XML Implementation Process Model in Enterprise Applications – An MES Example

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Abstract

The purpose of our study is to propose an implementation process model for integrating XML (eXtensible Markup Language) into an MES (Manufacturing Execution System) system for Taiwan's MIRL (Mechanical Industry Research Laboratories) MES group to easily develop its XML data exchange functionality into their MES system. This process model is intended for the MES group members to meet their EAI (Enterprise Applications Integration) needs for producing the data exchange specifications. The process model not only satisfies the internal requirements of other application systems, but also is compatible to RosettaNet specifications. There are seven stages in this process model that includes requirements analysis, initial planning, process analysis and design, system design, system implementation, production, and system maintenance & support. Most of the stages are similar to implementation processes of other information systems, such as enterprise resources planning (ERP) and Web Portal. However, the analysis and design is specific to XML characteristics for defining Data Type Definition (DTD) to be used with XML in the data exchange between applications. Current progress in XML technology is that the newly established XML Schema is ideally a better tool than DTD in defining XML data structure while being compatible with XML itself. Consequently, the assumption of adopting DTD rather than XML Schema is to comply with the public RosettaNet standard. This paper illustrates the core sub-process in defining DTD and producing XML document in the stage of analysis and design with a MIRL example about information exchange between work-in-process (WIP) of MIRL-MES and the IBM MQSeries connecting to the ERP system. In this illustration, the four steps of the sub-process, including confirmation of exchange information, transformation of hierarchical tree structure, definition of DTD, and production of XML document, will be presented.

1. Introduction

As the application of supply chain management (SCM) grows its popularity in business, the concept of adopting an inter-organizational data exchange standard becomes a common recognition among top managements. However, data exchange was an old issue that was often ignored or underestimated in internal enterprises applications. It may be even more difficult to design and implement an internal data exchange than the external one for SCM since not only the external requirements, but also the internal requirements from different business applications need to be met.

The R&D group of Manufacturing Execution System (MES) at Mechanical Industry Research Laboratories (MIRL) in Taiwan has been devoted to MES development and already implemented its MES software in eighteen Taiwan's semi-conductor manufacturers over the last few years. Recently, enterprise applications integration (EAI) has just been setup as the next-level goal across the R&D groups in MIRL, and XML (eXtensible Markup Language) is adopted as the data exchange standard at MIRL due to XML's recognition being the potential industry standard [24]. Therefore, the MES group hopes to define an XML implementation process to meet the internal EAI needs of MIRL as well as the external RosettaNet standard that has been adopted by many of its existing clients for their SCM applications.

This purpose of our study is to propose an implementation process model for integrating XML into an MES system for the MIRL MES group to easily develop its XML data exchange functionality into their MES system. The organization of this paper consists of the literature in Section 2, the process model in Section 3, an example of the XML design in Section 4, followed by the conclusions in Section 5.

2. Literature Review

2.1 XML in Manufacturing Applications

XML 1.0 was first published by W3C (World Wide Web Consortium) in 1998, which is a subset of SGML (Standard Markup Language) for describing information for computer to easily understand its meanings [8]. Roy [20] indicated the relationships between SGML, HTML and XML as follows: HTML is suitable for quickly publishing simple web pages; SGML is appropriate for applications of complex structure, but cannot be widely accepted in Internet; XML is good for documents that is structured and for long-term usage, and thus very applicable for Internet applications.

In addition to the its own standard, there are other XML related standards, such as Document Type Definition (DTD) for describing the schema of a structured document, eXtensible Style Language (XSL) for displaying and translating the document style, and eXtensible Link Language (XLL) for defining the linkages of documents. The above standards make XML development reaching its maturity for practical use [6]. Therefore, XML has the following characteristics: (1) XML can directly apply on internet; (2) XML can support widely used software applications; (3) XML is compatible with SGML; (4) it is easy to develop related software for processing XML documents; (5) the options for XML functionalities should be minimized as much as possible; (6) XML documents should be easy-to-read and clearly understood; (7) the design of XML should be concise and careful; (8) the production of XML should be quick; (9) XML syntax should not be unclear [3]

The applications of XML in manufacturing is increasingly popular, typical references includes: Huang et al. [13] listed the advantages of XML/EDI (Electronic Data Interchange) for building B2B (Business to Business) information exchange, including readability, popularity, flexibility, heterogeneous, rich format and low cost. Shiau et al. [23] used CORBA (Common Object Request Broker Architecture) communication framework and distributed multi-agent for solving extended distributed collaborative design in concurrent engineering task, and XML for setting Manufacturability Markup Language (MML) in data exchange for extended product information or production equipment. Glushko et al. [12] proposed using XML and Web Agent for replacing CORBA and traditional EDI for achieving inter-business data exchange and electronic commerce. Ziao et al. [7] used XML as the data exchange standard for IC SCM and referred RosettaNet as the process standard between businesses

In XML related standard making, Lu [6] pointed out that XML's standard can be classified into (1) Basic standard, such as XSL, Xlink, Pointer and DTD; (2) Vertical XML business standard in referring to XML specifications for certain domain or business; (3) Horizontal XML business framework in referring to common data element, DTD, schema and framework for XML specifications. The most popular progress in vertical XML standard is RosettaNet for semiconductor industry, while the counterpart in horizontal business framework includes BizTalk and ebXML. RosettaNet organization was established as a not-for-profit organization called by the largest SCM software and services provider-Ingram Micro and joined by IBM, HP, Intel and Microsoft. The goal of RosettaNet is to develop and promote global industry SCM standards, and currently include Information Technology (IT), Electronic Components (EC), and Semiconductor Manufacturing (SM) committees. RosettaNet emphasized on Dictionaries, Framework, PIP (Partner Interface Processes) and eBusiness Process [21].

To summarize the above findings, XML has becoming the mainstream in data exchange. Many organizations involved in setting XML related standards, and academic references also showed that XML is the de facto standard in data exchange. Currently, XML defines its traditional format based on DTD, but W3C has listed a better alternative, XML Schema. Because RosettaNet is still adopting DTD as the structure definition style, this research followed but suggested observing the future development in XML Schema.

2.2 MES Related Research

Parker [19] mentioned that MES utilizes the integrated relational database for tracking variables, such as personnel, materials and production, and outputs detailed instruction to work floors. Stephen [22] also indicated MES must take manufacturing information, including bill of materials transformation, production routes, and item numbers from engineering systems. Also, in the management cycle of Plan-Do-Check-Action, in order for ERP (Enterprise Resource Planning) or SCM to work in production, they must be able to make information delivery transparent by making production information system and work floors (Do) under careful production control (Check, Action) for advanced planning (Plan) [4], where information gap between information systems can be bridged by MES.

MESA (Manufacturing Enterprise Solutions Association) defined MES as an information deliver who promotes the optimized production activities from work order to final product. When a situation occurs, MES quickly responses to reduce non-value added production activities based on available real-time information in order to maintain production efficiency [18], MIRL has devoted to research in manufacturing operational control system over the years. MIRL-MES integrated solution include six function modules, including BASIS Module, Customer Order Management (COM), Material Management System (MMS), Production Scheduling System (PSS), Work-in-Process Tracking (WIP), Equipment Management System (EMS) and Statistical Process Control (SPC) [2]. Compared to MESA International [1] functionalities, MIRL-MES system has an extra module in order management, whose major role is to proceed order information exchange with ERP system, while MESA has additional modules in performance analysis, human resources management and document control.

2.3 Related Research in Introducing Information Technology

There are many literature and methodologies for implementing information technology (IT) in a business, but not yet on XML. It is therefore necessary to establish an XML implementation approach by referencing critical success factors or implementation methodologies for other ITs. We briefly summarize the literature review from specialized versus generalized information application systems below.

(1) Specialized Information Application Systems

Three areas of information system applications are associated with our interest, which are ERP, concurrent engineering and manufacturing technology. A typical ERP implementation approach can be seen from SAP's ASAP (Accelerated SAP) [25], which includes five phases in project preparation, business blueprint realization, Final Preparation and Go Live & Support.

Two major concurrent engineering information applications are Engineering Data Management (EDM) and Product Data Management (PDM). The implementation approach proposed by Chen and Tsao [10] consists of nine steps: business analysis, process analysis & modeling, process reengineering, requirement analysis & system planning, system dsign, system modeling, software component selection, system implementation, system integration & testing, and improvement.

Chen and Small [9] proposed an integrated planning model for Advanced Manufacturing Technology (AMT). AMT has a wide application scope, such as CAD/CAM (Computer Aided Design/Computer Aided Manufacturing), CAPP (Computer Aided Process Planning), FMS (Flexible Manufacturing System) and FAS (Final Assembly Schedule). AMT classified implementation activities into eight units of strategic planning for AMT adoption, product and process matching, AMT monitor, management and control, inter-department relationship, external environment relationship, AMT and measuring system performance evaluation.

(2) Generalized Information Application Systems

In the process model for information technology by Copper and Zmud [11], implementation of information technology is defined as an organization focusing on expanding proper information technology to employee users. Zmud and Apple [27] proposed a process model, which corrects IT implementation through merging some behavior models. In other words, Zmud and Apple viewed IT implementation from the technology translating perspective, which takes every opportunities seeking IT applications in order to globally root IT in an organization. Launi [14] proposed an eight steps of off-the-self software structure, which includes defining and evaluating needs for software packages, preparing projects and confirming needs, installing and modifying baseline products, correcting business internal processes, translating static data, translating transaction data, providing training, and providing related documents.

3. Process Model for Integrating XML into MES System

A brief analysis of the implementation methods cited in Section 2.3, we learned that SAP's ERP approach emphasized less on business process analysis, which can be contributed to its level of customization; Chen and Tsao's [10] concurrent engineering approach contains process reengineering and system modeling in additional to SAP's ERP approach, which combines the rationality of business process into the reengineering process; Chen & Small's AMT approach further considered financial and strategic evaluations. Accordingly, we concluded seven generalized stages from three specialized information application systems, including requirements analysis, initial planning, process analysis and design, system design, system implementation, production, and system maintenance & support as depicted in Fig. 1. The description in the following sub-sections is MES-centered.

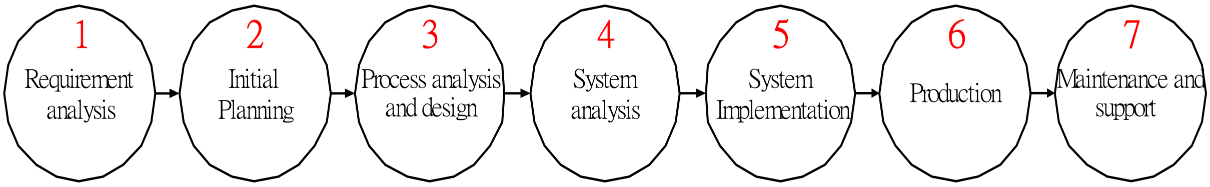

Fig. 1 Implementation process

3.1 Requirement Analysis

In requirement analysis stage, data exchange in requirement analysis, system evaluation, requirement confirmation and requirement management are required as follows:

(1) Data Exchange Requirements Analysis

The data exchange for MES is classified into internal information systems and business-to-business data exchange. Internal information systems exchange addresses data exchange between enterprise information systems. Therefore, the applicable enterprise systems need to be identified first. Then, requirements for data exchange between these identified systems are analyzed. For example, if only ERP and APS (Advanced Planning System) are interacting with MES for data exchange, data exchange activities between ERP and MES, and ERP and APS need to be listed, such as when WIP entering a certain workstation, WIP will report the work order to ERP about the status of the workstation

In the business-to-business data exchange environment, business are mostly upstream or down stream partners within the same supply chain. Therefore, there are needs for upstream manufacture sending their parts to downstream partner for the final products, such as the relationship between a semiconductor foundry and a packing/testing foundry. Accordingly, the requirements in this setup are mainly the production data exchange. For example, a semiconductor foundry manufacture may query the location of their WIP and the status of the production progress, and MES at packaging/testing foundry can respond with a status update report.

(2) Data Exchange System Evaluation

With the results of requirements analysis, a system evaluation will make sure the required environment for data exchange and the adequate capabilities for supporting these requirements.

(3) Data Exchange Requirements Confirmation

Confirmations of the requirements and system capabilities, based on the evaluation, determine which requirement is validated, and verifies the validity by certain validation principles.

(4) Data Exchange Requirements Management

In the system life cycle, requirements should be continuously tacked, controlled and managed, in order to expect proper corrections regarding to any changes.

3.2 Initial Planning

The purpose of initial planning is to identify potential risks in organizational software development, and corresponding strategies for overcoming risks. This is the only way to prevent disaster results for unexpected effects. Planning items include item implementation plan or software development plan, quality assurance plan, software testing plan, document assemble plan, user training plan and total support plan.

3.3 Process Analysis and Design

In this stage, all processes related to MES data exchange either internally or externally, need to be analyzed, and optimum processes and data exchange style will be designed. For instance, XML requires both parties agree on a set of common DTDs in order to mutually understand the XML contents. In other words, this phase conducts XML document analysis and design for internal and external needs based on the requirement analysis. The internal requirements can be illustrated as shown in Fig. 2 that the production information flows between enterprise WIP, ERP and SCM. The WIP subsystem will routinely request production status in manufacturing lines from ERP or SCM systems, and ERP can query WIP database for production batch information real time.

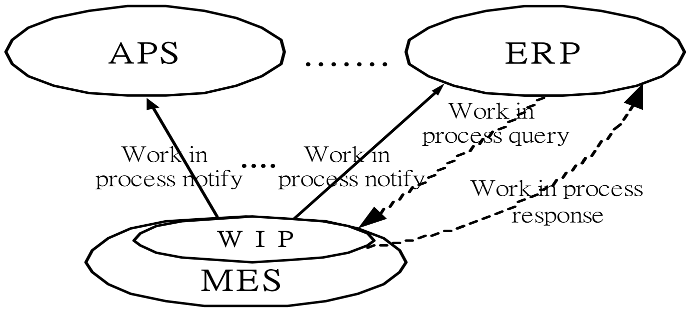

Fig. 2 Intra-organizational MES system data exchange process

On the other hand, business-to-business data exchange addresses the processes between production partners. Fig. 3 illustrates the semiconductor foundry, such as TSMC and UMI, is the upstream partner of the downstream packaging/testing foundry, such as ASE and SPIL. When a semiconductor foundry outsourcing a work order to its packaging/testing foundry, it continuously monitors production status as the testing/packaging foundry routinely reports updated information.

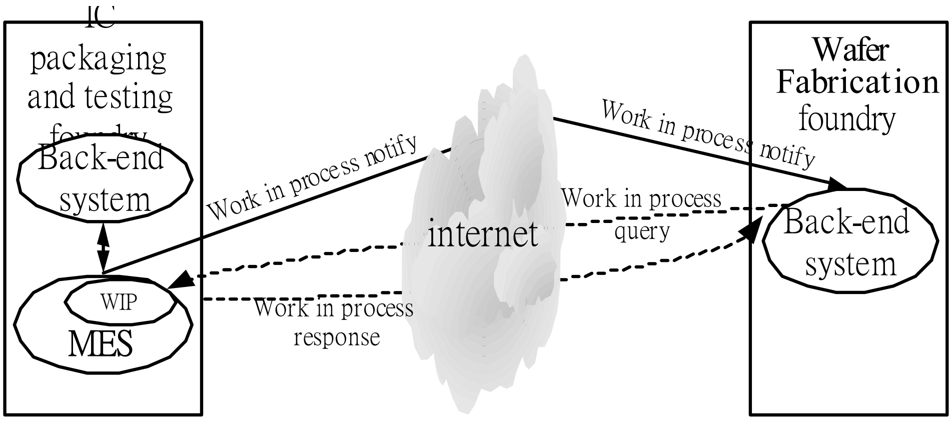

Fig. 3 B-to-B MES system data exchange process

3.4 System Analysis

This stage addresses the system environment where the MES operates its XML data exchange. An example would be the WIP exchanges product data through IBM MQSeries, which requires an adds-on XML translation module on the WIP end, in order to translate raw data to an XML format for ERP to receive. Similarly, ERP system can do the reversed process to translate the XML format into WIP system format as seen in Fig. 4.

Businesses communicate WIP information through intranet as shown in Fig. 5. The infrastructure on both ends is the same, and follows the same XML translation module as indicated in Fig. 4. But, the information delivery and receiving are performed on the Web Server, which exchanges data via HTTP Post to the Web Server of the counterpart.

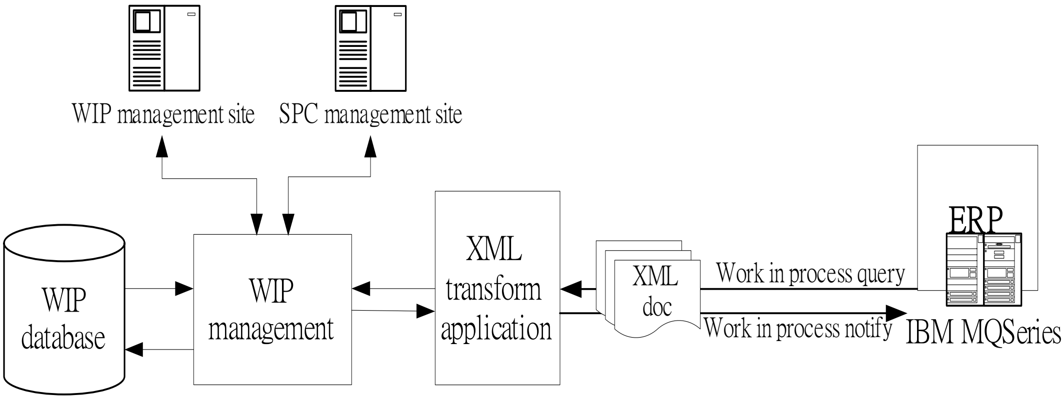

Fig. 4 Enterprise internal system framework

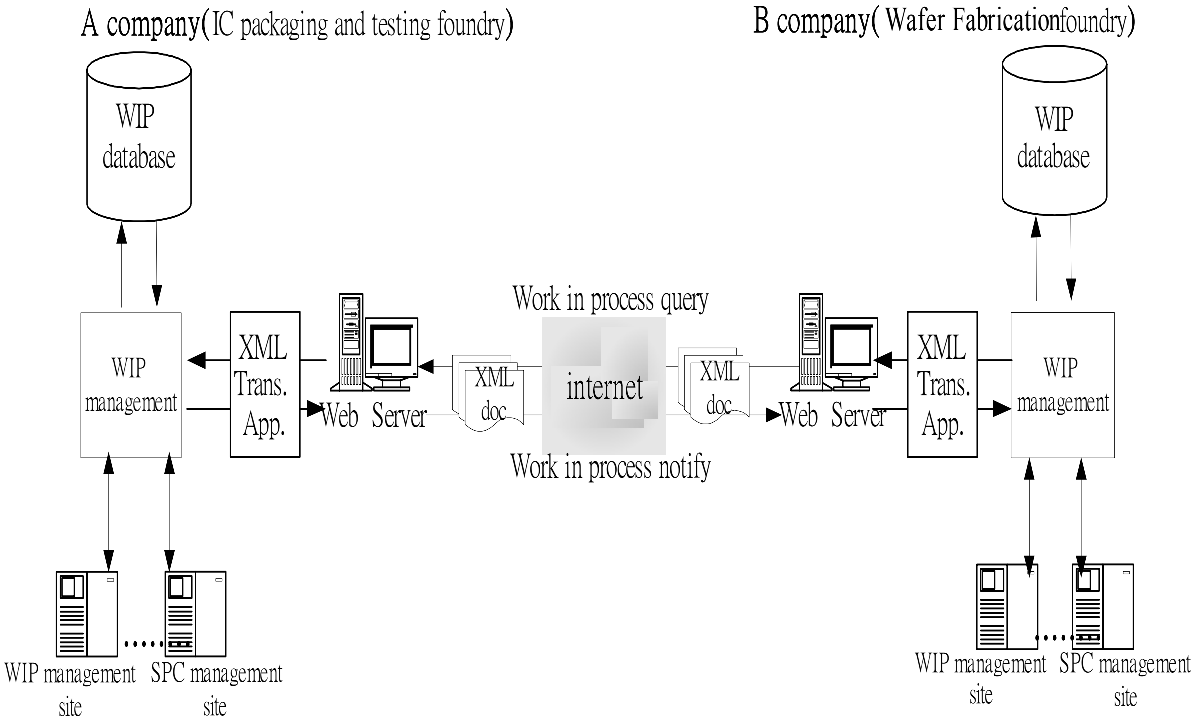

Fig. 5 B-to-B system framework

3.5 System Implementation

The system implementation in XML integration domain refers to the design of DTD specifications and the corresponding XML documents. With the proper preparation from above stages, system implementation can have a safe start. The steps involve in system implementation include confirmation of delivered information, translation of hierarchical tree, design of DTD, and production of XML document.

XML system implementation is the core stage of this process model, an example will be illustrated in Section 4. There is an important assumptions in MIRL-MES decisions, i.e., MIRL-MES needs to meet the international data exchange standard for higher compatibilities among its existing clients, and thus RosettaNet standard is followed as well as the internal requirements not discussed in RosettaNet. But XML Schema will be carefully monitored. In order to make sure the DTD meets both requirements internally and externally, the process first fills the requirements of data types that are already available in RosettaNet, and then adds the remaining data types only required for internal information exchange.

3.6 Production

The goal of this stage is to prepare related operations before the system goes into production so that the system can be stable for organizational members to fully operate.

3.7 System Maintenance and Support

The types of maintenance work includes corrective, adaptive, and comprehensive. Corrective maintenance corrects any problems due to unexpected input data and interfacing with other software or hardware. Adaptive maintenance is to make software adjustments in order to adapt the changes caused by external environment. Comprehensive maintenance is to increase the software usability by expanding its functionalities. To sum up, not only the mistakes or inappropriateness in the original software design need to be modified, but also the functionalities and usability need to be enhanced in this stage repeatedly and continuously.

4. An Example of System Implementation

Among the seven steps of the proposed process model, system implementation is the core and the most unique step in XML integrating process model. In this section, a simple example the work order from MIRL-WIP sending to IBM Mqquery, is presented.

4.1 Confirmation of delivered information

The information of the work order entering the production line is displayed in Table 1. MIRL-WIP informs ERP system through this MQ system.

Table 1 Work Order Data

Type	Date field
OffLineOrderData	[A], OrderNum, FactoryNum, ORG, ProductNum, OrderQuantity, ProcessNum , StandardTotalCycleTime , [InsideOutsideOrder] , OrderType
OffLineMaterialPreparationData	[B], OrderNum, MaterielNum, Quantity, OperationNum
OffLineReturnedMaterialData	[C], OrderNum, MaterielNum, Quantity

4.2 Translation of hierarchical tree

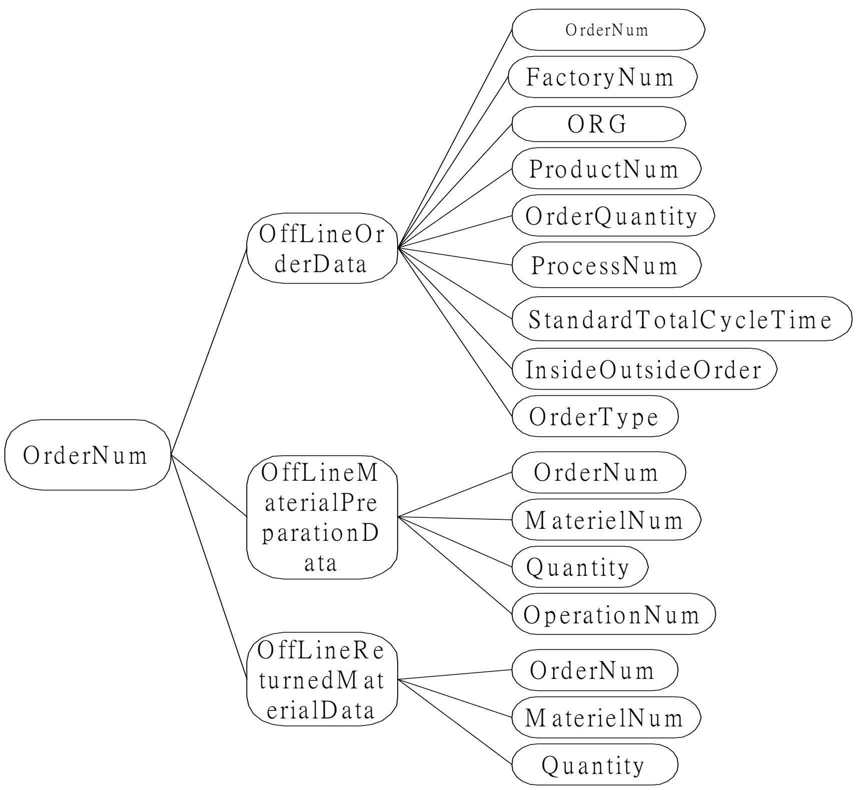

Fig. 6 Hierarchical Tree

The work order information is transformed into a hierarchical tree as shown in Fig. 6. With this hierarchical tree, the DTD specification can be written as described in Section 4.3. In Figure 6, the root element is the work order itself, which branches down to three descendant nodes as the sub-elements, namely offline work order, offline work order material preparation, offline work order returned remaining material. Offline work order consists of nine elements, offline work order material preparation consists of four elements, and offline work order returned remaining materials consists of three elements, such as the common element of work order number.

Table 2 DTD Specification

```
<?xml version="1.0" encoding="big5"?>
<!ELEMENT OrderNum (OffLineOrderData, OffLineMaterialPreparationData,
OffLineReturnedMaterialData)>
<!ELEMENT OffLineOrderData (OrderNum, FactoryNum, ORG, ProductNum, OrderQuantity,
ProcessNum, StandardTotalCycleTime, InsideOutsideOrder, OrderType)>
<!ELEMENT OffLineMaterialPreparationData (OrderNum, MaterielNum, Quantity, OperationNum)>
<!ELEMENT OffLineReturnedMaterialData (OrderNum, MaterielNum, Quantity)>
<!ELEMENT OrderNum (#PCDATA)>
<!ELEMENT FactoryNum (#PCDATA)>
<!ELEMENT ORG (#PCDATA)>
<!ELEMENT ProductNum (#PCDATA)>
<!ELEMENT OrderQuantity (#PCDATA)>
<!ELEMENT ProcessNum (#PCDATA)>
<!ELEMENT StandardTotalCycleTime (#PCDATA)>
<!ELEMENT InsideOutsideOrder (#PCDATA)>
<!ELEMENT OrderType (#PCDATA)>
<!ELEMENT MaterielNum (#PCDATA)>
<!ELEMENT Quantity (#PCDATA)>
<!ELEMENT OperationNum (#PCDATA)>
```

Table 3 XML Document

```
<?xml version="1.0" encoding="big5" standalone="yes"?>
<!DOCTYPE OrderNum SYSTEM "E:\XML_project\final_report\workorder.dtd">
<OrderNum>
  <OffLineOrderData>
    <OrderNum>W042001-67-001</OrderNum>
    <FactoryNum>One factory</FactoryNum>
    <ORG>TEST</ORG>
    <ProductNum>PCB001-23</ProductNum>
    <OrderQuantity>500</OrderQuantity>
    <ProcessNum>3</ProcessNum>
    <StandardTotalCycleTime>1000</StandardTotalCycleTime>
    <InsideOutsideOrder>0</InsideOutsideOrder>
    <OrderType>1</OrderType>
  </OffLineOrderData>
  < OffLineMaterialPreparationData >
    <OrderNum>W042001-67-002</OrderNum>
    <MaterielNum>A-0002</MaterielNum>
    <quantity>200</quantity>
    <OperationNum>FT2C</OperationNum>
  </ OffLineMaterialPreparationData >
  < OffLineReturnedMaterialData >
    <OrderNum>W042001-67-003</OrderNum>
    <MaterielNum>A-0003</MaterielNum>
    <Quantity>100</Quantity>
  </ OffLineReturnedMaterialData >
</OrderNum>
```

4.3 Design of DTD

The hierarchical tree can be easily transformed into DTD specification as shown in Table 2. Line 1 in Table 2 indicates the version and number of this DTD document. Line 2 is the root element consists of three sub-elements, which can be seen in Line 3 to 5, respectively. Elements after Line 6 are called the basic elements because they do not have any descendant element. The (#PCDATA) next to the element name indicates that this value can be analyzed as text data, which is not other Markup or ELEMENT

4.4 Production of XML Document

With the DTD specification available from Section 4.3, the XML document can be constructed accordingly. Table 3 is a sample XML document based on the DTD in Table 1. Line 1 in Table 3 indicates the norm of XML version 1.0 is used for describing this XML document and Big5 code is chosen. 'Standalone' equals to yes representing this document will call up other documents, where in this case workorder.dtd (DTD file specified in Section 4.3) is called. Line 2 describes the source and file name of the DTD file. After line 3 are the data area, which are the main purpose of this data exchange activity.

The above example is a most straightforward case in designing the DTD for enterprise data exchange. However, it can be easily expanded to include RosettaNet defined DTD in the first two steps with the assumption that considering RosettaNet DTD first. The last two steps remain unchanged in this external requirement data exchange scenario.

5. Conclusions

This research proposed a process model for integrating XML into the MIRL-MES system. During the process of transferring this research results, we noticed that the MES group at MIRL desires a user-friendly XML development environment for efficiently executing tedious XML integration task. Accordingly, an immediate future work is to embed the process model into a computer-assisted integrated development environment for the XML engineers, which would lift the effects of this research effort. .

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