Service Oriented Architecture Case Study – Solution Overview

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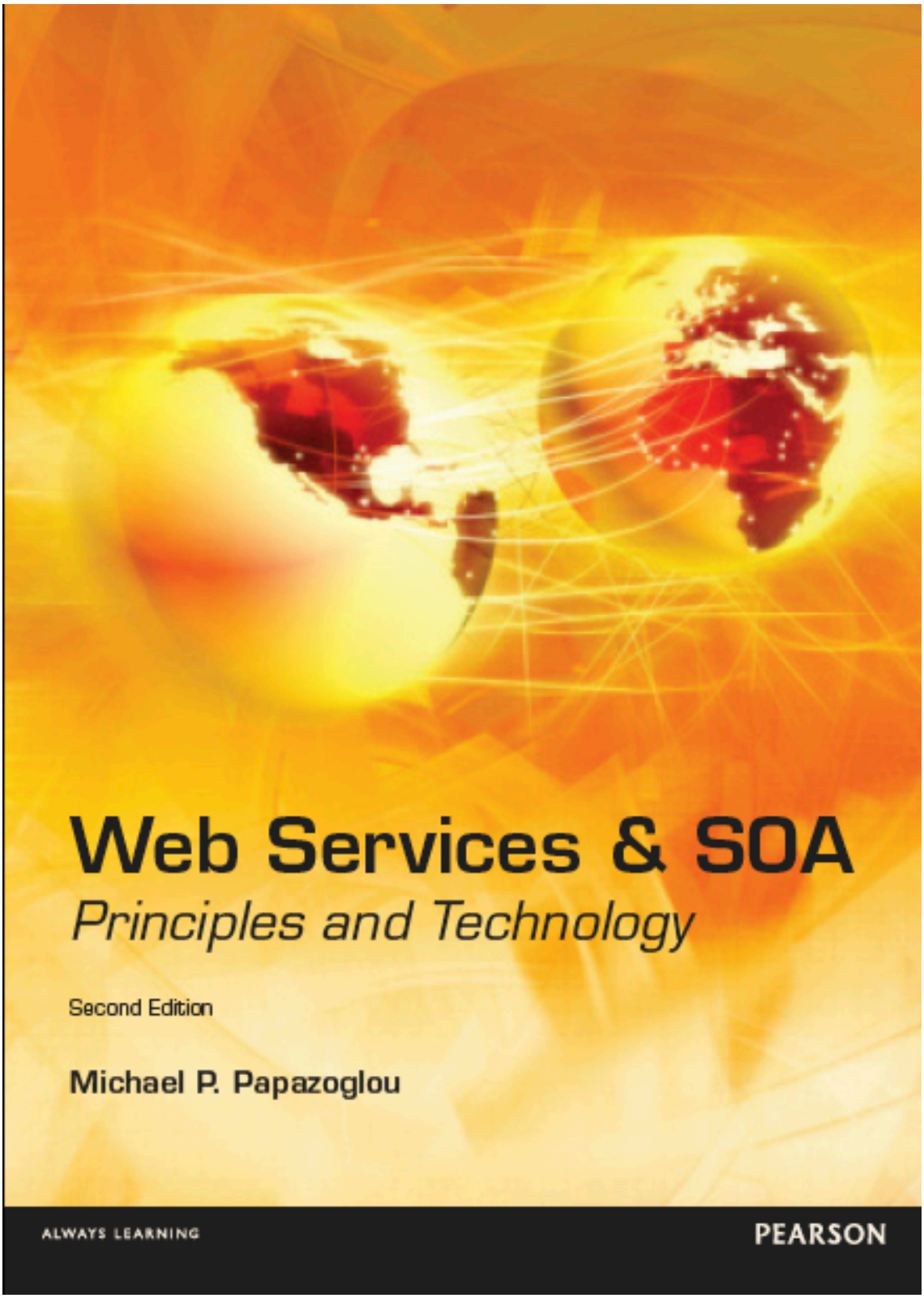
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Solution Overview: Business Process Modelling, Analysis, Design & Implementation[1]

1. Introduction

This report aims at the application of a top-down Service Oriented Architecture (SOA) development approach to the AVERS Supply Chain, which was described in detail in the literature review of part-1.

The remainder of this report is structured as follows: The next section describes the core business processes involved in each domain of the Supply Chain – i.e. Supply, Manufacturing and Distribution. Section 3 covers service analysis and explains the identification of the business services that perform the activities. It provides an abstract view of each service by covering its functionality along with its input and output parameters. Section 4 describes service design and how SOA principles are applied in order to create a complete SOA solution for the entire AVERS Supply Chain. This includes consolidation and composition of services. Finally, section 5 describes the interactions between the core processes using the BPMN 2.0 Modeling approach.

2. AVERS Supply Chain Core Processes

As mentioned in the part-1 of this case study, the ANSI/ISA-95 is a standard that provides models and terminology for defining the interfaces between an enterprise's business system and its manufacturing control systems. In this assignment, ANSI/ISA-95's functional flow data model presented in Figure 1 will be used to define the core processes involved in each domain of the Supply Chain.

ANSI/ISA-95 standard defines 12 core functions regarding manufacturing enterprises and further defines for each of those their inherent sub-functions. Initially only 3 of the functions were defined as vital, since the scope of the document was to deal strictly with the order processing and manufacturing domain of AVERS. However, given the improvements suggested in section 4.3 of part-1 of this case study, it will be required to include 4 additional functions to cover all 3 domains of the AVERS supply chain.

It was decided to leave out of the scope of this project the following functions: Quality Assurance; Product Cost Accounting; Maintenance Management; Marketing and Sales; and Research Development and Engineering. It is believed that these are support

[1]

functions for the core domains of the supply chain, and for the sake of simplicity should not be detailed in the AVERS solution.

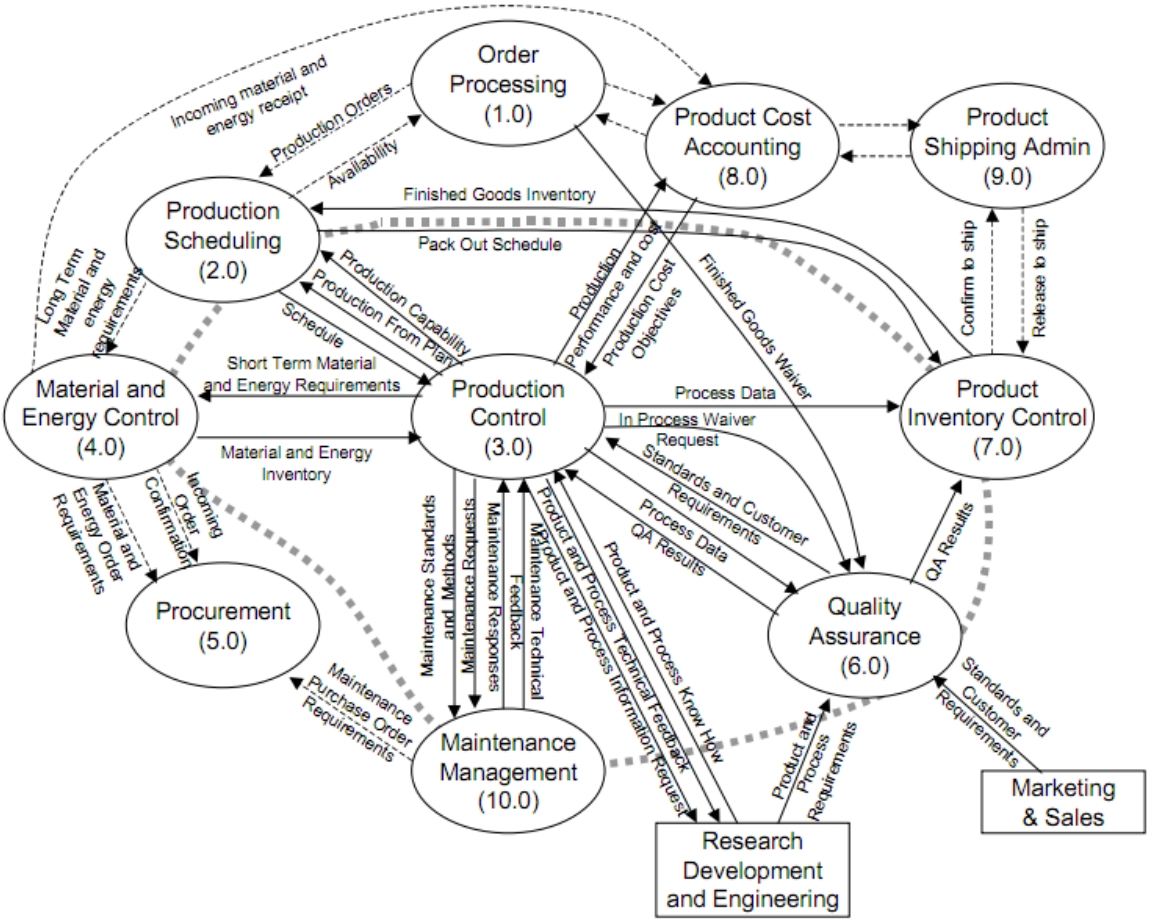

Figure 1 – The Main Manufacturing Functions and Information Flows

The functions, which are identified as our core processes – including sub-processes as defined in the ANSI/ISA-95 standard, are as follows:

- **Order Processing**
  - Customer order handling, acceptance and confirmation;
  - Sales forecasting;
  - Waiver and reservation handling;
  - Gross margin reporting;
  - Determining production orders.
- **Production Scheduling**
  - Determine production schedule;
  - Identify long-term raw material requirements;
  - Determine pack-out schedule for end products;
  - Determine available product for sales.
- **Production Control**

  - Controlling the transformation of raw materials into end product in accordance with production schedule and production standards;
  - Performing plant engineering activities and updating of process plans;
  - Issuing requirements for raw materials;
  - Producing reports of performance and costs;
  - Evaluating constraints to capacity and quality;
  - Self-test and diagnostics of production and control equipment;
  - Creating production standards and instructions for SOPs (standard operating procedures), recipes, and equipment handling for specific processing equipment.
- **Material and Energy Control**
  - Managing inventory, transfers, and quality of material and energy;
  - Generating requests for purchasing of materials and energy based on short- and long-term requirements;
  - Calculating and reporting inventory balance and losses of raw material and energy utilization;
  - Receiving incoming material and energy supplies and requesting quality assurance tests;
  - Notifying purchasing of accepted material and energy supplies.
- **Procurement**
  - Placing orders with suppliers for raw materials, supplies, spare parts, tools, equipment and other required materials;
  - Monitoring progress of purchases and reporting to requisitioners;
  - Releasing incoming invoices for payment after arrival and approval of goods;
  - Collecting and processing of unit requests for raw materials, spare parts, etc., for order placement to vendors.
- **Product Inventory Control**
  - Managing inventory of finished products;
  - Making reservations for specific product in accordance with product selling directives;
  - Generating the pack-out end product in accordance with delivery schedule;
  - Reporting on inventory to production scheduling;
  - Reporting on balance and losses to product cost accounting;
  - Arranging physical loading/shipment of goods in coordination with product shipping administration.
- **Product Shipping Administration**
  - Organizing transport for product shipment in accordance with accepted orders requirements;
  - Negotiating and placing orders with transport companies;

- Accepting freight items on site and releasing material for shipment;
- Preparing accompanying documents for shipment (BOL, customs clearance);
- Confirming shipment and releasing for invoicing to general accounting;
- Reporting on shipping costs to product cost accounting.

Even though it is believed that these processes are all important to the AVERS supply chain, they are still too complex due to the detail placed on some support processes, such as accounting and energy management. Therefore, for the sake of simplicity, a thorough revision in all sub-processes was made, in order to leave only those entirely relevant to the core supply chain.

It was decided to group several the top-level processes that are closely related, such as the grouping of *Order Processing* and *Production Scheduling* in a single core process, to simplify the SOA modeling task.

The modified core processes and their sub-processes can now be defined as follows:

1) **Order Processing and Production Scheduling**
   a. Customer order handling, acceptance and confirmation;
   b. Waiver and reservation handling;
   c. Determining production orders, schedule and available product for sales.
2) **Production Control**
   a. Check accordance of schedule with production schedule and standards;
   b. Performing plant engineering activities and update of process plan;
   c. Issuing requirements for raw materials;
   d. Transformation of raw materials into end products.
3) **Material Control and Procurement**
   a. Managing inventory;
   b. Managing transfers of material;
   c. Placing orders with suppliers for raw materials, supplies, spare parts, tools, equipment and other required materials;
   d. Monitoring progress of purchases and reporting to requisitioners;
   e. Receiving incoming material supplies;
   f. Releasing incoming invoices for payment after arrival and approval of goods.
4) **Product inventory control and Product Shipment Administration**
   a. Managing inventory of finished products;
   b. Making reservations for specific product in accordance with product selling directives;
   c. Organizing transport for product shipment in accordance with accepted orders requirements;

d. Negotiating and placing orders with transport companies;
e. Releasing material for shipment;
f. Preparing accompanying documents for shipment;
g. Confirming shipment and perform invoicing.

These processes and sub processes will be further detailed in the next session of this document in BPMN models.

3 – Business Service Analysis

In this section, the various business services that perform all the process activities in the previous sections are defined in the abstract. A business service basically consists of a template specifying the main functionality of a sub-process, the input and the output parameters.

The Business Services defined in each of the core processes of the AVERS Supply Chain Are shown below.

Order Processing and Production Scheduling:
Order Management Services:

Register Purchase Order		
INPUT	Purchase Order	Customer Name
		Customer Address
		Customer SSN / Tax Number
		Customer Credit Card Number (IF individual)
		Ordered Item
		Quantity
OUTPUT	Purchase Order (Registered)	Order ID (Primary Key)
		Customer Information
		Ordered Item
		Quantity
Verify Purchase Order		
INPUT	Purchase Order (Registered)	Order ID (Primary Key)
		Customer Information
		Ordered Item
		Quantity
OUTPUT	Verification Result	Order ID (Primary Key)
		Boolean (Accepted/Rejected)
Consolidate Single Order		
INPUT	Purchase Order (Verified)	Customer Status (standard/preferred/individual)
		Order ID (Primary Key)
		Customer Information
		Ordered Item
		Quantity
OUTPUT	Purchase Order (Consolidated)	Order ID (Primary Key)
		Customer Information
		Ordered Item(s)
		Quantity

Create BILL		
INPUT	Purchase Order (Consolidated)	Order ID (Primary Key)
		Customer Information
		Ordered Item(s)
		Quantity
OUTPUT	BILL	Order ID (Primary Key)
		Customer Information
		Ordered Item(s)
		Quantity
		Product(s) Price (excluding Shipping Cost)

Customer Relationship Management Services:

Check Customer Type		
INPUT	Purchase Order (Registered)	Order ID (Primary Key)
		Customer Information
		Ordered Item
		Quantity
OUTPUT	Customer Type	Standard/Preferred Retailer / Individual
Check Credit Worthiness (Individual Customers)		
INPUT	Customer Information	Customer SSN / Tax Number
		Customer Credit Card Number
OUTPUT	Credit Worthiness Status	Boolean (Success / Failure)

Production Control:

Production Request Services

Create Production Request		
INPUT	Production Request Information	Product Type ID
		Product Rule ID
		Production Line ID
		Quantity
		Storage Warehouse
OUTPUT	Production Request Order Information	Production Request Order ID
Create Product Rule Not Found Alarm		
INPUT	Product Request Information	Product Rule ID
		Product Type ID
OUTPUT	Alarm Information	Alarm ID
Create Not Enough Raw Material Alarm		
INPUT	Material Information	Material ID
		Quantity
OUTPUT	Alarm Information	Alarm ID
Reschedule Production Request		
INPUT	Production Request Order Information	Production Request Order ID
		Error Type

Production Rule Services

Check Existence of Product Rule		
INPUT	Production Rule Information	Product Type ID
		Product Rule ID

OUTPUT	Production Rule Information Response	Is Production Rule Available (Boolean)
Check For Substitute Product Rule		
INPUT	Production Rule Information	Product Rule ID
		Product Type ID
OUTPUT	Substitute Production Rule Information	Substitute Product Rule ID

Production Line Services

Check Compliance of Production Line to Product Rule		
INPUT	Production Schedule Information	Product Rule ID
		Production Request Order ID
		Production Line ID
OUTPUT	Production Line Information Response	Is Production Line Ready for Product Rule (Boolean)
Prepare Production Line		
INPUT	Production Schedule Information	Product Rule ID
		Production Request Order ID
		Production Line ID
OUTPUT	Production Line Information Response	Production Line ID
		Production Line Resetting ID
		Is Production Line Ready (Boolean)
Allocate Raw Material To Production Line		
INPUT	Production Schedule Information	Product Rule ID
		Production Request Order ID
		Production Line ID
		Quantity
OUTPUT	Material Allocation Data[]	Material ID
		Quantity Allocated
		Location ID
		Product Line ID
		Production Request Order ID
Produce End Product According To Product Rule		
INPUT	Production Schedule Information	Product Rule ID
		Production Request Order ID
		Production Line ID
		Quantity
OUTPUT	Production Data[]	Production Response ID
		Production Lot ID
		Product ID
		Temporary Storage Location ID
Move Product to Inventory		
INPUT	Production Data	Production Response ID
		Storage Warehouse
OUTPUT	Product Movement Data[]	Product ID
		Origin Location ID
		Destination Location ID
		Production Response ID

Raw Material Services

Check Availability of Raw Materials		
INPUT	Production Rule Information	Material ID
		Quantity
OUTPUT	Production Rule Information Response	Is Raw Material Available (Boolean)
Request Transfer of Raw Material to Production Line		
INPUT	Material Movement Request Data[]	Material ID
		Quantity
OUTPUT	Material Movement Data[]	Material ID
		Quantity Moved
		Origin Location ID
		Destination Location ID

Material Control and Procurement:

Inventory Management Services

Check Inventory Status		
INPUT	Material Information	Material ID
		Needed Quantity
OUTPUT	Inventory Information	Amount Avaialbility (Boolean)
		Material Data (ID, name, characteristics, etc)
		Stock Data (number, location)
Create Transfer Material Order		
INPUT	Material Transfer Information	Material ID
		Source Location
		Destination Location
		Requested Quantity
		Requisitioner Data
OUTPUT	Material Transfer Order Information	Transfer Order ID
		Material Data
		Quantity
		Source Location
		Destination Location
		Estimated Delivery Date and Time
Stock Received Material		
INPUT	Material Information	Replenishment Order ID
		Material Data
		Storage Location
		Quantity
OUTPUT	Stock Operation Information	Material Data
		Quantity Stored
		Storage Location
		Operation Success Flag (Boolean)

Material Request Services

Create Material Request		
INPUT	Material Request Information	Material ID
		Requisitioner Data
		Quantity
		Delivery Location

OUTPUT	Material Request Order Information	Request Order ID
		Requisitioner Data
		Material Data
		Quantity
		Delivery Location
Collect Material Requests To Replenishment Order		
INPUT	Material Request Information	Material ID
		Requested Quantity
OUTPUT	Grouping Replenishment Order Information	Replenishment Order ID
		Is Ready to Dispatch (Boolean)
Update Materials Delivery Schedule		
INPUT	Material Delivery Schedule Change Information	Replenishment Order ID
		Material Data
		Quantity
		Delivery Location
		Estimated Delivery Date and Time
OUTPUT	Material Delivery Schedule Information	Replenishment Order ID
		Material Data
		Quantity
		Delivery Location
		Estimated Delivery Date and Time
Check Order Compliance		
INPUT	Replenishment Order and Received Material Information	Replenishment Order ID
		Received Material Data
		Received Quantity
OUTPUT	Order Compliance Information	Replenishment Order ID
		Material Compliance Flag (Boolean)
		Material Quantity Compliance Flag (Boolean)
Check Material Specification Compliance		
INPUT	Replenishment Order and Received Material Information	Replenishment Order ID
		Received Material Data
OUTPUT	Order Compliance Information	Replenishment Order ID
		Material Specifications Compliance Flag (Boolean)

Supplier Relationship Services

Find Supplier		
INPUT	Requested Material and Location Information	Material Data
		Requisitioner Data
		Requested Delivery Location
		Requested Quantity
OUTPUT	Supplier Information	Supplier ID
		Supplier Data (name, address, etc.)
Release Replenishment Order Invoice		
INPUT	Replenishment Order Data	Replenishment Order ID
		Expected Payment Date
		Payment Method
OUTPUT	Replenishment Order Invoice	Replenishment Order Data
		Invoice Data

Notification Services

Notify Requisitioners Material Request Status		
INPUT	Material Request Information	Request Order ID
OUTPUT	Notification Information	Request Order ID
		Requisitioner Data
		Request Order Status
		Notification Date
Notify Requisitioners Delivery Schedule		
INPUT	Request Order Information	Request Order ID
OUTPUT	Notification Information	Request Order ID
		Delivery Location
		Estimated Delivery Date and Time
		Quantity
		Notification Date
Notify Requisitioners Available Material		
INPUT	Replenishment Order Information	Request Order ID
OUTPUT	Notification Information	Request Order ID
		Material Data
		Stock Location
		Available Quantity
		Notification Date

External Supplier Services

Quote Material Price		
INPUT	Material Information	Material Data
		Requested Quantity
		Requested Delivery Date
OUTPUT	Quote Information	Material Data
		Price
		Payment Data
Place Material Replenishment Order		
INPUT	Requested Material Information	Material Data
		Quantity
		Requested Delivery Date
		Delivery Location
		Agreed Price
OUTPUT	Replenishment Order Information	Replenishment Order ID
		Material Data
		Estimated Delivery Date and Time
		Delivery Location
		Final Price
		Payment Data
Check Material Replenishment Order Status		
INPUT	Replenishment Order Information	Replenishment Order ID
OUTPUT	Replenishment Order	Replenishment Order ID

	Status Information	Current Status
		Estimated Delivery Date and Time
		Delivery Location
Check Payment Confirmation		
INPUT	Replenishment Order Information	Replenishment Order ID
		Payment Data (date, amount, mean, etc.)
OUTPUT	Payment Confirmation Information	Replenishment Order ID
		Payment Confirmation Flag (Boolean)

Product inventory control and Product Shipment Administration:

Prepare Inventory Results for Logistics Provider		
INPUT	BILL	Order ID (Primary Key)
		Customer Information
		Ordered Item(s)
		Quantity
		Product(s) Price (excluding Shipping Cost)
OUTPUT	Shipment Information	Ordered Item(s)
		Number of Items
		Warehouse Address (Shipment Pickup)
		Delivery Address
Collect Shipment Quotes		
INPUT	Shipment Information	OrderID
		Ordered Item(s)
		Number of Items
		Warehouse Address (Shipment Pickup)
		Delivery Address
OUTPUT	Shipment Details	OrderID
		Carrier
		Expected Shipment Date
		Expected Delivery Date
		Shipment option
		Total shipment price
Book selected route/carrier		
INPUT	Shipment Details	Carrier
		Number of Items
		Expected Shipment Date
		Expected Delivery Date
		Total Shipment Price
OUTPUT	Approval Status	Order ID (Primary Key)
		Boolean (Approved/Rejected)
Inform pick-up date for products *(Notification)*		
INPUT	Shipment order details	Order ID
		Shipment Order ID
		Shipment Pickup Date
		Warehouse Address (Shipment Pickup)
		Delivery Address
Inform updated Shipment Status *(Notification)*		
INPUT	Shipment order details	Order ID
		Shipment Order ID
		Carrier

		Number of Items
		Expected Shipment Date
		Expected Delivery Date
		Shipment Selected
		Warehouse Address (Shipment Pickup)
		Delivery Address
		Total Shipment Price
Send Invoice *(Notification)*		
INPUT	Shipping Order Confirmation	Order ID (Primary Key)
		Carrier
		Number of Items
		Delivery Address
		Shipment Date
		Customer Information
		Total Shipment Price
		Ordered Item(s)
		Quantity
		Total Price (including Shipping Cost)

4 –Modeling of Core Processes in BPMN

This section describes the modeling of the four AVERS core processes and their sub-process described in section 2 using the BPMN 2.0 notation. The tool used to model the processes was Signavio.

4.1 Order Processing and Production Scheduling

The 'Order Processing and Production Scheduling' directory contains four order processing and production scheduling sub-processes. The sub-processes 'Making reservations for specific product' and 'Supply of Raw Materials' that are invoked in the order processing sub-processes are covered in the 'Material Control & Procurement' core process directory.

4.2 Production Control

The directory 'Production Control' contains sub-processes that model the entire production control process. When a Production Request is received, the process first assures that it has means to fulfill the order by checking if the production process is well known (existence of product rule) and if it contains enough raw materials. If none of these conditions are met, the order is then rescheduled so that these constraints can be further met. If the conditions are met, the process verifies if the needed raw materials are already available and allocates it to the production line. If not it requests its movement to the production line before allocation. When the raw materials are finally reserved for production, the process schedules the order with the allocated

resources and, when finished, transfers the products from its temporary storage to the destination warehouse.

4.3 Material Control and Procurement

This 'Material Control and Procurement' directory contains the sub-processes that are performed by the raw material supply department of AVERS OEM as well as the interactions with the external material suppliers.

There are basically three important entities that the raw material supply processes deal with: the material request orders, the replenishment orders and the material transfer orders. The first correspond the internal requests within AVERS from different departments to the raw material supply department. The second are the purchase orders sent to external material suppliers. Finally, the third are the orders to move stock from warehouses to the locations which requested them.

4.4 Product Inventory Control and Product Shipment Administration

The 'Product Inventory Control' directory contains the BPMN process model covering shipment details like selecting a logistics carrier, organizing the shipment, etc. Furthermore, it models inventory activities such as updating the inventory after sending a product to a customer, sending an invoice to the customer, and so on.

5 – Application of SOA Design Principles

The design of a SOA system is based on a clear definition and description of underlying services, which can then be composed in required ways to execute complete business processes. The Business Services, as we may call them, provide a technical grounding to execute a function, or provide an interface to access a system. The design of these services must be done in such a way that each piece of functionality is modularized properly into a Business Service that can be invoked independently, with the appropriate input parameters. Finer operations that must be executed in a special sequence, or ones that require state to be maintained, must be encapsulated into business functions that can be invoked on their own.

The following is a description of a few design decisions that have been made based on the SOA design principles [13] as outlined in the problem description:

- **High Cohesion**: The business services that have been described must be flexible enough to be able to be executed in any order. The arguments it accepts as input must contain all the information required to perform that business service, so that any chaining of information interchanges between services is not necessary. In the Order Management Business Services description, it can be seen that all the business functions accept the Order Id as the main key for

performing operations. To get any details about orders, or customers related to that order, the Order Id can be supplied to get the initial information, which can then be used to perform additional operations. Any new application or service bus that needs to interface with these services just needs to know the interface definition and make the corresponding calls. This allows us to have an architecture with a high degree of cohesion. If this is absent, we might have different applications with unstandardized interface definitions, different message formats etc. which reduce interoperability. In such a case, more intermediaries like adapters and message transforming components will have to be added. In some cases, the interface return type definitions can be missing key information that is not retrievable by other ways. We have attempted to keep these issues in mind while designing the business services.

- **Loose Coupling**: This is closely related to the principle of High Cohesion. It deals with standardized and self-contained input and output parameters, which means that any application which has this information can invoke the business service. This means that there is no implied information or shared database which supplies working data that is not passed through the business service interface. At the physical implementation level, it will also mean that there is a common infrastructure for invoking a business function, which allows any service to be invoked seamlessly of its physical implementation details (e.g. CORBA, Web Services). Loose coupling also includes asynchrony in operation. For example, the Ordering process is divided into functions like Customer checks, Quantity retrieval, payment processing etc. Each business service operates on its own, and can execute in parallel with the others. On the level of a single process, all operations that can be done in parallel, such as customer checks and quantity retrieval, can be done in parallel. Execution can move on without waiting for the results of any business function. On a process engine level, components that that have a higher priority and/or larger volume, can be made redundant to be able to service requests from many process instances simultaneously.

- **Appropriate Granularity**: Determining the level of granularity for a business function is of prime importance. Choosing a level of granularity that is too fine will result in a very large service portfolio. This will typically include many services that are executed in the same orchestration, and hence which belong to the same logical service. It will result in a cluttered SOA design which might complicate the design of the end business processes. If the level of granularity is too coarse, it might result in a design that makes it impossible to invoke specific business functions. For e.g., in the order process, if approve shipping details is included in the bill generation function, they will be tied together, and

it will be impossible to approve shipping details at a later time, in an asynchronous manner.

It is important to note that the business services defined will be further developed from infrastructural and component based services, so it will always be possible to drill down the business services to finer components. These lower level details of the physical SOA design are out of the scope of this case study.

6 – Overview of the SOA Solution for the AVERS Case Study

This section describes the steps for the implementation of a top-down Service Oriented Architecture (SOA) approach to the AVERS Supply Chain case study, which was described in detail in this document.

The Web Services Description Language (WSDL) files define the business services described earlier in this document, therefore identifying their constituent operations and required parameters. The Business Process Execution Language (BPEL) files define the orchestration of the WSDL services. The BPEL processes are enhanced with transaction-oriented features by the use of scopes, fault and compensation handlers. Finally, we explain of how the designed BPEL processes fit into the BPMN processes described in section 4.

Note:

The processes **Product inventory control and Product Shipment Administration** and **Production Control** are identified to be the "richest" of the processes. They contain most possibilities to show, how BPMN processes can be refined and implemented using BPEL. They also contain interaction with external partners, thus providing transactions. Compensation is modelled explicitly, as well as fault handling. These processes are modelled with all needed "assign"-actions, instantiating all variables correctly. All activities that imply any message exchange like the invoke- and receive-activity are implemented based on the corresponding WSDL-files. Thus, correct operations are assigned to these activities. It should be possible to come up with an executable version of these BPEL processes, needing little effort. (The services need to be implemented, of course.)

The other two processes (Order Processing and Production Scheduling and Material Control and Procurement) are only modelled as skeletons. They can be mapped properly to the BPMN models but they are not ready to execute. They do not contain valid assign-code and the operations are not mapped to the corresponding WSDL-files. (Howver these files are provided and described below.)

7 – WSDL Definitions

In this section, the various Web Services required for the AVERS Supply Chain are identified and designed corresponding to the core processes defined in sections 2 and 4 as per the ANSI/ISA-95's functional flow data model. A total of twelve Web Service Description Language (WSDL) files are defined corresponding to the four basic processes listed below:

Order Processing and Production Scheduling:

- Order Management Services: *OrderManagementService.wsdl*
- Customer Relationship Management Services: *CRMService.wsdl*

Production Control:

- Production Request Services: *ProductionRequestWS.wsdl*
- Production Rule Services: *ProductionRuleWS.wsdl*
- Production Line Services: *ProductionLineWS.wsdl*
- Raw Material Services: *RawMaterialWS.wsdl*

Material Control and Procurement:

- Inventory Management Services: *InventoryMgmtWS.wsdl*
- Material Request Services: *MaterialRequestWS.wsdl*
- Supplier Relationship Services: *SupplierRelationshipWS.wsdl*
- Notification Services: *NotificationWS.wsdl*
- External Supplier Services: *ExternalSuppliersWS.wsdl*

Product inventory control and Product Shipment Administration:

- Customer Services: *ProductInventoryControlCustomerServices.wsdl*
- Carrier Services: *ProductInventoryControlCarrierServices.wsdl*
- Process-internal Services: *ProductInventoryControlProcessInternalOperations.wsdl*

For the Product Inventory Control and Product Shipment Administration process, a WSDL definition for internal services has been designed. BPMN provides the concept of tasks, which was used when modelling. This concept cannot be transferred to BPEL, since BPEL basically knows only the invoke-activity to do some processing. Internal execution of scripts or data collection is not possible. Thus, the internal service provides operations like data collection for the BPEL-process. Furthermore, interaction with external services is split in two parts to clearly show the impact of external collaborators. In this case, there is a carrier service which provides interaction with external carriers and a customer service for customer interaction. Note that there is only one WSDL definition for all carriers. It is assumed that all carriers provide the same operations and data schema.

All the WSDL definitions are designed using the 'Top-Down' approach with the help of the Eclipse WSDL Editor. The details regarding the operations – input and output of each Web Service has already been described in section 2.

Modeling Procedure:

This section describes the procedure that was followed for the WSDL definitions using the Top-Down approach using the Eclipse Editor. Only the Order Management Service has been described in detail here. The same approach was followed to define all the remaining WSDL services.

Definition of Operations:

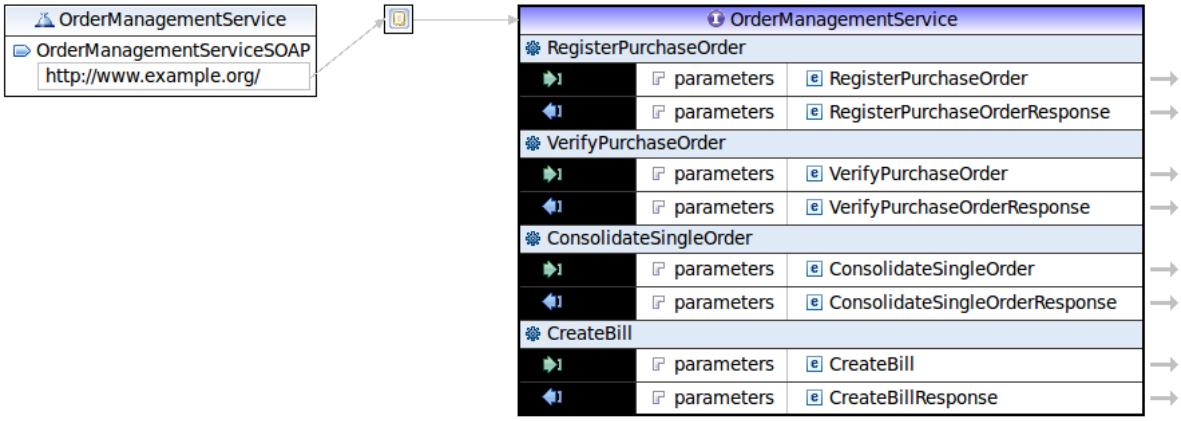

Figure 2 : Web Service Operations Definition in WSDL

Definition of Input and Output:

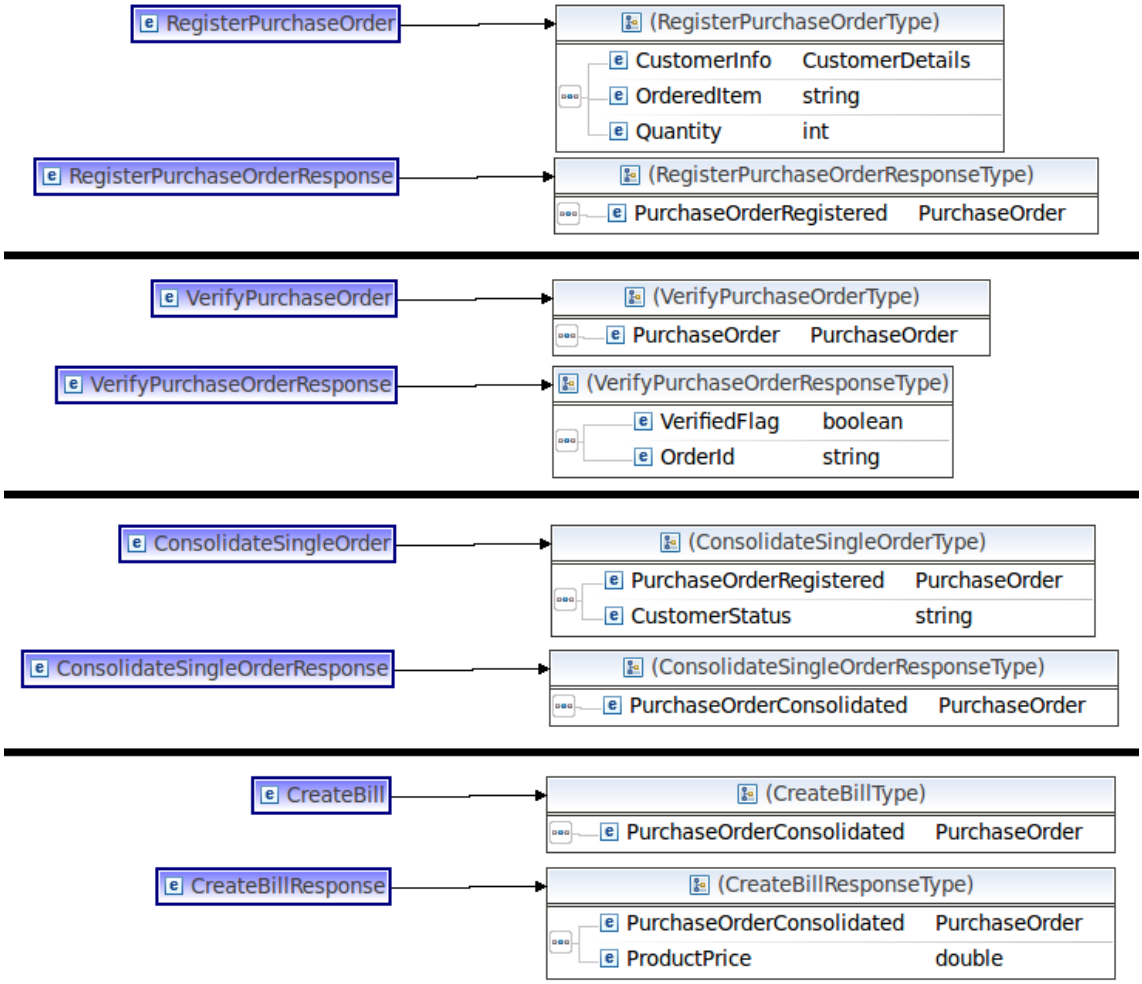

Figure 3: Input and Output Definition in WSDL

Definition of Custom Types:

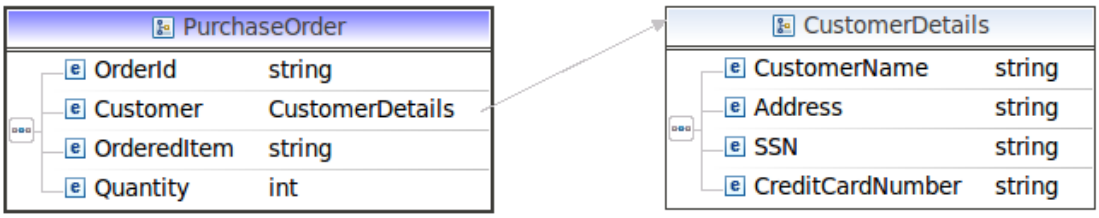

Figure 4: Message Type Definition in WSDL

8 –BPEL Definitions

Four BPEL Orchestration processes are defined in the BPEL directory to reflect the four basic processes of the Supply Chain. The main focus on interactions was given to transactions with external partners. Scopes are defined around the activities that execute transactions.

This section describes the Product Inventory Control and Product Shipment Administration core process. The remaining three core processes follow a similar trajectory.

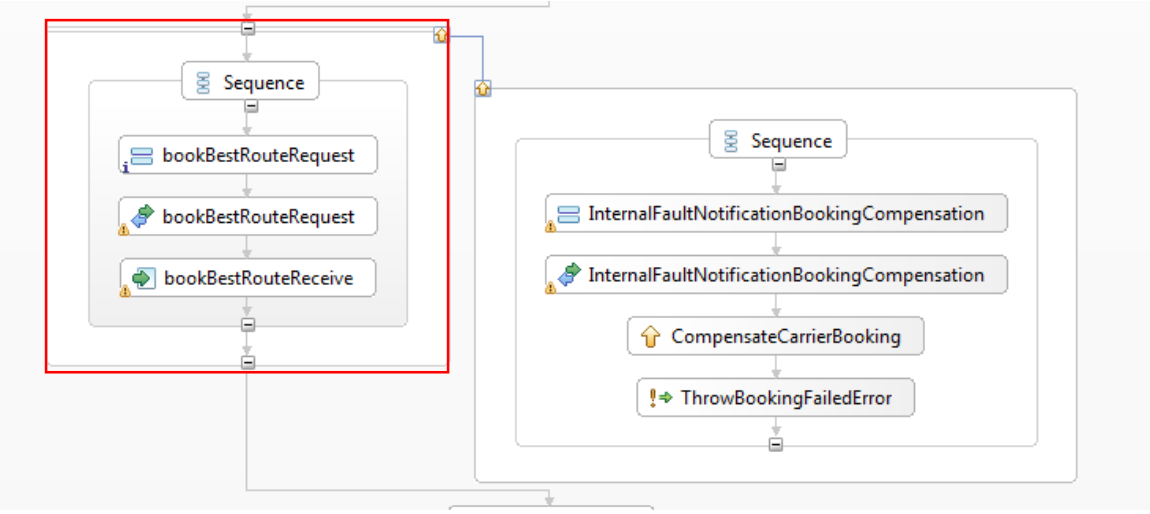

Figure 5: Scope and Compensation

The red frame above marks the scope in a part of the process. Within the scope, a selected route is booked with an external carrier. This transaction is modeled in an asynchronous style. In case anything goes wrong within this scope (or transaction), this booking has to be compensated, which is shown in the right part. Compensation is done in this case be notifying an internal program about this error. Then, further compensation is propagated, in case other activities have to be compensated. An error is thrown, because without carrier, the process cannot continue and terminate successfully. Manual action is needed in this case.

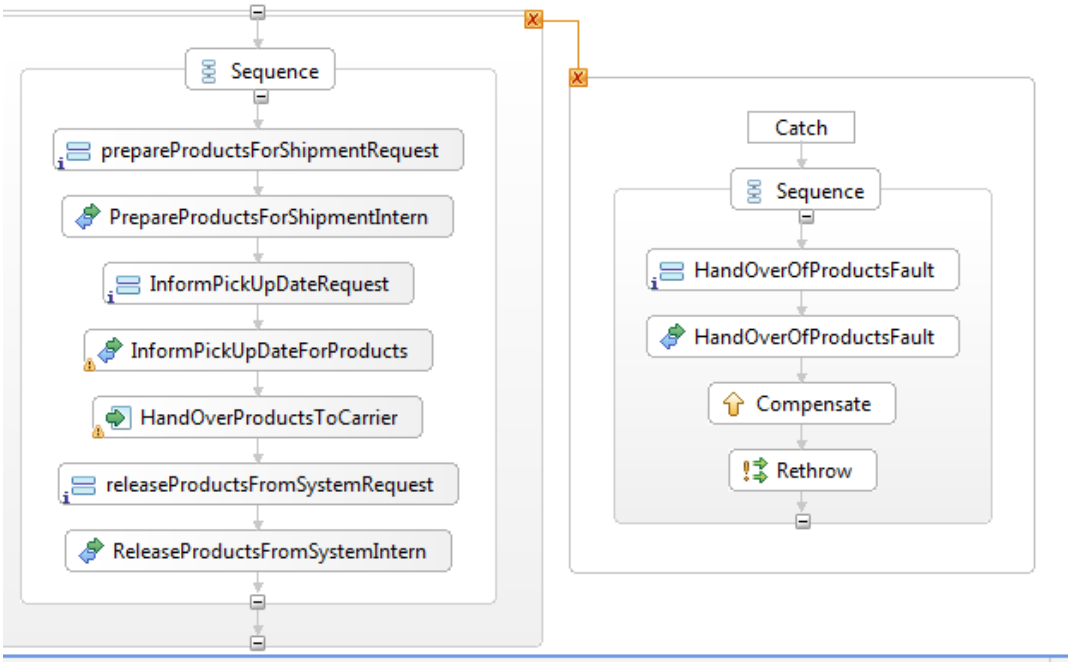

Figure 6: Fault handling

Another example is error handling as described above. Again, the left side shows activities within a scope. Products are prepared for shipment and when they are handed over to the carrier, the process gets a notification. In case something goes wrong here within this scope, e.g. the products are not handed over to the carrier for any reason, a fault is thrown. An internal notification is sent and compensation is triggered. Thus, other activities or scopes that implement compensation and are already completed are compensated this way. Compensation as well as fault handling is propagated from bottom to top. Consequently, the booking of a carrier is canceled automatically by compensation propagation (see example above, which is from the same process).

9 – Relating BPEL Definitions to the BPMN Models

This section explains how the BPEL processes that are designed fit into the BPMN processes that were modeled in section 4.

Four core processes were defined in section 4 to foloow the ANSI/ISA-95's functional flow data model. One BPMN 2.0 diagram was given for each of these core processes. In this section we relate each of these four BPMN diagrams to a corresponding BPEL process.

- Order Processing and Production Scheduling
- Production Control
- Material Control and Procurement
- Product inventory control and Product Shipment Administration

All four BPEL Processes are defined in the asynchronous mode with correlation sets in order to maintain context for a single Purchase Order Request. The scope and compensation spheres have also been modelled in each of these BPEL processes.

9.1 BPEL 01: Order Processing and Production Scheduling

The main functions of this BPEL process are the Customer Order handling, Order Acceptance and Confirmation. It involves verifying the order, registration of the order, verifying the customer liquidity, checking the type of customer in order to consolidate the order and finally preparing the final Invoice (or Bill) for the Customer.

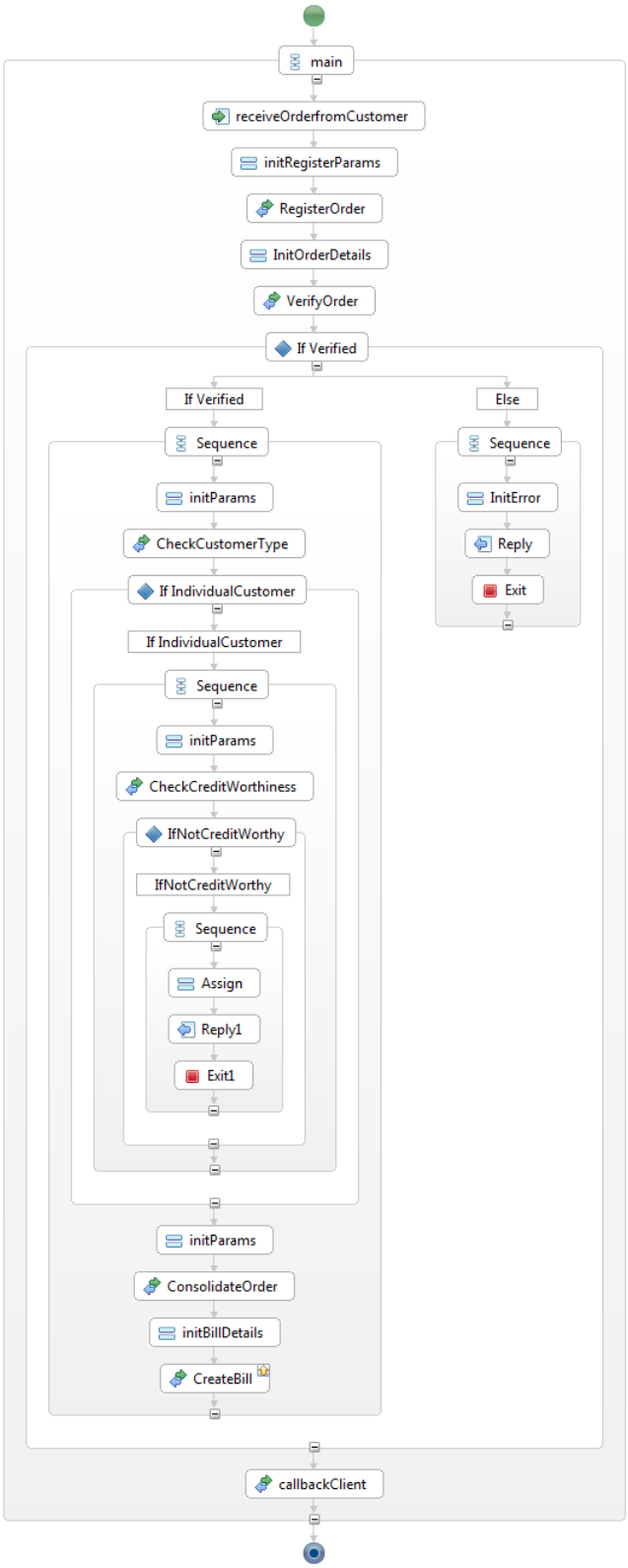

Figure 7: Order Processing Production Scheduling BPEL Process

9.2 BPEL 02: Production Control

This BPEL process performs the main functions such as checking the accordance of schedule with production schedule and standards. It also involves performing plant engineering activities and update of process plan. Furthermore, it also issues requirements for raw materials and transformation of raw materials into end products.

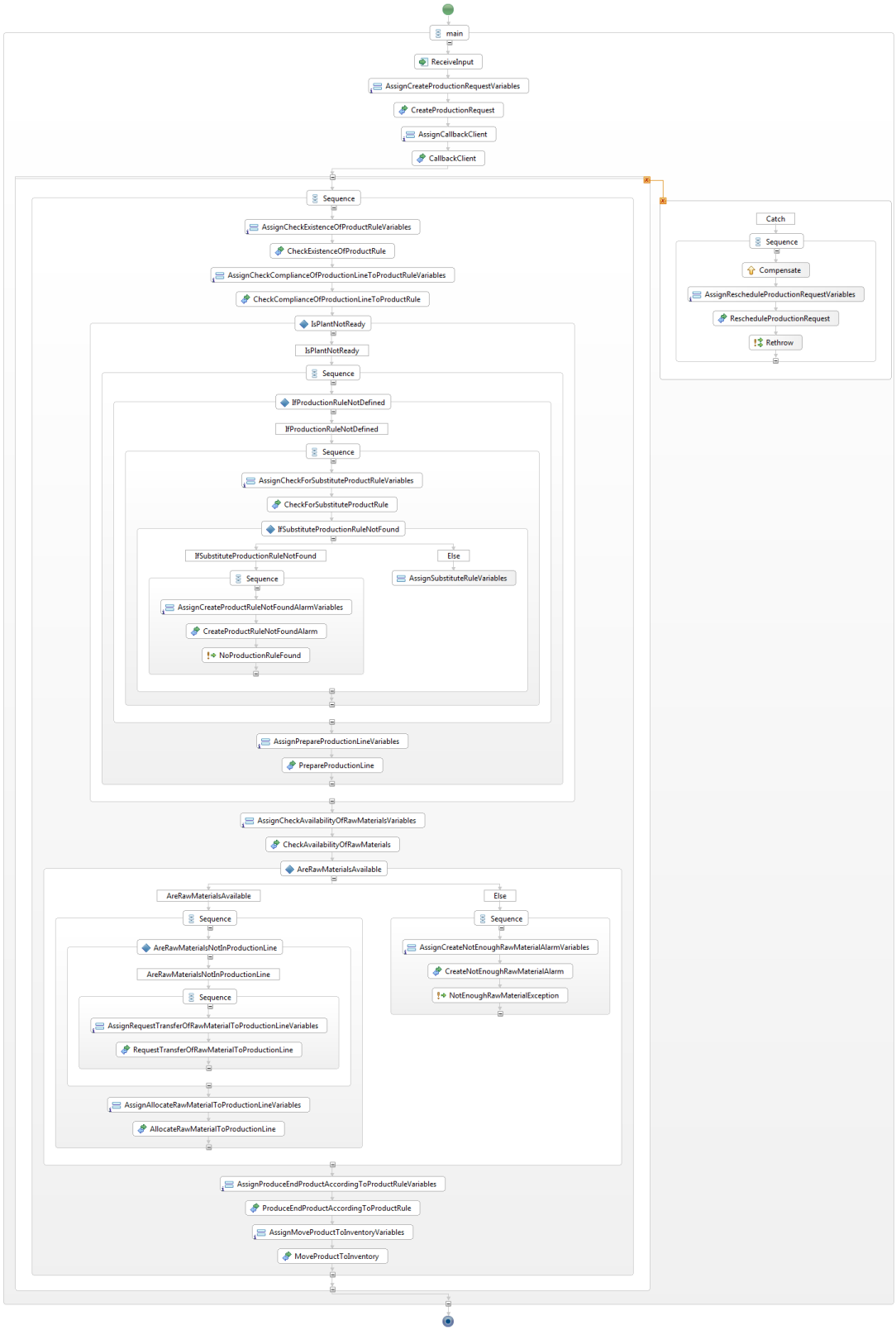

Figure 8: Prodution Control Process

9.3 BPEL 03: Material Control and Procurement

This process is primarily about managing the inventory. It also performs other functions like managing transfers of material and placing orders with suppliers for raw materials, supplies, spare parts, tools, equipment and other required materials. It also monitors progress of purchases and performs reporting to requisitioners. Furthermore is also handles receipt of incoming material supplies, and release incoming invoices for payment after arrival and approval of goods.

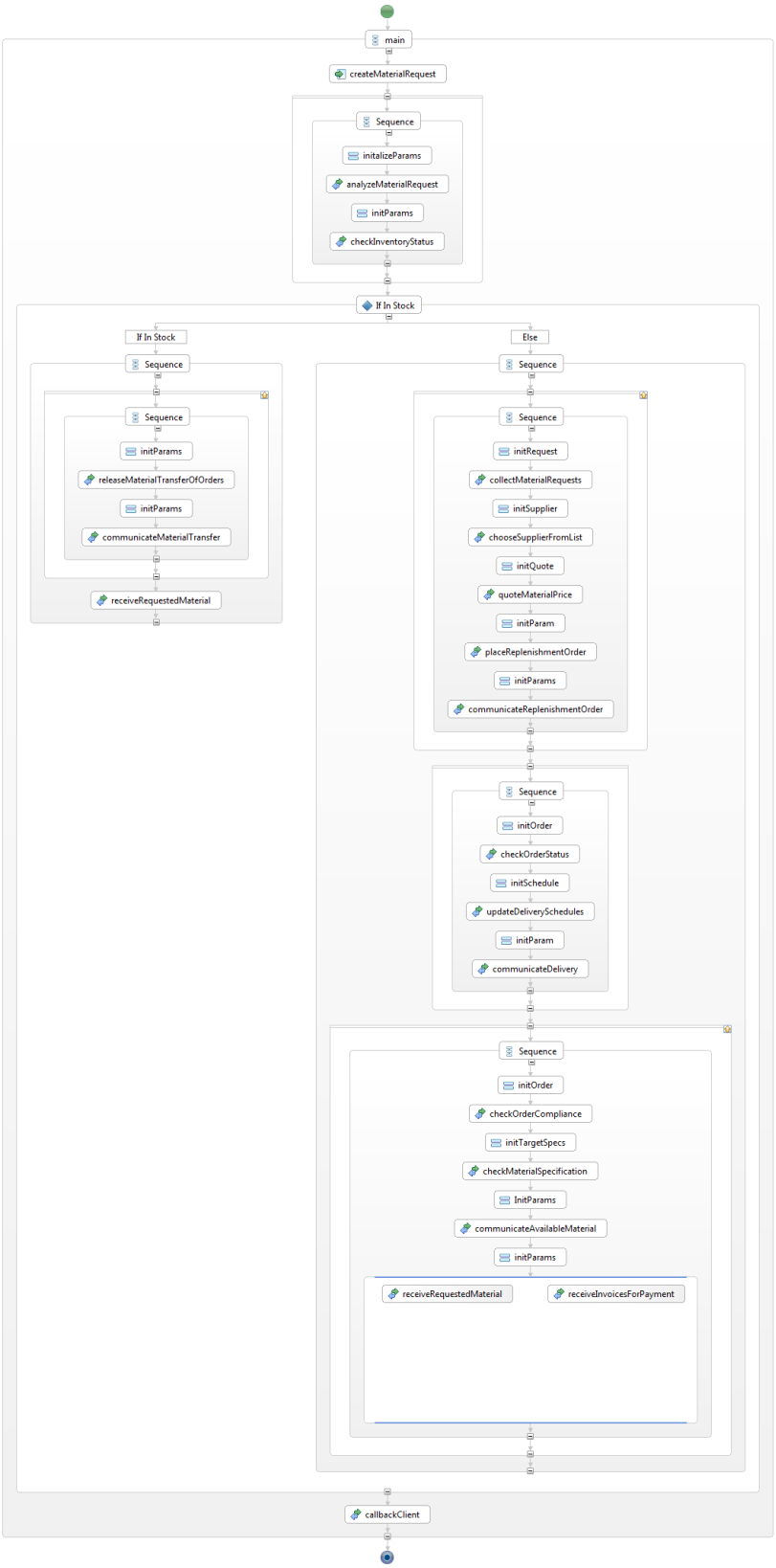

Figure 9: Material Control Procurement BPEL Process

9.4 BPEL 04: Product inventory control and Product Shipment Administration

This BPEL process deals with managing inventory of finished products, making reservations for specific product in accordance with product selling directives and organizing transport for product shipment in accordance with accepted orders requirements. It also involves negotiating and placing orders with transport companies, and releasing material for shipment. Finally, it prepares the shipment confirmation and performs invoicing to be sent to the customer.

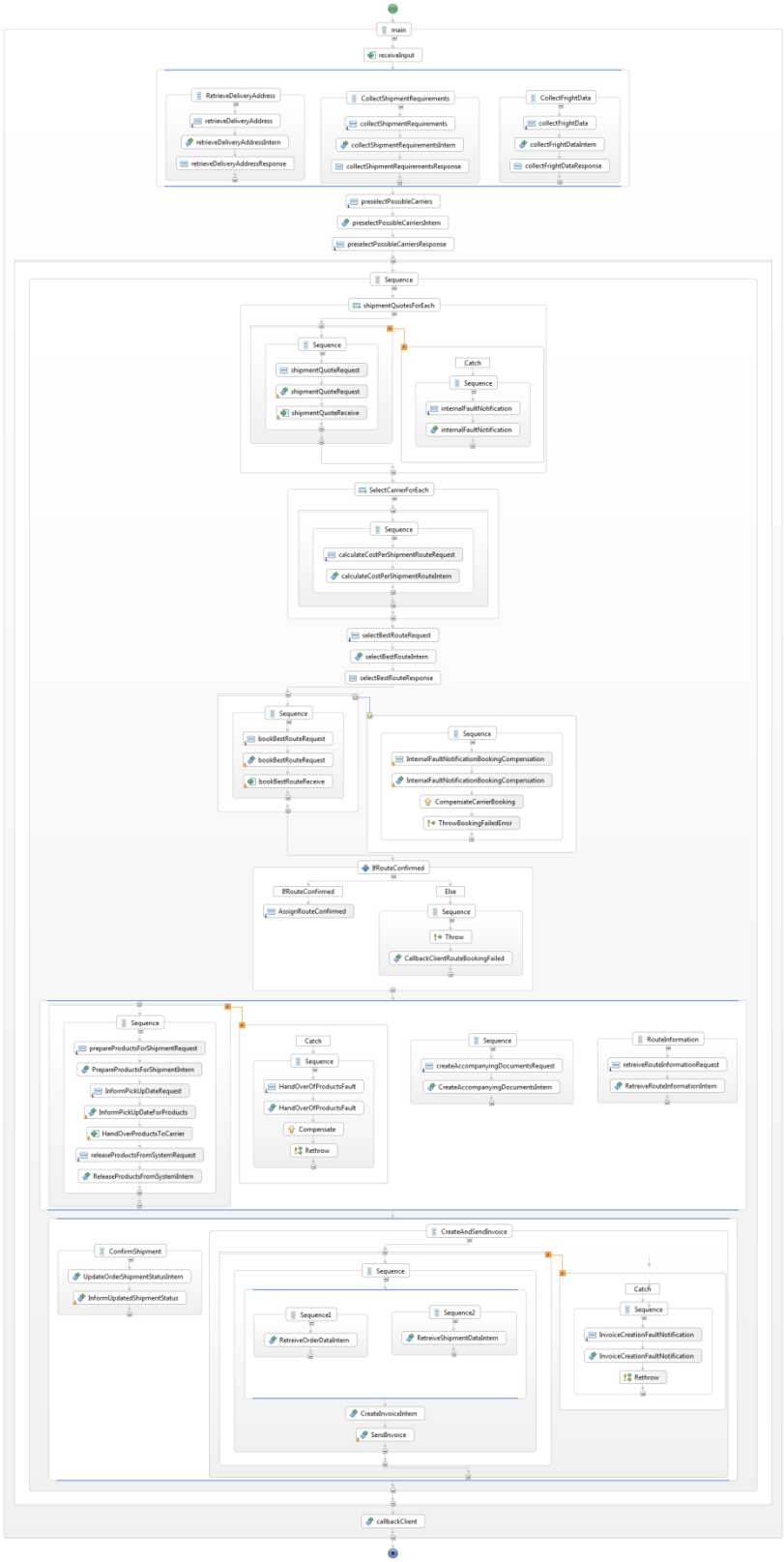

Figure 10: Product inventory control and Product Shipment Administration

9.5 Observations

Basically, the BPEL processes above show the same activities like the BPMN model. BPMN provides the concept of tasks, which was used when modelling. This concept cannot be transferred to BPEL, since BPEL basically knows only the invoke-activity to do some processing. These tasks in BPMN performed mostly some data gathering, such as getting data from a database for example. The idea was to keep the data flow of each process instance low when data is not needed frequently. In BPEL however, data is often modelled using global variables, thus being available during the whole instance life. These activities are not repeatedly modelled in the BPEL since they would not add any value.

Furthermore, BPEL does not understand the concept of multiple instance activities which are activities in BPMN that are executed multiple times and in parallel. This was modelled as a for-loop that executes activities in parallel. Its range depends on the activity before, that means how many activities have to be run in parallel. The for-loop loops exactly that many times, thus it is determined dynamically using variables.

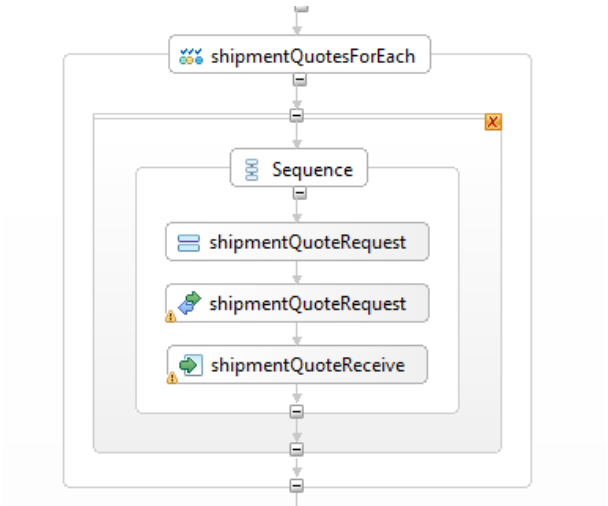

Figure 11: Mapping of multiple-Instance activities from BPMN to BPEL

10 – Summary

The Business Process Modeling of the AVERS supply chain described in this document shows the importance of the top-down SOA development approach. The ANSI/ISA-95 standard is used to define the core processes, along with the respective sub-processes in each domain of the Supply Chain. In the next step, the business services that perform the process activities are designed in an abstract manner, specifying main Functionality, the input parameters and the output of the functionality. The purpose of such an abstract design is for the ease of implementation by any software service. Then, the BPMN 2.0 is used to model the identified processes and sub-processes using

the Signavio Tool. Following this the business services are consolidated and streamlined by applying the different SOA design principles.

The SOA solution provides a BPEL model for a supply-chain scenario. Based on previously modeled BPMN processes, BPEL processes were modeled and refined. WSDL-files for several services in the described supply-chain scenario were created. BPEL is seen as a valid process modeling language to refine a BPMN model. Executable solutions can be achieved. However, this did not go entirely smoothly. BPMN and BPEL have different scopes and expressive power. BPMN in its version 2.0 provides many new modeling artifacts which cannot be mapped easily to BPEL, e.g. simple tasks, human tasks, or more specifically, multiple instance activities. Error handling is even more complex to model from BPMN to BPEL. Thus, it was not easy to map all concepts modeled in BPMN to the BPEL processes.

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