A FRAMEWORK TO INTEGRATE MANUFACTURING INFORMATION SYSTEMS

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Information systems play a critical role in today's manufacturing business, and the need for enterprise-wide integrated information system has grown rapidly. Although there are different integration approaches reported in the published literature, in today's industrial practice, most of the information system integration projects are still done on a trial-and-error basis owing to the lack of practical and feasible integration methodologies. This research proposed an integration framework which provides a logical and structured methodology to tackle information systems integration problems in real-world manufacturing environments. The framework is driven by the corporate strategy of manufacturing enterprises. The 'Decomposing-and-Mapping' method, normally used in the engineering axiomatic design approach, has been utilised here in a novel setting to design an integrated manufacturing information system.

1. INTRODUCTION

Information systems play a critical role in today's manufacturing business, and the need for enterprise-wide integrated information system has grown rapidly, as isolated information systems represent inadequate business solutions. In order to successfully and profitably operate in rapidly changing markets, we need to integrate different information systems such as enterprise resource planning system (ERP), supply chain management (SCM), and customer relationship management (CRM) in a company (Chang, 2000). The current interests in manufacturing industry focus heavily on integrating isolated computer-based systems into a unified system, which handles and transforms information among these systems to facilitate a smooth production environment (Aldakhilallah and Ramesh, 2003).

This paper proposed an integration framework which provides a logical and structured methodology to tackle information systems integration problems in real-world manufacturing environments.These rules should be followed in order to guarantee the consistency in the proceedings book.

2. MAIN ISSUES FOR THE DESIGN OF INTEGRATED INFORMATION SYSTEM

Although manufacturing companies have benefited from integrated information systems, some disappointing results from the heavy investment in the large information systems are an obvious signal to the companies to suggest there lacks a sound framework to align business strategy, information flow, and the design of integrated information systems.

Four types of integration in the Enterprise Integration have been identified (Vernadat, 1996), i.e., Presentation integration, Data integration, Functional integration and Process integration. Presentation integration aims to provide a uniform look and feel for user interfaces of different programs. Data integration is the system integration to which application tools are able to share common data and information. Functional integration is the system integration to which applications are able to interact with each other by requesting and providing functional services. Application tools communicate by means of events or requests. Process integration concerns the ability to embed function of different applications in one process. Integration can also be classified as internal and external integration. Within enterprise information system, there are different sub-systems which provide different functions to organisations. External integration, such as integration between ERP system and CAD, even NC machines, bridges the information system with other applications. The benefits of such external integration are greater, however, they are difficult to achieve. An integrated information system should enable various functions within an organisation to obtain the right information in real-time thereby enabling the company to gain competitive edge over competitors.

Another main issue identified by international researchers is the alignment of manufacturing strategy with integration process of information systems (Grant, 2003). Ellis (1999) pointed out that the implementation of an integrated manufacturing information system formed part of the strategic approach to satisfy the corporate objectives. There is a general weakness in the current manufacturing integration approaches, i.e., it lacks specific guidance or techniques to help the manufacturing companies to integrate their information systems, especially in linking their manufacturing strategy to the integration project. Manufacturing strategy is the set of co-ordinated tasks and decisions in manufacturing environment which need to be taken in order to achieve the company's required competitive performance objectives. Therefore, the information system and other systems should be integrated and serve the purpose defined the manufacturing strategy. The manufacturing strategy needs to be converted into a set of detailed and achievable targets for information system implementation.

3. DESIGN OF THE PROPOSED FRAMEWORK

This section explains the underlying principles of the proposed framework for information system integration. The proposed framework is divided into five stages with fifteen steps to give a step-by-step procedure for the analysis and implementation. The stages should be followed sequentially, as each stage requires the information and analysis input from the preceding stage, as shown in Figure 1.

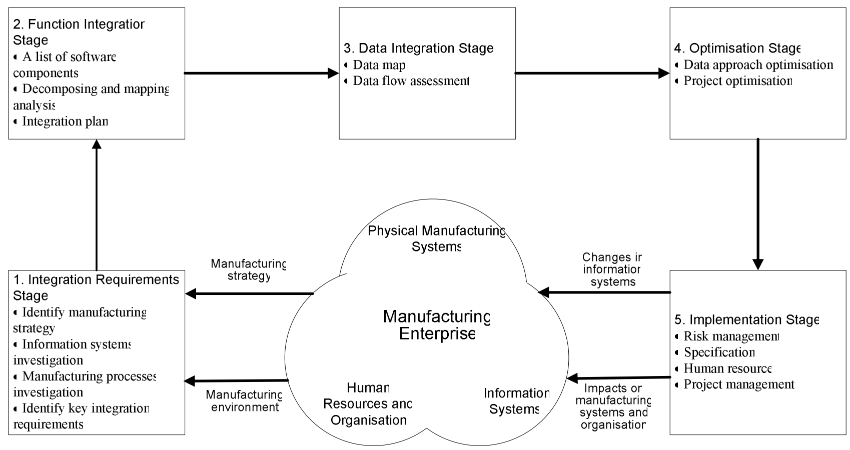

Figure 1. The Proposed Framework for Information System Integration

3.1 Integration Requirements

The first stage of the proposed framework is integration requirement stage. This stage focuses on the identifying manufacturing strategy, investigation of information systems and manufacturing environments, and captures the key integration requirements. This allows the manufacturing information system designers to formalise and increase their understanding of the vision of the business, manufacturing functions and information systems and to provide a record of the state of the enterprise when the objectives of integrating manufacturing information systems was proposed, and the integrated systems was designed. The key integration requirements are then captured.

Manufacturing strategy is about a set of co-ordinated tasks and decisions in manufacturing environment which need to be taken in order to achieve the company's required competitive performance objectives. During the integration process, the manufacturing strategy needs to be converted into a set of key integration requirements which are detailed and achievable targets for information system development and implementation. They are highest level functional requirements that cover different systems or different sub-systems within information system. Integration between the systems is a crucial task in the system development.

The key integration requirements should also be made with the knowledge of the limitations and the functional attributes that manufacturing information systems are able to achieve, after the investigation of manufacturing information system.

3.2 Function Integration

Once manufacturing strategy and key integration requirements have been identified, the information system integration plan can be developed based on the requirements. Integration plan will be produced against each key integration requirements at the end of this stage. Upon obtaining the information about manufacturing functions and information systems, a ‘decomposing-and-mapping’ methodology has been utilised to design an integrated manufacturing information system.

Suh (1990) defined design as the creation of synthesised solutions in the form of products, processes or systems that satisfy perceived needs through the proper mapping of the functional requirements (FR) in functional space with the design parameters (DP) of the physical space, as shown in Figure 2. A decomposition process named zig-zagging is used. Only after the higher level requirement is satisfied, can the lower level functional requirements be decomposed. Since new information about the functional requirements and the design parameters have to be updated in order to be processed with synthesis, neither functional requirements nor design parameters can be decomposed independently. Two important techniques used in this design methodology are decomposition and mapping. More importantly, the definition of functional requirements and the selection of design parameters are governed by the two design axioms, i.e.,

- **Axiom 1: The Independence Axiom, which maintains the independence of functional requirements (FRs); and**
- **Axiom 2: The Information Axiom, which minimises the information content of the design.**

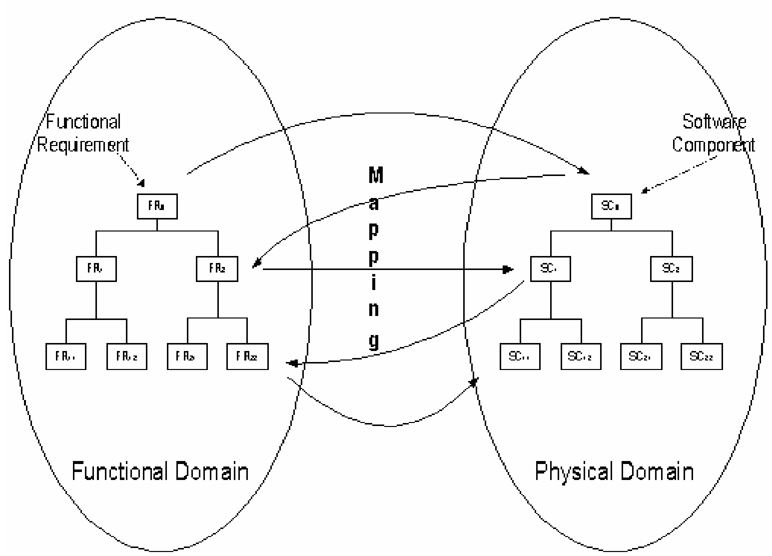

Figure 2. Decomposing and Mapping in Suh’s Axiomatic Design Theory

This methodology is used not only in product design (Suh, 1990, Jiao and Tseng, 1999) but also in manufacturing system design (Suh, 1990).

The following points should be noted in the design of the integrated information system , i.e.,

- The hierarchical structure of the functional and physical domains can be decomposed and prioritised;
- There is a correspondence between each level of the functional and the physical hierarchies; and
- It becomes meaningless if FRs at the i level are decomposed into the next level without proper mapping onto the physical domain and then develops a solution that satisfies the i level FRs with all the corresponding DPs.

In this stage, the functions in the information system need to be decomposed into more detailed sub-functions further down the structure hierarchy in this stage. The higher-level function describes the main purpose of the subject system and the lower-level function blocks describe the supporting sub-systems which exist to serve the upper levels. At the uppermost level, it is the key integration requirement derived from manufacturing strategy. Data and function are considered together. An integration plan will be generated at the end of this stage. A structured procedure which subdivides the key integration requirement into further processes can help in practice to solve the difficulties in developing the integration plan.

3.3 *Data Integration*

The third stage of this framework is data integration using data analysis techniques. The main tasks are to investigate information flow in the integration plan, and identify any information flow bottleneck.

The first step of this stage intends to model the high level information flows within the manufacturing organisation. It intended to give system integration designers a detail level of the manufacturing information systems from data point of view. In this step, it employed standard methods such as Data Flow Diagram to specify its functionality, and the Logic Data Model to define its data and data flow structure among manufacturing processes and software components. At the end of this step, it might be possible to find that there are no information flow between manufacturing functions, or the data entities links are insufficient to pass information needed by from one manufacturing function another one, further investigation on the proposed integration plan are needed.

The second step of this stage intends to identify any data flow bottleneck in the proposed integration plan, and to determine the best integration solution by utilising data measure techniques to access the information flow between the software components of information systems. This constitutes two levels of data flow assessment, i.e., Simple data measurement and Comprehensive data measurement. Simple data measurement is a technique which only measures the data flow within the software system. It focuses on the software program and related data entities. Software metrics or software measurement is suggested to be most appropriate method for measuring data flow if it only considers the data flow within software system. Comprehensive data measurement is a technique to measure the data flow from different angle in order to provide a comprehensive view of the data flow. In the real life situation, measuring data flow could be much complicated than just investigating software system. Not only software system, but also the volume of data, computer network and user interface affect the data flow. This research considers six integration criteria, i.e., currency, content, quality, flexibility, importance and scalability, to provide a comprehensive view to evaluate the data flow within information systems of manufacturing organisations.

3.4 *Integration Optimisation*

In this research, various tools are used to optimise the resource allocation in achieving the strategic goals. One of the difficulties in the integration process is how to balance the different contributions of individual software components and the investment. The Goal Programming techniques are used to produce the best solution according to a set of criteria. Whilst appreciating this difference, the proposed method considered all software components and their inter-dependencies to propose an optimal solution relative to the business objectives.

This stage starts with the optimisation of the software and related resource allocation using the results from data map. There is a relationship between the software size and data density/data flow. A high count for data input and output in software means a large or complex task for the software. Therefore it costs more time and labour in an integration project comparing with others. If the total number of days is already allocated to an integration project, the number of days for each software component can be computed according to the data entities. It is intended to give optimisation solution for a single project in this step.

3.5 *Integration Implementation*

The final stage of the framework consists of planning and performing the actual implementation of the integration project, including risk management, specification, human resource management, and the progress of the implementation.

Risk management is a tool to help users to identify the potential risk in the integration project, and to understand what investment and work might be at risk if the integration is abandoned and what delays might result if potential, identified events come. Specification, human resource management, and project management specify the needs for controlling the implementation project, which will help to convert the integration plan into a working system.

Integration specification is a comprehensive document describing the integrated system. All user requirements and functions should be considered for their relevance to the system being designed, and all the required data are included. Based upon the analysis done in previous steps, a new system design is already confirmed. At this step the requirements are expanded to give detail necessary to build the system. A typical specification should at least include hardware, software, database, networking, interface, schedule of the implementation and the cost.

Implementing integrated information systems is not a matter of changing software systems, rather it is a matter of repositioning the company and transforming the business practices. Due to enormous impact on the competitive advantage of the company, top management must show its commitment before embarking on the project. The project management tool should be used to ensure the integration project finish on time and on budget. The project control assumes that the overall integration project has been signed off, and has been decided that complete project is going to start. At the outset, a blueprint needs to be produced for the project. This will give the whole project a purpose, with appropriate benchmarking at strategic project landmarks. The formulation of the implementation plan should revolve around the key integration requirements, by taking each in turn and identifying the requirements needed to satisfy them.

4. APPLICATION DEVELOPMENT OF THE FRAMEWORK

The framework discussed in the previous section has been implemented within an Enterprise Resource Planning (ERP) system. User interface is Graphical User Interface. The main part of the implemented framework, or the prototype system, was developed based upon a Baan ERP environment which is installed on the Unix server. Some parts of the prototype system were located in a Microsoft Window server, and can be accessed through the main interface. Users can access the prototype system through the a Local Area Network (LAN). The five modules of the prototype system are Integration Requirements Module, Function Integration Design Module, Data Integration Module, Optimisation Module, and Implementation Module, as shown in Figure 3.

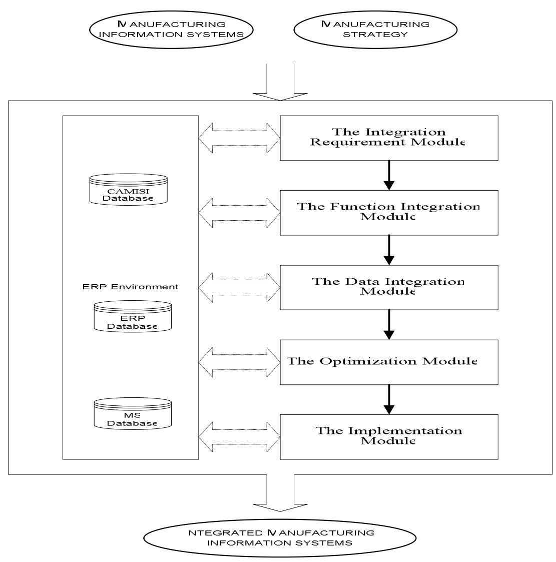

Figure 3. The Structure of the Application System

An application has been carried out and tested in an UK rail transportation company. The company intends to offer customers a complete range of attractive, modular rolling stock, support services, signalling and total rail systems. Its mission is to be in a position to be the single source providing fast, efficient and reliable solutions for rail transport needs. An integration project in the sales and marketing department of the company has been used to demonstrate how to use the framework and prototype system. The sales and marketing department of the company plays a pivotal role in the business. Integrating the parts tendering process in the information systems is the main goal of this project. The parts tendering is the most difficult job in the sales and marketing department. There are five people employed in the department to handle this process, including the customer enquiries, purchasing and scheduling of the production order. And even that, occasionally there were mistakes in the order scheduling and parts purchasing due to the human error. The management hoped that an integrated information system would improve the quality of the parts, reduce human error, and reduce the costs. This eventually leads to high quality products and services. On successful implementing the integrated information system, the staff on controlling Parts Tendering had been reduced from 5 to 3. The company also found error made during the process has been reduced significantly. Customer order delivery on-time has been improved to new high level.

5. CONCLUSIONS

This project proposed, implemented and tested a novel framework for enterprise information system integration. At the centre of the framework, is the manufacturing strategy which drives the information system integration process. This approach considers information systems in a holistic manner and emphasises the importance of the corporate strategy in the whole process of integration. The developed framework provides practical guidelines for industrial implementation and a software tool which can be used to go through the five stages and fifteen steps to give users a comprehensive solution. The proposed framework enables a company to assess its own business problems and the availability of its resources so that it is able to establish a realistic integration plan. The use of example application of the prototype software suggests that the proposed framework is valid and can bring real benefits to business. The framework includes a ‘decomposing-and-mapping’ methodology based on the axiomatic design approach, which is a technique so far used for physical product design. This project proves, for the first time, that this technique can also be used for information system integration design.

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