Enterprise modeling and its applications in China

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Agenda

- Background (“informationization” in China)
- Correct understanding of CIM system architecture and its views
- The requirement for building an international standard of “Process model/view” was raised.
- Effects of applying enterprise modeling and system architecture in practice.
- How many ISO standards in this field have been translated into Chinese and applied in industries.
- “Economic view” as Annex B in the revised 15704 was raised from CIM implementations in China.
Historical Background
(“informationization” in China)

- "Informationization," the term increasingly employed to describe this overall process, has in recent years become a linchpin of central and many local development strategies, turned the Chinese people into true denizens of the 21st century, and plugged China into the wider world.

- The wide use of this term started from 1995, but the work has been going on for many years.
Propagating the CIM concept and industrial implementation

In 1986, a strategical R&D program, 863 Program, was launched in China. One of the important themes was Computer Integrated Manufacturing Systems (CIMS).

The basic idea was how to introduce computer technology, information technology, advanced manufacturing technique, advanced management mechanism to the industries for system integration—enterprise integration.

In practice, people recognized that the work should not become establishing a few automation islands. System integration was implemented. Thus the requirement of enterprise modeling was raised.
What means “Enterprise Model”?

- It is impossible to describe a complicated manufacturing company by using a single modeling format.
- A collection of different models with different purposes and different modeling methods is used to model and analyze the manufacturing plant.
Function model in IDEF0 for Aviation Industry
Function model in IDEF0 for an enterprise
Information model in IDEF1x for a university
**Decision model (Grai grid) for an enterprise**

<table>
<thead>
<tr>
<th>EI</th>
<th>ME</th>
<th>PS</th>
<th>PL</th>
<th>MR</th>
<th>MM</th>
<th>CQ</th>
<th>II</th>
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<tr>
<td>Functions</td>
<td>External information</td>
<td>To manage engineering</td>
<td>To plan purchase &amp; supply</td>
<td>To manage resource</td>
<td>To manage maintenance</td>
<td>To control quality</td>
<td>Internal information</td>
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<td></td>
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</tr>
<tr>
<td>H = 3 y P = 1 y</td>
<td>Market forecast &amp; national standard</td>
<td>To make 3 y Eng. plan</td>
<td>To make 3 y Prod. Plan</td>
<td>To make 3 y Equip. inve. &amp; personnel recruit. plan</td>
<td></td>
<td>Production capability</td>
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<tr>
<td>H = 1 y P = 1 y</td>
<td>Customer orders</td>
<td>To make annu. Eng. plan</td>
<td>To make annu. Prod. plan</td>
<td>To plan MPS</td>
<td>To plan major &amp; medium production</td>
<td>To determine quality &amp; resource control</td>
<td>Raw material inventory &amp; resource information</td>
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<td></td>
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<tr>
<td>H = 3 m P = 1 m</td>
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<td>To make 3 m Prod. Plan</td>
<td>To plan 3 m major &amp; medium maintenance</td>
<td></td>
<td>Production status</td>
<td></td>
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<tr>
<td>H = 1 m P = 1 m</td>
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<td>To make 1 m P/S plan</td>
<td>To make 1 m Prod. Plan</td>
<td></td>
<td></td>
<td>Inventory information</td>
<td></td>
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</table>

* Due to the width limit, the numbers of rows, (10) (20) (30) and (40), are put inside the table. According to the rule, they should be outside of the first column.
Decision model (Grai net) for an enterprise

To produce the annual production plan

To collect data

Collected data

Infor. & feedback from P/S plan

Infor. & feedback from engin. plan

Annual prod. tech. preparation plan

New annual production plan

Annual purchase/supply plan

Year end

Obj: meet the required yield & output value

Var: variety of products, possible invest.

Infor. & feedback from engin. plan

DC(ME,20)

DC(PS,20)

DC(P,10)

DC(Me,20)

DC(PP,30)

DC(PS,20)

Customer orders

Inventory & resources information

(CQ,20)

(EI,20)

(I1,20)

(CQ,20)
Sales functions of an enterprise in ARIS

Customer inquiry processing

Customer order processing

Determine taxes

Customer offer processing

Customer order processing

General agreement processing

Open Customer inquiry

Configure product

Determine price

Determine taxes

Determine surcharges/discounts

Convey export check

Supervise customer order

Core business process: product assembly

Sales

Production planning

Final assembly

Delivery

Marketing

Billing

Core business process: product assembly

Production planning

Final assembly

Delivery

Marketing

Billing
Sales (Organisation) of an enterprise in ARIS

- **Sales Europe**
  - **Direct Sales**
    - Direct sales Cars east europe
    - Direct sales Cars west europe
  - **Sales Management Europe**
  - **Partner sales**

- **Sales team Germany**
  - Sales team manager
  - Secretary
  - Sales employee
  - **M. Bernardy**

- **Order processing Germany**
  - Order team manager
  - Secretary
  - Employee
  - **W. Jost**

- **Orders**
  - Direct sales Cars west europe
  - Direct sales Cars east europe

- **Partnersales**
  - Sales Manage-ment Europe
  - Sales Europe

- **Sales**
  - Direct Sales
  - Sales Management Europe
  - Partner sales

- **Orderprocessing**
  - Germany
  - Direct Sales
Sales processing (eEPC) of an enterprise in ARIS

- Customer contact
  - Customer contact development
    - Inquiry is received
      - Inquiry to be created from contact
        - Offer to be created from Inquiry
          - Need for offer
            - Inquiries (pos.) are cancelled
          - Export forbidden
        - Offer positions undeliverable
          - Need for offer exists
            - Offer is sent
              - Order to be created from offer
                - Sales team Germany
              - Order confirmation sent
                - Sales requirements created
                  - Sales team Germany
                  - Order processing Germany
                  - Cancelation prepared

Example of Tree/Link (T/L) Method*

*(Huang, Q., Chen Y. and Xie, B., 1996)
Example of hierarchy for economic model by using ABC (Activity Based Costing) method

For intangible factors, AHP (Analytical Hierarchy Process) is used.
Process model of an enterprise in IDEF3

1. Request material

2. Identify potential suppliers

3. Identify current supplier

4. Request bids

5. Evaluate bids

6. Order requested material

X

J1

J2

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EasyIDEF3 Model Transfer
Transfer to eIDML

图5.11 由EasyIDEF3模型导出的eIDML文件
图5.12 由eIDML模型导出的XPDL模型
Transfer to Workflow
Three Layers for System Integration

- Information integration
- Process integration
- Enterprise Integration

Computer Integrated Manufacturing System has been extended to “Contemporary Integrated Manufacturing System” in China.
Layer No.1 (Information Integration)

Definition: Information integration means to guarantee to provide the right information to the right person at the right time and right place in the right way. (or, the right person can receive the right information).

- The Experimental Engineering for CIMS
  - The design methodology, design standards and design tools have been adopted by Chinese CIMS area.
  - In 2000, the integration methods and techniques have been applied to more than 200 enterprises (directly supported by MOST) for heterogeneous systems (hardware and software) and devices.

- Integrated Platform for CIMS Application Development
  - Integrating Chinese software for CIMS with commercial software.
  - The integrated platform for Information integration and application integration has been developed, to reduce the duration of CIM implementation and to ensure quality.
Layer No.2 (Process Integration)

After the completion of information integration and coordination among processes, “process integration” refers to ensuring that all redundant and non-value adding sub-processes (or activities) and those obstacles related to human factors and resource constraints, which produce negative influences on process efficiency, are eliminated, so that the overall process can work synergistically and achieve overall optimization.

- Concurrent Engineering
  - Mainly in the middle of 1990s
  - Product development process management
  - Integrating CAD/CAPP/CAM based on PDM and STEP
  - Distributed CAD/CAPP/CAM through INTERNET

- Applications
  - Aircraft, motor cycle, etc.
Layer No.2 (continue)

- Process integration connects and combines people, processes (including activities), systems, and technologies to ensure that:
  - the right processes have the right information and the right resources at the right time,
  - most obstacles that affect the inter-processes or intra-process efficiency are overcome,
  - the redundancy and non-value added parts are eliminated,
  - the overall process and sub-processes work synergistically.
Layer No.3 (Enterprises Integration)

“CIM is the joint application of human and business knowledge and capabilities with information and manufacturing technology to increase the productivity and responsiveness of manufacturing enterprises, whereby all human, functional, information and organizational aspects of an enterprise are part of an integrated whole.” (ISO TC184/SC5/WG1, 1993) Anyway, the integration of people, technology and business is emphasized.

☐ Research on Next Generation Manufacturing
☐ Agile Manufacturing (CPC,ASP)
  ■ CIMSNET has been created, covered all of main research organizations, more than 100 enterprises
  ■ Research on Enabling Technology
  ■ Research on Internet/Intranet/Extranet
  ■ Virtual enterprise modeling
  ■ Agile Supply chain modeling and management

☐ Applications
  Aeronautics and astronautics, Shipbuilding, Textile, Oil refining, Machinery engineering, Consuming electronics, Automobile, Motorcycle, etc.
Structured Approach for Implementing CIM

Life Cycle of CIM Development

• Requirements Definition
• Feasibility Study
• Primary System Design
• Detailed System Design
• Engineering Implementation
• System Operation and Maintenance
• Decommission
All these considerations and experiences converged into this very term----CIM system architecture.
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Correct understanding of CIM system architecture and its views

Definition: CIM system architecture is a collection of models representing multi-levels and multi-views of the entire system.
What is model?

A model is a representation of a set of components of a system or subject area. The model is developed for understanding, analysis, improvement or replacement of the system.

Systems are composed of interfacing or interdependent parts that work together to perform a useful function. System parts can be any combination of things, including people, information, software, processes, equipment, products, or raw materials.

The model may describe what a system does, what controls it, what things it works on, what means it uses to perform its functions, and what it produces.
The definition of Model

M models A if M answers questions about A.
CIM-Open System Architecture

CIM-OSA

Generation

Instantiation

Organization View

Resource View

Information View

Function View

Generic Requirements Definition Building Blocks

Partial Requirements Definition Models

Particular Requirements Definition Model

Generic Design Specification Building Blocks

Partial Design Specification Models

Particular Design Specification Model

Generic Implementation Description Building Blocks

Partial Implementation Description Models

Particular Implementation Description Model

Views

Building blocks

models
Basic concept of GIM

An enterprise includes **Decision System, Physical System** and **Information System**.

Now it can present decision, function and information modeling methods.
Basic concept of IMPACS

This Architecture has the same views with GIM. It emphasizes the relationship among subsystems.
Basic concept of PERA
Information System Architecture (ARIS)

ARIS (Architecture of Integrated Information System)
**GERAM (ISO 15704:2000 Annex A)**

**Views**
- Generic
- Partial
- Particular

**Instantiation**
- Customer service
- Management and control
- Software
- Hardware

**Life-cycle phases**
- Identification
- Concept
- Requirements
- Preliminary design
- Design
- Detailed design
- Implementation
- Operation
- Decommission

**Subdivision according to genericity**
- Subdivision according to purpose of activity
- Subdivision according to physical manifestation
- Subdivision according to model content
- Subdivision according to means of implementation

**Reference Architecture**

**Particular Architecture**
Based on Chinese situation, Stair-Like CIMS Architecture (SLA) was proposed in 1993. SLA first presented the concept of Economic View in an enterprise architecture context on May 14-15, 2001, at the ISO/TC184/SC5 conference held in Beijing. SC5 accepted our proposal to add an Economic View in Architecture.
Explanation

☐ 1. Not need to be limited in discrete parts manufacturing industry.

☐ 2. Mapping from models designed to realization is needed.

☐ 3. Add new views, especially the economic view and process view.

☐ 4. Do Reverse Mapping to check if the realization has met the aim of TO-BE model design.
A good way to see the elephant: “Stair-Like CIM System Architecture” (SLA)

Function View
Information View
Decision View
Organization View
Economic View
Resource View
+Process View
Minimal views vs. optimal views

ISO/FDIS 19439 SLA

Function view Function view
+ Process view
Information view Information view
Resource view Resource view
Organization view Organization view
+ Decision view
+ Economic view
A precise understanding of the definition of “View” is required.
A definition of “view”

It can be found the definition of “view” from ISO 15745-1:
projection of a model, which is seen from a given perspective or vantage point and omits entities that are not relevant to this perspective.
The problem involved

- Relationship and difference between View and Model
- After having Function View, is it necessary to establish Process View
- After having Organization View, is it necessary to establish Decision View
- Can we put “What to do” and “How to do” in one model? Together or separate?
- Why do we divide the enterprise model into several views?
Reasons for having views of a model

- Accommodate multiple users
  - Examining content
  - Defining content
- Expose content to enable interoperability
- Reduce apparent complexity
- Provide focus
- Enable modularity of process
- Enable “need to know” restrictions
- Move toward particular domain knowledge
- Enable interoperability with larger knowledge sets
Definition of enterprise model view

selective perception or representation of an enterprise model that emphasizes some particular aspect and disregards others

- “one aspect” or “a few aspects” (just like, except hologram, a photo can only take one plane.)
- “one form of representation” or “several forms of representation”
- “What is the purpose to divide enterprise model into several views?”
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After distinguishing the differences between function and process, the requirement for building an international standard of “Process model/view” was raised.
Definitions

☐ 3.32
☐ function view

   enterprise model view that enables the representation and modification of the processes of the enterprise, their functionalities, behaviours, inputs and outputs

☐ 3.33
☐ functionality

   referring to the purpose for which the process exists
Method Comparisons
(IDEFØ, 1X, and IDEF3)

**IDEFØ**

- **What you do**
- **Functional dependencies**
- Used to “target” activities that need improvement
- A modeling method

**IDEF1x**

- **What you need to know**
- **Information Management or Database Design**
- Information or Data Requirements
- Analysis method (1) / Design method (1X)

**IDEF3**

- **How you do it**
- **Precedence and Cause-&-Effect**
- Reduce Cycle Time
- A description method
The important role of “Process view” has been recognized widely
Why it is necessary for us to develop the standard?

- There are lots of process-modeling methods, such as IDEF3, EPC, Gantt chart, PERT chart, Petri Net, etc. It is necessary to develop a method to converge all of these methods.

- Workflow becomes the core technique of management information system. It is necessary to integrate these systems based on interoperable process modeling methods.

- TC184 and other technique committees are preparing to develop standards for supply chain, e-business, value-chain and concurrent engineering. All of these standards will use process description methods. We should develop a process modeling standard at first to support these tasks.
Necessity (continue)

- Reference models are the base of knowledge management. They are certain kinds of enterprise knowledge and can support new system constructing and restructuring. In order to reuse these models, it needs a standard to support process model information exchange.

Provide a total solution for all kinds of process modeling for system integration

- In different stages and different aspects of the work for system integration, there are different requirements for process modeling. For example, capturing of basic process information is most important in stage of requirement analysis; status of resource is focused on in stage of project management; effects of process running is cared about in stage of implementation of process models. SPM must satisfy all these requirements.

- It can help understanding and communication between enterprise manager, process experts, and process analyzer; it can provide plenty of means for analyzing process, including value chain analysis, simulation, ABC calculation, etc; it can support many implementation methods, including workflow management, project management, and process monitoring, etc.
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Effects of applying enterprise modeling and system architecture in practice

(Due to time limit, only introduce some of our direct experiences)

What CIMS-ERC has done in accordance with this understanding.
The distribution of CIMSNET nodes
The Progress in Engineering of CIMS-ERC

- More than 60 enterprises CIMS engineering undertaken
- More than 10 industrial areas covered
  - Machinery, Textile machinery, Electronics
  - Chemical, Metallurgy, Light Industry
  - Aeronautics, Astronauts, etc.
- More than 13 provinces distributed
- A close relationship between enterprises and CIMS ERC has been created
- More than 200 million Yuan (RMB) funds obtained
The List of CIMS Engineering projects undertaken by CIMS ERC

[Map showing various locations with names of companies and projects marked on it.]
Chinese Aviation Industry Integrated Manufacturing System

**Users' Requirement**

- **Group Headquarters**
  - Project Management Subsystem
  - Network

**R&D Divisions**

- **Project and Process Management**
  - Global Design, Process check, Detailed Design, Engineering Design...
- **PDM**
- **Mathematic Models**

**Manufacturing Enterprises**

- **Project and Process Management**
  - Process Preparation, NC Programming, Part Manufacturing...
- **PDM**
- **Mathematic Models**

**Intranet/Internet**

- Collaborating Working Environment
- IPT
- Analysis
- Design
- Plan
- Manufacturing
- Maintenance
- Error Feedback

**Users**
Typical Awards

• CIMS ERC
  University LEAD Award” on Development and Applications of CIMS issued by ASME of the U.S. in 1994

• Chengdu Aircraft Co.
  “Enterprise LEAD Award” on Applications of CIMS issued by SSTC in 1996
  Second class, Prize of “National Advance in Science and Technology” in 1997

• Jingwei Textile Machinery Co.
  “Enterprise LEAD Award” on Applications of CIMS issued by SSTC in 1996

• Accelerating the product innovation with VPD
  Second class, Prize of “National Advance in Science and Technology” in 2000
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A list of Chinese National Standards in the field of manufacturing
<table>
<thead>
<tr>
<th>标准号</th>
<th>标准名称</th>
<th>主要内容</th>
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<td>GB/T 15312-1994</td>
<td>制造业自动化术语</td>
<td>本标准规定了与自动化技术有关的生产、工程、科研和教育等部门。</td>
<td>北京机械工业自动化研究所</td>
<td>张锡麟、孙珍芬。</td>
<td>L60</td>
<td>1994-12-22</td>
<td>1995-10-01</td>
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<td>GB/T 16978-1997</td>
<td>工业自动化词汇</td>
<td>本标准定义了工业制造环境中有关的自动化名词术语。</td>
<td>北京机械工业自动化研究所</td>
<td>郝淑芬</td>
<td>J07</td>
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<td>GB/T 18725-2002</td>
<td>制造业信息化技术术语</td>
<td>本标准定义了制造业信息化领域的有关技术术语。</td>
<td>北京机械工业自动化研究所</td>
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<td>J07</td>
<td>2002-05-20</td>
<td>2002-12-01</td>
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<td>GB 16655-1996</td>
<td>工业自动化系统集成制造系统安全的基本要求</td>
<td>本标准规定了集成系统安全的基本技术要求。</td>
<td>北京机械工业自动化研究所</td>
<td>全国工业自动化系统标准化技术委员会秘书处起草。</td>
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<td>GB/T 16642-1996</td>
<td>计算机集成制造系统( CIMS ) 体系结构</td>
<td>本标准适用于支持企业 CIMS 建模，进而指导 CIMS 的实施运行。</td>
<td>本标准收录的术语来自 GB/T 16720 系列标准。</td>
<td>本标准起草单位：北京机械工业自动化所</td>
<td>本标准起草人：邓子琼等</td>
<td>1996-12-17</td>
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**ICS 25.040.40J 07**
本标准规定了工业自动化系统 制造报文规范中常用的术语。
本标准适用于 GB/T 16720 系列标准。

**ICS 35.100L67**
本标准适用于 GB/T 16720 系列标准。

**ISO 7498**
Information technology -- Open Systems Interconnection -- Basic Reference Model

**ENV 40003**

**GB/T 19662-2005**
Industrial automation system: terminology for manufacturing message specification
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<td><strong>工业自动化系统 制造报文规范（MMS）第2部分：协议规范</strong></td>
<td><strong>工业自动化系统 制造报文规范（MMS）第3部分：工业机器人伴同标准</strong></td>
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<td>本部分的服务定义</td>
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<td>本部分为数值控制制造设备和装置的语义。</td>
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<td>本部分的目的是定义制造报文规范提供的各种服务。</td>
<td>本部分为各种制造和过程控制设备提供广泛的服务。是便于信息系统和制造报文规范互连而制定的成套标准之一。它作为其他标准的应用服务元素（ASE）被开放系统互连模型和开放系统互连环境的应用层中。</td>
<td>本部分是为便于信息处理系统互连而制定的系列标准之一。它作为其他标准的应用服务元素（ASE）被开放系统互连基本参考模型列入开放系统互连环境的应用层中。</td>
<td>本部分为制造报文规范定义了数值控制的语义。它被用于数值制造系统或设备连到符合OSI模型的通信网络并使用MMS服务和MMS协议的场合。</td>
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<td>“工业自动化系统 制造报文规范”(的总标题)下，由以下四部分组成：第1部分：服务定义 第2部分：协议规范 第3部分：工业机器人伴同标准 第4部分：数值控制用伴同标准</td>
<td>本标准起草单位：北京机械工业自动化所、北京四方继保自动化有限公司。</td>
<td>本标准起草单位：北京机械工业自动化所。</td>
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本标准制定并促使与技术信息系统（TIS）相关的不同软件系统提供信息交流的中间件。这些软件主要以下几类：PDM、CAD、CAPP等。

本标准适用于指导企业在实施技术信息系统集成的过程中，定义不同软件的动态接口或在选购相关软件时作为判断其可集成程度的参考。

“工业自动化系统车间生产”由两部分组成：第1部分描述参考模型和方法论，为的是确定可能的标准需求。第2部分讨论该参考模型和方法论在工业自动化车间生产标准的一般领域的应用。

本标准提出和描述了一种手段，以判别什么地方可能需要一些新的或应修订的制造标准。

本标准建立了一个车间生产的参考模型，并进而用作开发一种方法论的基础，以便识别和抽取标准的内容范围。
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<td>idt ISO16100-2: 2003</td>
<td>本标准定义了应用集成框架——描述集成模型和应用互操作专规的一组元素和规则。</td>
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Agenda

- Background ("informationization" in China)
- Correct understanding of CIM system architecture and its views
- The requirement for building an international standard of "Process model/view" was raised.
- Effects of applying enterprise modeling and system architecture in practice.
- How many ISO standards in this field have been translated into Chinese and applied in industries.
- "Economic view" as Annex B in the revised 15704 was raised from CIM implementations in China.
“Economic view” as Annex B in the revised ISO 15704 was raised from CIM implementations in China

(with little modification in the text of 15704 about the introduction of economic view)
Introduction

- Entrepreneurs or business managers can scarcely implement CIM based on their confidence in advanced technology. They expect that the return on investment can be known in the designing phase of a new system.

- As a farseeing business-person, he/she should take into his/her consideration not only tangible benefit, but also, more importantly, intangible benefit.

- However, how to evaluate this return is a difficult but "must-be-solved" problem. Similarly, when it is required to evaluate different alternatives, the models in those existing system architectures are not able to connect functionality with economic consequences so that design trade-off can be made. Especially, the evaluation of the intangible benefits has been a barrier for enterprise investors to decide whether Computer Integrated Manufacturing should be carried out.
Economic View consists of a group of models, which is used to describe economic factors and their relationships in an integrated system. There are many methods, such as graphical, mathematical, and even descriptive methods, to describe economic factors. In order to improve the competitive edge of an enterprise and assure its successful operation, a three-layer framework is constructed, expressed as graphic form, based on enterprise modeling methods and reference models in the general enterprise reference architecture.
The Released Economic View

Figure 1: Framework for Economic View
The framework has established the relationships between different layers from the top-level strategic targets of an enterprise to some operable factors, then the bottom elements. It also provides some analysis methods to collect data to support decision optimization of the enterprise. After that, optimization results can be imposed on these factors to realize enterprise strategy and improve its competitive ability.
Application of Economic View

ABC Model

- The modeling formalism is based on IDEF0 method. Since ABC focuses on functional activities and so does IDEF0 method, IDEF0 model has been extended to include activity based costing data. It can be assured that no activity will be missed for cost assignments with the integration with IDEF0 model. Here, a separate economic model that corresponds to the IDEF0 model of function view will be constructed. There are four attributes in each model block: 1) node number, 2) activity name, 3) cost driver and 4) cost value. The first two attributes are taken directly from IDEF0 model, whereas the latter two are to be defined by designers.
Example of a cost hierarchy

- The cost model forms a hierarchy exactly like the IDEF0 model. Sub-processes are defined down to bottom-level activities that are the most basic elements.

Fig. 2. Example of a cost hierarchy
Treatment of intangible factors

- AHP Model

Since investing in CIM is not for the sake of the technology itself, it is important to have the resulting business and manufacturing processes meet the target performance. These operational measures should be derived from the company goals that align with corporate strategies. The questions are 1) whether the invested technology can effectively bring the business to the target, and 2) if the investment is economically sound. Activity-based costing technique discussed in the above slide takes care of the tangible aspect and deals with the second question. Hence, the first question will be handled by using Analytic Hierarchy Process (AHP) method.
(continue)

Fig. 3. The hierarchy of advancement investment

Goal
- Continual Growth

Strategy
- Increase Market Share
- Enhance Profitability

Characteristics
- Lower Costs
- Shorter Production Lead Time
- Better Product Quality
- Better Customer service

Investment Alternatives
- Advanced Manufacturing Technology
- Advanced Information Technology
- Innovative Design Capability
Thanks!