Chapter 1

Healthcare Supply Chain Information Systems Via Service-Oriented Architecture

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Healthcare supply chain management differs from other applications in terms of its key elements. The misalignment, high costs for healthcare providers and heavy dependence on third parties, distributors, and manufacturers are the main trouble making issues for the healthcare supply chain. At the same time, some of the supply chain components of the health sector have a different position compared to the other materials that are taking place in the other supply chains. In particular, the specific consumables used in the surgical operations bear a significant importance in terms of the usage and the costs. In some cases, the doctors may not have a strict opinion on the exact quantity of the consumables they will use during the operation before starting it. On the other hand, it is not always possible to have all these materials in the stock because of their high cost. Moreover, due to the inefficiencies in the social security system in Turkey, the social security institutions do not always accept to pay the price of the materials used. Worse still, the related information generally reaches with a significant delay to the hospital management.

Keywords: Healthcare; supply chain management (SCM); service oriented architecture (SOA); vendor managed inventory (VMI).

1. Introduction

Ferihan Laçin Hospital is a medium-scale 53-bed hospital. Four different groups of materials are used during a work day:

1. *Ordinary Supplies*: These are the materials used in a hotel management like paper towels, bedclothes, soap, cleansing agent, or disinfectants. This kind of material is not included in the scope of this research.

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2. *Drugs*: This group consists of the typical drugs used in a hospital including anesthetic drugs.
3. *Medical Materials*: This group contains medical disposable items, surgical dressing, medical papers used in medical devices such as electrocardiographs, etc.
4. *Special Surgical Materials and Equipment*: This group contains special surgical materials such as stents, thin tube inserted into a tubular structure (e.g., a blood vessel) to hold it open or remove a blockage, or prosthetic and orthopedic products. This group has a difference from the other groups. For the other groups, the hospital's employers such as doctors, practitioners, nurses, and technicians have the opportunity to decide the quantity of materials that they are going to consume while working. The decision on the use of materials by this group may only be made by specialist(s) like surgeon(s); however, even they, most of the time, do not have any exact idea on how many they will consume during the operation. They need to make this decision during the operation. Because of this constraint, the management of supply chain of these materials is completely different from the others.

Currently, in the hospital, there are neither any rules defined for the inventory management nor for a complete SCM. There is only a pharmacist and a staff member working in the hospital's pharmacy. All purchasing affairs for all materials are done by them. In fact, working understaffed is a very common feature that we face in small- and medium-sized hospitals. The pharmacist's mission is to control and audit all the drugs used all over the hospital, especially the anesthetic drugs. They are also responsible to assure the presence of the medical materials. It is also the pharmacist's responsibility to update supplier information, net cost of procurement, batch sizes, and so forth. On the other hand, their performance measure is to provide the correct materials, at the required time. In healthcare cases, time is a big constraint because even a delay of a second may cause a big problem for the life of a person.

The staff working with them are not qualified personnel who have a formation of pharmaceutics. They are responsible to manage the orders and the payments, control the bills, enter the bills' information to the information system of the hospital, check the boxes, and get the proposals from the suppliers. The proposal must contain the information about medical supplies' unit prices and the conditions of payment. All the proposals are examined by pharmacist and purchasing director, and they decide together on the supplier from which the materials will be purchased.

A simple order process done by the staff consists of following steps:

1. Taking the proposal from the different suppliers.
2. Introduce the candidate suppliers' proposal to pharmacist and purchasing director to determine the right one.
3. Call the supplier determined by the pharmacist and the purchasing director via phone, fax, and e-mail.
4. Make the order.

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This system has several weaknesses. First, there are no prescribed parameters to define the quantity of such orders. The pharmacist decides the quantity of the materials intuitively. This process is also time consuming because the pharmacist must check the materials one by one every day and the staff must spend hours and hours to communicate with the suppliers to get the proposals, and place the orders. On the other hand, the system has also a bad effect on the suppliers' side. They are always enforced to provide the necessary item in a short period, sometimes in a day. They always have to be ready to answer the hospital's demands quickly and this causes a big competition in the market.

The last weakness is caused by the payment schedule of Turkish government. The major part of the healthcare costs in Turkey is still being covered by the government. The market share of the private health insurance companies that exist in this sector is not significant. Today, only 1 out of 162 people has a private health insurance. However, the Turkish government can only disburse the payments to private hospital in 3 months. Under these circumstances, the hospitals also propose to suppliers to make payment with a delay of 3 months. Most of the medical materials are very expensive with a big cost; both suppliers and hospitals face the difficulties to manage their financial situation. All these problems are getting worse in the case of special surgical materials and equipments.

On the other hand, the competition among the small- and medium-scale hospitals is growing intensely; therefore, all hospitals have to improve their quality of healthcare services while reducing their operational cost.

The research has started with analysis of business process and system requirements of this specific application in a hospital.[a] Then, a new idea has been developed to control the purchases and consume the special medical and surgical devices especially during the operation.

A telemedicine application is implemented between the hospital information system and government system to provide a real-time online observation for the surgical operation. On the other hand, all processes have been designed according to service-oriented architecture (SOA) because SOA provides a much more agile environment for process orchestration, for integration across applications, and for collaboration between users. Each process has been defined as a Web Service (WS). With this architecture, another problem may be possible: The structure of the information exchanged. Allowing cooperation among distributed and heterogeneous applications is a major need for the current system. In this research, we try to model an efficient pharmaceutical SCM to eliminate the problems cited above. The new system is developed to optimize inventory control, reduce material handling cost, and manage the balance of payment among the government and the suppliers. SCM is a strategy for optimizing the overall supply chain by sharing information among material suppliers, manufacturers, distributors, and retailers (Dona *et al.*, 2001). Our supply chain consists of suppliers, hospitals, and the government. The

[a] Ferihan Laçin Hospital, Istanbul, Turkey. www.ferihanlacin.com

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key element of SCM is information sharing (Dona *et al.*, 2001). Information sharing improves collaboration among the supply chain to manage material flow efficiently and reduces inventory cost (EHCR Committee, 2001). Therefore, we decided to adopt a vendor-managed inventory (VMI) model to optimize the inventory control and then reengineer the processes according to a new architecture SOA. Besides, we try to propose a different management style for the usage of special surgical materials and equipment and their SCM.

In Sec. 2, the suggested process remodeling will be revealed item by item while defining VMI. Section 3 illustrates all the technologies used. Finally, benefits of the developed system will be discussed.

2. Process Remodeling

2.1. *Constraints*

It is very difficult to design an efficient pharmaceutical system to improve the Quality of Services (QoS) given to the patients, while there are not any rules determined by the hospital management. Of course, the hospital's management takes the TQM rules seriously, but the processes are never examined, and never documented. On the other hand, the nature of supply chain is very complex. The first objective of this supply chain is not only to lower procurement cost and improve cash flow, but also to assure the appropriate drug, medical materials, or special surgical materials at the right time, in the right place. Another important issue is the preservation of the drugs. Each drug has an expiry date and some of them, for example, anesthetic drugs need to be more safely preserved. The innovation and changes in the drug sector are very often and it is very usual to substitute a drug not found with an equivalent one. Then, an information system adoption is needed but information sharing (IS) adoption in healthcare affects and is affected by human and organizational actors (Vasiliki *et al.*, 2007). Thus, it is not only the information systems that need to be put in place, but also an effective process solution for how to transfer demand is needed (Riikka *et al.*, 2002).

As there is no efficient and effective inventory control in the hospital, we decided to adopt our new SCM system modeled according to SOA principles with VMI techniques. Before implementing our system, the information shared between supplier and hospital, between hospital and government, and between supplier and government was insufficient. Eventually, this results in a high rate of emergency order calls, high stock levels, bad balance of payments, and, of course, patient dissatisfaction. To solve this problem, we first started to implement a VMI system in hospital warehouses. We show that by effectively harnessing the information now available, one can design and operate the supply chain much more efficiently and effectively than ever before.

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2.2. *What is VMI?*

VMI approach can improve supply chain performance by decreasing inventory-related costs and increasing customer service. Unlike a traditional supply chain wherein each member manages its own inventories and makes individual stocking decision, VMI is a collaborative initiative where a downstream customer (a hospital in our case) shifts the ownership of inventories to its immediate upstream supplier and allows the supplier to access its demand information in return.

In particular, a VMI process involves the following two steps: (1) a downstream customer provides demand information to its immediate upstream supplier and leaves the stocking decisions to that supplier; and (2) the upstream supplier has the ownership of the inventories till the inventories are shipped to the customer and bears the risk of demand uncertainty. It is not difficult to see that the VMI structure promotes collaborations between suppliers and customers through information sharing and business process reengineering. VMI is an alternative for the traditional order-based replenishment practices. VMI changes the approach for solving the problem of supply chain coordination. Instead of just putting more pressure on suppliers' performance by requiring ever faster and more accurate deliveries, VMI gives the supplier both responsibility and authority to manage the entire replenishment process. The customer company (a hospital in our case) provides the supplier access to inventory and demand information and sets the targets for availability. Thereafter, the supplier decides when and how much to deliver. The measure for supplier's performance is no more delivery time and preciseness; it is availability and inventory turnover. This is a fundamental change that affects the operational mode for both the customer and at the supplier company. Therefore, the advantages to both parties must be evident to make the shift to VMI happen (Lee and Whang, 2000).

We cannot deny the advantages of VMI in our case. Before implementing VMI, it was the pharmacist's mission to manage the inventory which resulted in inefficiencies. The adoption of VMI is started by contracts among suppliers and hospital. These contracts are realized not only on the paper, but also via WSs too (which will be described in the next section). In the contracts, the role of controlling inventory level of each drug or medical supply is given for an appropriate supplier by defining the unit price and payment schedule.

With this system, the suppliers' experts control the stock level instead of the pharmacist. The new system allows the pharmacists do their own job, and also create the time available for the supplier to plan deliveries. It is obvious that the more time the supplier has for planning, the better it is able to serve the hospital and optimize operations.

The other problem faced in hospital inventory management is having no proper classification schema. There are so many different drugs and medical supply. Each of them is produced by different manufacturer and may be used as a substitute for

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a different one. It is very inefficient to manage all these products without a proper classification because it is not possible to make a contract for each of them.

We already mentioned that the stock control will be done by suppliers' experts. Here, the main question is who will decide for order quantity. We did not leave the decision of order quantity either to supplier's expert or to pharmacist. Order quantities are calculated by the information system based on demand forecasting and safety stock levels. The hospital has its own information system to manage the stock level of each product. Our system will use information produced by this system to get order quantities.

2.3. *Information and Document Sharing*

IS is a collaborative program in which the downstream firm (referred to as the hospital herein) agrees to provide demand and inventory status in real time to the upstream firm (referred to as a supplier herein) (Lee and Whang, 2000). VMI provides a closer collaboration between the supplier and hospital in our case. That is why the hospital must be able to reengineer its process through real-time information sharing, enabled by electronic data interchange (EDI).

With this system, we propose to provide an integrate information sharing between hospital and suppliers, and between hospital and government. By sharing information about product usage between them, it is much easiest to keep the inventory level at a proper level. Besides, the system must have the ability to keep the logs of products, insurance codes, and information about new drugs. We designed the system to be accessible in real time, and to be integrated via WSs with any service provider including government. With the new architecture, all the processes are remodeled according to SOA principles. While remodeling the processes, we took into consideration the WSs policy defined by the Turkish government, the standards, and protocols produced by Health Level Seven which is one of several American National Standards Institute (ANSI)-accredited Standards Developing Organizations (SDOs) operating in the healthcare arena, for a particular healthcare domain such as pharmacy, medical devices, imaging or insurance (claims processing) transactions, the codes defined by Anatomical Therapeutic Chemical Classification System with Defined Daily Doses (ATC/DDD) index published by WHO, and by National Information Bank (UBB) published by Ministry of Health of Turkey.

On the other hand, the hospital's traditional method of exchanging and processing orders and orders' documents via phone or fax machine results with time inefficiency and high rate of error. The process depends totally on staff's performance, which is not acceptable in the healthcare case. The system offers the to suppliers to get the order requirements, to control the inventory level of hospital's central warehouse and exchange documents in XML formats, via WSs. With this system model, order processing of supply chain participants can be enhanced significantly.

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2.4. *What is Service Oriented Architecture (SOA)?*

With the growth of real-time computing and communication technologies like the Internet, batch interfaces were posing a challenge. When the latest information about a given business entity was not updated in all dependent systems, it resulted in a loss of business opportunity, decreased customer satisfaction, and increasing problems. SOA may be seen as the new face of enterprise application integration (EAI). We can also define SOA as a business-driven information technology (IT) architectural approach that helps businesses innovate by ensuring that IT systems can adapt quickly, easily, and economically to support rapidly changing business needs.

SOA is not a technology. It is an architectural approach built around existing technologies. SOA advocates a set of practices, disciplines, designs, and guidelines that can be applied using one or more technologies and being an architectural concept, it is flexible enough to lend itself to multiple definitions. SOA offers a unique perspective into business that was previously unavailable: It offers a real-time view of what is happening in terms of transactions, usage, and so forth.

In anticipation of the discovery of new business opportunities or threats, the SOA architectural style aims to provide enterprise business solutions that can extend or change on demand. SOA solutions are composed of reusable services, with well-defined, published and standards-compliant interfaces. SOA provides a mechanism for integrating existing legacy applications regardless of their platform or language.

The key element of SOA is the service. A service can be described as "a component capable of performing a task" (David and Lawrence, 2004). Although a service can be seen as a task or an activity, it is more complicated than these concepts. This is due to the fact that every service has a contract, an interface, and an implementation routine. Josuttis (2007) states that a service has the following attributes:

- *Self-contained*: Self-contained means independent and autonomous. Although there can be exceptions, a service should be self-contained. In order for the services to be self-contained, their inter-dependencies should be kept in a minimum level.
- *Coarse-grained*: It indicates the implementation detail level of services for consumers. Implementation details are hidden for a service consumer because the consumer does not care about such details.
- *Visible/Discoverable*: A service should be visible and easily reachable. This is important also for reusability which means that a service can be used multiple times in multiple systems.
- *Stateless*: Services, ideally, but not always, should be stateless. This means that a service request does not affect another request because service calls do not hold invocation parameters and execution attributes in a stateless service.

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- *Idempotent*: Idempotent means the ability of redo or rollback. In some cases, while a service is executing, a bad response can be returned to the service consumer. In such a case, service consumers can rollback or redo the service execution.
- *Composable*: For a composable service, the service can contain several subservices, where they can be separated from the main service. A composable service can call another composable service.
- *QoS and Service Level Agreement (SLA)-Capable*: A service should provide some non-functional requirements such as runtime performance, reliability, availability, and security. These requirements represent QoS and SLA.
- *Pre- and Post-conditions*: Pre- and post-conditions specify the constraints and benefits of the service execution. Pre-condition represents the state before the service execution. Post-condition represents the state after the service execution.
- *Vendor Diverse*: SOA is neither a technology nor a product. It is also platform (or vendor) independent. This means that it can be implemented by different products. When calling a service, one does not need to be familiar with the technology used for the service.
- *Interoperable*: Services should be highly interoperable. They can be called from any other systems. Interoperability provides the ability of different systems and organization to work together. In other words, services can be called from any other system regardless of the types of environment for them.

The second important issue is to define explicitly two key roles in an SOA: *the service provider* and *service consumer*. Service provider publishes a service description and provides the implementation for the service, whereas service consumer can either use the uniform resource identifier for the service description directly or can find the service description in a service registry and bind and invoke the service.

In Fig. 1, the relationship between a service provider and a service consumer is illustrated.

As we mentioned above, a service is a software resource with an externalized service description. This service description is available for searching, binding, and invocation by a service consumer. The service provider realizes the service description implementation and also delivers the QoS requirements to the service consumer. Services should ideally be governed by declarative policies and thus support a dynamically re-configurable architectural style.

The services can be used across internal business units or across the value chains among business partners in a fractal realization pattern. Fractal realization refers to the ability of an architectural style to apply its patterns and the roles associated with the participants in its interaction model in a composite manner. It can be applied to one tier in architecture and to multiple tiers across the enterprise architecture. That is why defining the services according to SOA concepts must be the most

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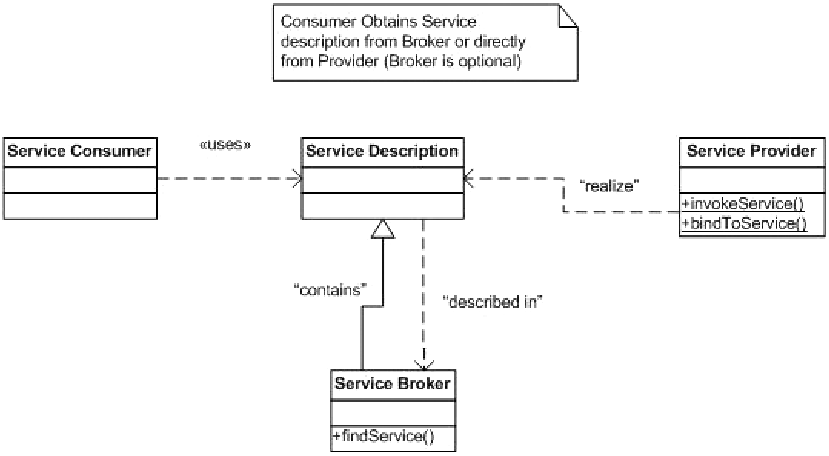

Figure 1. SP&SC relationship (© IBM).

crucial step while modeling a system. Conceptually, there are three major levels of abstraction within SOA:

- **Operations:** Transactions that represent single logical units of work (LUWs). Execution of an operation will typically cause one or more persistent data records to be read, written, or modified. SOA operations are directly comparable to object-oriented (OO) methods. They have a specific, structured interface, and return structured responses. Just as for methods, the execution of a specific operation might involve invocation of additional operations.
- **Services:** Represent logical groupings of operations.
- **Business Processes:** A long running set of actions or activities performed with specific business goals in mind. Business processes typically encompass multiple service invocations.

According to Ali Arsanjani, PhD, Chief Architect, SOA and WSs Center of Excellence, IBM, the process of service-oriented modeling and architecture consists of three general steps: identification, specification and realization of services, components and flows (typically, choreography of services).

- **Service identification:** This process consists of a combination of top-down, bottom-up, and middle-out techniques of domain decomposition, existing asset analysis, and goal-service modeling. In the top-down view, a blueprint of business use cases provides the specification for business services. This top-down process is often referred to as domain decomposition, which consists of the decomposition of the business domain into its functional areas and subsystems, including its flow or process decomposition into processes, subprocesses, and high-level business use cases. These use cases often are very good candidates for business services exposed at the edge of the enterprise, or for those used within the boundaries of the enterprise across lines of business.

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In the bottom-up portion of the process or existing system analysis, existing systems are analyzed and selected as viable candidates for providing lower cost solutions for the implementation of underlying service functionality that supports the business process. In this process, you analyze and leverage APIs, transactions, and modules from legacy and packaged applications. In some cases, componentization of the legacy systems is needed to re-modularize the existing assets for supporting service functionality.

The middle-out view consists of goal-service modeling to validate and unearth other services not captured by either top-down or bottom-up service identification approaches. It ties services to goals and subgoals, key performance indicators, and metrics.

• **Service classification or categorization:** This activity is started when services have been identified. It is important to start service classification into a service hierarchy, reflecting the composite or fractal nature of services: services can and should be composed of finer-grained components and services. Classification helps determine composition and layering, as well as coordinates building of interdependent services based on the hierarchy. Also, it helps alleviate the service proliferation syndrome in which an increasing number of small-grained services get defined, designed, and deployed with very little governance, resulting in major performance, scalability, and management issues. More importantly, service proliferation fails to provide services, which are useful to the business, that allow for the economies of scale to be achieved.

• **Subsystem analysis:** This activity takes the subsystems found above during domain decomposition and specifies the interdependencies and flow between the subsystems. It also puts the use cases identified during domain decomposition as exposed services on the subsystem interface. The analysis of the subsystem consists of creating object models to represent the internal workings and designs of the containing subsystems that will expose the services and realize them. The design construct of "subsystem" will then be realized as an implementation construct of a large-grained component realizing the services in the following activity.

• **Component specification:** In the next major activity, the details of the component that implement the services are specified:

- Data
- Rules
- Services
- Configurable profile
- Variations

Messaging and events specifications and management definition occur at this step.

• **Service allocation:** Service allocation consists of assigning services to the subsystems that have been identified so far. These subsystems have enterprise components that realize their published functionality. Often you make the simplifying

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assumption that the subsystem has a one-to-one correspondence with the enterprise components. Structuring components occurs when you use patterns to construct enterprise components with a combination of:

- Mediators
- Façade
- Rule objects
- Configurable profiles
- Factories

Service allocation also consists of assigning the services and the components that realize them to the layers in SOA. Allocation of components and services to layers in the SOA is a key task that requires the documentation and resolution of key architectural decisions that relate not only to the application architecture but also to the technical operational architecture designed and used to support the SOA realization at runtime.

- **Service realization:** This step recognizes that the software that realizes a given service must be selected or custom-built. Other options that are available include integration, transformation, subscription, and outsourcing of parts of the functionality using WSs. In this step, which legacy system module will be used to realize a given service and which services will be built from the "ground-up" will be decided. Other realization decisions for services other than business functionality include security, management, and monitoring of services. In reality, projects tend to capitalize on any amount of parallel efforts to meet closing windows of opportunity.

Top-down domain decomposition (process modeling and decomposition, variation-oriented analysis, policy and business rules analysis, and domain specific behavior modeling (using grammars and diagrams) is conducted in parallel with a bottom-up analysis of existing legacy assets that are candidates for componentization (modularization) and service exposure. To catch the business intent behind the project and to align services with this business intent, goal-service modeling is conducted.

In SOA terms, a business process consists of a series of operations which are executed in an ordered sequence according to a set of business rules. The sequencing, selection, and execution of operations are termed service or process choreography. Typically, choreographed services are invoked to respond to business events. Therefore, we have to model our business processes according to service concepts.

SOA and design are another concepts from the other analysis and modeling. Service-oriented modeling requires additional activities and artifacts that are not found in traditional OO analysis and design. Experience from early SOA implementation projects suggests that existing development processes and notations such as Object Oriented Analysis and Design (OOAD), Enterprise Architecture (EA), and business process management (BPM) only cover part of the requirements needed to

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support the SOA paradigm. While the SOA approach reinforces well-established, general software architecture principles such as information hiding, modularization, and separation of concerns, it also adds additional themes such as service choreography, service repositories, and the service bus middleware pattern, which require explicit attention during modeling (Olaf *et al.*, 2004).

There is one more important point that we have to mention here. When one starts an SOA project, the first thing that comes to mind is to define WSs. Yet, the SOA research road map defines several roles. The service requester or client and provider must both agree on the service description (Web Service Definition Language — WSDL definition) and semantics that will govern the interaction between them for WSs to interact properly in composite applications. A complete solution must address semantics not only at the terminology level, but also at the levels that WSs are used and applied in the context of business scenarios — the business process and protocol levels. Thus, a client and provider must agree on the implied processing, context, and sequencing of messages exchanged between interacting services that are part of a business process. In addition to the classical roles of service client and provider, the road map also defines the roles of service aggregator and operator. Service modeling and service-oriented engineering — service-oriented analysis, design and development techniques, and methodologies — are crucial elements for creating meaningful services and business process specifications. These are an important requirement for SOA applications that leverage WSs and apply equally well to all three service plans.

SOA should abstract away the logic at the application or business level, such as order processing, from non-business-related aspects at the system level, such as the implementation of transactions, security, and reliability policies. This abstraction should enable the composition of distributed business processes and transactions.

The software industry now widely implements a thin Simple Object Access Protocol (SOAP)/WSDL/Universal Description Discovery and Integration (UDDI) veneer atop existing applications or components that implement the WSs, but this is insufficient for commercial-strength enterprise applications. Unless the component's nature makes it suitable for use as a WS (and most are not) properly delivering components' functionality through a WS takes serious redesign effort (Papazoglou *et al.*, 2007).

On the other hand, our job would not be complete by only defining these services according to SOA. While migrating to SOA, there are some other points that should be taken into consideration. These include:

- *Adoption and Maturity Models*: Every different level of adoption has its own unique needs; therefore, the maturity level of enterprise in the adoption of SOA and WSs must be determined at the beginning.
- *Assessments*: During the migration, controls and assessment must be done after each step.

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- *Strategy and Planning Activities*: The steps, tools, methods, technologies, standards, and training which must be taken into account must be declared at the beginning. Therefore, a roadmap must be represented.
- *Governance*: SOA has the ability to use legacy application's API as a service. Every API must be examined to decide which one is eligible? Every service should be created with the intent to bring value to the business in some way.

3. Case Study

Our main goal in this study is to implement the application of both new working areas to transform the supply chain to a single, integrated model to improve patient care and customer service, while decreasing procurement costs. The first one is to reengineer business processes with SOA. The second one is to be able to make an SOA modeling. As stated in the paper of Zimmerman *et al.* (2004) SOA modeling is a very new area, and there are no defined strict rules on this subject. Therefore, we first debuted by modeling VMI that we described above according to SOA. All the departments request necessary items and the items are delivered from hospital's warehouse to the requesting departments. As a requirement of the definition of VMI, the supplier needs to manage the hospital's overall inventory control system and order processing system and then makes the order delivery schedule according to the contract signed by the supplier and the hospital. In a traditional VMI system, the supplier takes both responsibility and authority to manage the entire replenishment process. The customer company provides the supplier access to the inventory and demand information and sets the targets for availability (Riikka *et al.*, 2002). Here, instead of allowing the supplier to intervene directly to the legacy system used by the hospital, we believe that it would be more appropriate to produce the information needed by the supplier by a service architecture and orchestration on the system. Although one may think that such a business process modeling may be realized by other modeling types like OOD or EA, it is certain that Service Oriented Architecture Design (SOAD) will be more efficient in defining the human-based task that we eventually need in this modeling.

SOAD must be predominantly process, rather than use-case driven. The method is no longer use case-oriented, but driven by business events and processes. Use case modeling comes in as a second step on a lower level. In the SOA paradigm, business process choreography, maintained externally to the services, determines the sequence and timing of execution of the service invocations. SOAD provides an excellent solution to these issues. As it groups services on the basis of related behavior, rather than encapsulated (behavior plus data), the set of services will be subtly different from a business object model.

The order is created when stock amount is less than Stock Keeping Unit (SKU) calculated by the legacy system of hospital. For each pharmaceutical, a separate

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order item is created, containing details of order quantities and the rules defined in the contract. As the supplier manages the hospital's stock, he's ready to provide the necessary amount of this pharmaceutical. The main problem is the delivery lead time. A suitable shipping way needs to be scheduled for each pharmaceutical. Each dispatch may contain one/several pharmaceutical. It must be determined which pharmaceutical has urgency, or which one may be dispatched with the others. When the items come to the hospital, the pharmacist and the employee must verify the boxes and approve the task waiting on the system to declare that the order is correct. If it is not correct, they must specify the details, and a new job will start for the mistakes. When they approve that the order is correct, the supplier's legacy system will produce the invoice and send the invoice via WSs to hospital to get the payment.

The second part of supply chain is the receipt of the payment of the necessary amount of the consumed products either from the insurance companies or the government. In this way, it is expected that the invoices of the products that have been used for the favor of the patients should be sent to the Ministry of Health and the payment should be done against these invoices. The payment part includes the payment that will be done to the suppliers from the hospitals and to the hospitals from either the government or the insurance companies upon the control and the approval of the invoices. These transactions are structured again on the WSs and the orchestration among them. The main point here, as we mentioned before, is to provide the supply of the expensive products that have been decided to be used during the operation while their usage number and their payment conditions are still unknown. The system established may send the necessary information to the information systems of both suppliers and of the Ministry of Health or the related insurance company once the date and venue of the operation, and the type and the estimated amount of the products that will be used during the operation are decided. The telemedicine support that we explained earlier, steps in here. To enable the doctors to communicate easily and to access the system from anywhere independently from their daily computers, a "telemedicine" module has been designed by using the Adobe Flash technology, which is very common nowadays. With the help of this module, the end users may communicate with each other either interactively or in the way of one-sided video conference. To make all the correspondence possible to be watched again, the file extension ".flv" has been selected. These files are stored under the folders that have been named by the variables that belong to the system and that determine the owners. There is also another separated database where all the data related to these files are stored. This method has been selected to facilitate the management and to diminish the load into the database. The Red5 Open Source Flash Server that uses the Real Time Messaging Protocol (RTMP) protocol that provides the simultaneous exchange of information has been selected as server. On the other hand, the Flash Media Server can also be used as an alternative to this server. In this way, the operation may be watched both in real time or later on in the desired period. This also provides

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the opportunity of making a decision on the necessity of the products used during the operation not only from the epicrisis, but also from watching the actual operation. This is certainly an important step to decide unbiasedly without any external influence.

Processes are modeled according to SOA and we obtained the services cited below in the figure:

1. Supplier service
   a. Lookup the supplier by contract
   b. Create the new supplier
   c. Get the supplier information
2. Inventory service (legacy system)
   a. Determine the quantity on hand of item
   b. Comparing with SKU level
   c. Determine the order quantity
   d. Expected arrival date
   e. Inventory management
      i. Physical review
      ii. Closing
3. Order service
   a. Create the order
   b. Schedule the order date and time
   c. Get the offerings
   d. Delivery order
   e. Receive the delivery
4. Scheduling service
   a. Take the delivery schedule
   b. Schedule the delivery date and time
5. Payment service
   a. Hospital-Supplier
   b. Government/IC-Hospital
6. Telemedicine service
   a. Approval of medical supply usage and its quantity
   b. Rejection of medical supply usage and its quantity
7. Utilization service
   a. Create the new utilization by departments
   b. Status tracking of delivery request
   c. Decrease the stock quantity
   d. Increase the usage amount
   e. Markup the patient's file

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Services are modeled in Fig. 2:

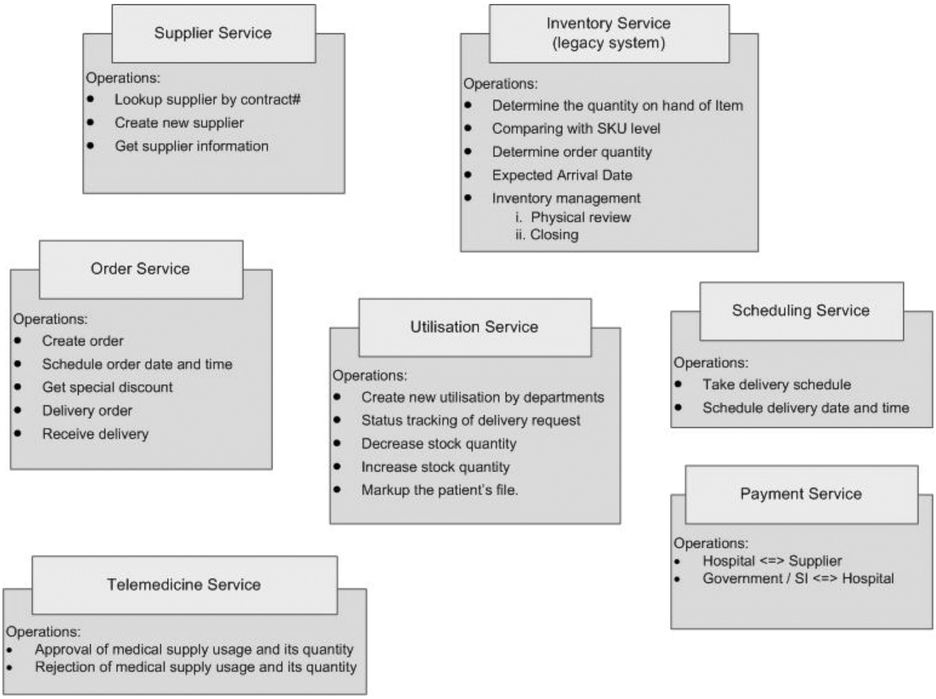

Figure 2. Services.

4. System Implementation

While modeling and implementing the system, we used IBM DB2 Express-C, IBM Websphere Application Server 6.1, IBM Websphere Business Modeler 6.1, IBM Rational Software Architect 6.1, IBM Websphere Integration Developer 6.1, IBM Websphere Process Server 6.1, and IBM Websphere Monitor 6.1.

We have used Websphere 6.1 Feature Pack for WSs, which has been installed on our application server, namely, Websphere Application Server 6.1. We decided to select this software because it allows us to communicate with other vendors in a more reliable, asynchronous, secure, and interoperable way. It also enables support for the Java API for XML Web Services (JAX-WS) 2.0 programming model and the SOAP 1.2 that may remove most of the ambiguities that existed in the previous versions of SOAP.

As it may be well known, JAX-WS 2.0 is a Java programming model to create WSs. Its most important feature is that it provides an asynchronous client model. This makes easier to develop and deploy WSs.

Another important feature of the JAX-WS can be cited as supporting WS-I Basic Profile 1.1. The WSs that have been developed by using the JAX-WS can be consumed by any client which has been previously developed by any programming language supporting this basic profile.

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XML Binding for Java (JAXB) enables data mapping between XML Schema and JAVA. XML is contained in the SOAP message, and without knowing how to parse SOAP and XML messages, JAXB defines this binding for us. On the other hand, SOAP with Attachments for Java (SAAJ) enables dealing with XML attachments in SOAP messages.

Figure 3 illustrates which product is used in which step.

Before coding the WSs, we have first modeled the BPM with Websphere Business Modeler 6.1. The process flow is shown in Appendix A. Then we define the services one by one as illustrated in Fig. 2.

For the service orchestration, SOA needs a middleware which is generally Enterprise Service Bus (ESB). In our project, we prefer to use WebSphere Business Process Execution Language (WS-BPEL) as service orchestration tool. WS-BPEL is an orchestration language. An orchestration mentions executable process which means to intercommunicate with other systems dynamically and the control of this process is done by an orchestration designer such as WebSphere Process Server. This language combines two notions:

1. BPM and
2. Web Services (WSs)

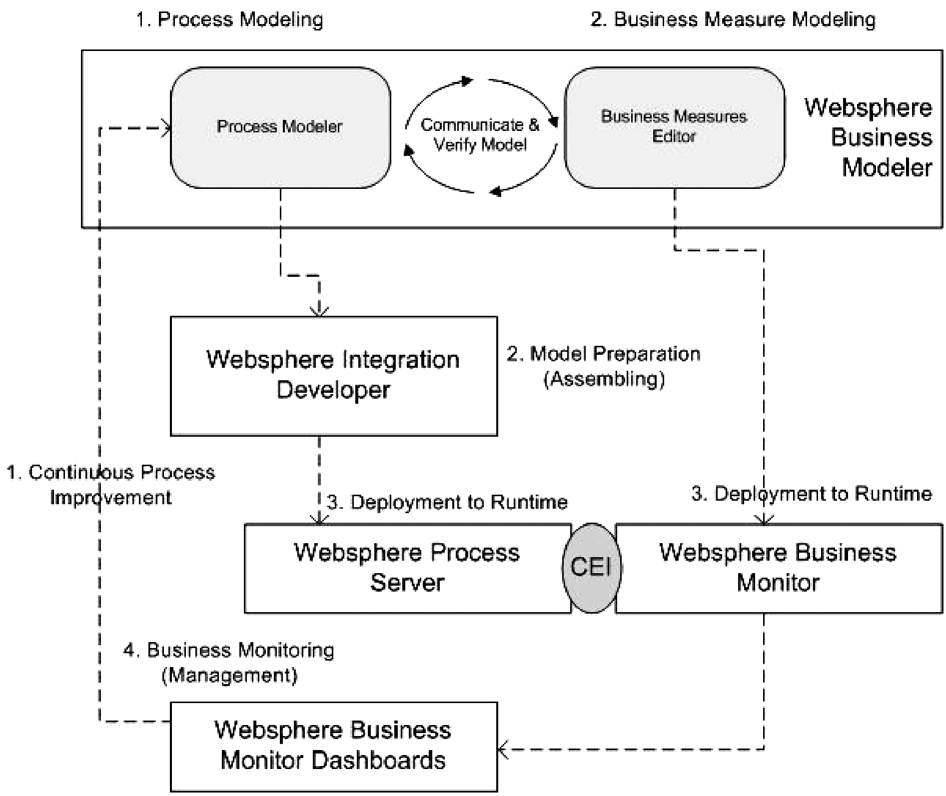

Figure 3. Software used.

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The most crucial step in today's business world is to manage and improve their business processes while workflow components must be loosely coupled and run interoperable. In this point, Web Services are in action. Web Services are self-contained, modular business blocks that achieve interoperability between applications. They use Web standards such as WSDL, UDDI, and SOAP. In real life scenarios, we need to join different WSs and to use them as a whole entity of WSs. This is where, we need a new language that encapsulates, all WSs needed and exposes the business process as a unique WS: the WS-BPEL.

In WS-BPEL technique, the business process is defined as follows: "A business process specifies the potential execution order of operations from a collection of WSs, the data shared between these WSs, which partners are involved and how they are involved in the business process, joint exception handling for collections of WSs, and other issues involving how multiple services and organizations participate." (Sanjiva and Francisco, 2002).

WS-BPEL extends the WSs interaction model and enables it to support business transactions. WS-BPEL uses WSDL to specify an interface between the business process and the world outside by describing actions in a business process and the WSs provided by a business process. The business process itself and its partners (services with which a business process interacts) are modeled as WSDL services. So, WS-BPEL has a role to compose existing services. The business process is described as a collection of WSDL portTypes, just like any other WS as illustrated in Fig. 4.

WS-BPEL is the top layer which uses a middleware layer WSDL using SOAP, a protocol to exchange structured information. UDDI is on top of SOAP, which is a registry of all publishing WSs. We prefer to model the orchestration of WSs with WS-BPEL because WS-BPEL can handle complex cases. For example, it is usable with loops and scopes in a business process logic, which is not supported by an ESB. We need long-running business processes where we need to maintain the state information of the process, which is also not supported by an ESB.

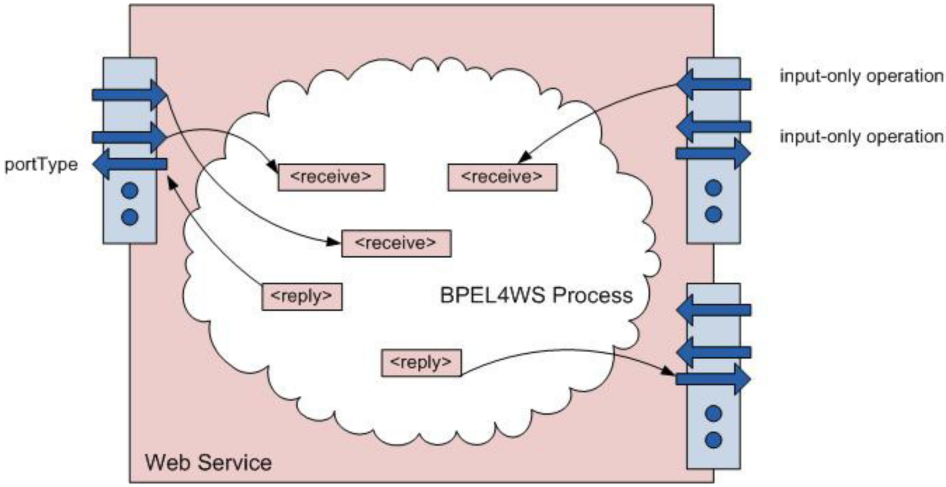

Figure 4. WS defined by WS-BPEL.

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With WS-BPEL, we are able to orchestrate a business process where we use WebSphere Process Server as the business process choreographer. One of the major features of WPS is that it supports human tasks, which enable human activities to be invoked as services. And human activities have an important role in healthcare industry. Our requirements are process-centric so WS-BPEL is the better choice in this project.

In our scenario, each pharmaceutical is provided from a specific medical supplier in a specific quantity. All this information is kept in database tables. In the SUPPLIER table, there is a field named "Endpoint Address," there is information about the medical supplier's end-point address. So when a pharmaceutical quantity is not sufficient in the stock, a trigger is fired and a WS request is sent to WS provider, the medical supplier. This is where we are a consumer.

There are WSs that we offer to our partner medical suppliers. They can control our stock to learn the quantity of pharmaceuticals that we have, and to hold ready their own stock. This is where we are a provider. In the big picture, we are a consumer and also a provider, this is where SOA begins.

5. Conclusion

When analyzed, it has been observed that the system that we try to establish has many benefits. First, thanks to the VMI application, the workloads of the pharmacists and the other employees have been decreased. In Turkey, there is no obligation of employing a pharmacist for the hospitals that have less than 100 beds. Taking this account, this system by the unification of the different applications of the telemedicine may also help the pharmacist to support more than one hospital. This situation will be the subject of another study. On the other hand, thanks to this application, the pharmacist is no longer expected to be knowledgeable about the stock management or the cost reduction but on the contrary these operations will be realized by the real experts. Moreover, there are many benefits in the stock management as well. The drugs are difficult materials to store and preserve. In fact, each drug has an expiry date. There is an enormous number of different drugs and most of the drugs may be used equivalently instead of each other. Besides, as we mentioned before, in the healthcare sector, the nonexistence may produce more serious results as the human life is concerned. Therefore, an effective stock management that has been structured in this way, and an efficient material handling at the same time, will certainly improve the quality of the service offered to the patients in the hospital.

Second, the information integration and a successful supply chain will eventually result in a strong integration among the partners of the system, i.e., the government, hospitals, and wholesalers. Thanks to the services produced, all the required information may be used by the other institutions within the limit of the permission given by the service provider institution. The only constraint here is that each provider and the consumer must work with the same semantic to understand the WSs. Furthermore, the applications liable to human error, such as lost papers among the files, the products that are forgotten to be ordered, and numerous phone calls, will be totally removed. When the specific importance of the sector studied is taken

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into account, it is extremely important to minimize the deadlocks arising from the human mistakes.

The system established provides also a serious profit both in making the orders and in the stock management. We still do not have feedback on the results of the government/insurance company — hospital integration that has been recommended especially for consumables, as this system has not been yet implemented when this chapter is written. However, it is obvious that the system is extremely interesting.

A pharmaceutical including the special purposed ones, SCM system to optimize the supply chain has been modeled and developed in this research. Although the whole supply chain is composed of raw material suppliers, pharmaceuticals companies, wholesalers, hospitals, and patients, we focused especially on implementing a new model, non-traditional VMI system in hospital warehouse by sharing electronic data via WSs between hospitals and wholesalers.

We cannot deny that there is a lot of effort still required to improve the efficiency of the total supply chain with regard to manufacturers, the government, and insurance companies. Also, hospitals must be willing to adopt this system, have total trust in their wholesalers, and share their inventory information with them.

To extend the benefits presented in this chapter, standards for exchanging information electronically must be established and adopted. This is where semantics of WSs begins and occupies a big place in exchanging the data.

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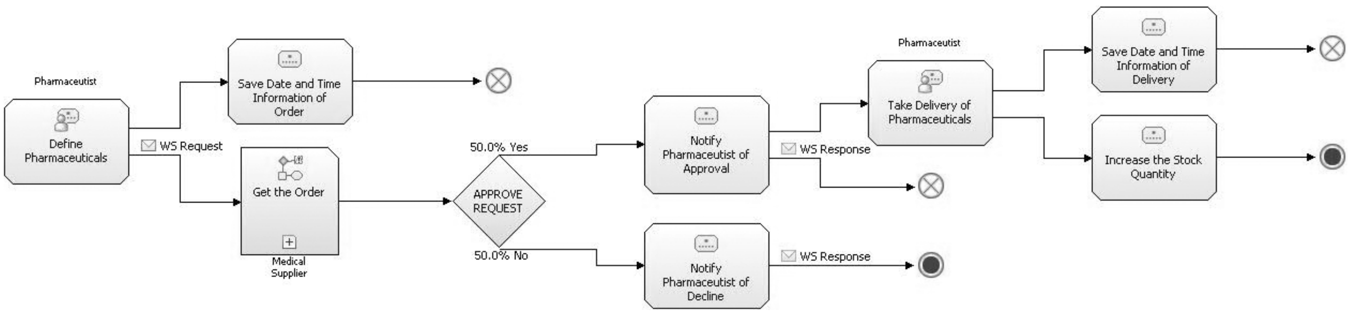
Appendix A



Workflow diagram

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