Service Oriented Architecture Case Study – Literature Review

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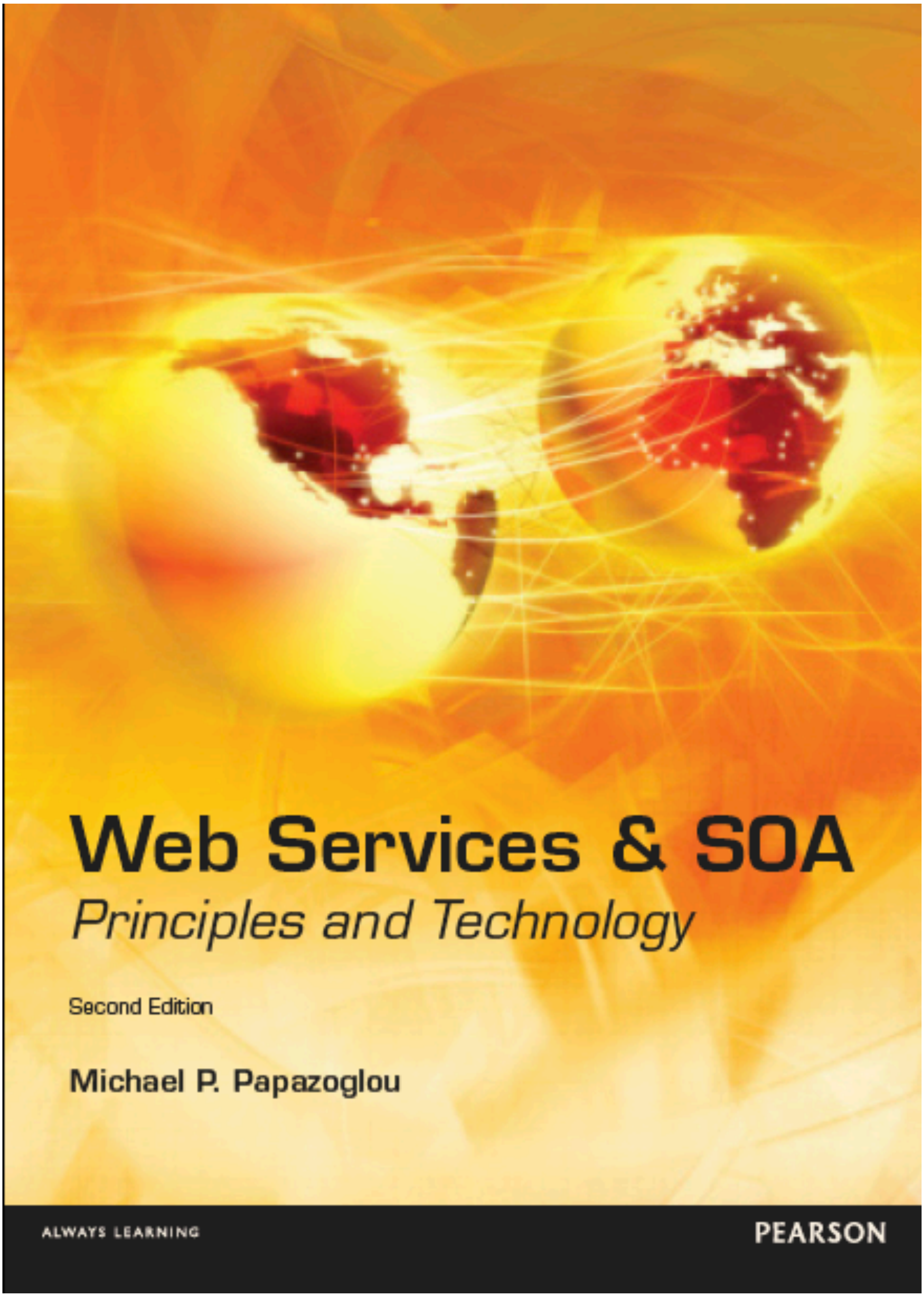
Web Services & SOA
Principles and Technology
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Problem Understanding & Literature Review[1]

1 - Introduction

This document aims at describing the first assignment of the Service Oriented Architecture subject, which consists on a literature review and a proposal of an enhanced description of a given case study.

The report is structured as follows: First the literature study is presented highlighting the role of IT in the manufacturing sector with special focus on SOA. Then, the case study is briefly described and the improvements proposed after the literature review are discussed.

2 – Literature Survey

2.1 - Original Equipment Manufacturers (OEM)

Original Equipment Manufacturers (OEM) appeared as a result of the changes in the manufacturing process and business model to use third parties as subcontractors or suppliers of specific parts in order to integrate them later into the final product, therefore an OEM takes an important part in the supply chain. A definition of the concept describes it as an enterprise who “manufactures products or components that are purchased by a company and retailed under that purchasing company's brand name. OEM refers to the company that originally manufactured the product. When referring to automotive parts, OEM designates a replacement part made by the manufacturer of the original part. In this usage, OEM means "original equipment from manufacturer" [1].

Our case study is related to the automotive industry, where the use of subcontractors in the form of OEMs is widely practiced. This is possible due to the nature of the car manufacturing process which comprises an assembly line where the components are brought together in a predetermined order. The characteristics related to the assembly line have been evolving over time; especially with innovative techniques developed in Japan where Toyota achieved a great success with their Toyota Production Line (precursor of the Just In Time inventory system). Standardization and definition of clear specifications has made possible the integration of OEM into the production line and the supply chain in general.

2.1.1 OEM/Supplier Integrated Model

The OEM/supplier relationship is highly integrated with a significant amount of interdependence. Although historically OEMs held the upper hand, the dynamics are changing such that suppliers can play an increasingly strategic role with OEMs going forward.

2.1.2 OEM Platforms

Platforms are typically developed by OEMs over a period of more than one year, to be used for a few car models over three to ten years, depending on the models' success. It costs less to change the exterior of a car and keep the same platform than to start a new platform altogether. Specific car model "programs" are generally won by suppliers by bidding on various systems and components used in OEMs' proprietary platforms. Suppliers winning programs on an OEM's platform will often do so for the various car models derived from this platform.

2.1.3 The Three OEM Sector Tiers

The original equipment supply sector is generally divided into several tiers. Tier 1 suppliers are the larger, more diversified companies that produce an important variety of finished parts and equipment and assemble them (including complete vehicle assembly in some cases). They also provide engineering and design services for their OEM clients. In producing modules, systems or assemblies for OEMs, Tier 1 suppliers may rely on other suppliers for some components or parts. Tier 2 suppliers, depending on their level of sophistication in the value chain, are typically more specialized in their product offering, and make the components that will be integrated by Tier 1 firms, such as transmission gears, electronics, speedometers and seat covers. Tier 3 suppliers generally sell basic components or raw materials to the other suppliers. Figure 1 shows this 3-tier schema. [2]

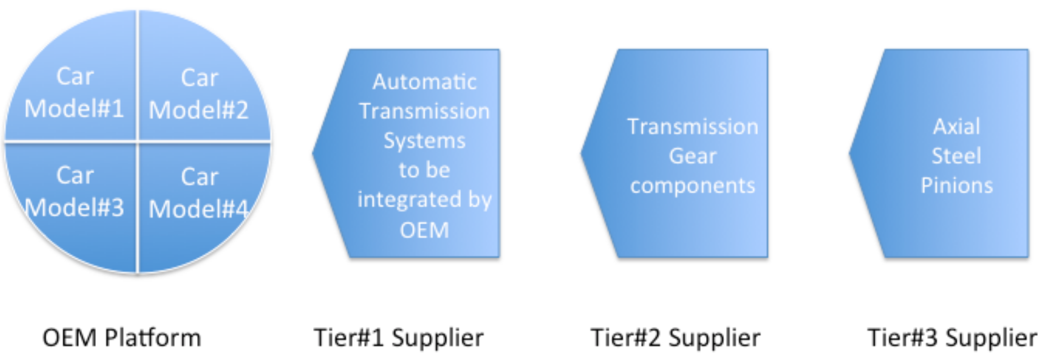

Figure 1 - Typical Auto Supply Chain

2.1.4 Automotive Parts Market

In spite of the latest setbacks, the automotive sector still plays an important part in the economic activities of many countries. The automotive parts consumption is linked to the demand for new vehicles, since roughly 70% of U.S. automotive parts production is for Original Equipment (OE) products. The remaining 30% is for repair and modification (aftermarket). If vehicle production goes down, automotive parts production and sales follow. For those suppliers that were able to survive the downturn in 2009 and lower their break-even point, 2010 was a better year than expected. Suppliers were able to increase efficiency and lower their break-even point based on U.S. sales of passenger cars and light trucks to between 9.5 and 11 million. U.S. sales were 11.5 million units in 2010, allowing many suppliers to see some profit. [3]

Competition was also growing as foreign suppliers opened shop in North America. An estimated 800-1000 suppliers from overseas built plants in North America in the past 20 years, creating a mass global "localization" of the supplier sector. Some foreign suppliers, especially European companies, that expanded businesses in North America to supply their Detroit 3 customers, are also trying to move away from Detroit 3 business to Asian automakers. However, Japanese suppliers are not immune either. Suppliers in North America all face competition, historically high material costs, and demanding customers, although the foreign suppliers face fewer legacy costs and so tend to operate more efficiently than their U.S. counterparts.

Automakers, such as Ford, are attempting to design global platforms allowing the vehicle to be made in Asia, Europe and North America using the same platform. Global platforms reduce engineering costs, simplify manufacturing processes, and improve quality by reducing variability. Other efficiencies gained by the volume of the shared platform include working closer with suppliers from the design of parts to the production of the car which will cut component cost and retail price. For example, the Ford Focus will use 80 percent common parts and 75% of the same supply base. Large regional suppliers are a shrinking part of the market. [4]

2.1.5 Impact of E-commerce, Globalization and Regional Clusters on OEM

The evolution of the market and development of new technologies have impacted the way in which manufacturing is performed and, in general, the aspects to be considered by the whole automotive industry for keeping its competitiveness. About 15-20 years ago Computer Integrated Manufacturing (CIM) was the paradigm for future competitive manufacturing. Already several years ago, the concept had lost its attractiveness as a holistic strategy, not least due to a re-assessment of its pre-dominating philosophy of centralization and technology-centrism. Today, to some extent similar concepts for the integration of the supply chains (SCM) and the interaction with (potential) suppliers and customers (e-commerce) are implemented. The knowledge management discussion could be mentioned in this context, too. The issue of excessive centralization and orientation at technological solutions is again on the agenda. And the automotive industry is at the forefront raising, for instance, the question of balance of power in supply chains and of access for small and medium sized enterprises.

The interviews as well as the literature underline the precursor role of the automotive OEM with respect to the use of new information and communication technologies like Internet based manufacturing concepts. The vision of universal digitalization (even including virtual reality) seems to drive strategy developments to a significant amount. The attempts go in both the directions of suppliers and consumers.

Internet (technology) is considered a major enabling and determining factor of the re-structuring of the supply chain. Furthermore, the expectations that the new communication possibilities mainly support globalization and global sourcing are to some extent contradicted by the increasing relevance and targeted development of regional automotive clusters which seem to make use of and profit even more from electronic communication.

Another important point in this respect is the commitment to general versus proprietary or sector-specific standards and solutions. The latter is or at least has been the dominant approach in the automotive sector as many existing standards with respect to manufacturing and the existence of an own net in Europe (ENX) indicate.

Data from the 2001 Fraunhofer ISI Manufacturing Innovation Survey in German industry reflect this situation (see Figure 2). While automotive suppliers only show average or less (compared to final producers) activities in e-business, the specific exchange of product, production or machine data (teleservice) is comparatively more common for them. Some suppliers expressed concerns about obligations to participate in OEM-specific electronic systems.

The impact of the automotive OEMs' e-strategies towards the consumers only has an indirect, nonetheless important, impact on manufacturing. The trend is towards build-to-order which is already common in Europe and finally towards online ordering by the consumer. This is combined with shorter lead times and more variants which might call for decentralized or localized solutions as small, flexible factories integrated in supplier parks and using desk top manufacturing processes in the long run. [5]

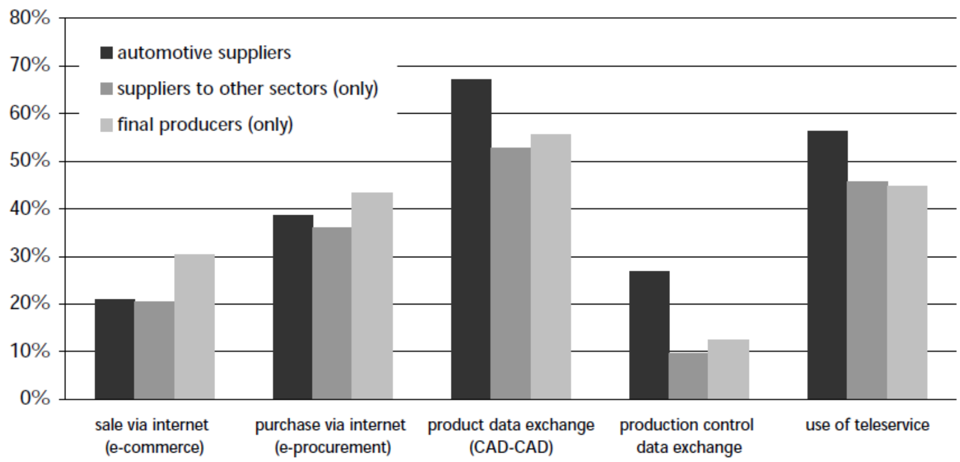

Figure 2 - Use of E-business-related Technologies with Automotive Suppliers Compared to other Company Groups in Germany

2.2 – The role of IT in Manufacturing

The trend for manufacturing companies is clearly given: they have to become more flexible and agile to face the challenges of today and tomorrow as business models change. But today's IT systems of companies are very often inflexible, hard to maintain, difficult to enhance or even difficult to support. Business relations between suppliers and OEMs change over time. IT systems of both sides, OEM and supplier, need to reflect this reality by increased flexibility. They need to be able to handle all these different requirements involved by different partners [6].

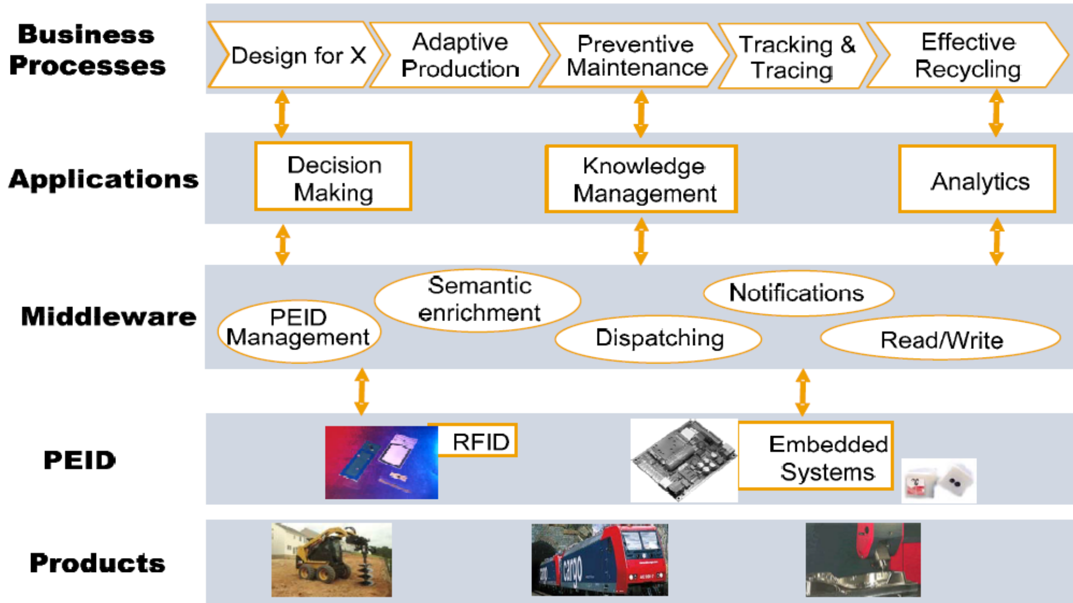

Figure 3: Example of System Architecture [8]

Figure 3 shows a high-level overview of possible system architecture for a manufacturing company. It shows clearly the fact that to manufacture proper products (or parts in the case of an OEM), different systems have to communicate with each other. These systems are heavily based on IT practices. Business processes are connected to application systems. Application systems rely on middleware to be able to communicate with other applications and systems. Given these interconnections and dependencies, IT plays today a major role in manufacturing.

Enterprises are separated into several layers, such as hop Floor, Plant Computer Room (Office Automation), Plant or Enterprise Manufacturing Operations Management, Enterprise Data Center, etc [6]. Figure 4 illustrates an enterprise from a logical point of view. The figure corresponds to the ISA-95 Enterprise Domain Hierarchy. ANSI/ISA-95 is an international standard. ISA-95 describes “integration of enterprise and control systems” [10] and provides models and terminology.

The highest level in the figure below describes planning and logistics tasks such as the basic plant schedule, delivery, shipping, etc. This layer is mainly based on enterprise systems and interconnecting middleware. [6]

Level 2 represents the operational level (work unit). Monitoring and control of production work processes are the tasks systems have to accomplish. Level 1 describes manipulation and sensing of these processes. Level 0 is defined as the shop floor where the actual production process is performed.

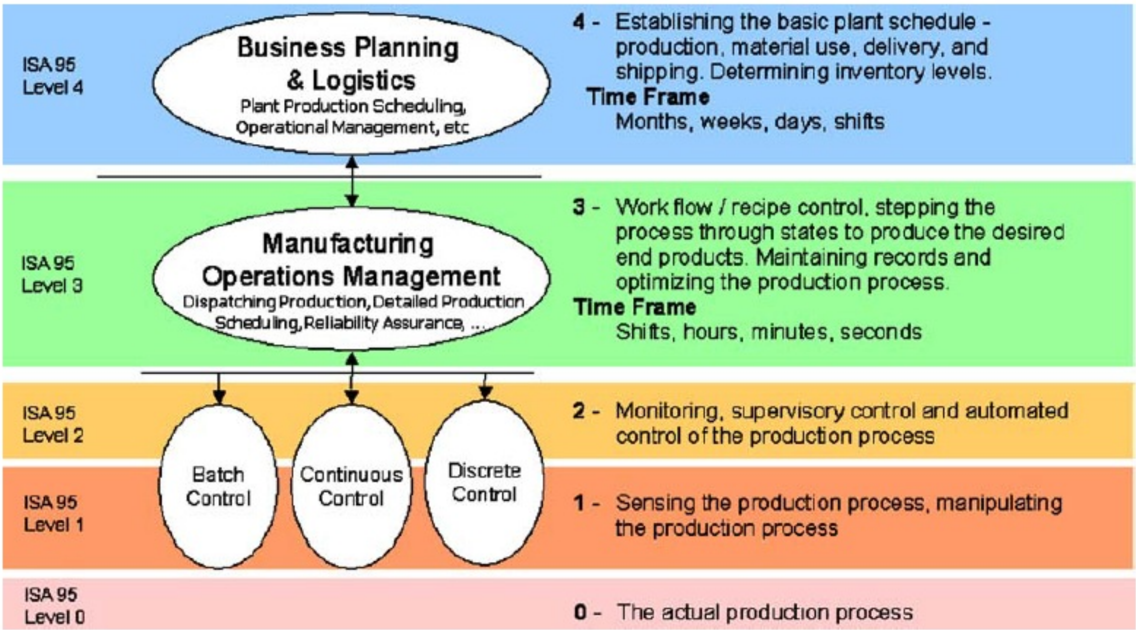

Figure 4: ISA-95: Domain Hierarchy [7]

In the 3rd level from the top manufacturing operations are managed. Main tasks are production dispatching, detailed scheduling of manufacturing. This level makes use of manufacturing systems which includes real-time middleware to exchange production data between different systems. Manufacturing Operations Management (MOM) is used to analyze and maintain data and possibly to optimize production processes. [6]

3 – Enterprise & Manufacturing SOA

As Figure 4 shows, it is impossible to imagine manufacturing today without the support of IT systems. Furthermore, IT systems must be able to represent the flexibility involved in changing business relations and requirements for fast changing environments. In many companies, the systems landscape is also very diverse and does not provide standardized integration. [11]

Service Oriented Architecture (SOA) is a way to tackle these problems and build a standardized and flexible service environment [12]. Recall that an SOA can be described as “a logical way of designing a software system by providing services via published and discoverable interfaces” [13]. Services are pieces of software that are accessible through well-defined interfaces. Implementation details of services are hidden. A service can be consumed when needed using the defined interface(s). SOA aims to create a highly interoperable and extendable architecture by loosely coupling services.

3.1 SOA in Manufacturing

SOA is a mean for companies to overcome problems as described above. It provides a flexible architecture that is better to maintain and in most cases easier to adapt to new requirements because of its architectural principles and style. According to AMR Research, companies see an increased need for integrated IT architectures in the manufacturing domain [6]. For manufacturing companies, it becomes more and more important to have appropriate information at the right time at the right place in the manufacturing factory. SOA is a way to adapt information flows and systems quicker than in tightly coupled systems.

Integration of suppliers into the OEM manufacturing systems or deployment of OEM systems at the supplier's side involves high expenses. This leads to the need for open, but secure communication with suppliers worldwide [6]. This publication also proposes a vision for manufacturing-integrated SOA which is shown in the figure below.

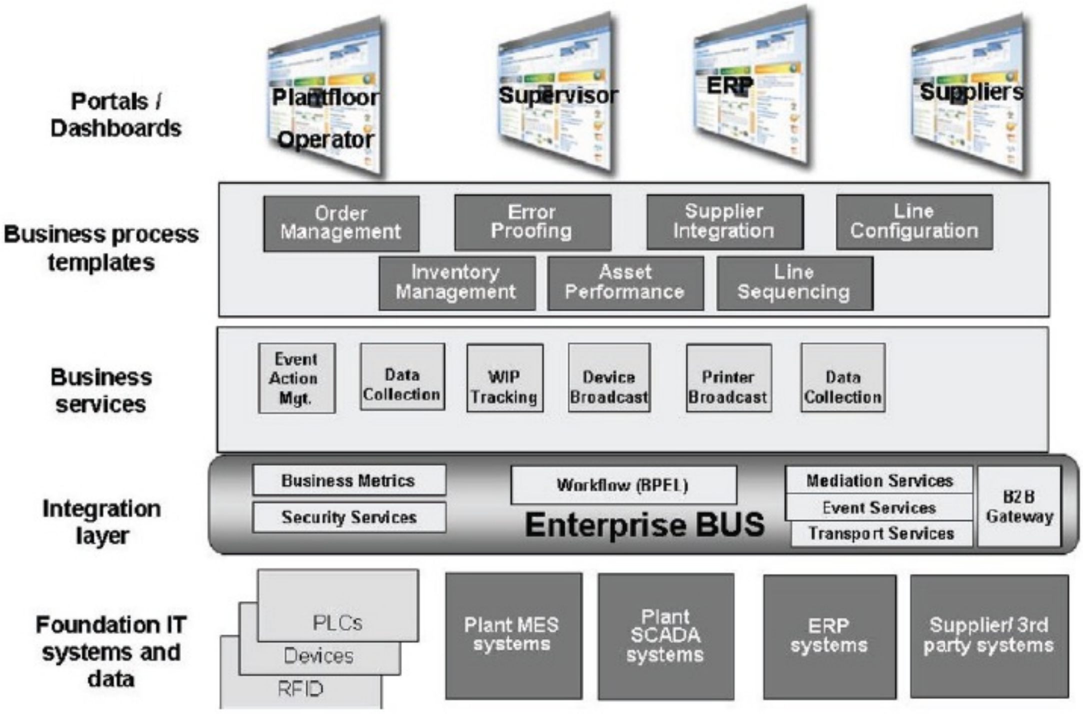

Figure 5: Overall SOA for Manufacturing Vision

Figure 5 shows the functional layers of the proposed SOA for manufacturing. The "Foundation IT systems and data"-layer includes existing and legacy applications. The basic usage of business' data is depicted by them since they represent so called mission critical systems and applications. On top of this layer, the Integration Layer can be found. A common way of representing integration is through an enterprise service bus (ESB) [13]. It offers transportation, security, mediation to applications and it can also provide a business process engine.

The middle layer represents Business services. It is seen as an abstraction layer of services that sits on top of the lowest layer, the Foundation IT systems. Services are wrapped business applications of this lower layer. The next layer is the Business process templates layer. Services of the layer below are combined together to more complex constructs and even new services. This is a fundamental principle of a SOA. These resulting constructs or services are represented by business processes. The top layer is the Portal/Dashboard layer. It provides visualization and data aggregation to users [6].

Finally, Figure 6 combines the Enterprise SOA and the Manufacturing SOA. Manufacturing SOA is part of the overall Enterprise SOA and it is designed for manufacturing operation specific purposes. The Enterprise SOA provides a higher-level view on systems, processes, services and data granularity. To the left of the figure, requirements and the focus of both SOAs are given. It is clear that the focus of an Enterprise SOA is different and on a higher level than the manufacturing's SOA which is more on product level than compliance or enterprise-wide processes.

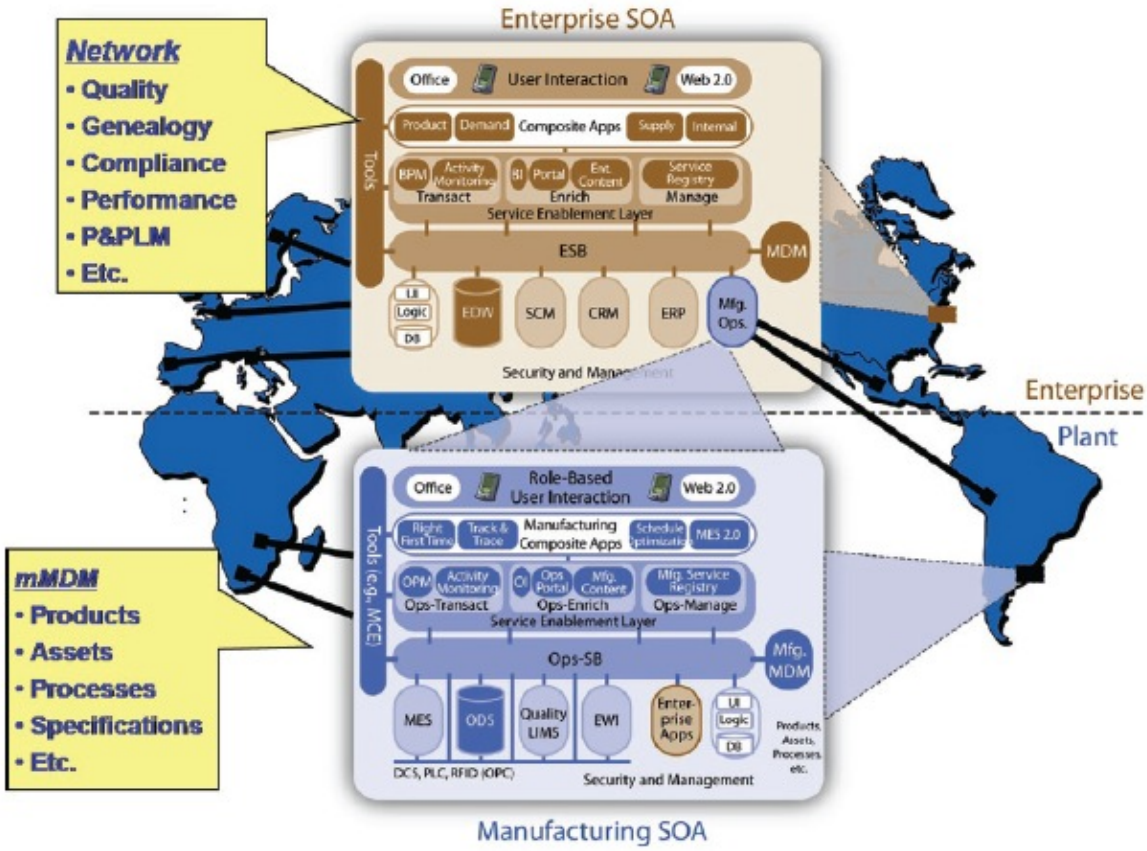

Figure 6: Manufacturing SOA as part of an Enterprise SOA [6]

4 – The AVERS Automotive Supply Chain Case Study

4.1 Introduction

The comprehensive case study consists of an automotive supply chain example that aims at the development of a Service Oriented Architecture (SOA) solution to effectively process the activities within this chain. AVERS (Advanced Automotive Parts) is a hypothetical manufacturer of specialty automotive parts, producing from power train components to steering and braking systems, thus playing the role of an OEM (Original Equipment Manufacturer).

The supply chain concept is on the core of the automotive industry. It essentially consists of three parts: supply, manufacturing and distribution. In this scenario, AVERS stands on the manufacturing part, acquiring simpler individual parts from its suppliers, combining them to produce the automotive parts and working with its distributors to ensure the built parts will reach its final customers, which, in turn, are basically car assemblers and automotive part dealers.

According to the case study, the current IT landscape of AVERS does not meet the performance, flexibility and adaptability requirements expected on an automotive supply chain. Systems are not well integrated, thus often requiring manual data entry, production planning and inventory level control are not managed and the level of detail and accuracy on the information available is not satisfactory, to summarize some of the problems. Therefore, an Order Management System (OMS) should be implemented to enable the SOA approach on AVERS supply chain, collecting information from disparate systems, producing data in an agreed common format and unifying the disparate processes into one consistent order process flow across not only all internal business units of AVERS, but also its chain partners.

4.2 The Proposed SOA Solution

In order to achieve a robust SOA solution for the AVERS' supply chain case, some main processing steps are proposed to be introduced on the OMS. They are listed as follows:

1) Registration of a new incoming purchase order from a customer;
2) Verification of order completion;
3) Check customer relationship type and credit worthiness;
4) Consolidation of all items on a single purchase order per customer;
5) Creation of a bill;
6) Check of inventory levels and triggering of stock replenishment if needed;
7) Sending of inventory data to a logistics service provider which is responsible for routing the shipment of the items to the customer;
8) Approval of shipment details and sending of final invoice to the customer;
9) Negotiation of payment details.

These steps present a simplified approach of the purchase order processing by the automotive supply chain around AVERS. Thus, based on the literature study described earlier in this document, some suggestions are made in order to improve the detail level and realism of the AVERS case study, specifically concerning the manufacturing part of the process. Such suggestions are depicted on the next paragraphs.

4.3 Improvements Regarding the Manufacturing Part

The part that concerns the manufacturing process of the automotive parts by AVERS in the problem statement is rather simplistic. It states that:
"The Inventory is checked against the appropriate quantities required by the purchase order. If there is insufficient stock of the parts required, an inventory replenishment process can be initiated to move stock from centralized warehouses to subsidiary warehouses."

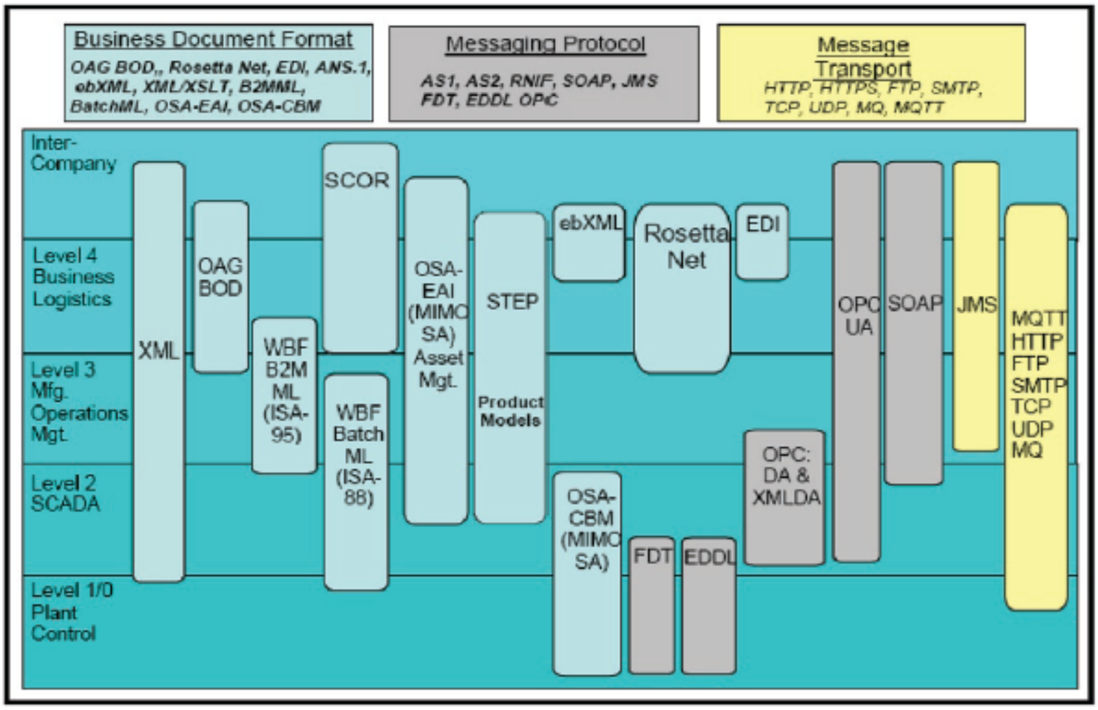

Figure 7 Standards for Manufacturing Systems Integration

As it can be observed, the problem statement does not mention the manufacturing process of the automotive parts. It considers only that AVERS replenishes its stocks by repositioning parts among its warehouses. Such parts, naturally, have to be produced at some point in time. Therefore, it is suggested to improve the case study by including the situation when stock levels run too low or even are empty, demanding that production orders are sent to the manufacturing units of AVERS.

To improve the description of the manufacturing scenario, one important approach is to apply industry widespread standards. Figure 10 [14] shows some typical standards used in the industry in general, either for intercompany communication or internally in an enterprise and, also, regarding different aspects, such as business documents formats or messaging protocols.

One of the standards typically used on the manufacturing level (Level 3 in Figure 4) is the ISA-95 norm. Applying this standard to the AVERS case study constitutes a sound approach as already mentioned in part VIII of the book "SOA modeling, design and development" [13].

4.3.1 ANSI/ISA-95 Standard

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. Its goal is to reduce the effort, cost and error while implementing such interfaces, as it can be checked with more detail in [10].

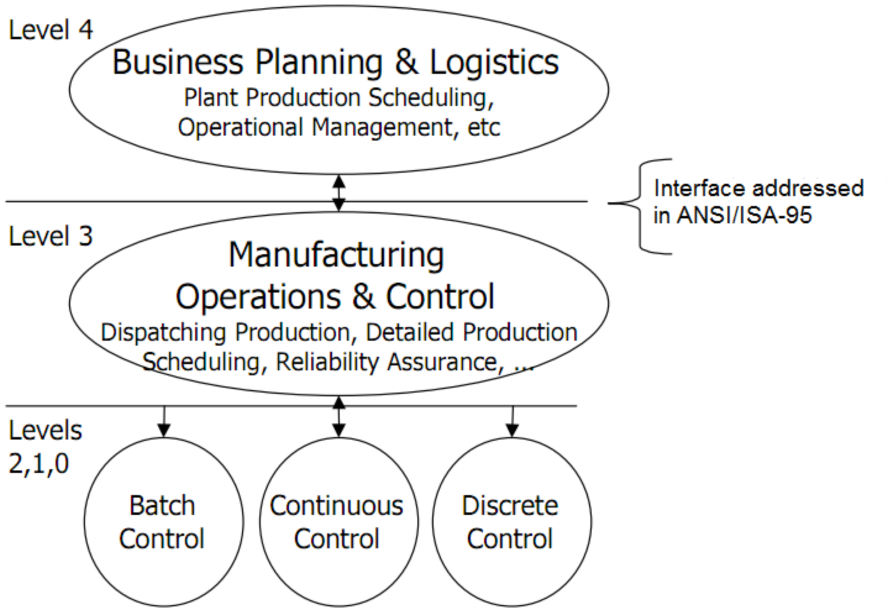

Figure 8 – Manufacturing Enterprise Levels

Figure 8 depicts the different levels in a manufacturing enterprise and presents a helicopter-view of ANSI/ISA-95's definitions. More precisely, the standard defines the scope of manufacturing operations and control domain, the organization of physical assets involved in manufacturing, the functions associated with the aforementioned interfaces and the information that is shared between control and enterprise functions.

Since the focus of this case study is proposing an SOA solution for the manufacturing operations of AVERS, it is believed that the solution would benefit greatly in complying at some level to this standard.

Equipment Hierarchy Model

The first definition provided in the standard is that of the physical assets of an enterprise. Usually, these assets are organized hierarchically as shown in Figure 19. This model defines the areas of responsibility for the different function levels.

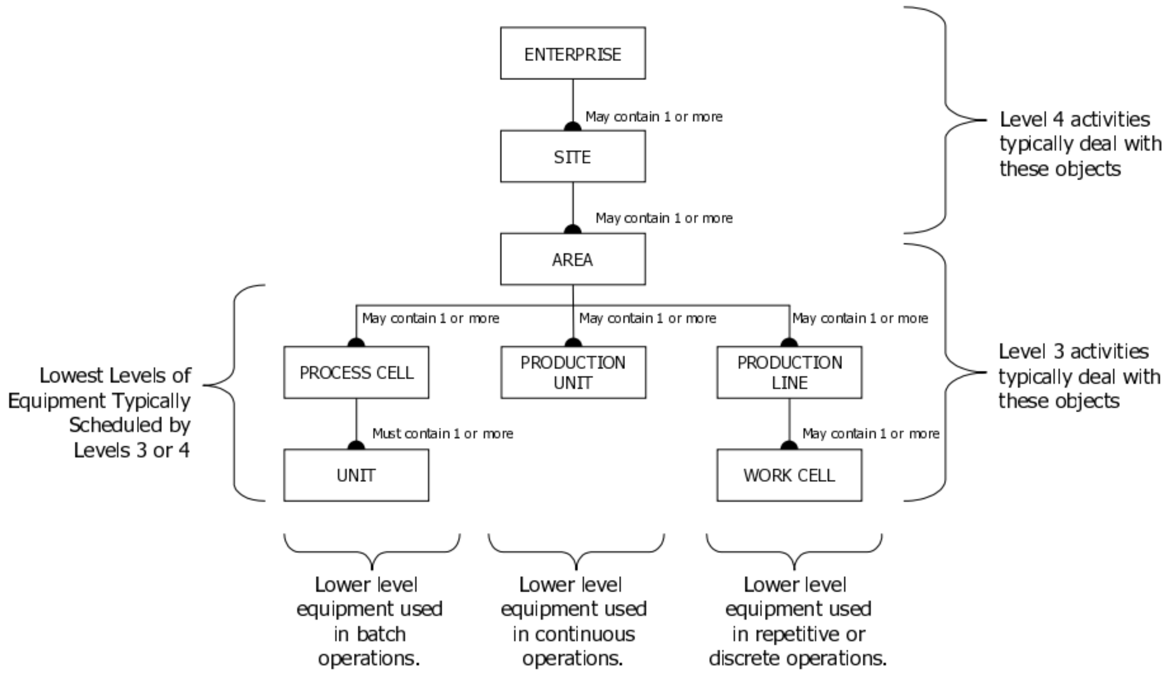

Figure 9 – The Equipment Hierarchy Model

It is believed that the modeling of the SOA solution for AVERS should adopt a similar hierarchic model for its physical assets. The use of a standardized model for a domain that trespasses the whole enterprise can ease in a great manner the interfaces defined in systems throughout AVERS.

Functional Flow Data Model

The model presented in Figure 10 defines both the main functions of an enterprise involved with manufacturing and the information flows between the functions that cross the enterprise-control interface.

Since the purpose of this document is to deal strictly with the order processing and manufacturing part of AVERS, only 3 main functions vital to these process will be studied in detail.

The functions and sub functions of interest are detailed as follows:

- **Order Processing** – Customer order handling, acceptance and confirmation; waiver and reservation handling; determining production orders.
- **Production Scheduling** – Determining production schedule and available products for sales.
- **Production Control** – Controlling the transformation of raw materials into end products in accordance with production schedule and standards; performing plant engineering activities and update of process plans.

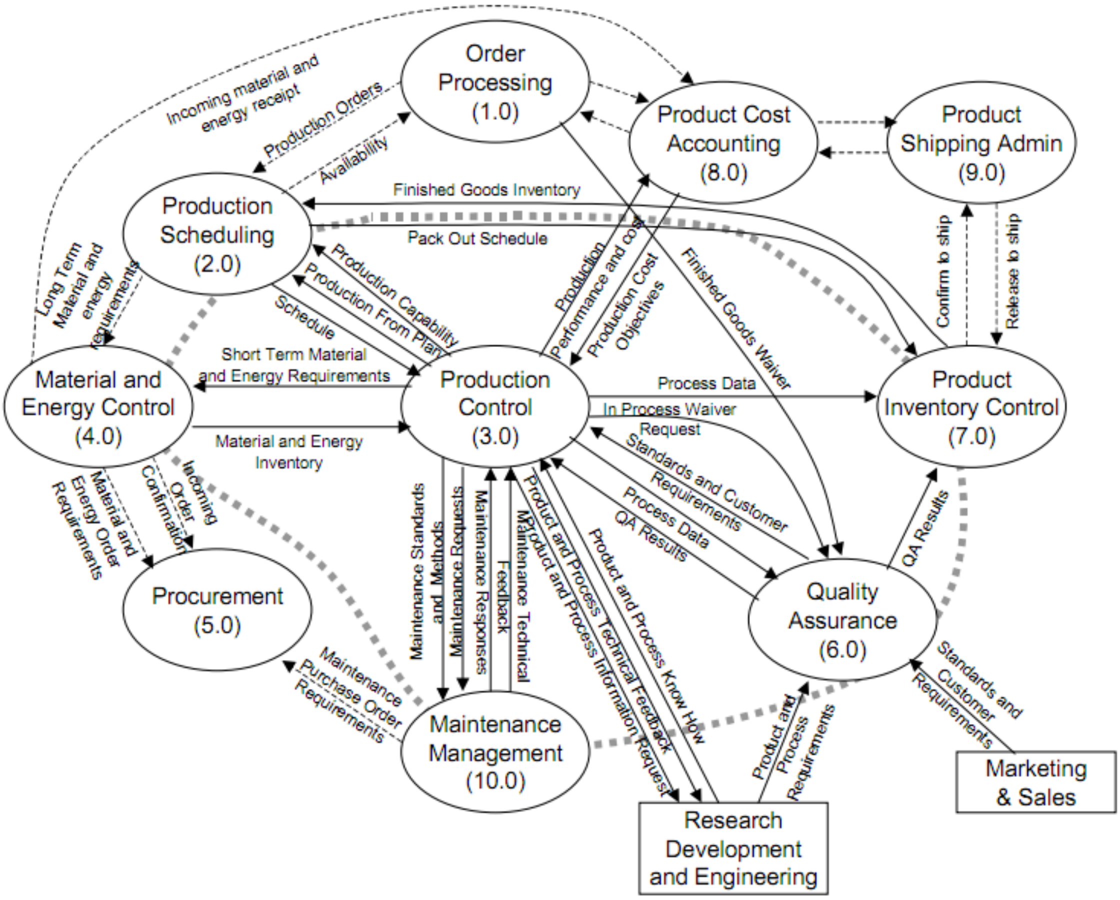

Figure 10 – The Main Manufacturing Functions and Information Flows

Having defined the 3 functions of interest, it is now possible to define the information flows of interest in the scope of this case study:

- **Production Orders** – Production order information flows from order processing functions to production scheduling functions and defines the accepted customer orders that will be later used to determine work for the plant;
- **Availability** – Availability information flows from the production scheduling functions to the order processing functions and defines the plant's ability to fulfill the order;
- **Schedule** – The schedule information flows from the production scheduling functions to the production control functions and contains the information on what product is to be made, how much is to be made, and when it is to be made;
- **Production Capability** – The production capability information flows from the production control functions to the production scheduling functions and defines the current committed, available, and unattainable capability of the production facility;
- **Production from Plan** – The production from plan information flows from the production control functions to the production scheduling functions and contains information about the current and completed production results from

execution of the plan, thus containing what was made, how much was made, how it was made, and when it was made.

Object Model

The standard presents also an object model and provides a context for the object models. Most of the information described in the data flow model falls into three main areas:

- Information required to produce a product
- Information about the capability to produce a product
- Information about actual production of the product

Figure 11 presents the proposed high-level model to describe the aforementioned areas. The production information defines what was made and what was used. Its elements correspond to information in production scheduling that defined what to make and what to use. The production scheduling elements correspond to information in the product definition that defines what must be specified to make a product. The product definition elements correspond to information in the process segment definitions that define what can be done with the production resources.

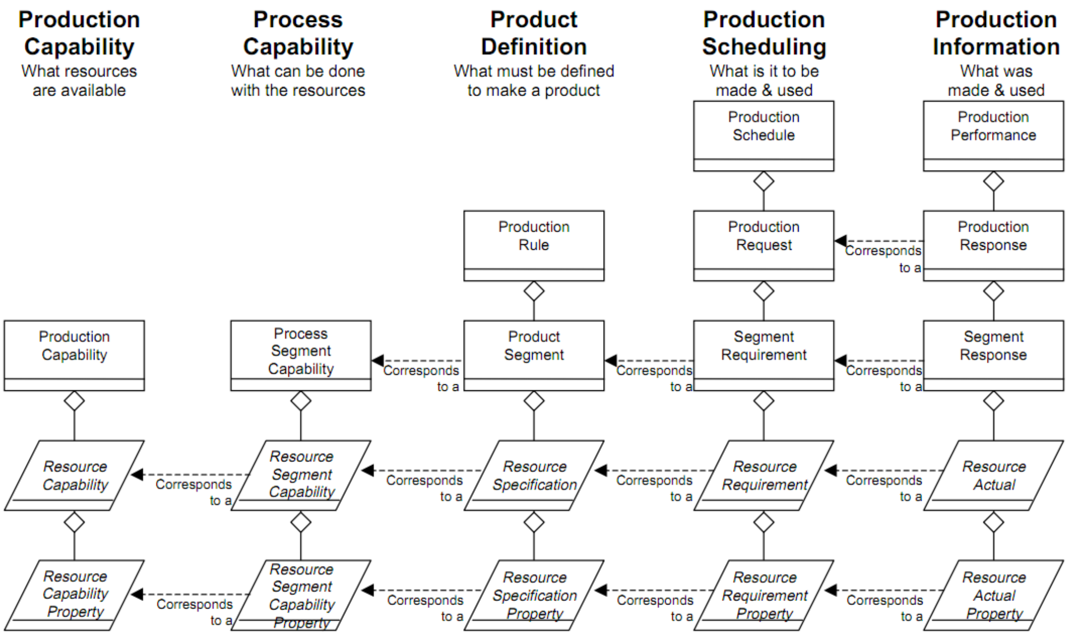

Figure 11 – The ISA Object Model for Production Data

Figure 11 illustrates how to interpret the previous picture. It shows how this interaction is made between 3 of the layers of the production control. It makes clear how the segments are all organized in a workflow while defining the way the product should be assembled. It also clarifies as well that the slanted rectangles in the figure represent any of the production resources such as personnel, equipment, or material.

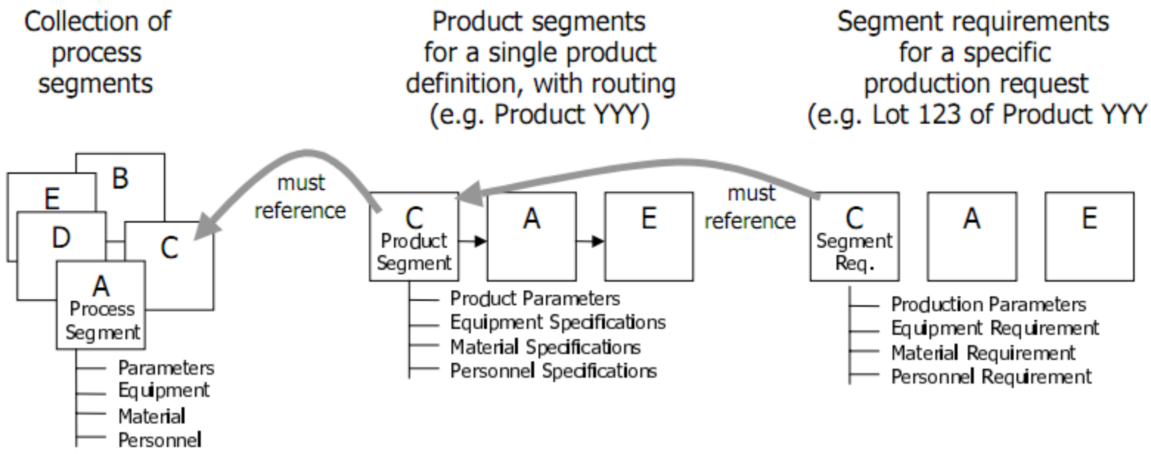

Figure 12– Schema about How To Interpret the Object Model for Production Data

The two previous figures imply that to provide a thorough model, the detailed models of various elements such as personnel, and equipment should be better defined. The standard provides also a detailed model for each of these elements. ANSI/ISA-95 defines the classes and also the attributes in each of the elements as shown in Figures 12 - 20. These models will be used as a reference while modeling the AVERS system. A brief description is presented for each model:

- **Personnel** – Contains the information about specific personnel, classes of personnel, and qualifications of personnel that will be later required to produce the manufactured goods.

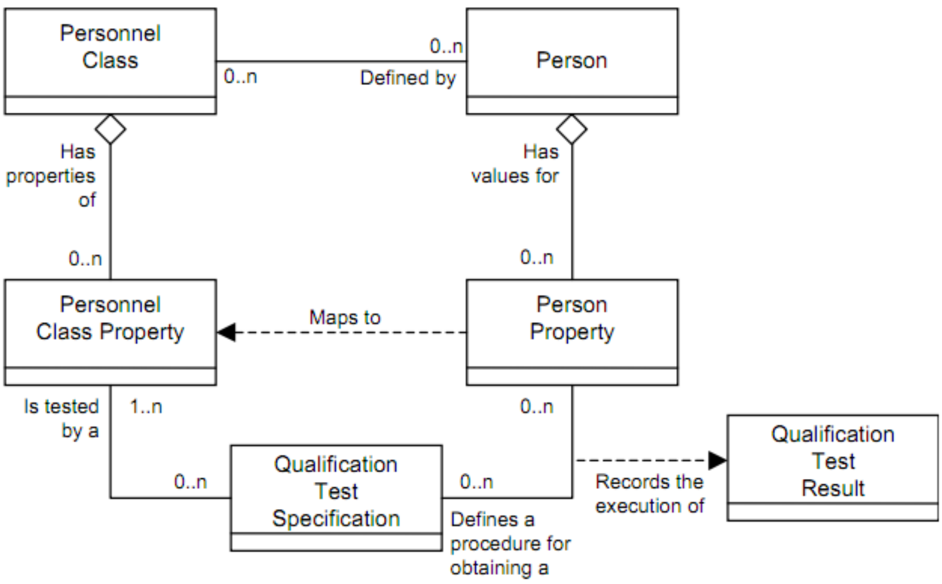

Figure 13 – The Personnel Object Model

- **Equipment** – Contains the information about specific equipment, the classes of equipment, equipment capability tests, and maintenance information associated with equipment that will be later used in the manufacturing.
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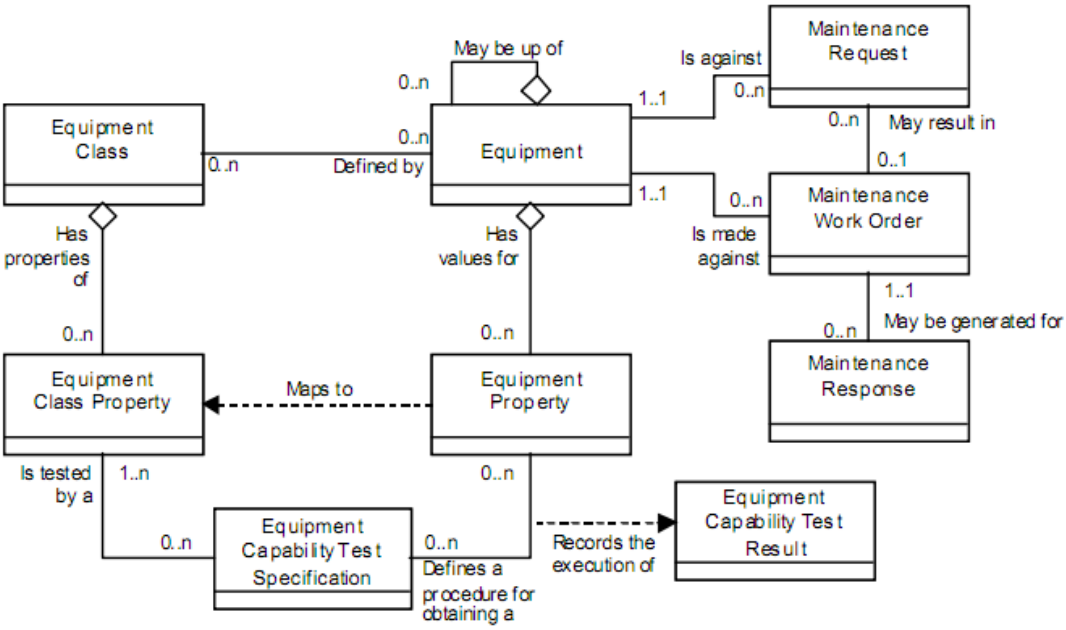

Figure 14 – The Equipment Object Model

- **Material** – Contains the inventory of raw, finished, and intermediate materials. Provides also current material information, which is contained in the material lot and material sublot information.
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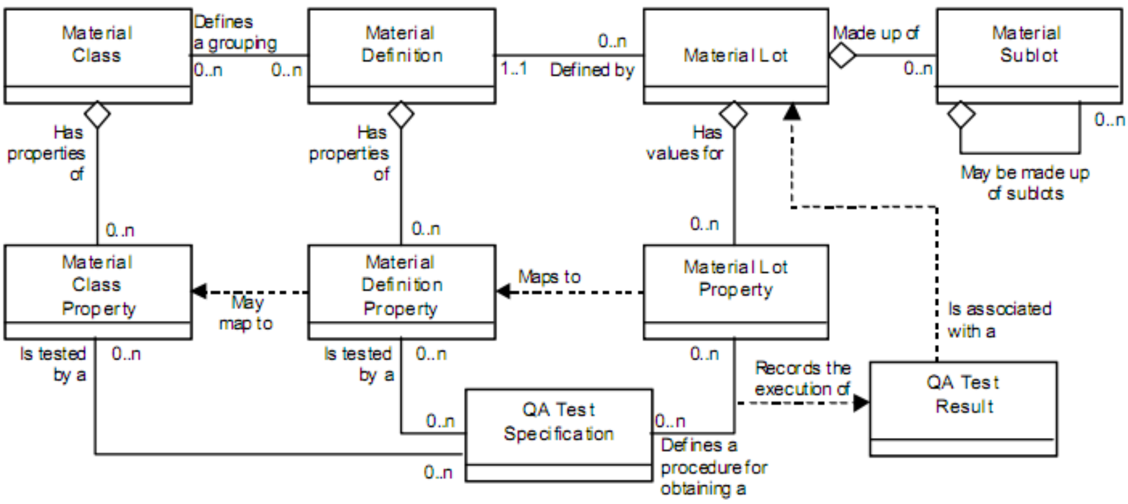

Figure 15 – The Material Object Model

- **Production Capability** – Contains information about all resources for production for selected times. This is made up of information about equipment, material, personnel, and process segments. It describes the names, terms, statuses, and quantities of which the manufacturing control system has knowledge.

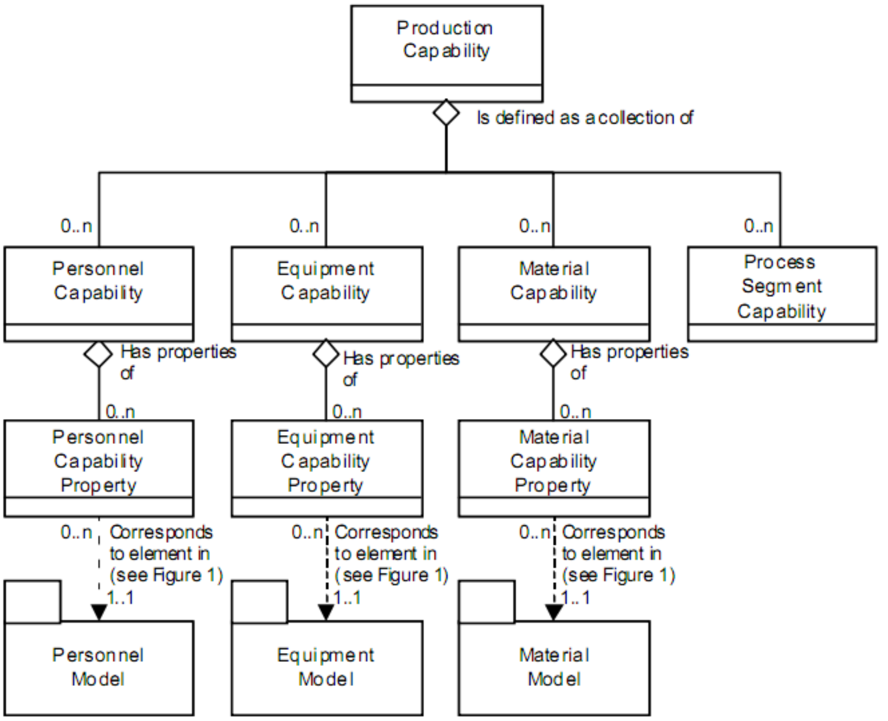

Figure 16 – The Production Capability Object Model

- **Process Segment** – Defines the collection of capabilities needed for a segment of production, independent of any particular product.

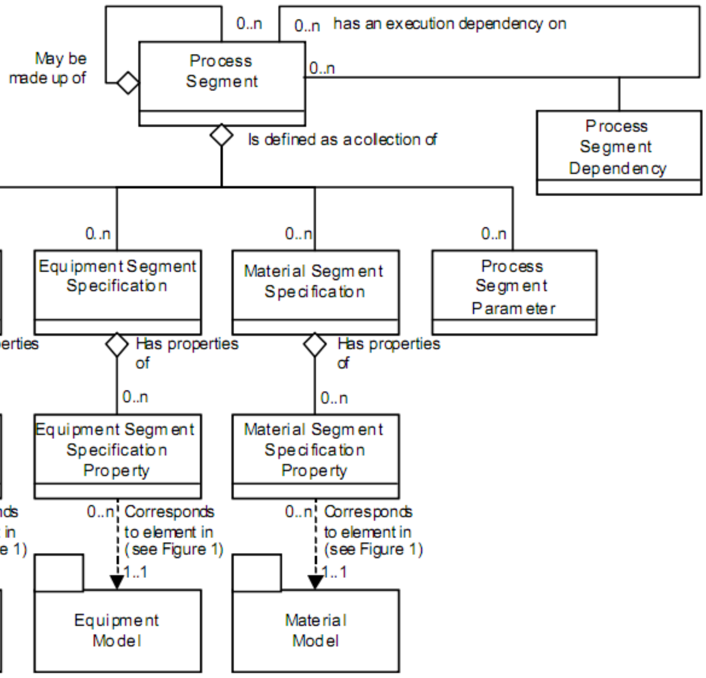

Figure 17 – The Process Segment Object Model

- **Product Definition** –Defines what steps, material and equipments are needed in order to produce one given product. Defines also the sequence of the segments that should be taken to manufacture the goods.

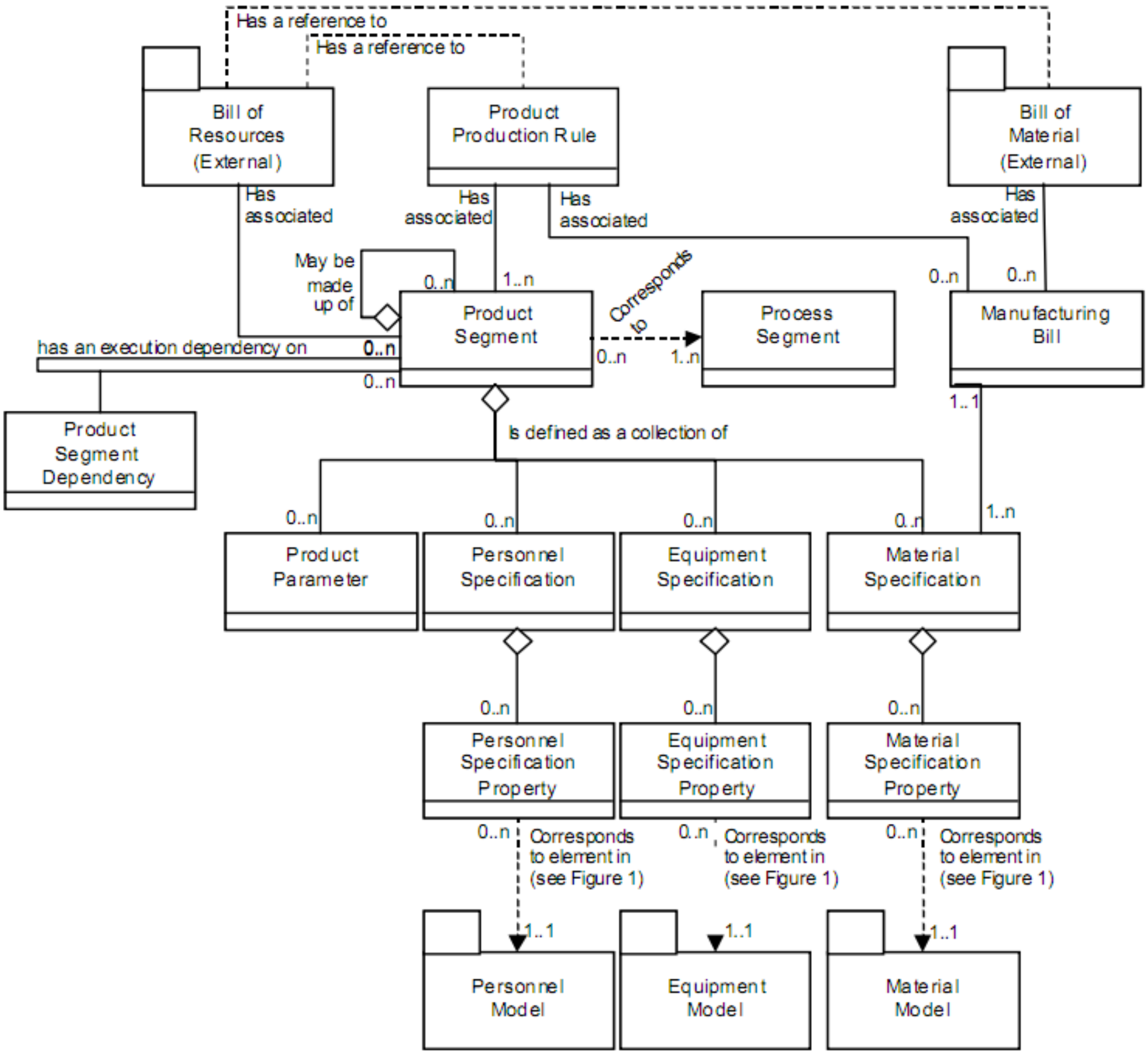

Figure 18 – The Product Definition Object Model

- **Production Request** – Defines the request for production for a single product identified by a production rule. It is aggregated in a Production Schedule to be mapped to the Production Orders. A production request contains the information required by manufacturing to fulfill scheduled production and might identify or reference the associated production rule.

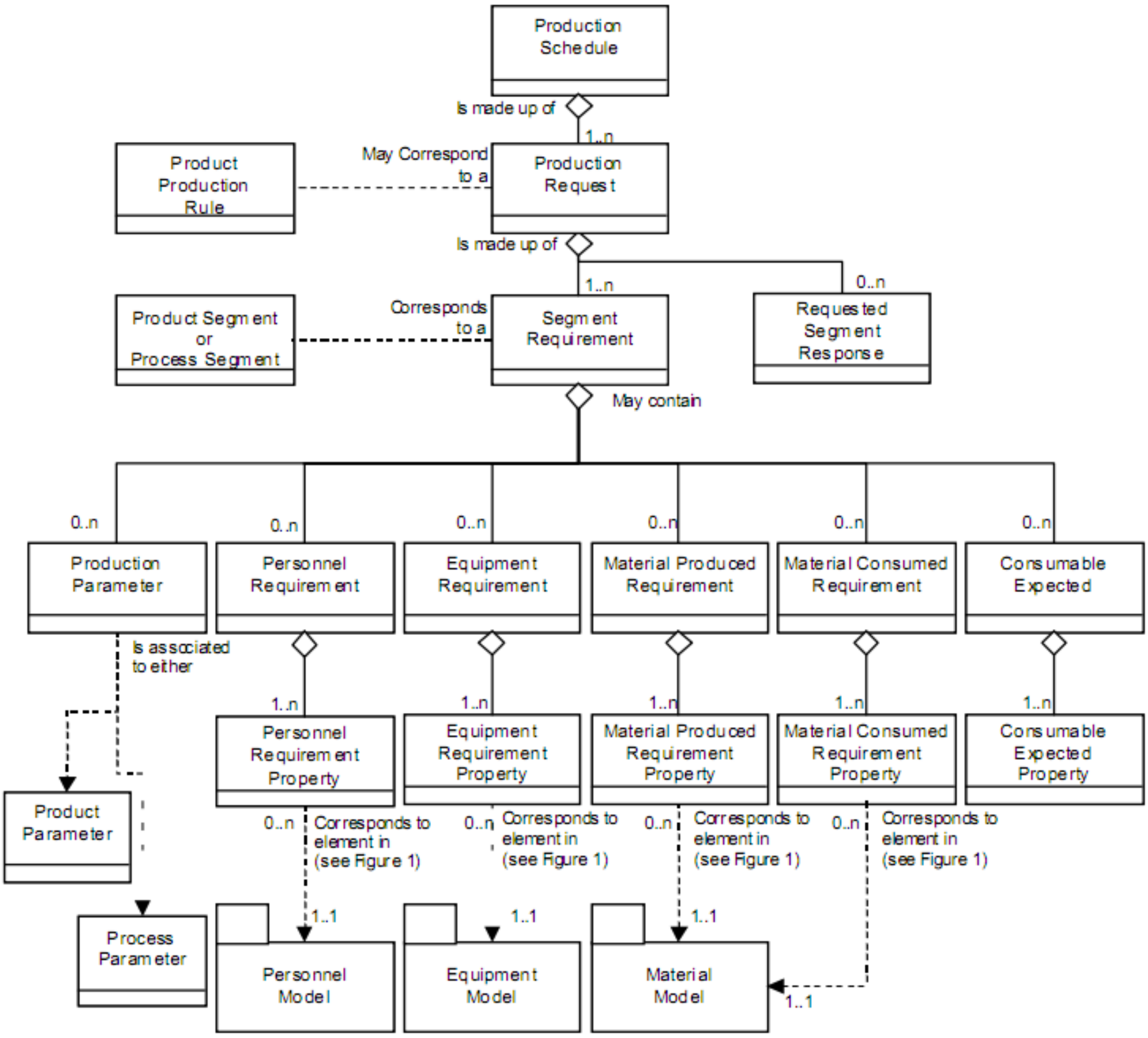

Figure 19 – The Production Request Object Model

- **Production Performance** – Defines the responses from manufacturing that are associated with a production request. There may be one or more production responses for a single production request if the production facility needs to split the production request into smaller elements of work.

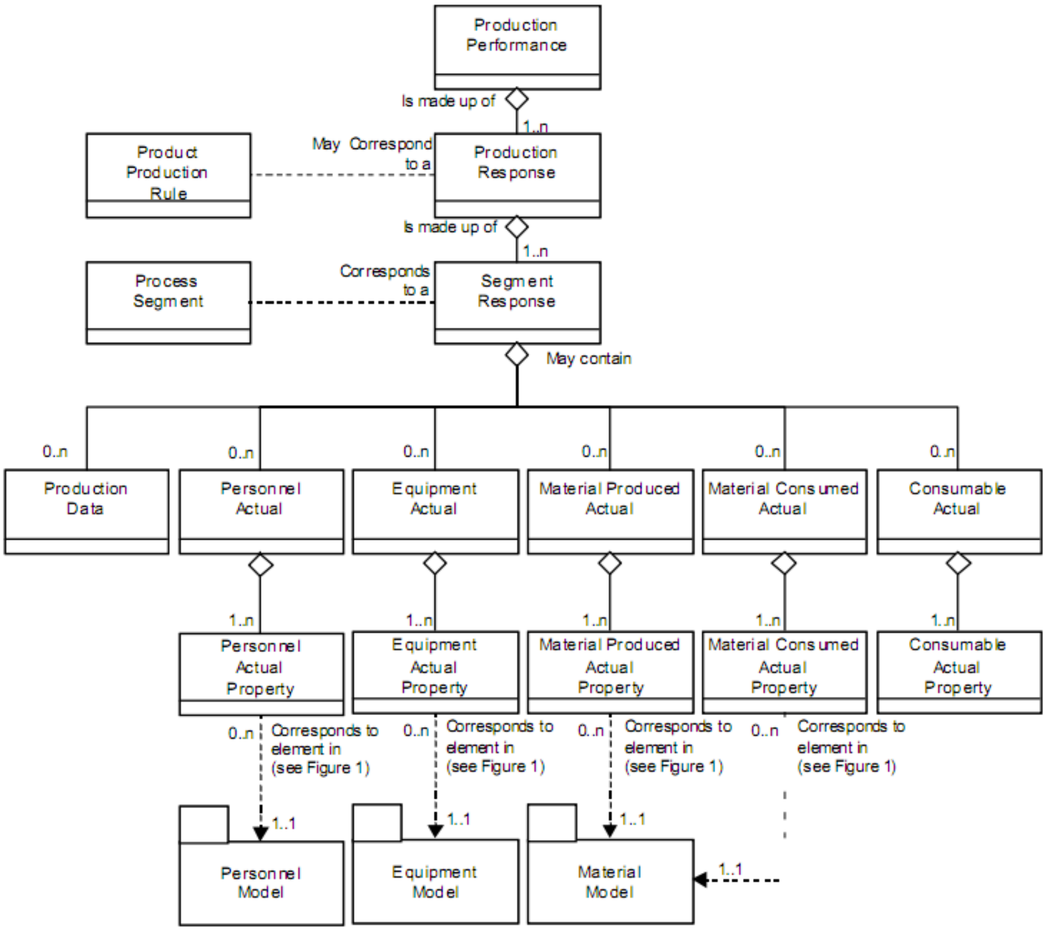

Figure 20 – The Production Performance Object Model

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A Survey