Such architecture, which is shown in Figure 17, has been fully validated with the management of three representative public hospitals and also with the staff of one of the largest private hospitals in Chile (Barros and Julio, 2010a, 2010b, 2011).

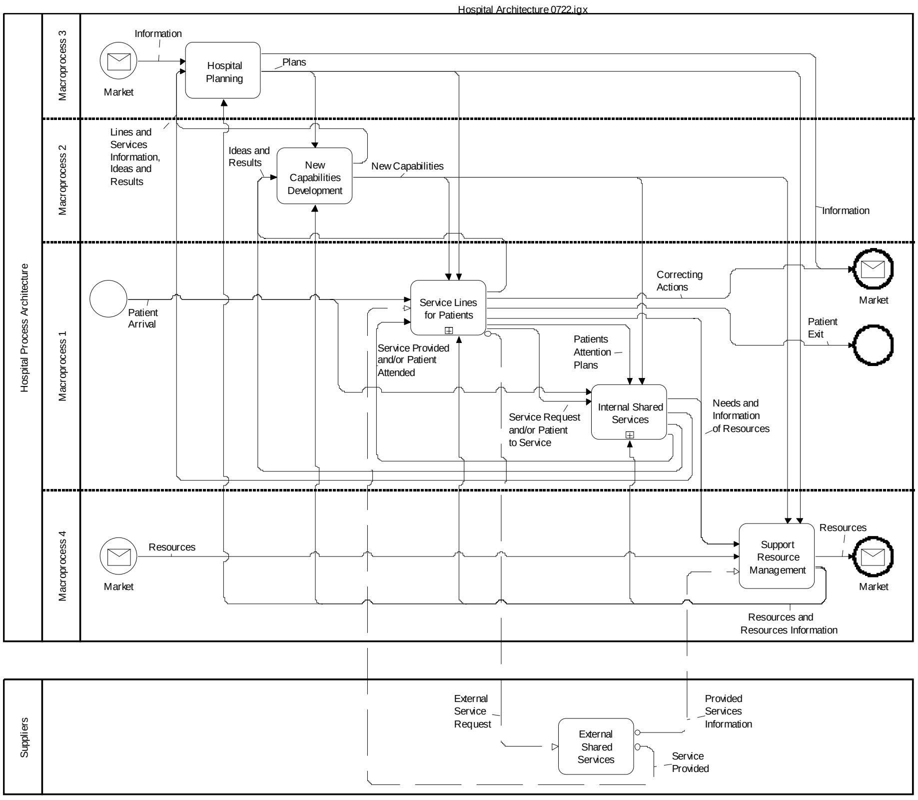


Figure 17. Hospital Process Architecture

The complete architecture was detailed by decomposing first level processes into two more levels of detail as we will present below. In Figure 18 the decomposition of Service Lines for Patients is shown. There are three service lines at hospitals, to which patients can access directly or by being referred from another line. The detail of these lines is as follows:

- Emergency Medical Service: Attends non-elective patients, e.g., that need urgent medical attention and, as a 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 first. 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 which medical attentions that 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.

Besides the above mentioned service lines, 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, which services are typically found in the private health system.

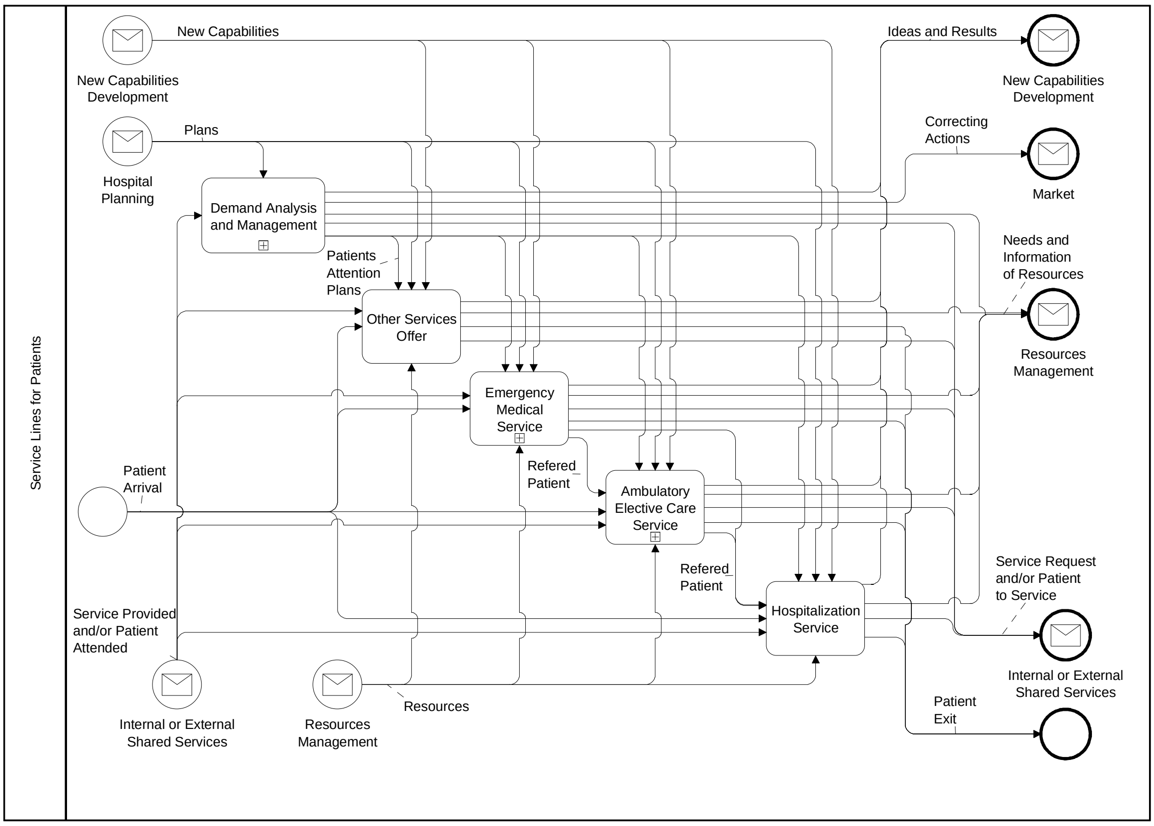


Figure 18. Service Lines for Patients process model

To exemplify the second level of the design of configuration and capacity, we will concentrate on the “Emergency Medical Service” Value Chain of Figure 18. In public hospitals there is usually excess demand, which means that patients have to wait long times before service; then our objective was to consider new configurations for the service that may reduce waiting time and evaluate them for a forecasted demand. We found in the literature several proposals for the configuration of emergency services (Marmor, 2010) of which we selected the option b in Figure 19, which considers a Triage, for patient pre evaluation, and a fast track line for patients that according to evaluation are more critical; this was complemented with parallel medical facilities for less urgent patients. For such a configuration we developed a simulation model, shown in Figure 20, which evaluates waiting time for a given demand (Barros et al., 2010). For the demand we tested several forecasting models, of which Support Vector Regression (SVR) gives best results with errors measured by MAPE in the range of 3-7% -for the forecasting of the test data set, not included in model estimation- for different types of medical demand (Barros et al., 2010).

The simulation model incorporates the stochastic behavior of the demand. Since the waiting time and length of lines have shown to be significantly higher for medical attention, the simulation will be performed for these patients only. The forecast has an error with a normal distribution. To simulate the different demand scenarios for each month, the forecast was adjusted several times by different values sampled from the normal distribution of the error. Due to the stability of its daily behavior, the demand of each scenario was distributed uniformly across every day of the month. The daily demand was further disaggregated into hourly demand. As a consequence, we were able to generate several scenarios of monthly demand disaggregated per hour. Using the hourly forecasted demand from each of the scenarios generated as described above, the average forecasted demand was calculated for each hour of the day. We assumed that the hourly demand arrives according to a Poisson process; then this average corresponds to the mean of the Poisson distribution per hour.[3]

Upon their arrival at the emergency service, patients are categorized and served according to the time distributions which are also stochastic. Now that the stochastic behavior of the demand and

[3] What follows in this section is based on (Barros et al, 2010).

the medical attention has been incorporated into the problem, we will discuss the construction of the simulation model and its role in the management of hospital capacity.

In capacity configuration management, we want to determine how different designs of the hospital facilities may affect the quality of service, measured in length of wait before the first medical attention (LOW). The simulation model allows us to observe how the expected flow of patients will use the different services offered in the facilities of the hospital, and how the available capacity performs when attending such demand. As a consequence, capacity can be redistributed or adjusted with the objective of eliminating bottlenecks and reducing idle resources. This provides a powerful decision tool for managing capacity in such a way that a given service level can be guaranteed at minimum cost.

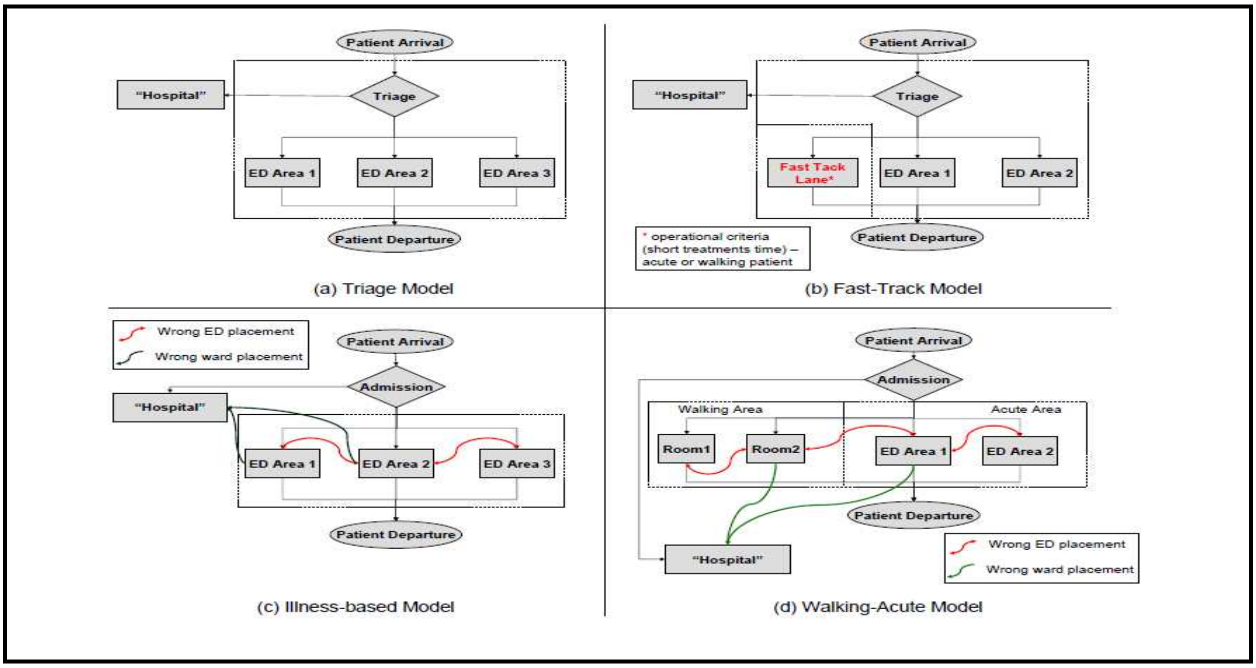


Figure 19. Alternative configurations for emergency services (Marmon, 2010)

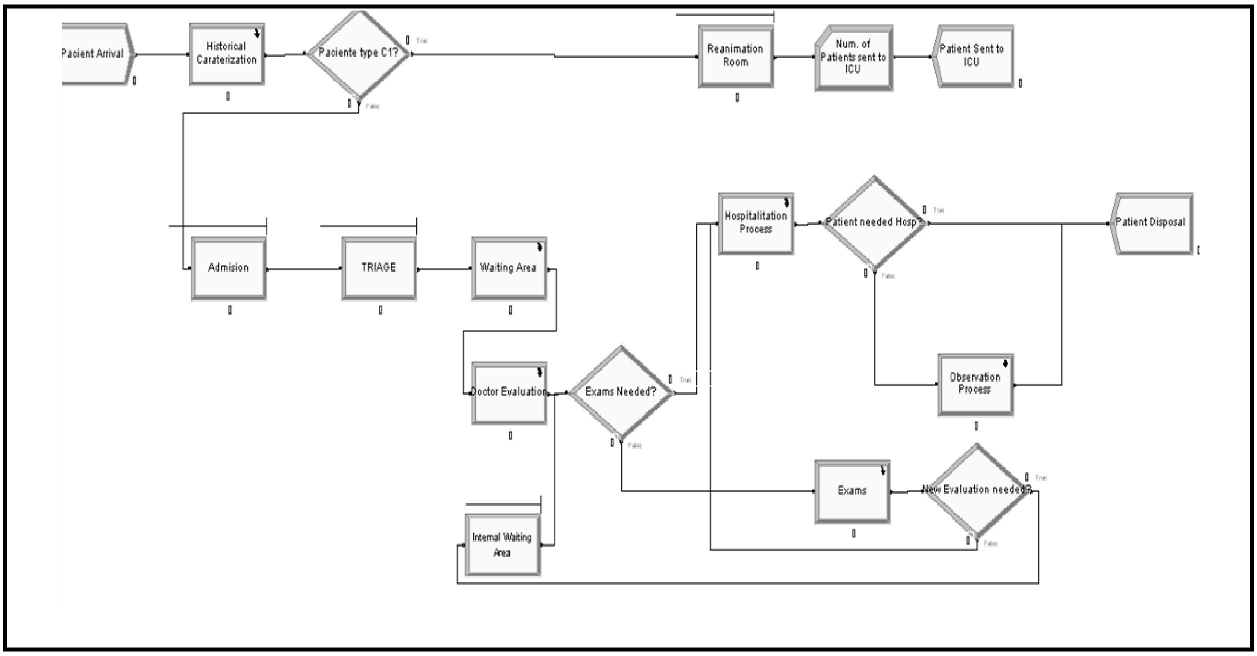


Figure 20. Simulation model for capacity analysis

As stated above, the average LOW will be used as the main criterion to compare the performance of the system designs. This metric was calculated weighting the demand per category by its respective average LOW. The results for this metric for the Base and Fast Track simulated configurations are presented in Table 1.

Configuration	Avg. (min)	Std. Dev. (min)
Base Case	64.2	1.2
Fast-Track with Triage	57.3	0.9

Table 1: Simulated LOW of Different Emergency Service Configurations

Based on the scenarios run in the simulation, a 95% confidence interval was generated for the LOW of each configuration. The intervals obtained were (55.5, 59.1) and (61.8, 66.6) for the Base Case and Fast Track with Triage, respectively. To test if the LOW differs significantly between these two configurations we applied the procedure proposed by Law and Kelton (1982). This comparison is established based on the difference of their respective statistical distributions, as displayed in Table 2. Since the confidence interval does not contain the value 0, we confirm that the difference shown in Table 2 is statistically significant.

Comparing Configurations	Avg. (min)	Std. Dev. (min)	Lower Bound 95% (min)	Upper Bound 95% (min)
Base Case / Fast Track with Triage	6.9	1.5	3.9	9.9

Table 2: Base Case / Fast Track Configurations Comparison

Based on the results presented in Table 1 and 2, we can observe that:

- The simulation model resembles the actual behavior of the system, since current average LOW is within the confidence interval of the simulated Base Case.
- The main bottleneck occurs in the medical consults and during the day-shift
- The Fast Track Box with Triage reduces the average LOW in 6.9 minutes, which corresponds to a 10.8% reduction of the current average waiting time.

Hence, is was decided to implement the Fast Track Box with Triage configuration and it is the one currently operating in the hospital in which this work was performed. Another hospital is replicating the forecasting and simulation based processes, due to the good results obtained in the first hospital.

5.3. Resource planning processes for hospitals

The third level of design in this case corresponds to resource planning, which decides how current available resources should be assigned to increase the service level, and which and where new resources are required to further improve the quality of service. The process will be also exemplified with the “Emergency Medical Service” of Figure 18.

The process to be executed corresponds exactly to the one in Figure 11, where the first step is “Demand Forecasting and Characterization”, for which we used the same models as in the previous section, but at a more disaggregated level. Then a capacity analysis had to be executed. Here the key resource is availability of doctors, since they are the ones who diagnose and provide treatments for emergency patients. Hence demand has to be converted into medicals hours needed of different specialties, which were determined through technical coefficients. Comparison with available resources defines lack or excess of resources, which is the basis for the following step which is the determination of correcting actions; of course there may be a feedback among these activities in order to analyze resources for given correcting actions, such as changing number or schedules of doctors. Then we want to evaluate the impact that a redistribution, reduction, or addition of medical resources would generate on the performance of the system. The resource management analysis, then, will be performed for the Fast Track configuration only. The same simulation model of the last section was then run for several assignments and number of doctors per shift under the Fast Track configuration with Triage and assuming a stochastic demand.

If the current structure of two 12-hours shifts is maintained, an initial scenario would consider only redistributing the doctors available in a different manner. Given the greater arrival of patients during the day, a possible redistribution could include the reassignment of doctors from the night to the day shift. As a consequence, more doctors would attend during the day shift than at night. The average LOW of this scenario would be 45.1 minutes.[4]

Further resource management considerations may determine the addition or reduction of medical hours for attending the patients. Since these resources are known to be quite expensive, the different scenarios were simulated by changing the existing capacity in 0.5 doctor intervals. The extra half doctor was included through the creation of a new shift of 6 hours, from 12:00 to 18:00, which is precisely the period in which most patients arrive at the service. Thus, the number of 6.5 doctors available means that 4 doctors attend on the day shift (8:00 - 20:00), 1 doctor on the half shift (12:00 – 18:00), and 2 doctors at night (20:00 – 8:00). The average LOW obtained with this configuration is 40.5 minutes.

The simulation was run using from 5 to 7 doctors within 24 hours, and distributed as explained above. The idea behind analyzing the reduction of the current number of doctors is to assess whether the performance of the system is affected in a significant manner when these resources are lacking, either by management decision or by absenteeism. The average LOW for different numbers

[4] What follows in this section is based on (Barros et al, 2010).

and assignments of resources are summarized in Figure 21, including the 95% confidence interval for each of the points.

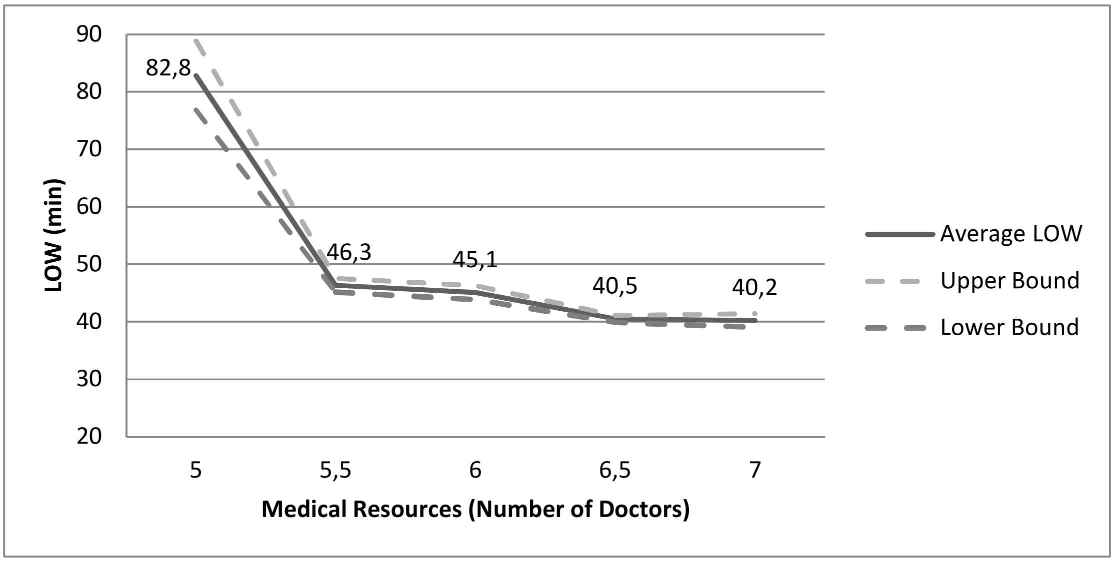


Figure 21: Average LOW and Confidence Intervals for Different Numbers of Doctors

As expected, the addition of medical resources improves the service quality, measured in average LOW. The interesting result is that the average LOW decreases dramatically when reducing the number of medical resources from 5 to 5.5 doctors, while it decreases more gradually when new resources are added. To test whether the LOW difference between all the scenarios included in Table 3 is statistically significant, we applied again the procedure proposed by Law and Kelton (1982). Table 3 shows the confidence intervals when comparing the LOW of these scenarios. As it can be observed, increasing from 5 to 5.5 doctors provides a significant improvement to the performance of the system, while the change between 5.5 and 6 doctors does not. Nevertheless, increasing from 5.5 to 6.5 doctors does show statistical significance.

Comparing Scenarios	5.5	6	6.5	7
5	[30.4 ; 42.6]	[31.6 ; 43.9]	[36.3 ; 48.3]	[36.5 ; 48.7]
5.5	-	[-0.4 ; 3]	[4.5 ; 7.2]	[4.4 ; 7.8]
6		-	[3.3 ; 5.9]	[3.1 ; 6.5]
6.5			-	[-1.1 ; 1.6]

Table 3: Confidence Intervals for Compared Scenarios

The previous analysis of the system performance provides hospital managers a decision tool for determining the number and distribution of medical resources on the emergency service, based on a cost/benefit analysis of resources and service improvement (Barros et al., 2010).

The results above were used to assign doctors to the different kind of boxes and define their work schedules and also to assign additional doctors. Each of the activities of the process in Figure 11 has computer system support, as defined in the model in Figure 15 for "Capacity Analysis". Notice that, in order to use these tools in a routine way, one has to embed the models and the application logic we have described in the supporting system to the actors of the process as specified in the design in Figure 15.

5.4. Resource scheduling for hospitals

The fourth type of design is the process for the scheduling of resources, which is included in the pattern modeled in Figure 16; we will consider the resource Operating Room (OR), which is one of the key resources in a hospital. The process starts with a demand analysis that, in this case, corresponds to prioritizing the patients´ waiting list in order to decide the order of surgery execution. Then selected patients are scheduled on several Operating Rooms, typically for a week ahead, making sure that, for a given patient, the right doctor and other resources are available at the chosen time in the room in which he is to be operated, and, at the same time, trying to make the best possible use of facilities. Finally, given a schedule, other resources, such as medical supplies, are determined in order to assure that they are available at operation time.

More detail is given for the Operating Rooms Scheduling (“Resource scheduling” in Figure 16), which is a complex activity; it influences the number of patients operated, waiting time and performance of the whole hospital. Hence there is the need to use good processes supported by powerful analytics and appropriate computer system support.

Complexity of scheduling has to do with the great variety of surgical interventions, the variability of operation time, patient priority, scarce available capacity, doctors schedule and many other factors. What is needed is to design a process that reduces cost and generates capacity by efficient use of resources and provides fairness in the access and quality of service for patients, particularly in opportunity of surgical procedures required. The main value to be given to patients is to base this fairness on criteria based on medical knowledge, resulting in the reduction of waiting time, specially for patients that cannot wait.

A simplified version of the design of the OR scheduling process is shown in Figure 22, where a full BPMN diagram is presented. Key ideas of the design are that the scheduling should be based on the current state of resources, priorities based on medical diagnosis and criteria calculated with current patient information, and an algorithm that meets all requirements for surgery and maximizes the number of relevant patients included. The System that manages data and execute analytical support is explicitly shown in the diagram.

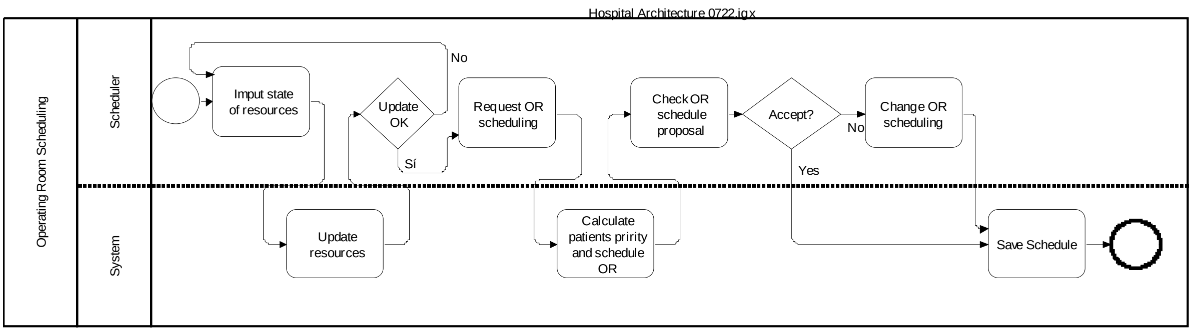


Figure 22. BPMN for OR scheduling

Next we describe the algorithm used for scheduling in Figure 22.

First, patients priorities have to be determined based on medical criteria. This starts, in previous processes, with a medical examination that determines how acute is the disease that originates the need for surgery, assigning the patient to a class among five alternatives that go from mild to very acute, and aggravating factors, such age and other conditions that make the operation more urgent. Then, based on criteria extracted from medical knowledge and experience, a maximum waiting time for surgery is determined according to the classification and aggravating factors, which determines a dynamic priority by comparing the date in which the patient should be operated (date of diagnosis plus maximum waiting time) and current date. This is a formal logic that originates an algorithm that is run by the System. Then prioritized patients are scheduled, for a given week, taking into account the following factors:

i. Patient cannot be operated twice in a week
ii. Detailed schedules of personnel availability of personnel, in particular doctors
iii. Load should be balanced among doctors within a week
iv. The programmed times of operation for each OR
v. Special patients are considered, which condition determines a particular timing for its surgery
vi. Priority can be violated because of patient limitations
vii. Two doctors should be assigned to each operation
viii. Specification of the operations a doctor can perform
ix. Patients can be prioritized for certain times within a day for reasons other than type of surgery

x. OR operating working times can be violated within certain limits to increase utilization

Two methods have been developed for scheduling:

- A discrete LP that defines constraints for each of the conditions stated above and others for logical consistence, and sets an objective function that establishes the maximization of the number of patients operated and the satisfaction of the order defined by the priorities defined above (Wolff et al, 2012) ; this model was implemented and results of its use are given below
- A heuristic that decides first the day in which a patient is to be operated and then the order within the day. First we explain, in a simplified way, a backtracking algorithm for a week scheduling of patients selected from a large group of prioritized patients, as follows (Wolff et al, 2012):
  - o Search for feasible solutions, within lists of all the time modules (half days), during the week, in which a given surgical operation for patient can be alternatively performed, taking into account its length, availability of a doctor who can perform the operation, and considering if the operation is “special” or ambulatory
  - o Create of combinations of feasible solutions taking into account that such combinations do not occupy more time than the one available in each time module, feasibility of each node included and that no more than two special patients are included in each day; several linked list are generated with the

nodes that contains the maximum numbers of different patients that can be operated, in order of priority, using all the time modules defined for a week

- In general patients are selected in priority order, but when it is not feasible to add one to a combination, the next patient with highest priority is selected.
- More than one feasible solution can be generated, due to the large number of patients from which to select, so an evaluation is made to select the best one using additional criteria not included previously, such as that more urgent patients should be included at the beginning of the week and that certain patients should be operated earlier during the day.

The selected patients selected for a given day are then ordered putting first the ones that are "special" and then by age, according to criteria given by doctors.

Both methods above generate schedules that are feasible, by doctors evaluation, of better quality in terms of satisfying all the constraints, which are difficult to assure by non formal methods, and makes much better use of capacity increasing occupation by at least 15% and up to 20% in certain cases. The method implemented in the process is the heuristic, because it gives results close to the optimization model and it is more stable in terms of always giving results. This is not true for the integer LP that sometimes runs long times without attaining a solution, due to the particular form of the objective function that includes weights to favor schedules that process priority patients. The heuristic is embedded within the System support and the whole process is executes by a process motor (BPMS) that allows to introduce a logic of the heuristic type be means of web services.

6. Results

We have shown that the Business Engineering approach, with the complement of process patterns, analytics and computer support, makes possible to establish general solutions for fourth related types of problems in the design of services. The use of these patterns in general and, in particular, for hospital services has resulted in the possibility of generating design solutions in short periods of time. For example, in hospitals in Chile we have been able to generate proposed designs for key parts of the service in a couple of months and implemented solutions in less than six months. Among others, solutions already working routinely in at least two hospital are the design of emergency service configuration implemented by mid 2010 with the introduction of a Triage and a fast track line; emergency capacity planning for the winter pick demand season, resulting in a reduction of patient waiting time of about half an hour with a medical resource addition and redistribution; demand analysis for waiting list prioritization, which has reduced the list by about fifty percent and greatly improved the decisions on who is to be operated sooner, including the identification of many cases of patients that had been overlooked with a risk for their lives. Currently we are implementing operating room scheduling in one hospital with very promising results, which show that current utilization of about 50% of programmed time can be increased up to 60% and more if some restrictions are eliminated. But the most important result is that all the designs we have done so far for hospitals services, which are based on general patterns, are themselves also general and can be readily applied to other hospitals with small adaptations, which is facilitated by the fact that they are based on formal BPMN models that can be easily edited in specializing them to particular situations at a given hospital. As a matter of fact we are already replicating the solutions in hospitals not involved in the initial development.

An extension of our work that we are already developing is the execution of our BPMN models by using BPMS-SOA technology. We have already implemented the patient prioritization and operating room scheduling design pattern using BizAgi technology and showed that it is feasible to execute the complete pattern workflow, including forms for people interaction with the system, using web services for the implementation of the analytical support and invocations to data bases that contain the data needed for execution. We are also working other designs with Activiti technology, which have also been shown feasible for executing our patterns at lower cost.

Main result we expect with these extensions is the capability of incrementing flexibility and rapidity in implementing our general design patterns for services design.

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